Historic American Land Surveys: The Mason Dixon Land Survey

4 Hours

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Final Exam

1. In 1761, Charles Mason and Jeremiah Dixon participated in a scientific effort to observe what rare astronomical event?
   a. The transit of Venus
   b. A total solar eclipse
   c. The conjunction of Jupiter and Saturn
   d. The Geminid meteor shower

2. William Penn, an advocate of religious freedom, was a member of what faith, informally referred to as the Quakers?
   a. The Religious Society of Friends
   b. The Church of Jesus Christ of Latter-Day Saints
   c. Jehovah's Witnesses
   d. Seventh Day Adventists

3. Sweden was at the height of its military power during this war?
   a. The Seven Years War
   b. The War of 1812
   c. The Crimean War
   d. The Thirty Years War

4. The peninsula containing parts of Maryland, Delaware, and Virginia is commonly called what?
   a. Mardelva
   b. Delmarva
   c. Virmardel
   d. Delmarginia

5. The stone monument placed at the point where Mason and Dixon established the meridian near Embreeville, Pennsylvania is known as the __________?
   a. Stargazer's Stone
   b. Rosetta Stone
   c. Cumberland Stone
   d. Piedmont Stone

6. The marker post placed at the southern terminus of the 15-mile line run south of the commencing point of the Mason-Dixon Line survey was called ___________?
    a. The Terminal Post
    b. The Post Mark'd South
    c. The Post Mark'd West
    d. The Post Mark'd East

7. The Proclamation of 1763 established this boundary between colonial settlement and native lands?
    a. The Mississippi River
    b. The Appalachian Mountains
    c. The Potomac River
    d. The 100^{th} Meridian of Longitude

8. In 1848 this commodity was discovered in California, propelling the soon-to-be state to status as an economic powerhouse?
    a. Coal
    b. Oil
    c. Silver
    d. Gold

9. The Prime Meridian on which the system of longitude is based runs through ________?
    a. Paris
    b. Barcelona
    c. Greenwich
    d. Rome

10. This basis for north is defined by the projection of the planetary axis upon the celestial sphere.
    a. Magnetic North
    b. Grid North
    c. Astronomical North
    d. Geodetic North

HISTORIC AMERICAN LAND SURVEYS – THE MASON-DIXON LINE SURVEY

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Objective:

As the retracement surveyors of today are called upon to "follow in the footsteps" of those original surveyors who went before, it is useful and instructive to learn how and why the early surveyors conducted their projects. It is likewise worthwhile to consider the outcomes and consequences of the early land surveys that shaped and continue to influence America.

This course seeks to study the historically important Mason-Dixon Line survey, the circumstances that led to the necessity of the survey, the surveyors who conducted the survey, and the methods and techniques they employed to complete their daunting project. Also, the lasting political and cultural effects of the survey will be examined and a timeline of events relating to the survey will be presented.

Course Outline:

The Mason-Dixon Line Survey

A. Biographical Overview of Charles Mason
B. Biographical Overview of Jeremiah Dixon
C. Mason and Dixon’s Initial Expedition

Section 1 – Historical Background

1. The Province of Maryland
2. The Province of Pennsylvania
3. The Penn-Calvert Boundary Dispute

Section 2 – Surveying the Lines

1. Scope of the Survey
2. Celestial Observation and a Commencing Point
3. The Point of Beginning
4. The Tangent Line
5. The West Line and the North Line
6. Extending the West Line

Section 3 – Lasting Effects of the Survey

1. The Delaware Wedge
2. Cultural Implications
3. The Mason-Dixon Line and the Civil War

Section 4 – Monuments of the Survey

1. The Star Gazer’s Stone
2. The Post Mark’d West
3. The Terminal Point
4. The Middle Point
5. The Tangent Stone
6. Tri-State Monument
7. The Fenwick Island Monument

Section 5 – Methods and Techniques

1. Astronomy and Surveying
2. Establishing North by Astronomical Observation

Section 6 – Resurveys of the Mason-Dixon Line

Section 7 – The Popular Legacy of the Mason-Dixon Line

Section 8 – Chronology of Events

Introduction:

The Mason-Dixon Line is familiar, in name at least, to most Americans but its origin, location, and cultural significance are certainly worthy of further study, particularly for those interested in historic land boundaries and the circumstances surrounding their creation. What began as a survey to establish the border line dividing the lands of Pennsylvania and Maryland in time came to signify the boundary line dividing the Union and the Confederacy. By use of conventional land surveying techniques in conjunction with astronomical and navigational methods, Mason and Dixon marked boundaries upon the ground that for over two and a half centuries have shaped the history and culture of America.

In an address before the Historical Society of Pennsylvania in 1854, Maryland inventor John H.B. Latrobe remarked of the Mason-Dixon Line:

> *"There is, perhaps, no line, real or imaginary, on the surface of the earth – not excepting even the equator and the equinoctial – whose name has been oftener in men's mouths during the last fifty years. In the halls of legislation, in the courts of justice, in the assemblages of the people, it has been as familiar as a household word. Not that any particular interest was taken in the line itself; but the mention of it was expressive of the fact that the States of the Union were divided into slaveholding and non-slaveholding – into Northern and Southern; and that those, who lived on opposite sides of the line of separation, were antagonistic in opinion upon an all-engrossing question, whose solution, and its consequences, involved the gravest considerations, and had been supposed to threaten the integrity of the Republic."*

Biographical Overview of Charles Mason

Charles Mason (1728-1786) was born in Gloucestershire, England. He spent the early years of his career serving as an assistant to Astronomer Royal, Reverend James Bradley. Mason devoted much of his professional effort toward the perfection of Tobias Mayer's Lunar Tables, a critical resource in maritime navigation.

In 1761, Mason embarked upon a sea voyage to Bencoolen in the Island of Sumatra to observe the transit of Venus (the passage of Venus across the face of the Sun as viewed from the Earth) for the purpose of collecting data as part of an organized international scientific effort to compute the distance between the Earth and the Sun. Due to a delay caused by an attack on the H.M.S. Seahorse by a French naval vessel, Mason's team observed the transit instead from the Cape of Good Hope in South Africa and then continued to the Island of St. Helena where Mason assisted famed British astronomer, Nevil Maskelyne in collecting tidal data until the end of 1761.

Beginning in 1763, Mason began his work with Jeremiah Dixon (who had accompanied Mason on the expedition) and a group of assistants, at the request of Lord Baltimore and William Penn, to survey and settle the boundary line between Pennsylvania and Maryland. Mason kept a detailed journal of astronomical observations and cultural information collected during the course of the survey.

Upon completion of the Mason-Dixon Line survey, Mason returned to Greenwich, England and in 1769, was employed by the Royal Society on an astronomical assignment at Cavan, Ireland. Upon this exceptionally eventful six-month assignment, Mason observed another transit of Venus, a partial solar eclipse, the moons of Jupiter, and the Great Comet of 1769.

Continuing his astronomical works, Mason catalogued 387 stars based upon James Bradley's observations, which were incorporated into the Nautical Almanac for the year 1773. Further, Mason resumed his work of perfecting Mayer's Lunar Tables on behalf of the Board of Longitude.

In 1786, Mason relocated with his family to Philadelphia, but became ill and died in October of the same year.

Biographical Overview of Jeremiah Dixon

Jeremiah Dixon (1733-1779) was born in Cockfield, County Durham, England, one of seven children born to a wealthy Quaker family of the Landed Gentry. Dixon was educated at Barnard Castle, taking an early interest in mathematics and astronomy.

Dixon served as an assistant to Charles Mason on his 1761 expedition, observing the transit of Venus from the Cape of Good Hope. Dixon later returned to the Cape of Good Hope to participate in Nevil Maskelyne's experiments with gravitation.

Dixon arrived with Charles Mason in Philadelphia in November of 1763 to begin their famed survey of the boundary line separating Pennsylvania and Maryland. Completing the survey in 1766, both men remained to conduct an additional survey on the Delmarva Peninsula, which is named for Delaware, Maryland, and Virginia, on behalf of the Royal Society and to perform several gravitational measurements prior to returning to England in 1768.

In 1769, Dixon traveled to Norway with William Bayly to observe another transit of Venus from Hammerfest Island.

Dixon was installed as a Fellow of the Royal Society in 1773.

Returning to England, Dixon resumed his profession as a land surveyor in County Durham. Dixon remained unmarried until his death in 1779 at the age of 45. He was interred in the Quaker Cemetery at the village of Staindrop.

Dixon's surname is the origin of the nickname "Dixie," commonly used to refer to the American South.

Mason and Dixon's Initial Expedition

Prior to becoming famous for their work in North America, Mason and Dixon achieved renown in England for their scientific work in observing the 1761 transit of Venus across the face of the sun, an event which had not occurred since 1639. The celestial phenomenon was to be visible in Asia, Australia, the East Indies, northern Europe, and the Arctic. To the observer, Venus would appear as a tiny black dot first appearing on the east edge of the Sun. For approximately six hours, Venus would make its way across the face of the Sun, completing its transit on the western side.

The time required to complete the transit was variable based upon the location of the observer. The transit time as well as the path of Venus across the face of the Sun was carefully recorded by teams of scientists at several different locations across the Earth. By comparing the data collected from the observations at the several locations, astronomers could attempt to compute the distance between the Sun and the Earth, which was at this time still unknown to science.

The geometric concept involved in the computation was fairly straightforward. Two observers separated by a known length, observing the same object at the same moment in time may construct an isosceles triangle with a known base and known vertical angles. However, the seemingly simple concept was extraordinarily difficult in reality. For example, the Sun and Venus appear to shift in position as the observer moves. Further, both Venus and the Earth are in constant rotation upon their axes and constant orbit about the Sun. Complicating the computations was the fact that the Earth was known to be an irregular spheroid, but the precise shape of the planet was not yet understood. These variables, when paired with the difficult task of measuring angles in fractions of seconds challenged the finest minds of Europe's scientific community.

Setting sail for Bencoolen in January 1761, Mason and Dixon arrived, out of necessity, at the Cape of Good Hope in April of the same year.

Mason and Dixon had been supplied by the Royal Society with the following equipment:

1. Two reflecting telescopes manufactured by James Short. Each telescope had a focal length of 24 inches and a magnification of 120 times. One of the telescopes was equipped with an "object-glass micrometer" with a focal length of 495.48 inches.
2. An astronomical clock manufactured by John Ellicott.
3. A quadrant with a one-foot radius manufactured by John Bird, which was loaned to them by the Earl of Macclesfield, president of the Royal Society.

Dr. James Bradley, Astronomer Royal, provided written instructions to Charles Mason as follows:

"Locate the observatory where there is a clear view toward the northeast, north, and northwest. Observe the first and second contacts of Venus with the limb of the Sun. Then measure the distance of Venus from the limb of the Sun to ascertain the nearest approach of Venus to the center of the Sun's disk. Measure the diameter of Venus. Set up the clock so that the observers at the telescopes are immediately accessible to it. Observers must be careful not to prejudice one another in their judgments of events and times. Make a preliminary trial of the clock with its pendulum adjusted as it was at Greenwich to ascertain how much it loses in a sidereal day. Then adjust it to solar time. Keep a record of the temperature in the clock case. Record how much the pendulum must be changed in length to keep solar time at Bencoolen."

After much preparation, Mason and Dixon made their observations of the transit of Venus on June 6, 1761. Remaining at the Cape of Good Hope through September, Mason and Dixon observed the positions of stars and astronomical phenomena for the purpose of establishing the latitude and longitude of their temporary observatory. They then set sail for St. Helena, arriving on October 16 to work with Nevil Maskelyne on further astronomical research.

This first scientific expedition by Mason and Dixon signified the beginning of a professional relationship that would span the next fifteen years and forever change the course of history.

SECTION 1: HISTORICAL BACKGROUND

The Province of Maryland (1632-1776)

George Calvert, or Lord Baltimore, was an English politician who served in Parliament and later as the Secretary of State to King James I. Calvert was interested in American colonization initially for financial gain but later for the establishment of a refuge for Roman Catholics being persecuted in England. Catholics were a minority in England in the seventeenth century, mistrusted and discriminated against by the Anglican majority

Calvert first became the proprietor of Avalon on the Island of Newfoundland but was demoralized by the harshness of the Canadian climate and determined to locate a more hospitable location further south along the Atlantic coast. Calvert sought a new royal charter for the settlement of the region which would become the modern-day State of Maryland.

Calvert died on April 15, 1632, just a few weeks before the new charter for the Province of Maryland was sealed. Calvert's son Cecilius succeeded him, while his son Leonard became the first Colonial Governor of Maryland.

On June 20, 1632, King Charles I in the eighth year of his reign granted to Cecilius Calvert, Lord Baron of Baltimore as follows:

"All that part of the Peninsula, or chersonese, lying in the parts of America between the ocean on the east, and the Bay of Chesapeake on the west, divided from the residue thereof by a right line, drawn from the promontory or headland called Watkin's Point, situate upon the bay aforesaid, and near the river Wighco on the west, unto the main ocean on the east, and between that boundary on the south, and that part of the Bay of Delaware on the north, which lieth under the fortieth degree of latitude, where New England terminates."

The Province of Pennsylvania (1681-1776)

William Penn (1644-1718) was born in London, educated at Oxford and was an early member of the Religious Society of Friends, familiarly referred to as the Quakers. He was an advocate of religious freedom and self-government. Like Calvert, Penn sought freedom from religious persecution.

In 1681, Penn received a royal charter from King Charles II to settle a debt that was owed by the Crown to Penn's father. Penn founded the proprietary colony to provide a place in which the Quakers could practice their religion freely. King Charles II named the colony Pennsylvania, which translates to "Penn's Woods" in the Latin language. Interestingly, the name was given by the king in honor of William Penn's father and not in honor of the younger Penn.

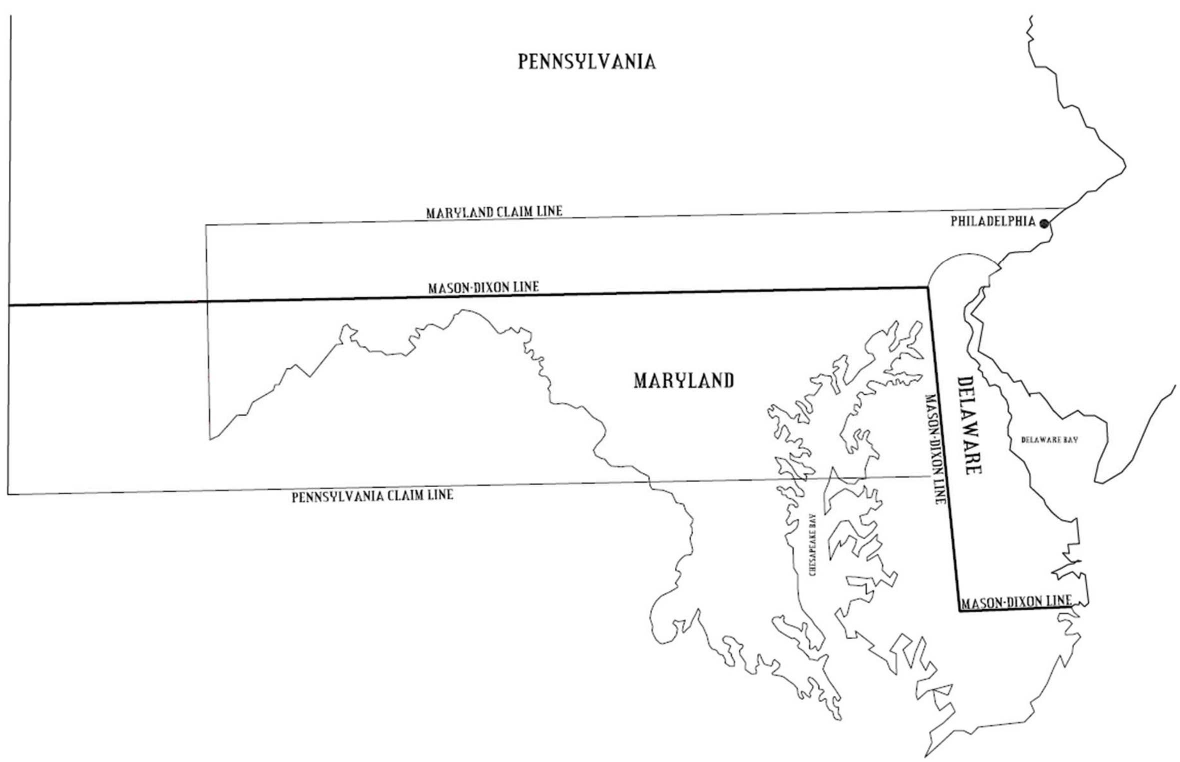
A portion of the description of the southern boundary of Penn's lands contained within the March 4, 1681 charter reads as follows:

"A circle drawn at twelve miles distant from Newcastle northward, and westwards unto the beginning of the 40th degree of northern latitude."

The uncertainties contained within this boundary line description are apparent to the land surveyor and may be expressed by the following questions:

1. "*A circle drawn at twelve miles*" may refer to a circle with a radius of twelve miles, a circle with a diameter of twelve miles, or a section of arc which is twelve miles in length.
2. "*...distant from Newcastle*" raises the obvious matter of where exactly in Newcastle shall the circle be centered.

The charter for the proprietary colony remained in the possession of the Penn family until the American Revolution, at which time the Commonwealth of Pennsylvania was formed and admitted as one of the original thirteen states.



The Penn-Calvert Boundary Dispute

The lengthy boundary dispute between William Penn and his heirs, and Charles Calvert (Third Baron Baltimore) and his heirs, was the source of the necessity of the Mason-Dixon Survey. The ambiguities and uncertainties within the land descriptions of the royal charters for both Maryland and Pennsylvania led to years of negotiations, surveys, and cases tried in the courts of England, none of which were enough to quiet the disputed boundary.

Following is background information on the attempts to colonize the area that is the subject of the Penn-Calvert dispute.

In the year 1631, agents of the Dutch West India Company purchased land at Cape Henlopen and formed a new colony called Zwaanendael in what is now Delaware. Constant conflict with the local Nanticoke Tribe, from whom the land was initially purchased, caused the new colony to fail in its first year. A subsequent effort at colonization was attempted the following year and likewise failed.

In 1632 Cecilius Calvert (Second Baron Baltimore) received a charter from King Charles I which included the Chesapeake Bay area. The charter was bounded on the north by the 40th parallel of latitude, and on the east by the Atlantic Ocean and the Delaware Bay. When the original colonists began to arrive and settle on the land, no survey was made to ascertain the location of the 40th parallel. Furthermore, the original immigrants did not settle the lands along the Delaware Bay.

Sweden established the Colony of New Sweden along the Delaware River (near what is now Wilmington, Delaware) in 1638 during the Thirty Years War when Sweden was at the height of its military power. Considering the establishment of this colony to be an incursion into Dutch lands, the Dutch established an outpost, Fort Casimir, in the location of present-day New Castle, Delaware in 1651. Three years later, the Swedish captured Fort Casimir, but the Dutch recaptured the fort the following year under the leadership of Peter Stuyvesant, Director General of New Netherland. Stuyvesant renamed the fort to Fort New Amstel.

The English protested the colonization by the Swedish and the Dutch in the lands which the King had granted to Lord Baltimore by Royal Charter. In 1659, Maryland sent a delegate to New Amstel to formally object to the Dutch presence in Maryland, but the English did not take action on this matter until 1664 when King Charles II granted James, the Duke of York (and the King's brother) all land situated between the Delaware River and the Connecticut River. The English took Fort Amsterdam in September of 1664, and Peter Stuyvesant was forced to surrender all the territories of New Netherland. The remaining Dutch outposts in the Delaware Bay region surrendered shortly after the fall of Fort Amsterdam. Further, New Amstel was given the English name of New Castle.

In the year 1681, William Penn received a Royal Charter from King Charles II for what would become Pennsylvania. Lord Baltimore (now Charles Calvert) stated no objection to the charter with the understanding that Penn's holdings would be entirely north of the 40th parallel. James, the Duke of York, was to retain New Castle and the surrounding area as circumscribed by a 12-mile circle. William Penn leased this land from the Duke for the purpose of securing access to the sea for his colony. In 1682, the Duke of York conveyed to William Penn the 12-mile circle around New Castle as well as the lands to the south extending to Cape Henlopen.

In May of 1683, Penn visited the Colonies and met with Calvert at New Castle. The men disagreed on their understanding of how the land boundaries were to be determined. The points of contention were the location of the southern boundary of Pennsylvania and the location of the 12-mile circle around New Castle. This meeting signified the beginning of the famous boundary dispute.

Penn's desire for his colony to have access to the Chesapeake Bay was in direct conflict with Calvert's steadfast assertion that Pennsylvania was to be limited to only the lands north of the 40th parallel. Calvert further contended that the original royal charter to Maryland had intended to include the land along the Delaware Bay. The two men being at an impasse, Penn sought a legal remedy in the courts of England, to which both returned in order to try the case. James, the Duke of York had, by the time of the trial, risen by ascendency to the English throne as King James II. Penn anticipated an advantage in the proceedings, given his alliance and past relationship with James II.

Penn put forth the position that the Maryland Charter had only included uncultivated lands and that the Dutch settlers had previously farmed the Delaware Bay area prior to the execution of the charter, thereby nullifying Calvert's claim on the land. The decision of the Committee for Trade and Plantations concurred with Penn's assertion that the Maryland Charter was to include uncultivated lands only and that the prior settlement by the Dutch fairly excluded the lands along the Delaware bay from the charter.

In 1685, King James II handed down a compromise decision ordering the division of the land lying between the Chesapeake Bay and the Delaware Bay by way of a line to be drawn west from Cape Henlopen to its intersection with a line to be drawn directly south from the 40th parallel. Also, the royal decree confirmed that the northern boundary of Maryland was to remain at the 40th parallel, however this boundary was not surveyed at the time allowing its physical location on the ground to remain uncertain. Three years later, King James II issued to Penn an updated charter which better defined the Delaware Bay region.

In 1701, the settlers in what is now Delaware, which at the time was referred to as the Lower Counties, petitioned William Penn with a request to establish their own legislature and public officials. Penn agreed to their petition and arranged for the survey of the 12-mile circle around New Castle with the goal of marking the border between the Lower Counties and Pennsylvania.

Surveyors Thomas Pierson of New Castle and Isaac Taylor of Pennsylvania were commissioned to survey what would be the first of many attempts to rightly survey the boundary arc.

In 1709, Calvert petitioned Queen Anne for the dismissal of the previous ruling which had granted to Penn the Delaware region, contending that Penn's lands must not extend south of the 40^{th} parallel. The queen denied Calvert's petition. Based upon the queen's edict, the assemblies of both Pennsylvania and Delaware agreed to accept the 12-mile boundary arc as surveyed by Pierson and Taylor. This agreement, however, did little to resolve the frequent boundary disputes between the settlers from Delaware and Maryland, which were exacerbated by the recurring cases of the Maryland government making land grants to Maryland residents which were within the borders of Delaware. In frustration, the Delaware assembly revoked its ratification of the 12-mile circle boundary.

The deaths of the original contestants to the dispute, Calvert in 1715 and Penn in 1718, led their heirs to carry on the controversy. Charles Calvert, the Fifth Lord Baltimore, and John, Thomas, and Richard Penn would continue in the dispute begun by their predecessors.

After a brief period of quiet, the dispute roared back to life owing mostly to two major discoveries. First among these was the fact that the 12-mile boundary arc around New Castle at no point actually intersected with the 40^{th} parallel. The other issue was that the 40^{th} parallel was found to lie north of Philadelphia, Pennsylvania's principal city, thereby placing it within the borders of Maryland. These disputes led each colony to conduct its own surveys of the borders, which only added to the confusion.

In 1730, a violent dispute that came to be known as Cresap's War began when ferry boat operator Thomas Cresap was almost drowned when his ferry boat was attacked by a pair of men from Pennsylvania. The attackers apprehended Cresap's hired man who was wanted in Lancaster County, Pennsylvania for delinquent debts. Cresap complained of the incident to the Pennsylvania magistrate, but received no satisfaction.

Continuing conflicts, sometimes escalating to the point of violence, coupled with uncertainty among the settlers as to which colony their taxes were owed compelled the leaders of Pennsylvania and Maryland to seek a final and equitable settlement.

Calvert petitioned King George II in 1731 to require the Penns to accept a final location of the disputed boundaries. The petition was sent to the Committee for Trade and Plantations. At the center of this latest round in the dispute was Calvert's claim that the 40^{th} parallel should be held as the boundary (thereby placing Philadelphia within Maryland) and Penn's assertion that the boundary should be placed 20 miles south of Philadelphia.

In 1732 King George II and the Committee compelled the Calverts and the Penns to agree to a compromise, whereby they executed an agreement placing the southern boundary of Pennsylvania to the south of Philadelphia. The agreement also provided for the division of the peninsula by a line drawn west from Cape Henlopen to the central point of the peninsula. From said central point, a boundary line would be drawn north to the point of tangency with the 12-mile circle around New Castle. From this tangent point, the boundary would run along the arc of the circle until it was directly north of the point of tangency, and from that point would run north to its intersection with the latitudinal line positioned 15 miles south of Philadelphia. It should be noted that the map used in the agreement contained an error miscalling Fenwick Island as Cape Henlopen, which represented a 19-mile blunder.

The agreement also directed the establishment of a body to govern its implementation and to supervise the placement of boundary monuments. Maryland and Pennsylvania appointed seven members each to the Commission, which was headed jointly by each colony's governor.

Despite regular meetings, the Commission could reach no agreement on several particular points regarding the 12-mile circle boundary. The Commissioners from Maryland argued that the circle did not have a definitive central point. Also, the Maryland commissioners contended that the circle was intended to be 12 miles in circumference, as opposed having a radius of 12 miles as claimed by the Pennsylvania group. Calvert also raised the issue of the aforementioned mapping blunder regarding Fenwick Island and Cape Henlopen.

With no resolution achieved, the Commissioners drafted a statement acknowledging their failure to resolve the dispute. Lord Baltimore then petitioned the courts of England and William Penn filed a petition to counter. As a temporary solution, King George II decreed that no further grants of land were to be made within the disputed territory. Meanwhile, proxies for each side began the legal process of obtaining depositions from potential witnesses.

In 1750 at the Court of Chancery, Lord Chancellor Phillip Yorke, First Earl of Hardwicke reviewed the charters and the prior agreements made between the Calverts and the Penns, and received testimony from witnesses on both sides. The ruling handed down by Lord Hardwicke ordered that the Agreement of 1732 was to be binding, and that a new slate of Commissioners was to be appointed for the purpose of establishing the boundaries set forth therein. Addressing three of the main queries specifically, Lord Hardwicke decreed that the center point of the 12-mile circle was to be held at the center of New Castle. Also, Lord Hardwicke determined that the 12-mile circle was to have a radius of 12 miles. Lastly, he decreed that the previous mapping error was to be corrected and that Fenwick Island, instead of Cape Henlopen, would represent the southern boundary line.

The new Commission convened later the same year, with representatives from Maryland, Pennsylvania, and Delaware. Among the first decisions made was the agreement that the center of New Castle would be defined as the cupola sitting atop the Court House.

The Commissioners next retained surveyors John Riggs, Thomas Garnett, Archibald McClean, and John Lukens to establish what would become known as the Transpeninsular Line, which was the line dividing the southern half of the peninsula from the northern half. As directed by the Court of Chancery, this line was begun at Fenwick Island and run west. After completion of the survey, discord came to light again as the commissioners could not agree upon the location of the western terminus of the line. With the position of the line's midpoint being critical to the overall division of the peninsula, and with the midpoint being impossible to ascertain without knowledge of the western terminus of the line, the parties were once again at an impasse. Further complicating matters was the question of whether the radius of the 12-mile circle should be measured along the contour of the ground or if it should be measured on a level line, neglecting the relief of the land. The method chosen would have a considerable effect on the size of the circle.

The Commissioners appealed to Lord Hardwicke, who ruled that the Chesapeake Bay was to be the western terminus of the line and that the radius of the 12-mile circle should be measured on a level line. Lord Hardwicke also accepted the Commission's decision to hold the New Castle Court House as the center point of the circle.

Upon the death of Charles Calvert, his son Frederick (6th Baron Baltimore) who had opposed his father's agreements, succeeded him. For nine years, the surveying of the agreed upon boundary lines ceased. Eventually, however, Calvert entered into an agreement concurring with the Agreement of 1732 and with the Decree of 1750. In 1760, the Commissioners ratified the results of the survey of the Transpeninsular Line, and set the Middle Point Marker, which can be found today between Delmar and Mardela Springs, Maryland. The eastern Transpeninsular Line monument is found near the Fenwick Island Lighthouse.

Over the course of three years, local surveyors* attempted to lay out the 12-mile circle in 1761 and again in 1763 but the progress made was disappointing. The Commissioners then agreed to hire experts from England to correctly complete the survey. Charles Mason and Jeremiah Dixon had gained renown within the scientific community for their excellent work in the observation of the transit of Venus plus further astronomical observations made during their time in South Africa. Furthermore, Dixon was widely regarded as a top land surveyor. With the determination of a latitudinal line being critical to the disputed boundaries, both astronomical navigation and conventional land surveying methods would be called upon.

In the Summer of 1763, the Penns and the Calverts being both in London, retained Charles Mason and Jeremiah Dixon to:

"mark, run out, settle, fix and determine all such parts of the circle, marks, lines, and boundaries, as were mentioned in the several articles or commissions, and were not yet completed."

Mason and Dixon left England in mid-September aboard the *Hanover Packet* and landed at Marky's Point, about 20 miles from Philadelphia on November 15, 1763 to begin their monumental work.

**Note: The local surveyors from the 1761-1763 surveys were John F.A. Priggs, John Lukens, Archibald McClean, Archibald Emory, Jonathan Hall, John Watson, John Stapler, Thomas Garnett, and William Shankland.*

SECTION 2: SURVEYING THE LINES (1763-1767)

Scope of the Survey

Shortly after arriving in Philadelphia, Mason and Dixon met with the commissioners from Pennsylvania first and then the commissioners from Maryland joined about two weeks later. A series of daily meetings was held to discuss the specific tasks required of Mason and Dixon.

The first major task was the establishment of the “West Line” of the boundary, which was decreed by the Court of Chancery to lie 15 miles south of the southernmost point of the City of Philadelphia. Prior to the commencement of Mason and Dixon’s survey, the City Commissioners of Philadelphia had sought to determine the southernmost point of the city for the purpose of establishing the initial basis by which to establish the boundary between the lands governed by the descendants of Lord Baltimore (Maryland) and by the descendants of William Penn (Pennsylvania). The officials walked the south border of the city and agreed that the north wall of the house owned by Thomas Plumsted and Joseph Huddle was the satisfactory location of the southernmost point of Philadelphia. The front wall of this house adjoined the street which represented at that time the southern border of the city. The Plumsted-Huddle house was in Southwark, which in the colonial period was a municipality in Philadelphia County, and which today is a neighborhood in South Philadelphia. Today, no trace of the original Plumsted-Huddle house remains.

The other major task was the establishment of the “Tangent Line,” or the boundary between Maryland and Pennsylvania’s three lower counties (present-day Delaware). This line would require the establishment of a line running from the midpoint of the Transpeninsular line to the tangent point with the 12-mile circle and from there a meridional line to a point 15 miles south of the southernmost point of Philadelphia.

In the course of the daily meetings, the commissioners disagreed as to which of the lines should be surveyed first. Maryland’s contingent was in favor of surveying the West Line first, proposing that the team survey westward to South Mountain. The Pennsylvania representatives favored surveying the Tangent Line first, suggesting that the terrain would only be traversable in the summer months.

The commissioners did agree that the task of first importance was the determination of the latitude of the southernmost point in Philadelphia, which point had been previously agreed upon. From there, the surveyors could reckon the latitude at a point 15 miles south as required, which would then be held as the latitude for the West Line.

The surveyors requested the construction of an observatory in order to make the necessary celestial observations. This was agreed to upon the condition that the surveyors pledged an oath to perform to the best of their knowledge and ability and to remain impartial in their work, taking care to not favor one side over the other. Also, the commissioners provided the surveyors with detailed instructions compiled from the decisions made during the series of meetings.

Celestial Observation and a Commencing Point

With their observatory built, the surveyors began the process of setting up their equipment, which included a 6-foot Zenith Sector: a vertically mounted telescope used to establish latitude by measuring the positions of stars. With this instrument, the observer could measure the zenith angle of a star (the angle created between the zenith, the observer, and the star’s location on the celestial sphere), and thereby could compute the zenith distance and declination. Using this data along with the Royal Society’s star table, the latitude of the observer could be calculated. The stated accuracy of the Zenith Sector by its manufacturer was two arc seconds. Additionally, the team set up a Telescope and Hanging Level configured as a tripod-mounted transit and equal altitude instrument.

These instruments were manufactured by John Bird of London, who was at the time considered to be the top maker of mathematical instruments in England. John Bird (1709-1776) worked in his youth as an apprentice to Jonathan Sisson (inventor of the theodolite) and had also worked alongside well-known instrument maker George Graham. By the time of Mason and Dixon's survey, Bird had invented the slow-motion tangent screw which allowed for the reading of fractions of seconds of angle.

The Zenith Sector consisted of a base and stand to which a telescope was mounted vertically. The telescope was positioned to aim straight up, or to the zenith angle. The telescope was mounted upon a pivoting device so the observer could move the scope along the vertical circle. A curved scale, which was called the sector, was affixed to the base of the instrument. The sector consisted of an ivory scale in the form of a segment of an arc of 6-foot radius, upon which was inscribed markings identifying the increments of degrees of angle. When observing the location of a star on the celestial sphere, the indicator on the sector would inform the observer of the angular measurement between the zenith and the observed object. The micrometer attached to the Zenith Sector enabled the user to make angular measurements of one-hundredth of a second of arc.

Interestingly, the configuration of the Zenith Sector with the eyepiece near the floor required the user to lie in the supine position. Further, with stellar observations necessarily being taken at night, an assistant to the observer was needed to illuminate the crosshairs of the telescope via candlelight shone through an aperture in the instrument's eyepiece.

The process of using the Zenith Sector first involved aligning the instrument with the meridian, which is the north-south line directly above the instrument's position. Mason achieved this by selecting a star to observe through the telescope. Due to the rotation of the Earth, a star observed through a stationary telescope will seem to travel in the path of an arc across the telescope's field of view, parallel with the celestial equator. By positioning the telescope in such a way that the star would appear to cross the horizontal crosshair twice. Mason would record the precise times that the star crossed the horizontal crosshair, and by determining the midpoint of the arc traced by the star relative to the crosshairs, it could be ascertained when the observed star was on the meridian. This process would be repeated on several different stars on a single night and by computing the positions of each star and at what time they were on the meridian, Mason could calibrate his instrument to the meridian.

Once the Zenith Sector was correctly oriented to the meridian, Mason and Dixon began the process of precisely computing the latitude of the agreed-upon southernmost point of Philadelphia, fifteen miles south of which the West line of their survey was to be run. A group of stars was selected for observation and according to their notes, zenith angles and right ascensions were recorded on these stars from December 19, 1763 to January 4, 1764. Upon completion of 17 nights of stellar observations and after two straight days of mathematical calculations, Mason was able to report to the commissioners his result, which was that the southernmost point of Philadelphia was at a north latitude of 39 degrees 56 minutes 29.1 seconds.

The Point of Beginning

With the latitude of the southernmost point of Philadelphia established, Mason and Dixon set about the task of determining the position of a beginning point fifteen miles to the south, which would control the latitude of the West Line. It was impractical for the team to attempt to survey directly south from Philadelphia and then to the west, as two crossings of the Delaware River would have been necessary. The more expedient alternative of first travelling west from Philadelphia for 30 miles and then surveying southward was chosen. This route allowed the team to avoid the two unnecessary river crossings.

John Harlan was a landowner near the forks of Brandywine Creek in the area of present-day Embreeville, Pennsylvania. Mr. Harlan agreed to provide lodging for the surveyors and further permitted them to construct an observatory on his land. Over the years in which the survey was conducted, the Harlan home served as a home base for Mason and Dixon.

Mason and Dixon returned to Philadelphia in order to gather their belongings and prepare for the westward journey. They arranged to have their observatory dismantled by a team of carpenters and carried by wagon along with their instruments to the Harlan residence. Once back at the Harlan residence, Mason and Dixon set up a temporary observatory for the Zenith Sector in a tent. Mason made celestial observations in order to determine their latitude and realizing that their present position was conveniently near to the latitude of the southernmost point of Philadelphia, instructed the team of carpenters to erect their observatory upon the site. After the completion of their observatory and upon additional observations and calculations, Mason and Dixon concluded that the observatory was located at 39 degrees 56 minutes 18.9 seconds north latitude, a mere 10.2 seconds south of the latitude of the southernmost point of Philadelphia.

The next objective was to survey southward to the latitudinal line 15 miles south of the latitude of the southernmost point of Philadelphia. One of the first steps taken was to mark the meridian on the ground, which would provide the surveyors with positional control in the daytime. A large stone monument was placed (and then replaced after a more accurate position was established) about 700 feet north of the Harlan house. This stone came to be known locally as the Star Gazers' Stone and still exists today. The Harlan farm, house, and Star Gazers' Stone were placed on the National Register of Historic Places in 1985.

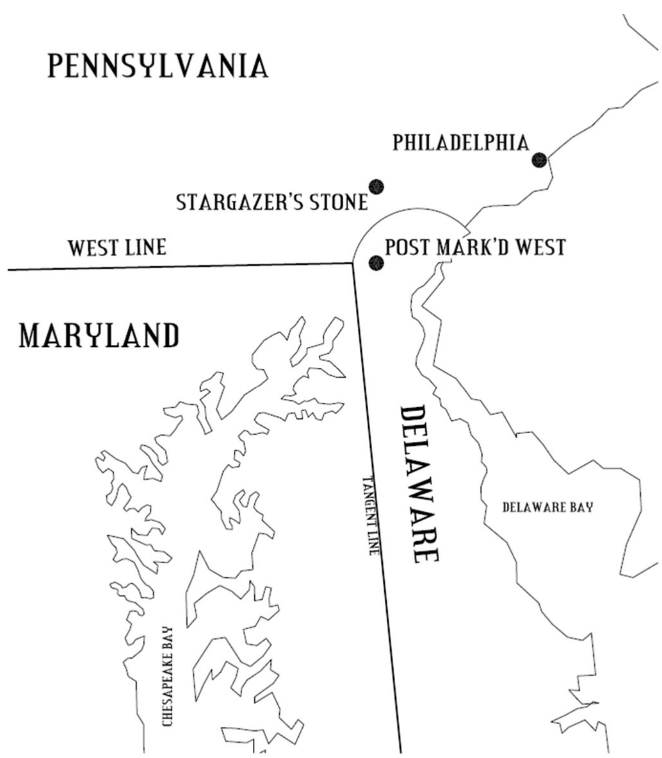
For the procession southward, laborers and experienced survey crew members joined Mason and Dixon. Their method was a line-of-sight technique setting out from the Harlan property. Dixon aligned his circumferentor (an instrument used for the measurement of horizontal angles) with the meridian line, sighted a line to the south and positioned a crewmember upon the meridian line to the south to set the first stake. The chainmen would then measure directly from the setup point to the stake which had been set and Dixon would move forward to the new stake to set up. Aligning the circumferentor with the setup stake and the back sight stake, Dixon would sight a line to the south again and the process would be repeated again and again while keeping a running total of the distances measured by the chainmen.

When crossing ordinary terrain, distances were measured using a Gunter's chain which was 66 feet in length. Rough terrain was often measured with a 22-foot or 16 ½-foot long rod called a level. This permitted the survey crew to maintain a level line of measurement, rather than measuring along the ground going up and down hills.

By April 12, 1764, the men had traversed their way southward approximately 15 miles. By Dixon's computations, the correct distance from their commencing point at Harlan's farm was calculated to be 15 miles, 2 chains, and 93 links, which placed them on the land of Alexander Bryan. At the southern terminus of the 15-mile line, the surveyors set a large wooden post which would come to be referred to as the "Post Mark'd West" owing to the fact that the men had carved the word "WEST" into the west-facing side of the post. The survey party then returned to Harlan's farm to collect their belongings.

The observatory was disassembled and placed into wagons along with the Zenith Sector. The hired laborers returned to the south terminus of the 15-mile line to reconstruct the observatory while Mason and Dixon traveled back to Philadelphia to meet with the commissioners to give report on their progress.

Upon returning to the field and making careful observations, the surveyors determined that the south point of terminus of the 15-mile line, where the Post Mark'd West had been placed, was at a north latitude of 39 degrees 43 minutes 18.2 seconds. With the first step of the process complete, Mason and Dixon shifted their efforts to the establishment of the Tangent Line, which had confounded earlier surveyors for years.



The Tangent Line

In June of 1764, Mason and Dixon began to make preparations for the surveying of the Tangent Line. This line of approximately 80 miles was to run from the middle point of the previously surveyed Transpeninsular Line to the tangent point with the 12-mile arc around New Castle. In preparation for this survey, the surveyors brought on additional hired hands and purchased a stock of medical supplies.

Mason and Dixon also hired Moses McClean to work as their steward. McClean was responsible for the logistical aspects of maintaining a large survey crew in the field for an extended time. His duties included the procurement of provisions, supplies, and horses, as well as handling the money and tending to the equipment.

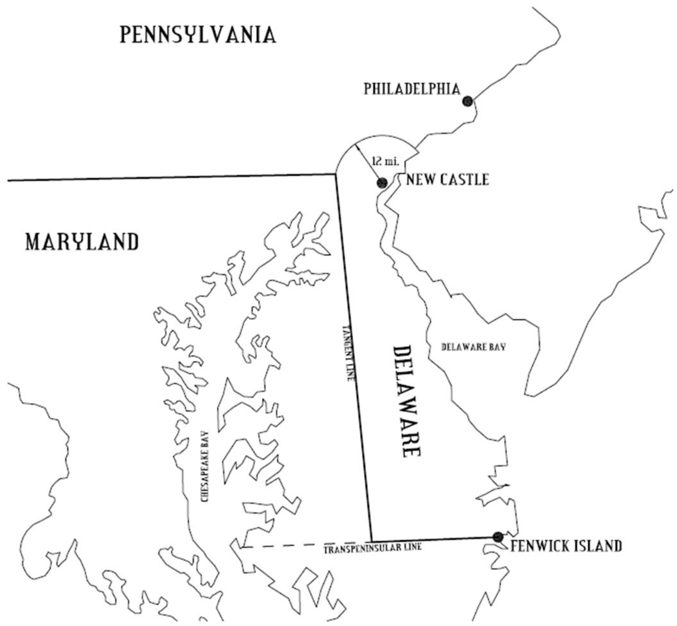
The crew, which had by this time grown to 39 men, traveled south down the peninsula toward the midpoint of the Transpeninsular Line to begin the survey northward to the tangent point. Previous surveyors had attempted, and failed, to run a line directly from the midpoint to the tangent point. Mason's plan was to run a straight line north to a point slightly west of the tangent point and then calculate an adjustment to the line to bring it to the tangent point. This adjusted line could then be established and monumented.

To correctly survey a straight line running north, Mason elected to use astronomical north. Interestingly, Mason did not use Polaris (the North Star) as his basis. Rather he chose to set his course upon the adjacent star in the constellation Ursa Minor, which is known as Delta Ursae Minoris. Mason's rationale was that Polaris appears to move on a very small arc during the course of a night, while Delta Ursae Minoris appears to move along a slightly larger arc, making the apparent movement much easier to observe. By night, the transit's position was fixed based on the stellar observations and by day the transit was used to sight the line running north, which was measured as before by chainmen, measuring ahead to each new line stake. The crew set a wood post at each mile interval. At every fifth mile, the chainmen took an offset measurement from their line to the line established by John Lukens, who attempted unsuccessfully to survey the tangent line in 1763. On August 25, the eighty-first milepost was set, which was determined to be north of the tangent point, thereby making the line long enough for the surveyors to compute the necessary adjustment.

The next task in this phase of the project was to locate the exact position of the tangent point. Hiking their way eastward toward the 12-mile circle, the surveyors eventually recovered posts that had been placed during the 1760-1763 survey, including the post marking the tangent point. Extending the radius of the 12-mile circle to its point of intersection with the newly surveyed north-south line, a distance of 22 chains and 51 links was measured. This distance would be the basis of the eastward adjustment of the north end of the line, as each milepost going south which was previously set could now be moved to the east by a prorated distance. This adjustment would successfully mark a line from the midpoint of the Transpeninsular Line to the Tangent Point.

The crew started back to the south, relocating each milepost along the way by the correct distance to place it correctly on the tangent line. Arriving at the midpoint, the crew discovered that the south end of the calculated tangent line was a mere 26 inches west of the midpoint. The crew then began working their way back north, taking additional measurements and making necessary corrections to the line's position and the locations of the mileposts. On November 10, Mason and Dixon arrived back at the north end of their line. They found that their line as surveyed was 16 feet and 9 inches east of the tangent point. Mason divided the discrepancy on a proportionate basis across the entirety of the line to learn if any of the mileposts were far enough offline to merit resetting them. However, the results were found to be satisfactory.

Just one day shy of completing their first full year in America, Mason and Dixon had established the latitude of what would become the east-west dividing line between Maryland and Pennsylvania, and had successfully surveyed the Tangent Line, the position of which had eluded all previous surveyors. Mason and Dixon spent the winter of 1764-1765 as the guests of the Harlans.



The West Line and the North Line

In the spring of 1765, after wintering at the Harlan Residence, Mason and Dixon set about the difficult task of surveying the West Line. Surveying a latitudinal line is far more complex than surveying a meridional line: a meridional line may be surveyed by making nighttime observations of a singular star for the purpose of finding the true astronomical north, while surveying along a specific line of latitude requires frequent repositioning of alignment based upon the repeated observations of a group of stars. It is much more difficult to determine one's longitude by celestial observation than is to follow the center of the arc traced by Polaris, or in the case of Mason and Dixon, Delta Ursae Minoris.

For the purpose of surveying the West Line, Mason selected five stars to observe: Vega, Deneb, Sadr, Delta Cygni, and Capella, which are located in the constellations familiarly known as Lyra, Cygnus, and Auriga.

On March 19, 1765, the crew began their arduous assignment only to be hindered by immoderate weather, first in the form of heavy rain and then in the form of a snowfall of more than two feet. Being delayed severely by the conditions, the westward survey got successfully underway on April 5. The complexity of surveying along a latitudinal line was evidenced by the fact that the surveyors could correctly plot their course westward only about ten miles at a time, placing mileposts at the completion of each mile chained. At the completion of that distance, it was necessary for Mason to make celestial observations to determine their position and their departure from the target of 39 degrees 43 minutes 18.2 seconds north latitude. Once their position was determined and the course adjusted if necessary, Dixon and his crew could continue chaining westward for another ten miles.

Mason and Dixon's team reached the Susquehanna River on May 11, which point was recorded in their field notes as being at 26 miles, 3 chains, and 93 links. At this point, the survey was on schedule. The crew then made their way back east to the Post Mark'd West, while along the way verifying the positions of the mileposts that had been set on their survey west. From there, the crew turned southward toward the Tangent Point for the purpose of establishing a line running north from the Tangent Point to the intersection with the West Line, thereby completing the boundary running from the midpoint of the Transpeninsular Line to the line of 39 degrees 43 minutes 18.2 seconds north latitude. This would come to be called the North Line and was only 5 miles, 1 chain, and 50 links in length. Its northern point of terminus was reached by the surveyors on June 6, 1765 at a field owned by Captain John Singleton. This point marked the common corner of Maryland, Pennsylvania, and the Lower Counties (now Delaware). It was monumented with a wooden post carved with a "W" on its west face and an "N" carved on its north face. In 1849, the wooden post was replaced with a stone marker and the point is contemporarily known as the Tri-State Point.

Satisfied with the present results of the survey, the commissioners agreed to have the surveyors set permanent boundary stones, quarried from the Isle of Portland in England, at the critical points of the survey that had been established, including at the Tangent Point and at the intersection of the West Line and the North Line.

The commissioners then instructed Mason and Dixon to resume their survey of the West Line from the Susquehanna River to as far west as the country was inhabited. The crew surveyed their way westward in the same method as they had east of the Susquehanna; however, the terrain was becoming much more disagreeable as they traversed into the foothills of the Allegheny Mountains, part of the vast Appalachian Mountain Chain. In October of 1765, the survey had reached North Mountain and had set a post at mile 117. With winter approaching, this point was declared to be the end of the survey for the 1765 season; however, they remained for three weeks to make astronomical observations and to verify the accuracy of the West Line up to that point.

The instructions received by the surveyors indicated that the boundary line was not to cross the Potomac River, which in this area runs generally from west to east and meanders significantly. The surveyors enlisted the aid of Captain Evan Shelby, a local resident, who traveled with them to the top of North Mountain and showed them the path of the river as it flowed from the west. This view informed Mason and Dixon that their West Line would not cross the Potomac River. The surveyors next packed up their instruments and left them to the care of Captain Shelby for the winter. The crew traveled back east, checking their mileposts along the way, toward the Susquehanna River, where the present phase of the survey had recommenced. On November 8, the crew arrived at Peach Bottom, where a ferry across the Susquehanna operated, and the hired men were released for the winter.

Mason and Dixon then traveled to York, Pennsylvania for a meeting with the commissioners at which they received the instruction to oversee the placement of fifty boundary stones beginning at the midpoint of the Transpeninsular Line, or the south end of the Tangent Line. At the completion of the setting of these boundary stones, Mason and Dixon returned once again to the Harlan property to spend the winter, this being the winter of 1765-1766.

In March of 1766, Mason, Dixon, and their hired men reassembled at the residence of Captain Shelby, which was in the vicinity of milepost 117 at North Mountain where the survey had stopped in the fall of 1765. Mason began by making the necessary astronomical observations needed to set the course of the survey line going west. Mountainous terrain, dense forests, and bad weather made for slow progress in the spring of the year; however, the team forged ahead, going over the very steep Sideling Hill at Mile 134, and continuing through the summer months to Mile 165 which traversed across numerous hills and mountains, finally conquering Little Allegheny Mountain. On June 9, 1966, Mason and Dixon once again set up the Zenith Sector to make astronomical observations.

On June 14, Mason summited Savage Mountain, which was part of the mountain chain that separated colonial settlement from the lands inhabited by the native people. By King George III's Proclamation of 1763, this signified the boundary of Indian Territory, and further settlement by the colonists was prohibited.

The Proclamation of 1763

> *After the French and Indian War, the British Empire began to exercise more strict control over the colonies in America. In reply to a Native American rebellion led by Chief Pontiac of the Ottawa, King George III decreed the Appalachian Divide to be the limit of western settlement by the colonists.*
>
> *The Proclamation of 1763 issued by King George III of Great Britain at the conclusion of the French and Indian War proposed to placate the Native American people by restricting the incursion of the European settlers onto their lands. Also, colonists previously settled west of Appalachia were required to move back east.*
>
> *The boundary created by this edict became known as the "Proclamation Line" and served as the division line between the British Colonies and the Native American*

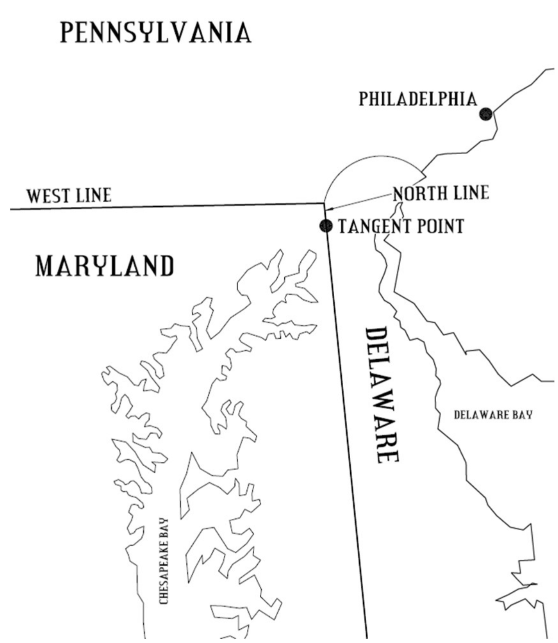
territory lying west of the Appalachian mountain range, thereby ending further western settlement by the colonists. Further, this measure prohibited any private citizen or colonial government from purchasing land or making any agreements with Native people to the west of Appalachia.

The Proclamation was largely flouted by the colonists and was loosely enforced by the British forces in North America, but it did become the source of considerable contempt for the British by the colonists and was one of many factors that contributed to the frustration that eventually set the American Revolution in motion.

With the limit of colonial settlement being reached, and therefore the requirements of the survey of the West line being satisfied, Mason, Dixon, and their hired men started back east, with the axmen cutting an 8-foot wide swath through the forests along the way. This chore consumed the remainder of the summer and on September 30, when the North Line had been reached, Mason and Dixon released all their hired men.

The surveyors had a month to spend before their next scheduled meeting with the commissioners, so with the permission of officials from both colonies they took on an unrelated scientific task for the Royal Society. As part of the scientific goal of determining the precise shape of the Earth, Mason and Dixon endeavored to precisely measure the length of a degree of latitude in America, so that the length could be compared with a degree of latitude as measured in Europe.

Upon the completion of their work on the Royal Society's project, Mason and Dixon received the instruction to set a stone at each milepost of the West Line, which was accomplished for 65 miles, excepting at Mile 64 where conditions made it impossible to set a stone.



Extending the West Line

Mason and Dixon had satisfactorily completed the tasks set forth in their original instructions; however, the commissioners desired to retain the team in order to perform additional surveys before they departed for their homes in England. First among these tasks was the running of a line from the Post Mark'd West, east to the Delaware River, which was important to know since the Royal Charter issued to William Penn provided that the western limit of Pennsylvania was to be five degrees of longitude west of the Delaware River. By obtaining a good position for the Delaware River upon the extension of the West Line, a correct length for the south boundary of Pennsylvania could be derived. This task was accomplished quickly and led to a second, related task.

The commissioners desired for Mason and Dixon to extend the West Line westward to a point exactly 5 degrees of longitude west of the Delaware River. This would require the crew to survey into Indian Territory, which was under the jurisdiction of the Six Nations, and where white settlement was expressly forbidden according to the Proclamation of 1763. Governor Penn of Pennsylvania and Governor Sharpe of Maryland each wrote to William Johnson, who was an Indian agent, to request his intercession on their behalf in requesting the consent of the Six Nations to allow the survey to proceed westward into their territory.

While awaiting word on consent from the leaders of the Six Nations, Mason and Dixon traveled once again to the Harlan residence to prepare for the next phase of their work. While there, the surveyors performed experiments relating to gravitation for the Royal Society in part of an effort to understand the effect, if any, on the earth's gravity imparted by the observer's latitude. The team spent most of January and February of 1767 conducting their experimental observations, the results of which were shipped back to England.

After lengthy negotiations with the leaders of the Six Nations, William Johnson was able to secure consent for Mason and Dixon to resume their survey of the West Line. As part of the consent agreement, a contingent from the Six Nations would join the survey party in their journey westward. In June of 1767, the group of 65 men made their way west to the where they had halted their survey the previous year. Moving ever westward and hiring willing workers along the way, the group ballooned to 110 men by September.

Disaster struck on September 17 at 221 miles west of the Post Marked West, when horse drivers John Carpenter and William Baker were struck by a falling tree and killed.

Twelve days later, doubtlessly distressed by the earlier tragedy, 26 members of the crew approached Mason and Dixon concerned that continuing westward across the Monongahela River into the lands of the Lenni-Lanape and the Shawnee would place them in serious jeopardy. Unable to be persuaded, the 26 men resigned their positions, were paid up, and were dismissed. Messages were sent to Fort Cumberland and Fort Redstone requesting men to replace those who had resigned. A group of willing men from Fort Cumberland arrived in early October.

Also, in early October, a party of eight members of the Seneca tribe arrived, which was welcome as the Senecas were part of the Six Nations and as such were friendly to Mason and

Dixon's native escorts. The Senecas were heading south to battle the Cherokee but remained with the survey party for two days before resuming their mission.

At a position of 231 miles and 20 chains, the surveyors reached an Indian warpath. The leader of the Mohawk escort asked for a meeting with Mason and Dixon. Following is an excerpt from the notes of the meeting:

> *"This day the Chief of the Indians which joined us on the 16th of July informed us that the above mentioned War Path was the extent of his commission from the Chiefs of the Six Nations that he should go with us, with the Line; and that he would not proceed one step farther Westward."*

Despite the urging of Mason and Dixon, the Indian escorts remained resolute in their unwavering refusal to travel any farther and the surveyors were forced to accept their conclusion and decided to end the West Line short of the true western boundary of Pennsylvania, (five degrees of longitude west of the Delaware River) rather than risk traversing into hostile territory without the aid of the escorts.

At Brown's Hill, Mason and Dixon spent the second week of October recording celestial observations to make a final determination of position and at a distance of 233 miles, 17 chains, and 48 links from the Post Marked West, the surveyors set a post with a "W" carved on the west-facing side atop a cairn of stones.

At this point, Mason and Dixon had accomplished the tracing of a parallel of latitude upon the ground by means of astronomical navigation and terrestrial surveying methods, a feat which had not been achieved at any prior time in recorded human history.

Having reached the western end of their line, the crew turned back east and started the job of clearing a vista back to Milepost 199 where the previous clearing had left off. Along the way, one of the Indian escorts died of a cause that was not entered in the record. His remains were placed in a coffin and carried back east for proper burial and his wages were sent to his widow.

In the first week of November, the escorts and most of the hired men were given their final payments and made their way back to their homes. Placing the permanent boundary stones along the West Line was all that remained to do. The boundary stones had been delivered and were located near Milepost 134. Mason and Dixon had received a quote to have the stones distributed along the line from Milepost 134 to Milepost 199, however finding the quote of 12 pounds to be much too high, they declined to accept the stones. Instead of placing the boundary stones, the surveyors erected cairns of stone on the ridgetops along the West line.

Battling the onset of winter as they made their trek back east, the surveyors encountered Robert Farlow at Town Hill. Farlow had been an instrument bearer on their crew for the past three years and had earlier been sent east to place the boundary stones on the east portion of the line. Farlow offered the good news that the boundary stones had been set from Milepost 135 going east to the Post Marked West, with the exceptions of Milepost 77 and Milepost 117 which had been placed at offsets due to topographical conditions.

On December 12, Mason and Dixon sent a message to notify the commissioners that they expected to arrive back in Philadelphia on December 15.

The commissioners requested two final tasks of Mason and Dixon. First, they asked that Dixon draft a map of the boundary as surveyed. Secondly, the commission asked that the length of a degree of longitude along the latitude of the West Line be calculated. The men returned to the Harlan house to undertake these final chores.

Mason and Dixon arrived at a length of 53.5549 miles per degree of longitude along the West Line, however this solution was paired with a disclaimer stating in brief:

> *"But the Earth is not known to be exactly a spheroid…We do not give in this as accurate."*

Dixon submitted his completed map on January 29. With their work for the colonial proprietors concluded, the men decided to stay in the colonies long enough to finish their computation of the length of a degree of latitude for the benefit of the Royal Society.

Eschewing the Gunter's chain for a set of brass-tipped wooden rods, the surveyors meticulously measured their way south from the Stargazer's Stone to the Middle Point, a project which ran from February 23 to June 4. Their finding that a distance subtended by a degree of latitude in their location was 0.69 miles longer that was a degree of latitude in England was an important contribution in the scientific understanding of the shape of the Earth; specifically the understanding that the Earth is not a perfect sphere but rather an oblate spheroid.

With all their work in the colonies completed, Mason and Dixon informed the commissioners of their intention to return home to England. The commissioners requested that the men remain until Dixon's map could be engraved and printed. Robert Kennedy of Philadelphia printed the engraving and furnished the surveyors with 200 copies on August 16.

The next three weeks were spent settling accounts, tending to outstanding matters, and meeting with the commissioners for a final time before heading to New York.

On September 11, 1768 Charles Mason and Jeremiah Dixon set sail for England aboard the *Halifax Packet,* bringing to a close, after nearly 5 years, a remarkably complex and incomparably important set of land surveys, the ramifications of which would be unknown to the responsible surveyors within the spans of their lifetimes.

SECTION 3: LASTING EFFECTS OF THE SURVEY

The Delaware Wedge

The Delaware Wedge is a 684-acre tract of land lying along the state borders of Maryland, Pennsylvania, and Delaware. The creation of the tract may be attributed to the limitations of the surveying methods at the time when the state boundaries were established. The Delaware Wedge is bounded on the north by the extended east-west portion of Mason and

Dixon’s line (The West Line), on the west by the north-south portion of Mason and Dixon’s line (The North Line), and on the southeast by the Twelve Mile Circle around New Castle.

The Delaware Wedge came into existence because Mason and Dixon’s North line from the Tangent Point of the Twelve Mile Circle left a small residual tract between the North line and the Twelve Mile Circle. At the time of the discovery of this wedge, the Penn family held claim to both Pennsylvania and Delaware, so there was no immediate need to resolve the issue. However, when Pennsylvania and Delaware separated into two different states, a dispute arose.

Pennsylvania officials claimed that the Wedge was outside of the Twelve Mile Circle so it could not be a part of Delaware, and it was east of the Mason-Dixon Line and could therefore not be a part of Maryland.

Delaware held the position that Pennsylvania was not to extend to any lands south of the northern border of Maryland. They further asserted that the North Line represented the logical extension of the Tangent Line and should form the border between Maryland and Delaware, regardless of the fact that the Wedge was situated entirely outside of the Twelve Mile Circle.

In 1849, Lt. Col. J.D. Graham of the United States Army Corps of Topographical Engineers surveyed the northeast corner of Maryland and the Twelve Mile Circle. This survey reignited interest in the dispute and prompted Pennsylvania to claim the Wedge as its own, a claim which was not honored by Delaware officials.

In 1892, W.C. Hodgkins of the Office of the United States Coast and Geodetic Survey placed monuments upon the east extension of the Pennsylvania-Maryland border, marking what became known as the “Top of the Wedge Line”. Finally, in 1921, officials from Pennsylvania and Delaware settled upon the location of the boundary and agreed that the Delaware Wedge would be part of the State of Delaware.

Today, the small community of Mechanicsville, Delaware is located within the Delaware Wedge.

Cultural Implications

Mason and Dixon’s survey was a tremendous technical achievement. They accomplished the complicated task of placing abstract lines upon the ground - lines which would become the permanent borders between colonies (and later, states). What they almost certainly did not realize at the time were the profound cultural and political effects that the newly surveyed boundaries would have on the development of a fledgling nation.

In the second half of the eighteenth century, the issue of slavery had become severely divisive within the colonies. Generally speaking, slavery was practiced in the southern colonies and not practiced in the northern colonies. In 1780, the newly formed State of Pennsylvania abolished slavery by way of gradual emancipation, which placed the state in union with the State of Massachusetts which had abolished slavery earlier in the year. By this time, other northern state had either abolished slavery or were working toward abolition. All of the abolitionist states were located north of the Mason-Dixon Line.

South of the Mason-Dixon Line were a tier of states that did not accept the abolitionist attitudes prevalent in the north. In these southern states, the agricultural economy was dependent on a large labor force and as such, the exploitation of slave labor was deemed not only a necessity but a fundamental aspect of southern culture.

Because of this ideological rift between the states, the Mason-Dixon Line came to be recognized as the practical boundary between the abolitionist North and the slaveholding South.

The newly created United States of America had declared its independence from England in 1776 and had finally secured its independence in 1783 after several years of war. However, the nation's domestic problems regarding slavery carried over from the colonial period. As the new nation began to develop, the leaders of the young republic were faced with defining questions: Would the United States be a free nation or a slave nation?

Slavery was permitted on a state-by-state basis, with the southern states permitting slavery and the northern states barring it, with the Mason-Dixon Line cited as the dividing line. As the nation began to grow physically, owing to the large tracts of land acquired from England expanding westward to the Mississippi River, organization of the new territories became necessary. In the division of these newly acquired territories, the federal government sought to maintain political balance between the advocates of freedom and slavery, taking care not to give one side or the other a legislative advantage.

In 1787 the Confederation Congress (which was the predecessor to the Congress which was established by the United States Constitution) crafted the Northwest Ordinance, organizing the lands that now comprise the states of Ohio, Indiana, Illinois, Minnesota, Wisconsin, and Michigan. The ordinance provided for territorial administrations which could petition the federal government for statehood once their territory reached a population of 60,000 residents. Of crucial importance was the Northwest Ordinance's prohibition of slavery throughout the territories. This ensured that the several future states which were certain to arise would be free states. The Ohio River was selected as the natural southern boundary of the territory and as a compromise to the southern states, all lands south of the Ohio River were not subject to the prohibition of slavery.

This decision had the effect of identifying a second symbolic dividing line between free territory and slave territory, effectively extending the concept first associated with the Mason-Dixon Line all the way to the Mississippi River. Both Mason and Dixon were deceased by this time but could have scarcely imagined that the ideals attributed to their remarkable technical achievement would come to represent the great line of demarcation across a nation and an ideological watershed by which a nation was nearly split asunder.

In the ensuing decades, the United States experienced rapid growth which led to the admission of new states. At the federal level, compromise between northern and southern interests was critical, as each side relied upon the other economically and it worked best for the North and South to coexist while downplaying the divisive issue of slavery. To ensure the balance of influence and representation in Washington D.C., it was necessary to maintain an equal number of free states and slave states. For this reason, new states were admitted into the Union in pairs, one free state and one slave state.

A political crisis arose in 1820 when Missouri reached the population threshold to qualify for statehood. Missouri had been mostly settled by slaveholders who had brought slaves with them into the territory. This fact paired with the physical location of the would-be state made it logical that Missouri would enter the Union as a slave state. However, its admission would upset the balance of free states and slave states.

With a political showdown looming and congress at an impasse that threatened to tear the new nation apart, Speaker of the House Henry Clay of Kentucky remarked that "the words civil war and disunion are uttered almost without emotion." Clay, working with other congressmen, developed a compromise based on the concept that had by this time been attached to the Mason-Dixon line, namely, a clear line of demarcation dividing the north from the south. In cooperation with other members of the House and Senate, Clay drafted a plan which would become the Missouri Compromise. In this compromise, Missouri would be admitted to the Union as a slave state while Maine would be simultaneously admitted to the Union as a free state, thereby maintaining the political balance.

At the heart of the Missouri Compromise was the establishment of a transcontinental line of demarcation between North and South. The line was to begin at the western terminus of the Mason-Dixon Line, follow the Ohio River southwest to a point on the Mississippi River at a latitude of 36 degrees 30 seconds, then West to the west edge of the Louisiana Territory (extending theoretically West to the Pacific coastline). With the exception of the State of Missouri which had been admitted to the union in 1821, any newly admitted state lying north of this line would be admitted as a free state and any newly admitted state lying south of this line would be admitted as a slave state. The lasting effect of the Missouri Compromise Line is evident by an examination of the American states, as the line forms the border between Missouri and Arkansas, and the border between north Texas and the panhandle of Oklahoma. While geographically quite distant from the actual Mason-Dixon Line, the Missouri Compromise Line stands as the ideological extension of a concept attached to the Mason-Dixon Line.

In 1846, the United States went to war with Mexico in an effort to gain control of the western portion of North America, including California and its natural harbor, San Francisco. The United States government was motivated by the concept of "Manifest Destiny," that is to say, a belief that the United States possessed a right to take control of the continent all the way to the Pacific Ocean. Manifest Destiny was pursued with the presumption that any lands acquired would be settled according to the conditions of the Missouri Compromise and the latitudinal line defined therein.

The United States defeated Mexico and took control of California in 1848. Shortly thereafter, gold was discovered in the foothills of the Sierra Nevada mountains. The famous gold rush ensued and within a year, California's population had grown sufficiently to permit a petition for statehood. California possessed a wealth of gold, the finest port on the Pacific coast, and vast expanses of arable land in its inland valley. With its remarkable resources, it was apparent that the new state of California was going to be an economic powerhouse, so the question of whether California would be admitted as a free state or a slave state was a question of national importance. Dividing California into two states, north and south, was not practical as the bulk of the economic resources (San Francisco and the gold mines) were located in the northern half and a split would have been deemed unfair to the South. A stalemate was the result.

Henry Clay proposed a new compromise in 1850 which allowed for the admission of California as a free state and granted the South the passage of the Fugitive Slave Law, which permitted slave owners to reclaim their escaped slaves who had fled to free states. Further, the law gave slave owners and their agents the authority to compel local officials to cooperate in the returning of escaped slaves. This compromise came to be known as the Compromise of 1850.

The result of the Compromise of 1850 was a heightening of tensions between the North and the South, as anti-slavery northerners were forced to allow slaveholders to enter free states to recover their escaped slaves, and worse, some anti-slavery northerners we forced to assist the slaveholders in the process. Against their will, many northerners who considered slavery to be a moral abomination became unwilling accomplices to its continuation. In the South, the admission of California as a free state was seen as an unfair attempt to unbalance the nation's economy to the advantage of the North. Southerners also worried that, by the prevention the expansion of slavery in the West, the North would gain momentum toward nationwide abolition.

On the other side of the country, the tension turned to violence and once again the Mason-Dixon Line was involved. On September 11, 1851 in Christiana, Pennsylvania, a Maryland slave owner, invoking the Fugitive Slave Law, crossed the Mason-Dixon Line into Pennsylvania to recover a group of slaves who had escaped. Christiana's free black population and the white residents of the town joined together to defend the fugitives. Armed men on both sides commenced fighting and the Maryland slave owner was killed. The remaining Marylanders retreated. In the North, the battle was hailed as a victory for liberty, while in the South it was condemned as an act of aggression contrary to federal law. Some historians consider this skirmish to represent the first spark that eventually drew the nation into civil war, and the battle lines had unwittingly been drawn decades before by two long gone English gentlemen, Charles Mason and Jeremiah Dixon.

The Mason-Dixon Line and the Civil War

Throughout the 1850s, the lines drawn across the nation in a spirit of compromise and balance had become largely obsolete owing to the concept of popular sovereignty, by which the voters of a state could determine their own status as a slave state or free state. This concept underscored the idea that had become self-evident: the North and the South had grown into two separate and hostile nations and that a tangible border between them was effective and necessary. Without a real barrier between the two nations, incursions and conflicts were inevitable.

In November of 1860, the anti-slavery presidential candidate from Illinois, Abraham Lincoln, was elected and in December of the same year, South Carolina seceded from the United States, proclaiming itself an independent state. The states of Mississippi, Florida, Louisiana, Alabama, and Georgia, in agreement with South Carolina's stated goal of preserving slavery, seceded from the Union in January of 1861, with Texas seceding in February. Officials from the seceding states convened in Montgomery, Alabama in February of 1861 and formed the Confederate States of America.

Slave states situated along the Mason-Dixon Line and the Missouri Compromise Line (Kentucky, Delaware, Maryland, West Virginia, and Missouri) that did not secede became known as "border states."

In the pre-dawn hours of April 12, 1861, a cannon was fired from the shore of Charleston Harbor, striking Fort Sumter, a United States Army fort located on an offshore island. This attack by South Carolina against a federal garrison signified the opening moment of the deadliest war in American history. With war now beginning, the uncommitted southern states of Tennessee, Arkansas, Virginia, and North Carolina joined the Confederacy.

The Mason-Dixon line quickly became a strategic point in the war. Maryland was a border state but had allegiance to the South. It was therefore critical to the North that Maryland did not fall into the control of the South, as it would place Philadelphia in severe jeopardy of being taken. Ironically, the Mason-Dixon Line represented the division between the North and the South, but in the time of war it was strategically crucial that the Mason-Dixon Line did not become the southern border of the Union. To keep the Confederates out of Maryland was to keep them at an arms-length from Pennsylvania.

From the Confederate point of view, the Mason-Dixon Line was viewed as a goal line to be crossed. To cross the line and attack into Pennsylvania would be considered a major blow to the Union cause and a demonstration of the strength of the Confederate forces. However, any incursion into the north would be fraught with risks. President Davis was well aware his army's vulnerabilities, having fewer men and less equipment, as well as the fact the Confederacy was lacking a naval force which made them susceptible to blockade of the coastline by the Union Navy. Davis employed a defensive strategy until a favorable opportunity to invade the North presented itself.

In the summer of 1864, General Robert E. Lee had captured some momentum, having recently turned back a major Union offensive on Richmond. General Lee approached President Davis with his idea to invade Maryland, which he thought would pose a direct threat to Washington D.C., thereby diverting the Lincoln administration's attention and resources toward the protection of the city. In a letter to President Davis, General Lee wrote that a victory in Pennsylvania would enable the people of the United States to determine whether they support politicians who favor continuing the war or those who wish to bring it to a termination. President Lincoln, perceiving the imminent threat, ordered his generals to destroy the Confederate army before it got near Pennsylvania.

General Lee led his army into Maryland heading toward the Mason-Dixon Line, positioning himself as a liberator of the people of the state. In a famous address to the people of Maryland, Lee stated that he intended to *"right the wrongs that have been inflicted upon the citizens of a commonwealth allied to the States of the South by the strongest social, political, and commercial ties."*

Eventually, in September 1862, the Union and Confederate armies clashed in Maryland at Antietam Creek, the location of which Mason and Dixon had recorded a century prior. General George McClellan and his Army of the Potomac battled Lee's army to a standstill in what still remains as the bloodiest one-day battle in American military history with approximately 23,000 casualties. There was no decisive outcome to the Battle of Antietam, but the North did claim victory since Lee's army left Maryland and fell back to Virginia.

Even in defeat, Lee remained focused upon the strategic value of crossing the Mason-Dixon Line. Likewise, the Union strategy was fixed on defending Pennsylvania and keeping Maryland attached to the Union. From the Union's perspective, the Mason-Dixon line had to be held as the dividing line between the North and South. Any advance by the rebels past the line would have the effect of conferring legitimacy to the Confederacy as a nation of its own.

By the summer of 1863, Lee had earned victories at Fredericksburg and Chancellorsville. In an attempt to capitalize on this success, Lee marched the Army of Northern Virginia again into Maryland and then crossed over into Pennsylvania with the plan of executing raids and causing disruption of Union communication and supply lines. General Lee's ultimate plan was to achieve decisive victory in a major battle, which would demonstrate to the people of the North that the Confederacy was a legitimate nation that could not be oppressed by the United States. Lee's plan came to a head just a few miles north of the Mason-Dixon Line, near the small community of Gettysburg, Pennsylvania, which interestingly did not yet exist at the time of the Mason-Dixon survey but now is known to Americans as the site of a pivotal point in the history of our nation.

The Battle of Gettysburg began when men from Lee's army and the Army of the Potomac, now led by General George Meade, encountered one another unexpectedly. What began as a skirmish broke out into three days of intense fighting. The rebel army had the upper hand in the early going, forcing Meade into a defensive tactic which had good effect. On the third day of fighting and frustrated by Meade's defensive strategy, Lee ordered an attack at the center of the Union line, which proved to be futile. Next, Lee commanded General George Pickett to lead an uphill charge at Cemetery Ridge, directly into the face of heavy Union cannon and musket fire. At the end of this fateful day, two-thirds of Pickett's men lay dead on the battlefield and the Union army had gained control of Gettysburg. Lee and what was left of his army crossed the Mason-Dixon line for the final time and fell back to Virginia, having lost nearly 30,000 men.

While Lee's army was in retreat, the unwelcome news arrived that Vicksburg, which had long been under siege by Union forces, had fallen, thereby cutting the Confederacy into two parts, and ensuring certain victory to the Union.

Mason and Dixon could have scarcely imagined what their survey line would come to represent and the effect it would have on a young United States.

Abraham Lincoln's brief but exquisite Gettysburg Address given in dedication of the battlefield cemetery follows:

> *Four score and seven years ago our fathers brought forth on this continent, a new nation, conceived in Liberty, and dedicated to the proposition that all men are created equal.*
>
> *Now we are engaged in a great civil war, testing whether that nation, or any nation so conceived and so dedicated, can long endure. We are met on a great battle-field of that war. We have come to dedicate a portion of that field, as a final resting place for those who here gave their lives that that nation might live. It is altogether fitting and proper that we should do this.*
>
> *But, in a larger sense, we can not dedicate—we can not consecrate—we can not hallow—this ground. The brave men, living and dead, who struggled here, have consecrated it, far above our poor power to add or detract. The world will little note, nor long remember what we say here, but it can never forget what they did here. It is for us the living, rather, to be dedicated here to the unfinished work which they who fought here have thus far so nobly advanced. It is rather for us to be here dedicated to the great task remaining before us—that from these honored dead we take increased devotion to that cause for which they gave the last full measure of devotion—that we here highly resolve that these dead shall not have died in vain—that this nation, under God, shall have a new birth of freedom—and that government of the people, by the people, for the people, shall not perish from the earth.*
>
> *—Abraham Lincoln*

In the time since the end of the Civil War, the Mason-Dixon line has retained its cultural and political significance as the dividing line between the northern and southern United States, two distinct cultures within the same nation.

SECTION 4: MONUMENTS OF THE SURVEY

Overview

The original milestone monuments created for use on Mason and Dixon's survey were made of oolitic limestone, quarried at Isle of Portland in England. The stone monuments were 4.5 feet long and 12 inches square with pyramidal tops and with all four sides featuring vertical fluting. Each of the nearly 400-pound monuments were prepared with an ornate capital letter "P" carved into one face to represent the Pennsylvania side and a similarly styled capital letter "M" carved into the opposite face to represent the Maryland side.

The Star Gazer's Stone

The Star Gazer's Stone is located near Embreeville, Pennsylvania and Marks the location of the temporary observatory created by Charles Mason and Jeremiah Dixon in January 1764. From this location, Mason and Dixon took critical early celestial observations with which to begin their survey work. The stone was set about 700 feet to the north of the Harlan House, which served as a home base for Mason and Dixon throughout their survey lasting over four years.

The stone's placement was approximately 31 miles west of what had previously been determined to be the southernmost point of Philadelphia. From the observatory at this site, Mason and Dixon were able to compute their latitude precisely. With the knowledge of this latitude, they computed the necessary distance to survey southward in order to arrive at the parallel of latitude situated 15 miles south of the southernmost point of Philadelphia, at which latitude would be established the east-west border line dividing Maryland and Pennsylvania.

The Star Gazer's Stone is found at a latitude of 39 degrees 56 minutes 21 seconds North and a longitude of 75 degrees 43 minutes 57 seconds West.

The Harlan House and the Star Gazer's Stone were listed on the National Register of Historic Places on May 9, 1985.

The Post Mark'd West

The Post Mark'd West was set by Mason and Dixon on June 12, 1964 and marked the initial point of their survey. It was placed on the land of Alexander Bryan which today is located within White Clay Creek State Park in New Castle County, Delaware.

According to Mason's notes, *"…the point 15 miles south of the southernmost point of the City of Philadelphia is situated in Mill Creek Hundred in the County of Newcastle, in a plantation belonging to Mr. Alexander Bryan."*

By Dixon's computations, the correct distance from their commencing point at Harlan's farm to the southern terminus of the line was calculated to be 15 miles, 2 chains, and 93 links.

The original monument set by Mason and Dixon was a post with the word "WEST" carved into the west-facing side of the post.

In 1952, S. Hallock du Pont donated a modern monument which presently marks the spot of the Post Mark'd West.

The Terminal Point

The Mason and Dixon Survey Terminal Point is a marker situated near the community of Pentress, West Virginia. It lies on the border between Greene County, Pennsylvania and Monongalia County, West Virginia. It marks the westernmost point of Mason and Dixon's survey reached on October 19, 1767 at Brown's Hill.

This monument is found at a latitude of 39 degrees 43 minutes 16 seconds North and a longitude of 80 degrees 07 minutes 07 seconds West and was listed on the National Register of Historic Places in 1973.

The Middle Point

The decree handed down by the Court of Chancery, Lord Chancellor Phillip Yorke, First Earl of Hardwicke had stated that the southern border of Delaware was to be a line across the Delmarva Peninsula, beginning at Fenwick Island and terminating at Taylor's Island. Furthermore, the west line of Delaware was to be a line running from the midpoint of this transpeninsular line to the point of tangency with the twelve-mile circle around New Castle.

The midpoint of the Transpeninsular Line had been marked with an oak post in 1760 by colonial surveyors prior to Mason and Dixon's arrival to the region.

Four stone monuments are found at the side of the Middle Point. The first monument set in 1760 is made of stone and has the coats-of-arms of both the Calverts and the Penns carved into it. Strangely, this monument was set 32 inches away from the calculated midpoint after the sons of William Penn and Lord Baltimore agreed that the corner would be "69 miles, 289 perches" west of the stone at Fenwick Island Marking the East end of the Transpeninsular Line.

In 1768, Mason and Dixon placed a "Double Crown" stone at the midpoint according to their measurements. This stone bears the Penn coat-of-arms on the north and east sides, and the Calvert coat-of-arms on the south and west sides.

Another marker on the site is the stone that had previously marked Mile #25 on the Transpeninsular Line. It was moved to this location due to being displaced by a road construction project.

There is a fourth stone monument at the site, the origin and purpose of which remains a mystery. A common belief is that it was placed there by a nearby landowner who found the stone and thought it looked like a mile marker stone and placed it next to the other stones.

Today, the stone monuments at the Middle Point are found under a pavilion that was erected on a parcel of donated land in 1961.

The Tangent Stone

The Tangent Stone is located at the intersection of the Tangent Line and Arc Line segments of the border dividing Maryland and Delaware. Mason and Dixon set a granitic gneiss stone at this position in June of 1765 and it was later replaced with a 12-inch by 18-inch granite stone marker set by Lt. Col. J.D. Graham of the United States Corps of Topographical Engineers (USCTE) in 1849. The monument has an "M" carved into the Maryland side and a "D" carved into the Delaware side.

Mason and Dixon had established this position in August of 1764 and confirmed the position in November of the same year.

The Tangent Stone is situated at a latitude of 39 degrees 23 minutes 22 seconds North and a longitude of 47 degrees 28 minutes 24 seconds West.

The Tri-State Point

The Delaware-Maryland-Pennsylvania Tri-State Point is the common point of the northwest corner of Delaware, the northeast corner of Maryland, and the south border of Pennsylvania. Mason and Dixon marked this point with a wood post in 1765, which was replaced by a stone monument in 1849. This monument disappeared and was finally reset by W.C. Hodgkins of the United States Corps of Topographical Engineers (USCTE) in 1892.

This stone is marked with “M” and “P” denoting the initial of the colony on each side. At the time of Mason and Dixon’s survey, Delaware was not yet a separate entity and therefore was not noted on the monument.

The Tri-State Point is found at 39 degrees 43 minutes 20 seconds North latitude and 75 degrees 47 minutes 19 seconds West longitude.

The Fenwick Island Monument

On Fenwick Island at the eastern end of the Transpeninsular Line lies a stone monument bearing on its north face the coat-of-arms of the Penn family and on its south face the coat-of-arms of the Calvert family. The position of this border point was accepted in 1760 and was ratified by King George III in 1769.

This stone marker stands just south of the well-known Fenwick Island Lighthouse. While not actually part of the Mason-Dixon survey, this marker still represents a point of interest and importance relative to the borders which they were employed to survey.

SECTION 5: Methods and Techniques

Astronomy and Surveying

In all the generations in which surveyors have made measurements upon the earth, excepting of course the present generation, the celestial bodies have been used to compute position and direction. Specialized knowledge, painstaking observation, and advanced mathematical skills were all necessary for the surveyors of the past to determine direction and to ascertain positions in terms of latitude and longitude. While modern technology, particularly advent of satellite-based navigation systems, has largely rendered skill in astronomical observation unnecessary to today’s surveyor, it is still worthwhile to at least make a cursory review of the terms and procedures relating to the subject of astronomy as it relates to the surveying field.

As we look to the night sky, millions of stars are visible to us. It is not possible with the naked eye to determine the varying distances that each star is from the earth. While two stars may appear in proximity in the sky, in reality they are likely light years distant from one another. For the sake of celestial observation, it is necessary to consider the stars as they appear on an imaginary spherical sky. This imaginary sphere upon which the stars appear to lie is referred to as the celestial sphere. The center of the earth is considered to be the center of the celestial sphere.

The point on the celestial sphere created by imagining a plumb line directly above the observer is known as the zenith. Likewise, the point on the celestial sphere created by imagining a plumb line directly below the observer is called the nadir. The zenith-nadir line is defined by two points: the center of the earth and the position of the observer.

The celestial horizon (also called the true horizon, the rational horizon, or the geocentric horizon) is defined by the great circle traced upon the celestial sphere by a plane which is perpendicular to the zenith-nadir line, which by definition passes through the center of the earth.

The two points at which the earth's rotational axis intersects the celestial sphere are called the celestial poles. The celestial equator is the great circle of the celestial sphere, the plane of which is perpendicular to the earth's rotational axis. The two celestial poles are considered equidistant from the celestial equator.

The sensible horizon is defined by a circle on the celestial sphere, the plane of which is tangential to the earth at the point of observation and the orientation of which is perpendicular to the earth's axis of rotation.

A vertical circle of the celestial sphere is a great circle passing through both the zenith and the nadir. By definition, it crosses the sensible horizon at right angles. The meridian, or the observer's meridian, of any point is established by the circle passing through the zenith and nadir of the point as well as through both of the terrestrial poles. The prime vertical is the vertical circle which lies at right angles to the meridian and passes through the east and west points of the celestial horizon.

Latitude is defined as the angular distance of any position on the surface of the earth relative to the equator and is measured on the meridian. A position of latitude is noted in terms of degrees and is further identified as being north or south of the equator. Latitude is also defined as the angle between the zenith and the celestial equator. The seldom used co-latitude of a point is defined as the angle between the zenith and the pole and is by definition the angular compliment of the latitude.

Longitude is defined by the angle between a point and the Prime Meridian in Greenwich, England. The Prime Meridian was established arbitrarily but has been adopted universally. The longitude of a point is expressed in terms of degrees (0-180) east or west of the Prime Meridian.

The altitude of a celestial body is expressed as the angle between its position and the horizon, as measured on a vertical circle passing through the body. The co-altitude of a body is the angle between the zenith and the body and is by definition the angular compliment of the altitude. A related term, the azimuth of a body is defined by the angle between the observer's meridian and a vertical circle passing through the body.

The declination of a star is the angle from the equatorial plane, measured along the star's meridian. Declination values range from 0 to 90 degrees and are noted "+" for bodies north of the celestial equator and "-" for bodies south of the celestial equator. Polar distance is the angle between the celestial body, and the nearest celestial pole and is by definition the angular compliment of the declination angle.

The hour circles are the great circles passing through both celestial poles. The hour angle of a celestial body is the angle between the observer's meridian and the declination circle which passes through the body. By convention, the hour angle is always measured westward.

The angular measurement of a point as measured eastward along the celestial equator from the Sun at the March equinox to the hour circle of the point above the earth is known as the right ascension.

Establishing Azimuth by Astronomical Observation

Prior to the advent of GPS, surveyors of ordinary parcels based their bearings upon section monuments, adjoining boundary lines, magnetic north, astronomical observations, a local basis, or an assumed basis. With GPS now readily available, it has become common to use public coordinate systems as a basis of bearing.

There are many ways to define "North" and the professional land surveyor is tasked with selecting the best method for the job at hand.

Magnetic North is defined by the forces of the earth's magnetic field. The locations of the north and south magnetic poles are constantly shifting and therefore the direction of Magnetic North shifts likewise. The compass user must be constantly mindful of the magnetic declination in his or her area as it may affect the needle by several degrees. The reliability of compass readings may be affected by mineral deposits and electromagnetic interference. Ease of use makes magnetic navigation useful in cases where accuracy and repeatability are not of first importance, but for the purposes land surveying magnetic directions are not especially useful.

Assumed North is based upon monumented positions between which a line is constructed and defined as "North" with an azimuth of 0 degrees. This method is convenient for independent surveys, however the monuments defining the bearing may be lost, thereby complicating the work of the future surveyor.

Geodetic North or Geographic North is defined by the average location of the earth's rotational axis. The earth's axis is not perfectly fixed and traces a narrow cone both above and below the equator. While Geodetic North is a precise direction, it is not able to be directly measured and is therefore impractical for use by the surveyor, except in the sense that many reference monuments are tied into the Geodetic basis.

Grid North is based upon any one of many map projection systems and like Geodetic North is not able to be measured directly.

Astronomical North or Celestial North will be the subject of the remainder of this Section. It is based upon the projection of the earth's axis onto the celestial sphere. A true North meridian can be established in the field with conventional equipment, with minor corrections made based on the location of the observer. For the purpose of large surveys, like the Mason-Dixon survey, the use of Astronomical North is the logical method with which to determine direction, as it can be determined from any location where the star Polaris is visible. Also, it is a permanent and consistent system which allows the retracing surveyor to "follow in the footsteps of the original surveyor." Long after the artificial monuments of a survey are lost to history, their original positions will remain in the same relationships to the celestial bodies as they were on the day they were placed.

> *The people of ancient civilizations had clever geometric methods by which to determine direction that required no modern technical equipment and no advanced knowledge of mathematics.*
>
> *One method, known by historians as the "Shadow Method," involves setting a vertical rod into an area of flat ground. Throughout the day at timed intervals, the position of the endpoint of the rod's shadow would be marked on the ground. After marking the procession of the shadow for the day, a rope would be pulled from the center of the rod to the arc of the shadow and used to trace an arc intersecting the shadow's path in two places. A chord would be constructed between the two points of intersection and a line would be drawn from the rod to the midpoint of the chord, thus defining the astronomical meridian. When done with extreme care, this method is considered to be accurate to within about a half of a degree of angle.*
>
> *Another more complex method is known as the "Equal Altitude Method," in which the vertical angle to the sun is measured in mid-morning and then the position of the sun in the mid-afternoon is observed when it is at the same altitude. The bisecting line of the horizontal angle created by these points of equal altitude represents the astronomical meridian through the observer's location. Like the Shadow Method, the Equal Altitude Method, when painstakingly exercised, may yield an accuracy of about a half of a degree of angle.*

Due to the rotation of the earth, the stars at night appear to rotate counterclockwise about the North Pole. This apparent motion of the stars causes their horizontal angle relative to the meridian to change throughout the night. Some definitions are necessary to aid in the explanation of the astronomical determination of azimuth.

Upper Culmination is the highest point of a star on its circle of rotation.

Lower Culmination is the lowest point on a star on its circle of rotation.

Eastern Elongation is the easternmost point of a star on its circle of rotation.

Western Elongation is the westernmost point of a star on its circle of rotation.

Polaris (the North Star) is the most common star used for celestial observation in the northern hemisphere. Polaris is easily located in the night sky and its path traces the smallest circle about the celestial pole of all the visible stars. A star map or a planisphere may be useful for locating stars. Other stars besides Polaris may be used, as was the case for Mason and Dixon who selected nearby Delta Ursae Minoris in the Ursa Minor constellation, because of its larger arc about the pole.

Simply explained, a determination of the meridian line can be achieved by sighting Polaris (or another nearby star) with an angle-reading instrument and making frequent observations of its circular path throughout the night and recording the reading of the horizontal and vertical circle at each time interval. Depending on the season of the year and the latitude of the observer, the period of nocturnal darkness varies dramatically. With the multiple observations, it is possible to then construct the arc traced by the star in the night sky and to determine the eastern elongation and the western elongation thereof. The horizontal circle reading at each elongation is used to determine the horizontal angle between the elongations and the bisecting line beginning at the observation station represents the meridian line, which may be marked on the ground and used as a reference bearing.

As meridian lines converge toward the poles and diverge toward the equator, a meridian line established at a particular observation station becomes inaccurate as the observer sets up either east or west from the original station. On ordinary surveys, this variance would be small to the point of insignificance but on large scale surveys, such as the survey of the West Line, frequent recalibration was necessary.

A working knowledge of basic astronomy was necessary for the surveyors of the past but as with many other things, technology has relegated surveying astronomy to little more than a matter of historical curiosity with little or no practical use. Still, as modern retracement surveyors must review and understand the surveys of old, it is important to at least understand how the surveyors of the past conducted their work.

SECTION 6 – Resurveys of the Mason-Dixon Line

In the lengthy span of time since Mason and Dixon's original survey, many resurveys of portions of the line have been conducted for a variety of purposes. Following is a brief overview of some of the important resurveys.

Lieutenant Colonel James D. Graham of the United State Army Corps of Topographical Engineers conducted a survey from the Tangent Point to the North Line to the northeast corner of the State of Maryland. This survey was conducted in the years 1849 and 1850 and brought renewed attention to the dispute over the Delaware Wedge, culminating with the State of Pennsylvania claiming the Wedge as its own. The Wedge would not officially become part of Delaware until 1921.

In the year 1885, United States Coast and Geodetic Survey surveyor C.H. Sinclair and his assistant C.H. Van Orden set out to resurvey the western extension of the Mason-Dixon line, with the instruction to rerun the line as previously established and to replace any monuments found to be missing. This survey ran from the southwest corner of Pennsylvania to the northwest corner of Maryland.

From 1900 to 1903, an ambitious resurvey of Maryland's northern border with Pennsylvania was led by W.C. Hodgkins of the Office of the United States Coast and Geodetic Survey. This survey was not intended as a correction or relocation of the Mason-Dixon Line, but rather was for the purposes replacing missing monuments, repairing broken monuments, and improving the stability of leaning and sinking monuments. Interestingly, the unused original stone monuments which had been left at Fort Frederick at the end of the original survey were used as replacement monuments for this resurvey. The scope of this resurvey also included the acquisition of topography and the preparation of a topographic map in the vicinity of the boundary line.

SECTION 7 – The Popular Legacy of the Mason-Dixon Line

A quarter of a millennium hence, the Mason-Dixon Line remains prominent in the collective American cultural consciousness. Following is a partial listing of references to the Mason-Dixon Line in American popular culture:

In the 2006 film *Rocky Balboa,* the antagonist is the fictional World Heavyweight Champion boxer, Mason "The Line" Dixon, played by Antonio Tarver. This was the sixth film in the successful *Rocky* franchise.

In 1978's cult-classic *Attack of the Killer Tomatoes,* Mason Dixon heads a federal task force attempting to resolve the titular crisis.

In Jeff Greenfield's novel, *People's Choice,* W. Dixon Mason is a preacher who has a hand in determining the next President of the United States when the president-elect dies after the election but before the formal vote of the Electoral College.

Mason & Dixon is a postmodernist novel by Thomas Pynchon presenting a highly fictionalized account of Mason and Dixon's exploits.

Johnny Cash's 1955 song, "Hey, Porter" contains the lyric, "*How much longer will it be until we cross that Mason-Dixon Line?"*

The 2000 song "Sailing to Philadelphia" by singer/songwriter/guitarist of Dire Straits fame, Mark Knopfler, tells the story of Mason and Dixon travelling to America to conduct their survey.

Singer and satirist Tom Lehrer mentioned the Mason-Dixon line in his song *"I Wanna Go Back to Dixie".*

Country music's Lady Antebellum penned the lyric "*It's just south of the Mason-Dixon Line"* for their song, *"Home Is Where the Heart Is."*

CHRONOLOGY OF EVENTS RELATING TO THE MASON-DIXON LINE SURVEY

Following is a chronological listing of the significant events of importance to the Mason-Dixon Line Survey. Italicized beneath each event are other major events that occurred in the same year to provide a historical context.

1632

Cecilius Calvert, known formally as Second Lord Baltimore, received a Royal Charter from King Charles I of England for what would become the colony of Maryland.

> *The Treaty of Saint-Germain-en-Laye was executed, restoring control of Quebec, which had been captured by the English in 1629, to the French.*
>
> *Galileo Galilei published his famous work,* Dialogue Concerning the Two Chief World Systems*, which compared the heliocentric Copernican System to the traditional geocentric Ptolemaic System.*

1681

William Penn received a Royal Charter from King Charles II of England for what would become the colony of Pennsylvania.

> *The last known dodo bird in the world was killed.*

1728

Charles Mason was born in Gloucestershire, England.

> *Astronomer Royal James Bradley calculated the speed of light using stellar aberration.*
>
> *The Copenhagen Fire of 1728 destroyed nearly a third of the Danish capital city.*

1733

Jeremiah Dixon was born in Cockfield, County Durham, England.

> *The Battle of Kirkuk took place as part of the Ottoman-Persian War and marked a crushing victory for the Persians, inflicting 20,000 casualties upon the Ottoman army.*
>
> *The Molasses Act was passed by the Parliament of Great Britain, which was unpopular with the American colonists.*

1763

Mason and Dixon arrived in Philadelphia to begin their survey of the border separating the lands of the Penns and the Calverts

> *The Treaty of Paris was signed by Great Britain, France, and Spain, formally bringing a close to the Seven Years War, which was, and still is known as the French and Indian War in the American Theatre. As part of the treaty, France ceded Canada to Great Britain.*

The Proclamation of 1763 was issued by King George III of England, prohibiting English settlement in North America west of the Appalachian Mountain range.

<u>1765</u>

Mason and Dixon, having finished their surveys of the twelve-mile arc around New Castle and the Tangent Line, resumed their work on the West Line of the border.

Great Britain passed the Duties in American Colonies Act of 1765, more commonly referred to as the "Stamp Act." This act required the purchase of a stamp to validate legal documents, newspapers, and playing cards. It was the first direct tax levied by the Crown on the American colonies and the revenue was used to defray the expenses of British military activity in North America, particularly the cost of the French and Indian War.

Great Britain caused further dissent in the Colonies with the passage of the Quartering Act, compelling private households to lodge British soldiers whenever necessary.

<u>1768</u>

Mason and Dixon presented their work to the officials of Maryland and Pennsylvania. Their line was accepted and became the recognized border between the two colonies.

The first modern circus was opened in London by Phillip Astley.

The first issue of the Encyclopedia Britannica was published in Edinburgh.

<u>1779</u>

Jeremiah Dixon died in County Durham, England.

The American Revolution was in full swing.

The world's first entirely iron bridge was constructed across the River Severn in Shropshire, England.

A joint Portuguese-Spanish survey of the Amazon basin was begun and would take 16 years to complete.

<u>1786</u>

Charles Mason died in Philadelphia, Pennsylvania.

Columbia College, now Columbia University, held its first commencement exercises with eight students graduating.

Mozart's famous opera, The Marriage of Figaro*, premiered in Vienna.*

The Confederation Congress established the United States Mint to produce a national currency and coinage to replace coins being produced by individual states.

Scottish poet Robert Burns' Address to a Haggis *was published in Edinburgh.*

1787

The Confederation Congress passed the Northwest Ordinance which prohibited slavery in the lands north of the Ohio River which had been acquired from Great Britain at the conclusion of the Revolutionary War.

> *The Constitution of the United States was signed in Philadelphia at the Pennsylvania Statehouse, now known as Independence Hall.*
>
> *Astronomer William Herschel discovered two moons of Uranus: Titania and Oberon.*
>
> *Delaware ratified the Constitution, becoming the first state of the new nation. Pennsylvania and New Jersey followed shortly thereafter.*
>
> *Captain William Bligh set sail from England for Tahiti aboard the HMS Bounty on an ill-fated voyage that would become the subject of a popular book and film.*

1821

Missouri was admitted to the Union as a slave state. The agreement which came to be known as the Missouri Compromise prohibited slavery north of the line of 36 degrees 30 minutes north latitude, and thereby extended the concept of the Mason-Dixon line as a division between the North and the South through the Louisiana Territory.

> *Russian explorer Fabian Gottlieb Thaddeus van Bellingshousen led an expedition that discovered the continent of Antarctica.*
>
> *French Emperor Napoleon Bonaparte died in exile on the Island of Saint Helena.*
>
> *Under the leadership of Simon Bolivar, Venezuela won its independence from Spain.*

1850

Senator Henry Clay proposed a plan by which California would be admitted to the Union as a free state, with the inclusion of the Fugitive Slave Law added as a compromise.

> *Nathaniel Hawthorne's classic novel,* The Scarlet Letter*, was published in Boston.*
>
> *American Express was founded by Henry Wells and William Fargo.*
>
> *Pope Pius IX ended his exile and returned to Rome.*
>
> *Los Angeles and San Francisco were incorporated as cities in the State of California and Kansas City was incorporated as a city in the State of Missouri.*
>
> *The Great Famine, also known as the Irish Potato Famine, subsided after five years of devastation.*

1854

The Kansas-Nebraska Act introduced the concept of popular sovereignty and eliminated the line of 36 degrees 30 minutes north latitude as the effective line dividing free states and slave states.

English author Sir Arthur Conan Doyle first created his fictional detective Sherlock Holmes.

The Republican Party was founded in Wisconsin.

The United States Naval Academy in Annapolis, Maryland graduated its first class.

1858

The Dred Scott decision declared that Congress had no authority to prohibit slavery in any state and had the effect of nullifying the Missouri Compromise.

Felix Mendelssohn's Wedding March *established its place as a popular wedding recessional after it is played at the wedding of Queen Victoria's daughter.*

The first pencil with an attached eraser was patented in the United States by Hymen Lipman.

Abraham Lincoln accepted the Republican Party nomination for a seat in the United States Senate representing Illinois.

Charles Darwin presented his findings announcing a theory of evolution by means of natural selection in London.

The first aerial photograph was made from a moored hot air balloon in France.

Macy's department store opened in New York City.

1860

Upon the election of anti-slavery President Abraham Lincoln, South Carolina announced its intent to secede from the United States of America. Ten other southern states followed South Carolina in secession and the separated states formed the Confederate States of America.

The Pony Express made its first run from St. Joseph, Missouri to Sacramento, California.

Abraham Lincoln defeated Stephen A. Douglas to become the 16th President of the United States.

The first British Open was played at Prestwick Golf Club in Ayrshire, Scotland.

Charles Dickens published the first installment of Great Expectations.

1861

The Civil War began with the attack on Fort Sumter off the coast of South Carolina.

President-elect Abraham Lincoln avoided an assassination attempt in Baltimore.

Martin Doyle was executed in Great Britain in what would be the last execution carried out in that country.

The Pony Express made its final run.

<u>1862</u>

Confederate General Robert E. Lee invaded Maryland and suffered a costly defeat at the Battle of Antietam.

Julia Ward Howe's Battle Hymn *of the Republic was published in the Atlantic Monthly.*

Victor Hugo's novel Les Miserables *was published.*

The Homestead Act is signed into law by President Lincoln.

The Bureau of Internal Revenue, which would evolve into the Internal Revenue Service was established.

<u>1863</u>

General Lee crossed the Mason-Dixon Line into Pennsylvania and was defeated by Union forces at the pivotal Battle of Gettysburg. This battle turned the momentum of the war to the favor of the Union.

President Lincoln signed the Emancipation Proclamation, confirming the abolition of slavery in Confederate states to be an official goal of the war effort.

Ground was broken in Sacramento for the construction of the first Transcontinental Railroad in the United States.

The first fire extinguisher was patented by Alanson Crane of Virginia.

President Lincoln proclaimed a national Thanksgiving Day to be celebrated on the final Thursday in November.

Linoleum was patented in the United Kingdom.

<u>1865</u>

The Civil War ended as General Lee surrendered to Union General Ulysses S. Grant at Appomattox Courthouse in Virginia, thus closing what still remains the deadliest war in American history. On April 16, 1865, President Lincoln was assassinated by John Wilkes Booth.

The New York Stock Exchange opened its first permanent headquarters in Manhattan.

Scientist Gregor Mendel presented his groundbreaking paper, Experiments on Plant Hybridization*, at the meeting of the Natural History Society in Moravia.*

John Deere received a patent for his revolutionary plow design.

Electric equipment brand Nokia was founded in Tampere, Finland.

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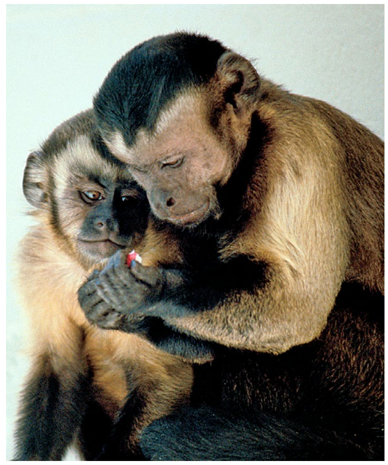

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SPEAKING OF OLDER BUILDINGS – Final Exam

Questions on pages 3 – 4

1. Ⓐ Ⓑ Ⓒ Ⓓ	5. Ⓐ Ⓑ Ⓒ Ⓓ	9. Ⓐ Ⓑ Ⓒ Ⓓ	13. Ⓐ Ⓑ Ⓒ Ⓓ	17. Ⓐ Ⓑ Ⓒ Ⓓ
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ARCHITECTURE FOR DISASTER RELIEF – Final Exam

Questions on pages 39 – 41

1. Ⓐ Ⓑ Ⓒ Ⓓ	6. Ⓐ Ⓑ Ⓒ Ⓓ	11. Ⓐ Ⓑ Ⓒ Ⓓ	16. Ⓐ Ⓑ Ⓒ Ⓓ	21. Ⓐ Ⓑ Ⓒ Ⓓ
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ACCESSIBLE RESTROOM DESIGN – Final Exam

Questions on pages 89 – 91

1. Ⓐ Ⓑ Ⓒ Ⓓ	5. Ⓐ Ⓑ Ⓒ Ⓓ	9. Ⓐ Ⓑ Ⓒ Ⓓ	13. Ⓐ Ⓑ Ⓒ Ⓓ	17. Ⓐ Ⓑ Ⓒ Ⓓ
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BLAST RESISTANT DESIGN – Final Exam

Questions on pages 109 – 111

1. Ⓐ Ⓑ Ⓒ Ⓓ	6. Ⓐ Ⓑ Ⓒ Ⓓ	11. Ⓐ Ⓑ Ⓒ Ⓓ	16. Ⓐ Ⓑ Ⓒ Ⓓ	21. Ⓐ Ⓑ Ⓒ Ⓓ
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SPEAKING OF OLDER BUILDINGS FINAL EXAM

1. **Decisions about what to preserve and what to demolish get much more complicated when ___________ was a previous choice for another owner.**
   a. Demolishing the entire structure
   b. Historic preservation
   c. Using the building for hospitality
   d. Obtaining a rezoning

2. **When determining costs to appease regulatory agencies, ____________ can be realized just by crossing lines between regulatory jurisdictions.**
   a. Better material pricing
   b. Significant savings
   c. Lower costs for comparable square footage
   d. More potential lessees

3. **_____________ is of primary concern when assessing flooring in existing buildings.**
   a. Infestation of finish materials
   b. The presence of antiquated patterns
   c. Solid wood parquet flooring
   d. Flooring on the lowest level

4. **Which of the following is NOT a predicator of the potential success of urban revitalization efforts?**
   a. An extensive police presence
   b. Heavy pedestrian activity
   c. Benches
   d. Nearby parks

5. **Unforeseen conditions that can be uncovered during demolition include ___________.**
   a. Insect infestations
   b. Water leaks
   c. Damages to wiring
   d. All of the above

6. **Another possibility before demolishing an older structure, simply because it does not fit the new use we have in mind for the site, is to _______________ .**
   a. Donate the building for use to be burned as training for firemen
   b. Move the existing structure to another site
   c. Demolish it and use the materials to raise the level of a lower property nearby
   d. Sell the building for a slight profit and move on

7. **The ___________ is the national agency that determines whether a building is worthy to be considered 'historic.'**
   a. North American Buildings Survey
   b. Bureau of Restorations and Renovations
   c. National Register of Historic Places
   d. Heritage Foundation

8. **One older structure that has become a symbol of national pride is the ____________ .**
   a. Public Shipyards of Great Britain
   b. Great Barrier Reef of Australia
   c. Great Wall of China
   d. Archipelagos of Paris

9. **Adaptive reuse was prevalent in earlier times because new building materials were difficult to acquire and _________________ was prohibitively expensive.**
   a. Finding Old World artisans
   b. Transporting them for any distance
   c. Obtaining building permits from newly formed governments
   d. Arranging guards for caravans

10. Many historic structures, because they occupied central positions in their cities, are in what are now ____________ .

a. Redevelopment districts

b. Inner city traffic loops

c. Centers of urban decay

d. Downtowns

11. The most sustainable buildings are _____________ buildings.

a. Those built with green roofs

b. Low rise residential flats

c. Those with reflective curtain walls

d. Existing

12. Which of the following is NOT an advantage realized by the shorter time involved in a project involving adaptive reuse, instead of demolishing and rebuilding?

a. Less carrying costs on construction loans

b. Misreading the market by eliminating adequate market research

c. Quicker cash flow from income on the property

d. A quicker turn around for cities seeking revitalization

13. The first difficult decision to be faced in adaptive reuse projects will be ______ .

a. Finding a patient, but innovative lender

b. Successfully choosing the new purpose for the structure

c. Finding renters before the first work is done

d. Deciding how to placate angry neighborhood protestors

14. Which of the following may be difficult to meet in current codes, zoning requirements and development regulations?

a. Energy codes

b. Handicap codes

c. Fire suppression requirements

d. All of the above

15. When a building is purchased as an investment, then decisions regarding adaptive reuse are driven by a desire for ___________ .

a. Community esteem

b. Short-term profits

c. Life-cycle benefits

d. Security for lessees

16. A ____________ is one agreement between building owners and architects that can ease the initial costs of exploring proposed renovations.

a. Two Part Contract

b. Predesign No-Lien Waiver

c. Cost-plus Fee Contract

d. Delayed Payment Waiver

17. Which of the following resources is NOT conserved by adaptive reuse projects?

a. Water

b. Energy

c. Raw materials

d. Labor

18. In one means of recycling, companies exist that salvage and store _________________ for reuse.

a. Recyclable metal structural members.

b. Historic components such as detailing, trim and ornamentation

c. Landscaping that would have been lost during demolition

d. Components of existing utilities existing on site

INTRODUCTION

When the question of what to do with older buildings arises, it usually resolves itself to choices of reusing them as is, repairing them, restoring them, repurposing them or replacing them. This presentation will examine criteria that may prove valuable in determining which of these options represents the best value for the owner, the buyer or the community in which the structure is located. It will also briefly examine a potential business opportunity in a collaboration between architects and commercial real estate agents.

There is an old saying regarding existing buildings that goes like this. "It has good bones." Any facility, free of structural defects and doing a reasonably good job of keeping water out, represents a tangible asset. The trick to maximizing the value of existing structures, especially in areas where changing economic factors have also resulted in changing market demands, is to approach their reuse from a different point of view. The judicious employment of renovation funds should not be based on restoring them to a previous use but making them suitable for other markets in which the existing bones might enable a whole new purpose.

Public sentiment often regards older buildings as historic treasures for the community. In many ways they are, but in many other ways, preserving them can become a nightmare for owners and designers. There are types of research, decisions and considerations that will make it easier to decide what to preserve and what to demolish. Those decisions can be much more complicated when historic preservation was a previous choice for another owner, or if restoring the building to a previous condition becomes added to the list of project goals.

Empty buildings became abandoned for a variety of reasons. Their previous purpose became no longer viable as conditions changed around them. One example of this would be a very old central neighborhood church that is now bordered on one side by a shopping center and on the other three sides by highways. No one is walking to that church anymore. Buildings also become unsuitable because their spatial configuration no longer fits the way original tenants lived or worked. It's unusual to find old buildings that accommodate open office designs. Some older structures simply can't be retrofitted for new technology like routers, manifold plumbing or fire suppression systems. Some buildings, like grist mills, cease to be useful because there is no more need for their original uses. With so many potential reasons for their earlier abandonment, adaptive reuse is a very viable option for preserving these community resources.

Unless it has been contaminated by hazardous waste, land in a community will always have an intrinsic value, regardless of what structure sits upon it. Therefore, reusing older buildings, in all fairness to both clients and communities, should be approached by considering each of the possibilities. Should they be reused as is, repaired, restored to former glory, repurposed for another use or just demolished and replaced?

In the discussions that follow, emphasis is placed on what options are the most attractive, or can be made desirable, to investors and developers. The reasoning behind this is simple; the private business sector has historically been far more successful at moving projects forward than government entities. Moreover, given the cost involved in these projects, there is only so much tax money available to accomplish them. Actual businessmen need to become involved as investors.

ASSESSING OPTIONS

AN OVERVIEW

Choosing the highest and best use for an existing building requires research into the physical condition of what exists, and the market conditions for what it could become.

Before any decision can be made regarding an existing building's final disposition, a thorough inspection of the facility must be made. This inspection should be dispassionate, carried out by someone with no financial or vested interest in the disposition of the building or any repairs that might need to be made.

A proper inspection should include all building systems and components. It should include research into the age of such components, as well as any records of maintenance done in the past. The report should indicate where repairs or replacements will need to be made now, or in the near future. Costs for needed repairs and replacements should be competently estimated and those costs then added to the cost to acquire the building.

At the end of this presentation, it is recommended that a matrix be developed to identify the optimum future uses for the building. If the use or occupancy classification of the building will change, bringing the building into compliance with current code regulations for that new occupancy will almost certainly be required. The cost to make such changes should be estimated and those costs then added to the cost to acquire the building.

Not all potential costs will be mandated. Some changes may be desired, just to give the building a newer, more updated or fresher look. Those estimated costs should also be added to the cost to acquire the building. If permits must be acquired to accomplish required repairs, replacements or code changes, the costs of such permits should be added to the purchase price of the facility. This may include the costs of multiple fees or of meeting requirements or restrictions placed on the project, just because regulatory agencies have the power to do so.

Some investigation should be made into of all the stipulations that will need to be jumped through before the property under consideration can be used for its intended purpose. If requirements in a regulatory environment are too onerous, some investigation should be done into surrounding areas with less governmental oversight, or more interest in aiding development or business endeavors. Significant savings can be realized just by crossing lines between regulatory jurisdictions.

Having a good idea of all costs involved in reuse or adaptation of an existing structure will go a long way toward determining the feasibility of intended reuse.

In addition to estimating costs, all parameters affecting the feasibility of a project should be considered in a holistic fashion, before determining how to proceed with the repair, restoration, repurposing or removal of an older building.

REGULATORY ISSUES HAVING AN IMPACT ON PROCEEDING

Projects are no longer done in a vacuum and without oversight by regulatory agencies. Enforceable regulations will matter to the success of the project and should be ascertained beforehand.

Some agencies have control over historic restorations or districts created for urban revitalization. Historic overlay or development districts may in place in the zoning for the site. Are any Main Street or other redevelopment funds in place that might be applicable to the project? If so, what restrictions accompany such funding? There are typically restrictions that accompany grant dollars given to building owners for restoration to buildings with historic significance. These restrictions, which constrain future allowable building changes, are often in place for the remaining life of the structure

Building codes often contain sections or clauses with less stringent requirements for both reuse and renovation to existing buildings, or for renovations to buildings of historic significance. These exemptions tend to be in the subject areas of handicap accessibility and required fire protection. The existence of such exemptions or special codes is certainly worth investigating, before deciding that code mandates will make the reuse or adaptation of an exiting structure unaffordable.

Some rules rise from past use of the structure. Verify with local agencies that there was never any condemnation of all or part of the structure, and no deficiencies were noted during past inspections that must be addressed prior to reuse. Interviewing long time neighbors to the structure can yield surprising information regarding past occupants, including information on potential soil contamination, use of hazardous materials or destructive insect infestation needing to be addressed. Expensive special hazardous cleanup or removal of hazardous finishes (asbestos pipe insulation, lead paint, asbestos flooring, etc.) may become necessary. Proper disposal of such materials is also costly.

If changes will be needed to reuse a building for the same occupancy, it is advisable to place a call to regulatory agencies from whom approval for reuse plans will be needed. They will likely be willing to discuss the degree and type of changes they would like to see, prior to issuing approval. Involve these agencies early to determine how they will view reuse of the building, especially for a different occupancy. What inspections will permitting agencies require? For that matter, what inspections or building changes will the agency providing project funding require?

It will also be useful in determining optional uses for an existing building and site, to obtain an estimate for complete removal of the existing structure and foundations, and restoration of the site back to its original (sort of) condition for reuse of the land. Knowing the value of an empty site, available for reuse in that location and zoning district, will be useful in making decisions regarding reuse. Understanding the real potential for reuse of the existing site will require some research into restrictions created by the existing zoning, in areas like setbacks, landscaping buffers, parking, traffic control, etc.

A BUILDING'S VALUE TO A COMMUNITY

There is some intrinsic value in acquiring a building with either cultural, community, personal or historic significance. It is difficult though, to place a value on such things that can be plugged into an equation to determine whether repair, reuse or replacement is the best option.

A place may represent a fond memory in the hearts of many members of the community. If the proposed building use is similar to what was in place in the structure in the past, others may utilize the services or goods provided in the building simply from nostalgia. If there is no similarity between past and proposed use, there still may be some loyalty and gratitude engendered by the decision to reuse the familiar structure, rather than demolishing it.

There may also be some personal value attached to an existing building. It may be where parents first met one another, or where one or both worked to provide a living for the family.

On a societal level, buildings may be significant in the history of a city. If such is the case, local regulatory agencies may be more inclined to help than hinder in its restoration and reuse, in lieu of seeing the structure demolished.

Deciding to restore older buildings may involve input and/or cooperation from the rest of society. Sometimes communities make the decision as a whole, whether to rebuild or remove. If a structure is deemed unsafe for use, it is condemned and slated for destruction. If an area is being revitalized with common elements creating a theme, a building's architectural style simply may not fit the final scheme being implemented. A fresh look and a new beginning may be planned for the area. The existing building may also just be in the way of the final plan for redevelopment. The estimated costs to historically restore, and afterwards maintain, the structure may simply be out of the budget.

A BUILDING'S VALUE TO THE INVESTOR

Understanding that the value of real estate depends as much on market conditions as it does upon the tangible asset, the investor or developer should be asking, prior to considering renovations to and restoration of an existing building. If I were to spend enough money to completely restore this, what would it actually be worth afterwards? Why was deterioration allowed to occur in the first place? Are the utilities to the area sufficient? Are there enough amenities or attractions nearby to make this location desirable? Are there flood plain issues? Is the neighborhood in general, improving or deteriorating? Are there problems with rising crime rates? What type of competition is out there in the market?

This assessment of the potential return must be done because investors whose initial investment and repair costs total more than the building's resulting worth, are probably not investors who will be around for the next project.

ASSESSMENT OF THE BUILDING CONDITION

It would be difficult to make an objective determination of the feasibility of building reuse, without first making an objective assessment of the condition of the existing facility. What systems and components will need to be modified, repaired or replaced to allow further use of the structure for more current purposes? Such inspections are not cheap, but they are less expensive than obtaining an aged structure for reuse, only to find the expense in the purchase and needed renovations cannot be recouped by market rental income. Inspections are also far cheaper than life or property lost, should an existing or deteriorating structural system collapse under the load of a new occupancy use.

Thorough building assessments need to be conducted by professionals. Some of the critical parts of a building needing evaluated are its structural integrity, roofing, masonry, plaster, wood-work, tiling, mechanical, electrical and plumbing systems. A building that was well built, but subjected to abandonment and subsequent decay, can continue to deteriorate in the foreseeable future, creating issues for new users. An inspection can pinpoint areas in which proper or ongoing maintenance might forestall more extensive repairs in the future. A detailed report is typically the product resulting from a thorough building assessment.

Assessment of Foundations

Two primary concerns are addressed in an assessment of existing foundations, crawlspaces and basements. An obvious safety issue is whether deterioration or settlement of these bearing components is occurring and if so, what must be done to repair and stabilize them? The second question is one of engineering. Will the existing systems be capable of supporting expected loads that would be imposed upon them in the intended use of the renovated building? Will additional fireproofing be required by new codes to protect the floor above from the basement or crawl space? In making such assessments, appropriate surveying equipment should be used to determine characteristics like square and level, rather than relying on the naked eye.

Assessment of Structural Systems

Simply put, as critical as it will be to the future safety of the occupants, this assessment should be made by a structural engineer. Future live and dead loads must be considered. If building plans exist, they should be made available to the engineer to use in conjunction with an on-site inspection. In the reverse of what occurs when inspections are made during construction, finishes made need to be removed to properly check structural systems behind them. Wood should be inspected for rot or infestation by insects. Metal should be inspected for any sign of extensive corrosion. All connections should be inspected to ensure they are not loose or have not, of themselves, caused failure at joints.

Assessment of the Floor System

Usually the floor systems of older buildings are strong enough to support current loading requirements. If not, it may become necessary to install new support beams to shorten spans. If so, understand that columns to support those beams must be extended down to points or pads where adequate load bearing can be obtained. Small areas of floors may also need to be opened and reframed, to create openings for new system, stairway or elevator chases.

Assessment of Exterior Walls

The outside walls should be carefully inspected, especially in the face of any evidence that water infiltration has occurred. Points of leakage should be found and sealed, along with an assessment made of why that infiltration occurred. Also identified should be points where additional openings can easily be made for more doors, windows and additional duct penetrations, if needed.

Assessment of MEP Systems

Needed improvements to these systems will likely constitute a large part of an adaptive reuse budget. Older structures tend to lack modern and energy efficient system components and appliances.

The existing HVAC system (assuming air conditioning is in place) will need to be assessed for its expected remaining life, as well as its capacity for occupants in the proposed reuse. More often than not, systems of significant age will need replaced. Sometimes the old units and their piping can be salvaged and sold for scrap. A primary concern will be spaces through which to run new ductwork or hydronic piping as needed. Ceiling space must be high enough to accommodate new ducts, when installing new air conditioning. Through-wall units can also be installed in lieu of central systems.

Existing ways to move air should be assessed. At the very least, ducts should be examined for any blockages, deterioration or leakages. Existing bathrooms and kitchens may or may not be vented, a desirable thing to accomplish for future use and often also required by code officials. In that case, ceilings must be high enough to accommodate fans and ducts to the exterior or to a common exhaust stack.

Old galvanized piping commonly used in the past for plumbing, tends to deteriorate over the years. It may need to be uncovered and replaced. Sewer connections going out of the building should be checked to ensure they are still watertight.

Electrical systems are a very common concern. In the unlikely event that wiring is up to current standards, the panels, junction boxes and feeders may still not meet present code requirements. It is likely that incoming services will need upsized and new transformer vaults and feeder lines may additionally need installed.

Assessing Stairs and Exits

Necessary locations and numbers of stairways needed for legal egress will be determined by current life safety codes. A designer will need to determine the best way to integrate existing stairways into a plan that meets those obligations. Additional loading imposed on the existing structure, by constructing new stairways, must be thought out carefully.

Assessing Energy Use

Utility costs will be of prime concern to potential lessees. Determining existing efficiency is best done by hiring a professional to conduct an extensive energy audit, but few are willing to purchase that. Simple ideas that could improve efficiency include; replacing appliances with those rated by Energy Star, adding insulation to the exterior building shell, replacing existing doors and windows with efficient units with insulated and efficient glazing as well as thermally broken frames, maximizing natural ventilation by utilizing chimney effects, using daylighting where possible and replacing light fixtures and lamps with energy efficient choices. Doing this last item will also free up some capacity on existing circuits.

Assessing the Building Envelope

The best way to minimize energy use by a building's HVAC systems is to ensure that the exterior building envelope is as efficient as it can be, without spending extraordinary amounts of money in renovations to accomplish that. As mentioned earlier, efficient doors and windows are an excellent beginning point. Also on the list are energy recovery ventilators, caulking or weatherstripping every gap that can be found, adding insulation and / or vapor barriers in the correct position on exterior walls and ceiling to roof assemblies, adding exterior façade materials to reflect or absorb solar heat gain as needed, and even exterior plantings to shade nearby paving, windows with large areas of glazing or selectively shade the building from western and southern solar exposure. Storm windows are an easy way to increase the efficiency of windows at a fraction of the cost of replacement.

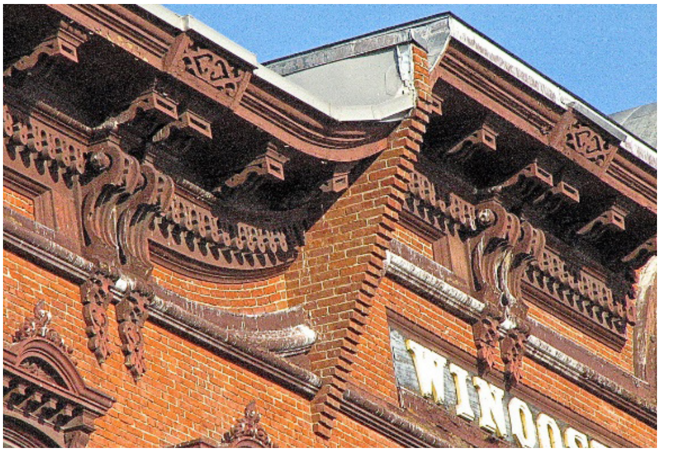
Assessing the Roof

Roofing systems generally include all the components of the building 'cap.' This incudes roof, curbs, parapets, cornices and copings. Joints, caulking, cant strips, etc. must all be inspected. If masonry was used for parapets, as is often the case in older structures, repointing of the brick, stone or block may be needed. If coping allowed water intrusion behind a face wythe of masonry, and ice accumulation has been pushing the veneer outward, more significant reconstruction may be needed before repairing the coping. The roof inspection should also include looking for signs of leakage on ceilings below the roof, then ascertaining where and how water is infiltrating through the roof.

A poorly performing roof is a huge source of energy loss in both heating and cooling seasons. Insulation can be added to improve this. Dead air space, created in attics or between ceilings and the roof structure, can help. If the roof must be replaced for purposes of weathertightness, investigate the use of 'cool' roofing materials appropriate for the slope of the roof.

Assessing the Flooring

Flooring on the lowest level is the primary area of concern in this type of assessment. If the floor is over a basement or a crawl space, insulation added below it will improve energy use by the building. If the floor is over a slab built on grade, not much can be done. The hope would be that insulation was originally installed around the perimeter of the slab, but that would be unusual to find in older buildings.



Assessing any Reusable Parts

In some cases, it may be possible to restore more historic parts of a structure by carefully sequencing demolition in other areas. In this approach, ornamentation and significant components are removed from more private areas of the building, including from inside of storage areas and from parts of the building that will be demolished before restoring the bulk of the building. These removed components are restored, refinished and then set aside. They are reused as needed in parts of the building that will be more visible with tenant and public use.

ASSESSMENT OF THE NEIGHBORHOOD CONDITION

A thorough assessment of the neighborhood in which a potential asset sits, can help determine whether money spent on acquisition and renovations represents a good investment. This would include a visual inspection of a neighborhood and studying zoning maps of the site in question, and those near the target property. Buildings can be purchased relatively inexpensively in decaying neighborhoods where there are incidents of vandalism. If an adaptive reuse project could stabilize that locale by creating community pride, creating such an upward trend might result in lucrative rental opportunities for nearby owners and occupants. In which case, purchasing multiple contiguous buildings might be a better strategy.

Other predicators of the potential success of urban revitalization efforts include; the presence of sidewalks, heavy pedestrian activity, benches, nearby parks, street lights and other businesses nearby that are busy and open for extended hours. A final step in neighborhood assessment is research to identify nearby amenities. Are there good roads, places to shop and eat, schools, libraries, medical facilities or stops for public transportation?

ASSESSMENT OF FINANCES

The building and neighborhood assessments help determine the up-front costs of investing in an adaptive reuse project. The back side of those considerations is a reasonable estimate of how much income can be expected from leasing out space in the completed structure. With upfront costs determined and potential rental in mind, a return on investment can be calculated. If the work can be done in parts, with portions of the structure rented out early while work continues in other portions, so much the better for the project cash flow. Such numbers can then be presented to sources of financing, like banks, foundations and even Real Estate Investment Trusts (REITs).

REVIEW QUESTIONS

1. **Unless it has been _____________, land in a community will always have an intrinsic value.**
   a. Contaminated by hazardous waste
   b. Obtained under fraudulent means
   c. Used previously for illegal activities
   d. Ceded as part of a previous lawsuit

2. **Thorough inspections of existing buildings should be made by someone ____________, before a decision is made regarding the building's final disposition.**
   a. Who has not participated in projects nearby
   b. Who has participated in the renovation of a nearby building
   c. Currently serving on the zoning commission controlling use of the property
   d. With no financial or vested interest in the building or repairs

3. **Knowing the value of ___________, available for reuse in that location and zoning district, will be useful in making decisions.**
   a. A gutted building shell
   b. Already permitted signage
   c. An empty site
   d. Neighboring complimentary businesses

4. **When assessing floor systems, those of older buildings ______________ strong enough to support current loading requirements.**
   a. Are almost never
   b. Are usually
   c. Are assumed to be
   d. Are accepted by most codes as

5. **Ornamentation and significant components can sometimes be removed from _________ areas of a building and reused in more ________ areas.**
   a. Private, visible
   b. Service, commercial
   c. Exterior, interior
   d. Public, rentable

REUSE

Such thorough research into the possible return on investment for a property of interest might yield a simple truth. The cleanest way to invest in an existing structure is to acquire it before additional or any significant deterioration occurs. Then reuse the building for the same business occupancy and purpose as it was used by the most recent tenant(s). Direct reuse for the same purpose is distinguished here from that further described as adaptive reuse, which involves changing the occupancy of the structure. How easy just continuing the previous use of the building will be, will depend on how long a building has been vacant. If some time has elapsed, cleanup of the grounds and exterior might be a practical investment to make the structure more attractive to potential tenants. In a similar fashion, freshening some of the interior finishes might also increase marketability. But the core idea of direct reuse is to avoid all issues with regulatory and special interest groups by simply continuing the old use of the building, purchasing it, cleaning it up a bit and leasing it back out to another tenant.

REPAIR

Historical significance aside, when is it better to renovate an existing structure than just demolish it and build another in its place?

Whether a building can be repaired is not the only question. It should also be asked whether the structure should be repaired, or would it be cheaper to demolish it and rebuild similar space on the site. Other factors include whether upgrades should be made during the rebuild process and whether the previous building had historical significance. At the end of the entire process, insurance companies will also have major input on whether they wish to finance a restoration, or a removal followed by a rebuild.

If a building under consideration was made unusable because of damage from flooding, from wind or from fire, a decision as to whether to rebuild or to demolish must be made with consideration for the safety of occupants in the renovated facility. This requires evaluation of the damaged building by a registered professional to determine the extent of repairs needed to ensure that safety. Local regulatory agencies also have input into whether a building can be reutilized. They may require an inspection from a licensed professional before making their decision.

The cost to refurbish an existing building depends on the scale of its prior deterioration and should be estimated before any more decisions are made. Perhaps the walls are sound and the primary problem with usability is a deterioration of existing timber trusses and the roof over them. Replacing those structural pieces would not be an easy task and would require investigative engineering beforehand regarding support for the new members. Nonetheless, an entire new roof structure and covering would surely cost much less than replacing an entire building. When considering costs of repair or demolition, keep in mind there are also expenses involved in taking down a structure, protecting the public during that process and properly disposing of the generated waste materials. Some of those may be considered hazardous waste.

In many cases, there are ways to support existing structural systems without removing and replacing them. In the aforementioned example, new roof framing members could always be placed alongside existing members, so long as there was a way to get them up and into place and on adequate bearing. Deteriorating foundations can have forms placed alongside and new concrete foundations poured against them. There is an old saying, “Where there is a will, there is a way.” Many easier solutions to building repair are conceivable, but there must first be a desire to find a good solution.

In every case, when considering repair versus replacement, it’s a very good idea to ascertain the building was never designated as a historic structure and never received grant money for restoration.

Otherwise, structural or even cosmetic changes, made without prior approval, can lead to time in court and the paying of penalties. In most cases, with older structures that are not obvious period pieces, this is not a problem.

In a case study of a deteriorating masonry building, a survey is made of what is existing. The report states the following problems exist; there is excessive moisture inside, but the structure itself is safe. Finishes need replaced and a moderate amount of substrate for wall finishes must be replaced to make rooms and corridors again usable. The outside masonry needs to be repointed and for purposes of energy efficiency, new windows should be installed. Should you be the building owner and intend to reuse the structure as an office building, it would be safe to say the cost of refurbishing the facility would be far less than the cost of demolition and rebuilding the same square footage from scratch.

CONSIDERATIONS PRIOR TO REPAIR / RENOVATION

The following considerations should be made before acquiring and deciding the best use for an older target property.

It is hard to accurately estimate expenses involved in this option. Costs to repair and renovate are just about guaranteed to escalate once work has begun and unforeseen conditions are uncovered during demolition. That is when leaks, insect infestations, damage to wiring and other ravages of time are uncovered. Deterioration due to water damage can cause mold and rot, destroy the integrity of framing, undermine foundations and so forth. Given its extensive and pervasive influence, water intrusion is a primary culprit of unexpected and costly repairs. An inspection beforehand can help identify some of these issues, but is not likely to catch them all.

Updating older buildings tends to involve overcoming some typical challenges. If an open plan with lots of natural light and flexible space is an end goal, that is often not terribly feasible in older buildings with many columns, bearing walls space carving up space into small rooms and having small windows. Since most were erected under less restrictive building codes than those currently enforced, restoring buildings may require meeting current life safety, energy and systems codes. Especially if the occupancy use of the building is expected to change.

It may be necessary to resubmit proposed changes and repairs to damaged buildings for zoning and planning approvals. The need for this is often predicated on the extent of the repairs as compared to the value of the structure. Again, this is especially true if the occupancy use of the building is expected to change.

Help for owners may be available for renovation projects. If renovations are substantial and the building is either considered historic or in a historic district, tax credits might apply. Some communities deliberately encourage renovation over demolition, by making it easier and cheaper to obtain the necessary permits for the work. Leaving part of the structure or foundation in place and adding to it, may also facilitate bypassing some regulatory hurdles. Building materials can be carefully removed prior to final demolition and donated for sale elsewhere (for tax deductions) or recycled for environmental benefits. Such phased demolition does add to the time needed to complete the work. Existing buildings being renovated can be LEED certified after three months of occupancy following renovations. If renovations can be properly phased, it may be possible to occupy already renovated parts of the structure during later phases, bringing income into the monetary stream to offset costs.

Consider another possibility before demolishing an older structure, simply because it does not fit the new use we have in mind for the site. Let's assume that the existing building is structurally sound and would have value elsewhere. Assume as well, that another empty site can be acquired nearby and a nearly open path lies between the existing building and the potential new site. It may well be possible to have a new foundation built on the new site and have the existing building moved to a new location. It can then be sold in that new location or donated to a not-for-profit, who would then pay for the new site and foundation, as well as making a handsome tax write-off possible for the donation of the building. Using this option would have also saved most of the costs of demolition and debris disposal.

Finally, remember to factor into the budget, possible increases in material costs. During certain seasons, like those in which lumber producing areas are prone to fires or coastal areas are subject to hurricanes, there is always a chance that natural disasters will create shortages and drive prices up further.

REVIEW QUESTIONS

6. ___________ will also have major input on whether they wish to finance a restoration, or a removal followed by a rebuild.

a. Neighborhood associations

b. Institutions holding funds in trust

c. Potential heirs of the developer

d. Insurance companies

7. It may be necessary to submit proposed changes and repairs to damaged buildings for zoning and planning approvals, if the ________ is expected to change.

a. Business name

b. Occupancy use

c. Exterior color scheme

d. Perimeter drainage

8. Material prices can be driven up by ___________ .

a. The rising costs of mortgage loans

b. Increasing scarcity of building sites

c. Onerous legislation by regulatory agencies

d. Natural disasters creating shortages

RESTORE

WHAT DETERMINES 'HISTORIC?'

There is a difference between buildings that are historic and buildings that are simply old. Old buildings are just ones which have been around for a while. Speaking in general terms, a building considered 'historic' is one that is at least fifty years old and somehow significant to the community, state or country. The National Register of Historic Places (NRHP) is a national entity that determines whether a building is worthy to be considered 'historic.' This designation is usually made on behalf of private individuals/organizations, local governments or tribal entities, requesting that designation. NHRP then conducts research to determine qualification as such, which if granted, will offer the building some level of protection from future demolition.

Historic preservation seeks to "sustain the existing form, integrity and materials of an historic property. New exterior additions are not within the scope of this treatment; however, the limited and sensitive upgrading of mechanical, electrical, and plumbing systems and other code-required work to make properties functional is appropriate within a preservation project." (Source: Technical Preservation Services of the American Park Service).

CULTURAL SIGNIFICANCE

Should old buildings, considered to be of historic value, continue to be protected or be demolished and replaced by structures of more economic benefit to society? Should history stand in the way of progress? This entire discussion leads to interesting questions about the value to society of reminders of our past.

These questions are of course predicted on the historical buildings actually being an impediment to progress. In a simpler phrasing, for progress to continue, must another building be built on exactly that site or can a new structure be located nearby and still serve the same purpose? An honest answer to that question might eliminate the most common answer to the reason behind a wish to demolish. It may also be driven by a need to eliminate expensive yearly maintenance costs, wanting to create a better income producer for land in a prime location or a lack of interest in continuing to deal with historic foundations, committees, tourism bureaus and so forth.

In deciding the value of preservation over progress, two questions rise to the top. How important to society (assuming they will contribute to their upkeep) is maintaining old buildings and should we really value history over progress, if they are truly in conflict.

I want to play devil's advocate for just a moment. I have seen many movements and organized efforts in my lifetime, where well-meaning community members bring people together to "save" a building of importance to a community, rather than having it demolished. They literally take the position that since a building holds memories for so many others, the owners have some obligation to maintain it as it used to be, paying out-of-pocket to do so, for the good of the community. Here is an idea. If the building is that important to the community, let the public or at least that organized committee, purchase the building from the owner, pay to restore and maintain it and open it as a nostalgia museum. A lot of people have really good ideas they wish to see implemented, so long as someone else pays for their vision.

If we are to keep historic structures, then maintaining them becomes important as well. At the point where maintenance ceases, expensive and extensive deterioration begins. We wish to keep older buildings, because as usable structures, they have an intrinsic economic value. We wish to keep them because have cultural and historic significance. They may have had an important function or played a pivotal role in an event of national significance.

Older structures may even be symbols of national pride. Take the Great Wall of China as an example. It is undoubtably expensive and difficult to maintain. But it was built by slaves under severe weather conditions during the rule of an Emperor. It stands as a monument to human perseverance and the desire for protection during a period of historic trouble. Given the desire of pretty much every tourist coming to China to visit The Great Wall, it is also of huge economic value to China. The wall also instills a sense of pride in the people of China, as a tangible example of their long-lasting history. It is doubtful whether many citizens of China would agree, that the Great Wall of China should be demolished to make room for modern buildings. Maintaining that old, historic structure is important to them.

People who consider themselves historic preservationists are typically opposed to demolishing historic buildings. They are willing to form groups to 'save' such structures when they learn their demolition is under consideration. Many historians argue for the preservation of these properties, regardless of how long it has been since their last use, or the state of their current condition.

Others argue differently. Newer buildings may not have historic significance, but since they are designed for modern uses and purposes, they contribute more economically to a given locale. Overcrowding can be alleviated through the removal of older, less useful structures and replacing them with new buildings designed to accommodate modern standards of living and work. Education can advance by housing students in schools designed to current standards. The land and space for beneficial changes must come from somewhere. Moreover, we should not seek to live in the past, but should embrace and move toward the future.

But does the preservation of history really hinder progress? To some extent, as with the preservation of the concentration camp in Auschwitz, such preserved monuments to past wrongs keep them fresh in our memories, so they are not so easily repeated. It serves as a visual reminder of the dangers of discrimination. And it is only in very rare instances, it could successfully be argued that a building of historic value is standing in the way of progress.

Note that, while on the face of it, it is the right of the buyer to do with purchased property as they wish, community opinion can carry weight. Demolishing buildings of historic or cultural significance can create tremendous societal opposition. While those in opposition may not be willing to help pay for restoration, they are sometimes willing to fund lawsuits against owners seeking to demolish the same. Even when such court cases are won, developers and business owners tend to find their reputations tarnished and additional business difficult to conduct in that community.

Restoration is sometimes a viable solution, dependent of course on the availability of funds. And if it were not for the efforts of preservationists, we would not be able to enjoy such wonderful places to visit as Mt. Vernon and Williamsburg. But since decisions to keep or lose buildings should be the prerogative of property owners in a free society, how can the pot be sweetened to encourage preservation?

POSSIBLE SOURCES OF ASSISTANCE

If a building has historic value, it might be possible to acquire grant money to alleviate restoration costs, if such can be acquired without the attachment of strings hindering future use or changes. If the building even seems in any way to have historic or cultural significance, it should be investigated whether any grant money was used in the past to make improvements. If such was sought and used, that money could have come from multiple sources. It's a good idea to determine whether such monies came with restrictions or limitations prohibiting future changes to the building.

For example, grant monies given by historic societies that are governmental in nature, often required recipients to give up future control of the façade to such societies. As a condition of receiving funds for desired repairs, recipients agreed that no future changes would be made unless they were approved beforehand by the historic society. If that granting organization or society no longer exists, or if it refuses to allow desired changes, that may become a huge factor in the decision to acquire a building. Private grant organizations may have also placed restrictions on the use of recipient structures in return for the funds.

In my personal experience with three such projects, such groups have no interest at all in negotiation or granting any leeway. In one case, they preferred the gutted and collapsed building finish falling inward after a fire, than allowing changes to be made to what no longer even existed. If a structure seems as though it might have historic value, a quick bit of preventative research is certainly worth the investment of the time to investigate.

REVIEW QUESTIONS

9. In general terms, in order for a building to be considered 'historic,' it needs to be at least _____ old.

a. Two hundred years

b. Over forty years

c. One century

d. Fifty years

10. If we are to keep historic structures, then ___________ them becomes important as well.

a. Maintaining

b. Publicizing

c. Designating

d. Subsidizing users of

11. Demolishing buildings of historic or cultural significance can create ________________ .

a. A void in a historic district

b. An unprecedented amount of hazardous waste

c. Tremendous societal opposition

d. Displaced older businesses

REPURPOSE

When discussing this option, we are referring to reusing an existing building for a different purpose than it was utilized for by the previous occupant. It is altering or adapting the structure, to make it suitable for that new use, hence the term, 'adaptive reuse.'

ADAPTIVE REUSE THROUGHOUT HISTORY

In earlier periods of our national history, adaptive reuse was a normal way of business. New building materials were difficult to acquire and transporting them for any distance was prohibitively expensive. In some cases, it wasn't even possible. If a building was structurally sound and reasonably appealing aesthetically, it simply made more sense to adapt the existing structure than build a new one. As shipping methods improved, new structures became more feasible. Now, with materials and labor costs rising, costs increasing to place construction debris in landfills, land becoming more expensive and more value being placed upon heritage, reuse is once again an attractive option.

PRINCIPLES INHERENT IN ADAPTIVE REUSE

Retrofit is a key word to use in this approach to aging structures. It is the art of finding value in what others may see as liabilities. With very little effort, other uses can be imagined for structures, beyond the purpose for which they were initially built. The best way to preserve historic resources is to make sure they can house modern uses and contain functional space. Otherwise, private investment will not occur. Usually this means preserving or restoring the exterior character while renovating and repurposing the interior space. The potential reuse of the exterior shell, utility connections and other site improvements carries a huge financial benefit to private investors.

Considerations for possible reuse include; assessment of existing conditions, identifying potential risks for future occupants, identifying regulations that will impact reuse of the structure, possible markets and going rates, nearby land uses and how they will impact building use, architectural features that can be reutilized and historical or heritage considerations. Market niches should be considered that will provide a mix of uses, respond to the building's character and defining features and maximize the use of the building's space. Conceptual plans and a scope of work will need prepared for each viable option. Cost estimates to accomplish each option will be needed. With those plans and a market analysis in place, feasibility studies can be completed to help an investor set a course for moving forward.

What might such extensive research uncover? Despite the desirability of doing so, some heritage buildings, those useful to keep memories of the past alive, simply cannot continue to be used for their original purpose. Nor can owners afford the expense of maintaining them as museum pieces, with no return on investment. At that point, a decision will need to be made regarding their future. With limited space, or only very expensive space available for new business ventures, more affordable space made available through adaptive reuse projects is increasing in frequency.

One of the biggest advantages to reuse might be the locations of some of these potential investments. Many once occupied central positions in the cities in which they were constructed, prior to subsequent community growth. Often built in areas that are now in downtowns, they have been, and are seen and visited by many. Moreover, many were built in an era when they were a visible symbol of the success and pride of their prominent owners. They incorporated exquisite detailing, unique to the time period of their construction, that still remains and often can be preserved at a fraction of the cost of recreating it.

When it comes to complying with building codes for a new use, safety and accessibility are the two biggest hurdles to overcome in retrofits. Repurposing still requires all precautions be taken to ensure the safety of new users. Some renovations are easier than anticipated, because new building materials tend to be of higher quality than past choices. In many cases though, electrical, plumbing and HVAC systems may need to be removed and replaced to meet new codes. Given the potential expense of these upgrades, a financial analysis of probable return should be made before investing such money in that location. Even if a little expense is incurred up front, meeting for discussion before beginning such projects, with building officials, contractors, architects and engineers can go a long way toward establishing the practicality of such endeavors. It may also be advisable to garner input from potential users, should the project be completed.

Adaptive reuse is a very viable way to preserve properties of historic or societal significance, while creating financial feasibility to recoup costs of restoration and maintenance. Hopefully, historic or significant features will be preserved in the process. There are various positives and negatives involved in attempting such reuse.

BENEFITS TO ADAPTIVE REUSE

In areas of urban decline, there are often buildings offering prime opportunities for adaptive reuse, in lieu of demolition. A few projects where buildings are restored and reutilized can spark revitalization efforts in areas otherwise abandoned to disuse and abandonment.

The most sustainable buildings are existing buildings kept intact, renovated and maintained. Reuse reduces the need for the production of building materials to replace them, the cost of energy and effort to recycle their components and saves space that would otherwise be used in landfills for the remains of buildings that were ultimately salvageable. Land available for other uses is also preserved in cities, when buildings need not be built to replace the functions of those left abandoned and then demolished. Urban sprawl costs more than just the land being used. The more compact the area where people come to work and play, the less fuel used to transport them from place to place.

There are cost benefits to be realized by not undergoing demolition, followed by reusing the existing site for another building. These costs include legal issues, costs of demolition, the potential need to dispose of contaminated materials or equipment, battles with community factions opposed to development, obtaining variances, design fees, construction permits and construction costs. Note that demolition costs alone can add five to ten percent to a project budget. All these expenses can be avoided by just reusing and restoring the existing building, for less cost than that of building new space. Since unused buildings are often found in areas of significant population and development, if space can be made available in renovated buildings, for less rental cost than in new facilities, start-up businesses will find occupying rehabilitated structures attractive. Their presence will also infuse new life into a previously decaying neighborhood. The work already done can encourage other investors to make similar investments, building a synergy where complimentary users bring common customers to an area.

Older buildings tend to be clustered in a higher urban density than new buildings, which are built to better accommodate automobile traffic and parking. The existing neighborhood density can be preserved by simply reusing the buildings as they sit in place. Historically, the more compact it is, the more vibrant the feel of the neighborhood. Young professionals are especially interested in living and working in areas offering a unique sense of place. Adaptive reuse projects which attract such residents have been key to the success of many urban revitalization projects.

Costs of materials and labor to build new structures just keep rising, but the cost of labor has risen far less drastically. This makes renovation using primarily labor more economical than building new and paying for both workers and materials. .

One rarely acknowledged savings found in adaptive reuse is the fact that where older buildings are found, infrastructure and utilities already exist. Sewer and water taps are already in place. Gas lines have already been tapped. Curb cuts already exist for drives in and out. On the one hand, this means existing underground improvements must be worked around with any site work. On the other hand, it's cheaper to reuse existing infrastructure than bring it to a new site.

As a general rule, there is less time involved in a project involving adaptive reuse, than one involving demolition and rebuilding. While this doesn't directly translate to money saved, it does mean less time is spent, paying carrying costs on construction loans. It also means income from the property can be realized more quickly, to offset loan payments. That same shorter time frame also equates to a shorter turn around for cities, in their efforts to revitalize decaying areas. In existing buildings, rentable space can be made available while work is being completed in other areas, enhancing a project's cash flow during construction.

Funds are sometimes made available for adaptive reuse projects by governmental entities. In numerous municipalities and locations, there are tax incentives available to developers to rehabilitate historic structures. The United States' National Historic Preservation Act of 1966 established matching grants-in-aid, which can be applied for through state offices. Community block grants are also available through HUD, to fund neighborhood preservation efforts.

Blending modern technology with historic detailing creates a sense of place that is impossible to imitate. Older buildings provide a direct link back to a community's heritage and history. Preserving these structures helps preserve a sense of place that pervades any location and sets it apart from others across the nation and often even the city. In many ways, the older structures in neighborhoods establish their local identity. Once lost, these heritage buildings are lost forever.

Besides their historic value, heritage buildings often showcase crafts, artisan skills and detailing no longer used or even available in modern construction. Preserving them provides a link to the past, cultural assets holding stories to the past and those who inhabited and touched them before we arrived. When well done, heritage buildings tend to become destination locations, key to urban revitalization. Large retailers across the nation are beginning to realize such beloved spaces can be used without changing their intrinsic character, and without facing the kind of opposition faced when attempting to develop new big box locations.

Revitalized residential buildings, due to the density they afforded when created, generally still result in higher population ratios than new projects. Historically, the more residents present and active, the more vibrant the neighborhood and the lower the crime rate. Such projects tend to be near and more oriented to commuting via transit hubs, so there is more of a pedestrian feel. With more pedestrians active in the area, more destination spots for dining and entertainment become viable for developer investment. The entire area becomes more vibrant and more intimate.

Well aware of such benefits, some municipalities are open and ease the way for adaptive reuse projects. In the past, urban sprawl directly contributed to inner city decay. Lack of maintenance of existing buildings led to displacement of residents, economic decline in areas, a decline in tax bases and loss of entire neighborhoods that became obsolete and abandoned. Projects to reverse these trends are welcomed and encouraged by real societal leaders, especially if investors are willing to take on the projects. Conservation, even at the level of adaptive reuse, is only possible when someone is willing to fund it. It is highly likely taxes alone won't get the job done.

Even when iconic exteriors can be preserved, there will always be a need to incorporate modern services, like internet, power systems, water systems and so forth into adaptive reuse projects. The effort to do so results in the integration of modern living into a context of heritage, benefitting us all socially, environmentally and economically. In some projects, this may involve basically gutting and rebuilding the interior of the building, replacing just about everything inside while preserving only the structure and the exterior facades. Hopefully, some interior detailing can also be preserved and reutilized.

If preserving the exterior while retrofitting the interior is cost effective for the business investing in the facility, then so be it. At the end, the project must be profitable or private money will abstain from involvement. If a 'big business' will profit from doing so, the end result is still far better than demolishing the structure and leaving the site as a parking lot. Urban regeneration works, regardless of the purity or motives of the preservation effort involved.

DIFFICULTIES ENCOUNTERED IN ADAPTIVE REUSE

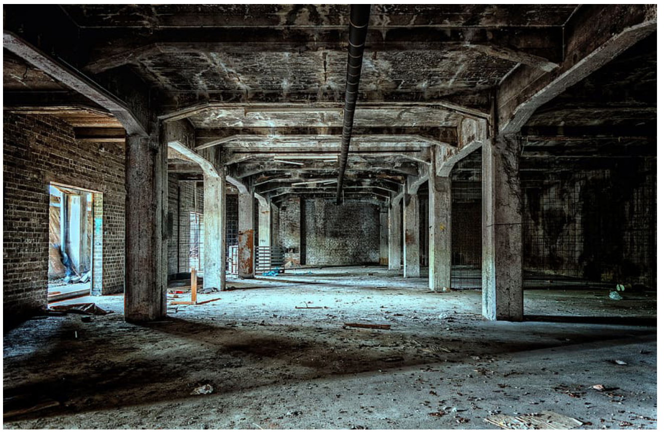
Make no mistake about it. Adaptive reuse projects present their own unique difficulties. In any renovation project, surprise are found during demolition that require flexibility and adaptability to resolve. Needed materials will be a bit more challenging and unpredictable to obtain than those used in new construction. With community interest high in such projects, and historic societies and foundations sometimes involved, there are generally more stakeholders to please than with projects being built from scratch.

Reusing buildings requires difficult decisions be made. The first will be in successfully choosing the new purpose for which the structure will be used. One in which the architecture and historic heritage might successfully be preserved. There are numerous parameters involved in choosing an occupancy that is both possible given the existing building and practical from a standpoint of marketing the space, once the renovations are complete. The section of this course discussing potential collaboration between realtors and architects, details a service that could provide valuable input into a decision regarding future use.

Older buildings also come with unique and marvelous features that we may or may not embrace, containing both desirable and undesirable components. Ornate detailing, high ceilings and tall windows are just a few of these. Some come with finishes, especially in flooring and ceiling treatments we could not afford to duplicate now elsewhere in the building. It may also be impossible to even find artisans who can still repair or create such treatments. Older buildings may come with materials that have since been deemed harmful to human occupants. Not only must such materials be either encapsulated or removed, but workers must be protected from them during their removal. Those discarded materials must be removed and discarded under special conditions, due to their designation as hazardous.

There are some instances where the layout of an existing building may create significant problems with reuse for any intended purpose. It those cases, the highest and best use for the property may really dictate tearing the existing down and building a usable facility. Otherwise, every little compromise made to reuse the existing, adds additional time and costs into the end product or space being sold, simply because preserving something old seemed important.

Structural conditions in an existing building, like large columns supporting short spans, can present challenges in converting the space for more modern uses. Moreover, existing floor systems may need reinforced before placing more modern loads, like rolling stack files, on top of them.



For example, let's assume an old industrial building is purchased for reuse by another manufacturer. Built before longer spans were available through the use of lightweight steel joists, it has many interior columns of significant size. The primary product to be produced, uses four machines, set up in a sequence to obtain the final result. But, the column spacing makes it impossible to place four machines in direct proximity. So two machines each are located in two adjacent building bays. Now the output from the second machine must be packed and carted across the floor to the third machine. In addition, it may need to be stored in a third bay until the operator of the third machine is ready for it, effectively turning space needed for production into storage space. What was a continuous process has now become an interrupted, and more space intensive process, adding cost to each final product. This is just a column spacing issue and doesn't factor in additional floor structure needed to support machinery, window upgrades to keep thermal expansion of materials from complicating the machine process, roof repair to keep water off the machines and so on. The up-front and ongoing costs of preserving the original building just keep adding up.

In another case study, lets assume an old warehouse building is being purchased for use as an upscale condominium project. The goal is to keep the original 'historic' structure, rather than removing it and building a more high-density project on the site. The first hidden cost becomes lost income from the number of units that won't be built, due to the decision to forfeit the potential for high density. The size of the available housing units will now be dictated by the space between existing columns, rather than sizing them according to current market demand for what buyers are seeking. Since egress needs to be made through the exterior walls, and the existing building is too deep for each unit to stretch from front to back, entry to each unit must be from a central corridor / atrium, with egress provided to the outside of the structure on each side. That central corridor eliminates a lot of viable square footage from consideration that can no longer be sold or rented. Moreover, the high ceilings of the original structure may require the installation of a complete system of lower ceilings, to make utility costs for the purchasers more affordable and attractive. Condenser units for each unit's HVAC will need to be placed in well landscaped exterior courtyards, since the existing roof has no structural capacity to bear their weight. The up-front and ongoing costs of preserving the original building just keep adding up.

Some buildings are not really good candidates for adaptive reuse projects. Buildings originally used for prisons have thick walls, not easily modified and containing a lot of reinforcement. Space is heavily carved up and rooms are small. They are difficult to reimagine and retrofit as profitable structures for other uses. Structures previously used as low rise apartments have a low ratio of rentable space compared to the lot size. If left unused, buildings that are difficult to retrofit can become structurally unsound, havens for criminal activity and in general, dangerous to the surrounding area. In these cases, it would be a better use of the land to demolish them and erect in their place, more modern structures containing far more usable space.

Older buildings predate current codes, zoning requirements and development regulations. Fire suppression, handicap codes, life safety codes, energy codes, parking and landscape buffer requirements may be especially tough to meet. Cooperation from regulatory agencies, and possibly waivers from them, may be a prerequisite for a successful project. Simply put, successful adaptive reuse often requires some level of cooperation between developers and municipalities.

Multiple communities recognize the significance of both historic and older buildings by placing provisions within district plans for their preservation and reuse. When possible, they encourage preservation of architectural and heritage character. Adaptive reuse is encouraged by sometimes providing incentives for reuse of older structures by private developers. The use of private funds is always preferable to spending tax monies and restoration of neighborhoods occurs more quickly when driven by capitalism instead of bureaucracy. Incentive programs allowing adaptive reuse help preserve character and neighborhood identity in efforts toward urban revitalization. They understand that a well done project that may be less than perfect, but is still safe for occupants, is more desirable than buildings left to further deteriorate. Allowing some leeway on zoning ordinances, subdivision and land development ordinances, historic area requirements and design guides can make them far more desirable to investors. They understand that a little flexibility in enforcing regulations will result in increased taxes generated by reuse of the structure. No one wins if the property is left vacant or torn down.

That being said, it is interesting that developers and designers alike, feel far more can be done by municipalities to encourage adaptive reuse, besides just claiming it is desired. Developers feel there is not enough support or incentive from local governments to make adaptive reuse projects more attractive than building new. Even building codes, supposedly specifically created to make renovation projects easier, are somewhat inflexible. Moreover, as there are only limited waivers on allowable densities that would make projects more attractive, in general, reuse is not truly encouraged, especially when innovative solutions are proposed. Designers in general feel too much emphasis is given to use of 'sustainable materials' and not enough credit is given to the overall resulting improvement of the surrounding environment. Fire safety codes and handicap codes are difficult to work around, when very little leeway is made regarding their implementation, even under tough conditions.

More progressive communities actively participate in moving adaptive reuse projects forward. Staff supports the efforts of investors with information and data, offering tax abatements, setting up meetings with community groups and allowing increases in densities. They may also assist in obtaining funding through grants, upgrading infrastructure going into the site and working together on mitigating environmental concerns. Though some municipalities do not yet recognize or prioritize it, it is truly in the best interest of communities to encourage and facilitate adaptive reuse projects.

ECONOMIC FACTORS FOR REUSE OR REMOVAL

The decision of what to do with older tangible assets is generally driven by economic factors of development costs, project costs, investment returns and market. These factors must be considered when considering the future of any older and empty building, because the cost of converting the building to another use may simply be too great. General statements regarding the attractiveness of one option over another may not be relied upon, because opinions vary wildly, depending on whose opinion is sought. Some claim adaptive reuse is far cheaper than new construction. Others swear that new construction represents a far more certain return on investment. If they have endured a difficult project in the past, some just begin swearing when asked to consider purchasing older assets.

When a building is purchased as an investment, then decisions regarding adaptive reuse are driven by a desire for short-term profits. Older buildings are acquired with a short return on investment in mind, based on the building's physical condition and the expected expense to make it reusable. With older structures acquired as capital investments, developer decisions are almost never driven by concerns of sustainability and environment. What developers and investors are somewhat concerned about, is the positive impact that building reuse and sustainability can have on their image.

For the most part, the amount of rent to be realized by leasing out space, will be determined by local market conditions. Lessees will not be so concerned about the status or the historic value of building components, so long as they function. So a delicate balance must be found when deciding how extensive upgrades should be, in an adaptive reuse project purchased for investment. If poorly performing systems, windows, etc. are left in place, owners can expect a shorter life expectancy for their asset, higher costs for monthly utilities for their tenants and higher maintenance costs in the future. It is a fact that higher quality finishes and appliances yield slightly higher rents. It is true that the better the condition of the renovated building, the higher the potential resale price. It is also true that character and ambience will result in space being leased much more quickly than that of competitors. But every bit of money spent still represents an investment, and the more spent up front, the longer the return on investment. Pride is a luxury investors can't afford. In every case, a cost versus benefits analysis will be needed.

TWO PART CONTRACTS

One expected cost that can be somewhat eased in the planning stages, is the expense of hiring a design professional. Many architectural firms are willing to explore changes needed to adapt a building to another use, in a two part contract. In such an arrangement, a partial fee is proposed to document the existing facility and develop preliminary drawings showing changes needed to make the facility meet the proposed use. These drawings can be used to establish project feasibility.

Such preliminary design drawings are usually sufficient to establish the scope of work involved in proposed renovations to the building. They can be used to obtain a preliminary estimate that will be fairly close to the final cost. They can also be used in discussions with regulatory agencies regarding the feasibility of the project. When combined with a preliminary cost estimate, such drawings can be used in presentations and discussions with lending agencies that might become involved. Only if a decision is then made to move the project forward, would the remaining engineering and construction documents be completed, needed to obtain final permits and bids. Those would be provided in the second portion of the contract for architectural services.

SUSTAINABILITY BENEFITS TO ADAPTIVE REUSE

One area of conservation involved in building reuse is the saving of water. This resource is used in the extraction of raw materials, the manufacture of building components, as part of many construction processes, by occupants during use of the building, to sustain and preserve landscaping and in the demolition and material reuse phases. Not having to repeat that cycle by replacing existing structures with new buildings, conserves the use of water.

Energy is also conserved when buildings are reused, certainly benefitting the environment. Electricity not used is power that need not be generated by burning fossil fuels. Power is also consumed in the extraction of raw materials, the manufacture of building components, during construction processes, by occupants during use of the building, by pumps used to irrigate landscaping and in the demolition and material reuse phases. Retrofitting a building uses but a fraction of the energy used in building a new one. And when the thermal performance of an existing structure's exterior is enhanced during renovations, additional energy is conserved moving forward.

Choosing to retrofit instead of demolishing and rebuilding, also conserves the supply of raw materials in the earth, that must be extracted prior to their conversion into building materials. For those concerned with our ecology, that is an important consideration. Environments are usually harmed by processes used to extract such materials. Moreover, the extraction of such raw materials depletes the existing, and for the most part, nonrenewable supply of these natural resources from the earth.

Despite the irritation factor in dealing with contaminants or hazardous materials found in the existing structure, the community, the neighborhood and the building occupants will all benefit once remediation has been completed.

Reusing rather than recreating materials to construct a new building shell carries sustainability benefits for the environment. According to the United States Environmental Protection Agency, it takes about sixty-five years for a new energy-efficient building to save the amount of energy used in demolishing an existing structure.

The greenest buildings are those which are already in existence.

REVIEW QUESTIONS

12. Retrofitting in adaptive reuse is the art of finding value in what others may _______.

a. See as liabilities

b. Simply transport to a landfill

c. Publicly disparage

d. Demand be removed

13. The two biggest hurdles to overcome in complying with building codes during retrofits are _____________ .

a. Reattachment of veneers and new copings

b. Safety and accessibility

c. Vehicular access and parking

d. Material staging and pedestrian safety

14. Older buildings provide a direct link back to a community's ________________ .

a. Founding fathers

b. Scandals about old money

c. Original intentions when founded

d. Heritage and history

15. At the end, the project must be ________________ or private money will abstain from involvement.

a. A source of pride

b. At least break-even

c. Profitable

d. Free from regulatory hassles

16. Which of the following is NOT a building component now deemed to be hazardous.

a. Plasticized paints

b. Asbestos insulation

c. Lead paint

d. Flooring containing asbestos

17. Simply put, successful adaptive reuse often requires some level of cooperation between ________________ .

a. Artisans and developers

b. Community leaders and investors

c. Developers and municipalities

d. Lenders and builders

18. According to the United States Environmental Protection Agency, it takes ______________ for a new energy-efficient building to save the amount of energy used in demolishing an existing structure.

a. Only eleven months

b. Eleven and one half years

c. About sixty-five years

d. A millennium

REPLACE

If consideration is being made to demolish an older structure and replace it with a more modern building, the advantages and disadvantages of doing that should first be considered. When is it a better idea to demolish a building, rather than attempting to restore it? If it is not a historic structure or one having cultural significance, you want to demolish any building costing more to restore than to rebuild from the ground up.

CONSIDERATIONS PRIOR TO DEMOLISHING

If the project is historic or located in a historic district, there may be ordinances and laws in place to protect such resources and their character. Many municipalities have commissions in place to govern such projects and processes which must be followed when considering either demolition, renovations or restoration. Oversight may be required by local building officials or even a local Fire Marshall. Costs of demolition are also highly variable, depending on locale and local requirements for permits.

Investigate what will be allowed on the site, before demolishing what is there, even if the existing structure was damaged. It may not be possible to obtain a permit to replace it after demolition, or even to use the site for a different purpose. New structures may be required to meet community or neighborhood standards for size and architectural character.

Demolition permits often require testing for the presence of hazardous contaminants. If lead or asbestos is found in the existing ducts, paint, flooring, roofing or siding, disposal of those contaminated materials can become quite costly. Various gases used for coolants require special handling. Underground tanks must be carefully disposed of, or opened and filled under strict guidelines. Brief research into past uses of the structure might save a lot of grief before moving forward with a tear-down.

Other site conditions, more specific to the building location, may come into play. Investigate and determine whether utilities will be able to be disconnected at the service entry or whether they will need to be disconnected back at the property right-of-way. If the site is in an area designated as environmentally sensitive, like wetlands or slopes subject to erosion, other precautions may need to be put into place.

If a mortgage is still in place on the property in question, the institution holding the note must give their permission for the removal of the building. Otherwise, the only way to legally demolish the building is to first pay off the remaining balance on the building loan. The lending institution paid for it and they own it until the money is repaid. Insurance proceeds or construction loans may be used to make such payoffs.

ADVANTAGES OF DEMOLITION

Sometimes, demolition of properties with historic value is still the right choice. The building may present a danger to those around it, due to hazardous materials used in its construction or because it is a fire hazard. Permission to remove it can be easy to obtain, since doing so will improve the value of the surrounding properties. It may actually be an eyesore, thereby pulling down the value of surrounding property. It may not be possible to obtain the pieces needed to restore the building accurately. If the vacated land will be used for another building that would be beneficial to the community for any reason, that will be considered in obtaining a demolition permit. If the reason the building is deemed significant is due to its association with tragedy, removing it may help bring healing to that society.

In some cases, demolition becomes more probable if resources are not available to restore the elements that give the building its historic value. Finding craftsmen capable of repairing sculptured plaster, terrazzo, cast iron elements, etc. may make actual restoration fairly impossible.

If a decision is made to demolish only part of a heritage building, historic detailing and elements inside the old facility may be able to be removed, stored and reused in portions that will remain and be renovated.

DISADVANTAGES OF DEMOLITION

There are some who deeply feel that leveling properties with historic significance is a moral deficiency. For whatever it is worth, taking such buildings down will earn the enmity of these objectors. Intentions of demolition will become known, since it will require acquisition of permits, giving public notice of intentions to do so. Opposition will be encountered from preservationists seeking to create societal disfavor for you and your enterprises. If the building truly does have historic value, its removal will hasten the day that history is forgotten. Out of sight equals out of mind. Once the structure is gone, so too is the opportunity to convert it to a museum or attraction to bring visitors to that area. Restored buildings need not be museum pieces, but can house other uses that provide income. Sometimes, restored buildings can draw users to other businesses and enterprises in their area, acting as a hub for neighborhood regeneration. On the other hand, if the building is torn down, it most likely will not be replaced with anything comparable, especially if the previous building had elaborate ornamentation.

If a historic property can be restored cost effectively or with financial assistance, doing so is often preferable to demolition. Especially if a modified approach is taken through adaptive reuse.

REPLACING THE BUILDING MAY NOT BE EASY

It is very difficult to build new square footage as economically as just renovating existing square footage. This is due to at least four major factors.

The cost of building materials can become extremely high. This can be attributed to difficulties in supply chains, especially those that cross national borders. These can be tensions created by political posturing, perceived or real trade imbalances, embargos put in place to protect domestic suppliers and restrictions on trade due to epidemics on one or both sides of borders. There may have been difficulty in finding workers to produce the needed materials. Prices may reflect a need to recoup the rising cost of fuel used in transportation of materials. Natural disasters create material shortages in two ways. The raw sources of the materials are destroyed by the natural disasters or existing supplies of materials are quickly depleted, in repairing or securing structures damaged by the disaster. The now global nature of commerce also puts our once primarily national supplies on the international market for use by any other country facing a sudden need or shortages of particular materials.

The labor pool for construction work is dwindling. Relatively few younger people have much interest in the physically challenging nature of construction, when societal heroes and millionaires are tech geniuses and gifted athletes. The older generation of artisans is retiring or passing away in large numbers and they are not being replaced by younger skilled tradesmen. It has become nearly impossible to find tradesmen still skilled in areas like terrazzo work, wrought iron creation and installation, the use of copper, the repair of plaster ornamentation and so forth. Wages are rising for entry level jobs, diluting much of the allure of traditionally higher paying construction jobs.

The rising cost of raw land, combined with high costs of new infrastructure, makes new sites for buildings sometimes cost prohibitive. At the risk of being the bearer of bad news, in some cases an existing site and location may be of more value with the existing building removed. It will matter what utilities and other infrastructure are near, or come into the site. A price will need to be determined for the costs of demolition and disposal of the existing structure. The value of the property may also be contingent on whether other nearby sites are available, that can be packaged together for a larger offering.

There is a very real cost to meeting the proliferation of community regulations that has occurred in the past several decades. Many of these, like fire safety regulations, stormwater drainage requirements and sewage treatment guidelines were justified as necessary to provide for the increased well-being of the community. From a pretty cynical viewpoint, many seem to also result in a great number of fees to be born by those desiring to develop new projects or renovate old ones. Some “fees” have nothing to do with protecting the public from new projects, like requiring parks to be built elsewhere or roadways to be upgraded at a cost to the developer. Those are basically just overt blackmail. But those costs of doing business must then added to the cost of new development and recouped through higher rental rates.

In some bureaucracies, it may be easier to demolish and replace a building, than to restore it. While less restrictive rehabilitation codes exist in many locations, inspectors may not be familiar with them and may still insist on sprinkler systems being installed, walls and ceilings being upgraded to fire-resistive barriers, flammable items like 100-year-old trim being removed from corridors, asbestos being removed instead of encapsulated, etc. Fighting with bureaucracy has caused many a well-meaning preservation effort to end on a sour note.

SELECTIVE DEMOLITION

Everything on a site need not be demolished. With larger scale projects, it may be necessary to remove one building from a group of many, that simply doesn't fit the desired goal of the redevelopment. In earlier times, it was not uncommon to find housing coupled with small factories or with shops, especially in an era when store owners lived above their places of business. If an old and dilapidated industrial building sits in the middle of brownstone homes that could be restored into a trendy neighborhood, restoring the old factory becomes somewhat of a moot point. If the space upon which it sits can be used for additional period homes, a neighborhood center or a small shopping area to provide services to the new neighborhood, that old building is likely in the way of progress.

MARKETS FOR EXISTING COMPONENTS

One side effect of the decision to demolish an older structure is the potential to create a resource for other projects. Stripping the building of elements that can be used in other projects is labor intensive, but usually yields enough salvageable parts to offset the cost of doing so. These components have been referred to as a 'treasure trove' and in keeping with this concept, older buildings slated for demolition have been referred to as 'mines of raw materials for new projects.' It is surely easier to reuse salvaged materials than to harvest and create them new from nature.

Such salvaged components, especially in the area of interior and exterior detailing, were often popular and used in the same localities during specific time periods. As such, pieces from another nearby building, not deemed to be salvageable, might be exactly what is needed to complete the historic restoration of one is in better condition. In a crude example of this, I was once tasked with restoring an original, one-room log schoolhouse, built in the mid 1800s. Approximately a fourth of the logs had deteriorated past the point of reuse. I was; however, able to find an old barn elsewhere in the county, made of logs the same size and of the same species of wood, erected about the same time and using the same joint detailing. The farmer donated those logs to be used as replacements for the schoolhouse, in return for the group paying to demolish his barn and level the land for a new use.

Companies exist that salvage and store historic components, such as detailing, trim and ornamentation for reuse in other projects. Some of these enterprises may bid for the right to strip an older structure of usable items before it is leveled.

In the event that items desired for restoration are not available in local existing buildings or through salvage companies, there are also businesses that recreate such items. These period pieces are often made by scanning existing pieces to create a 3-D model of what is desired for replication, then using CNC technology to duplicate what was scanned. Such period components are available in a wide variety of materials, ranging from cast bronze and brass to molded plastic and composite wood. An Internet search can turn up a surprising variety of resources for historic restoration needs.

Besides resell, another consideration in the demolition of existing buildings, is how many of the materials within them can be recycled. Besides the historic elements, how many components can be placed back into use in what has been described as a circular economy? A distinction must be made when considering such recycling, whether it would of a primary, secondary or tertiary nature. All building materials are not equally environmentally friendly or sustainable. But any reuse makes sense when considering that the most environmentally friendly building materials are those which need not be currently harvested or pulled from the environment, in order to come into existence for our use.

With that in mind, the terms used above in describing building recycling are best defined as follows. Maintaining, refurbishing and reusing existing buildings is primary recycling. This makes the best use of those materials already in existence inside the structure. Secondary recycling occurs when such buildings are demolished, but the building materials inside are gleaned beforehand or during construction, cleaned up and reused for other projects. Tertiary recycling occurs when a building is demolished and materials which are suitable, are crushed or shredded for use as other products or as fill in other projects, particularly in paving or under foundations.

Note that tear down and reuse of building materials is not nearly as kind to the environment as it may appear upon initial consideration. A lot of manpower, machinery, water and energy will be used in removing those materials from a structure prior to demolition. Money, fuel, energy, water and effort will also be expended in cleaning the materials, then fuel and labour will be needed to transport them to a location where they can be resold. Once resold, fuel and labour will be used to get them to their new location and manpower, machinery, water and energy will be used to reinstall them in a new building. Between the generation of the electricity used and the trucking needed, fossil fuels will be expended in large quantities. Obviously, it is more sustainable to the environment to leave materials in place by not engaging in demolition.

Sometimes, just choosing the right materials to use in preservation makes recycling old structures more feasible. For example, recoating an exterior with linseed oil-based paints will produce a finish lasting far longer than using paints made from plastic. It may be a bit more expensive up front, but life-cycle cost analysis yields the economic power behind many such choices. This is especially true in the replacement of existing with new and energy-efficient doors and windows. These are often available to match the appearance of those found in historic settings.

REALTOR / ARCHITECT COLLABORATION

Whenever an older existing building is purchased, an interesting opportunity presents itself for collaboration between professional architects and professional realtors, specializing in commercial real estate. In such a partnership, the realtor would propose and sell their combined services to a building owner seeking to sell an existing commercial building. The architect would then document the existing building and create a plan and at least a front elevation of the existing structure.

One valuable tool is the development of a grid showing the sweet spots, where intersections occur between potential uses allowed under current zoning and potential uses allowed by state building departments for that building's previous occupancy. Together, based on the locale and community composition where the building is located, the realtor and architect would determine the three or four best and most marketable uses for the facility.

In an ideal marketing collaboration, the architect would then design a quick prototype plan and elevation for each potential use. These plans, each paired with the layout of the existing plan, would be used by the realtor to market to potential users in those specific market segments. This section will conclude with additional thoughts regarding such a collaboration.

FINDING THE SWEET SPOTS

There is a sweet spot in the intersections of what is permitted in the zoning district where a building was constructed, and what is permitted by the use occupancy in the building code, under which the last building use fell. In these intersections of possible uses for the structure lies the least potential expense (mandated anyway) and the least hassle (no need to obtain zoning exemptions or changes) for building reuse.

Step 1 – Assessment of the building to determine which building components should be, or need to be replaced.

Step 2 – Determine what changes would be mandated by current building codes, prior to the building being reused as it is currently zoned and occupied.

Step 3 – Get estimates on the cost of making changes discovered to be necessary in the first two steps.

Step 4 – Establish a matrix to determine the sweet spots of potential reuse that represent intersections between allowable existing occupancy uses and allowable existing zoning uses

Step 5 – Develop an existing plan, then basic plans for reuse of the building for the three most viable building uses, discovered in the sweet spots of the matrix.

Step 6 – Use the existing and basic plans to market the building and its potential reuse to other businesses in those markets, currently working in smaller facilities and potentially needing more space to grow.

Below is an example of how such a grid might be used to find intersections of uses allowed in community zoning districts and state building occupancy categories. This was developed for a hypothetical property in Valparaiso, IN.

Exist building was an R-2 occupancy in a CP zoning	**Central Place Zoning (CP) – Permitted Uses**	Single Family	Traditional Neighbor-hood Develop-ment	Live Work Units	Public Service
Permitted Uses in Last Occupancy Group (R-2)					
Apartment houses			X		
Boarding houses (not transient)			X		
Convents			X		X
Dormitories					
Fraternities and sororities					X
Hotels (nontransient)					
Monasteries					X
Motels (nontransient)					
Vacation timeshare properties					
Congregate living facilities					X

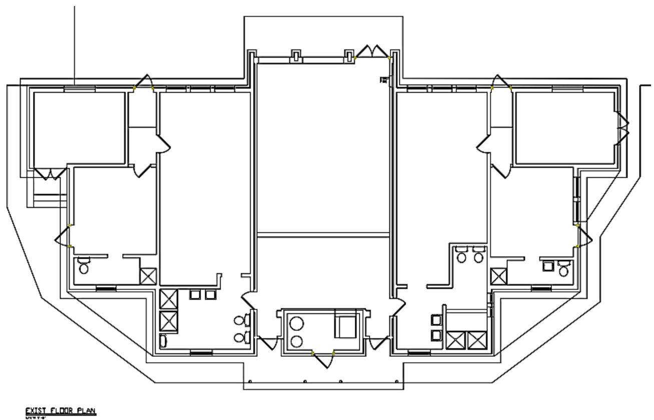
Given additional information (like there being no colleges anywhere close) the best potential customers for this property would likely be apartment developers, developers of congregate living facilities or religious entities seeking to erect housing for members.

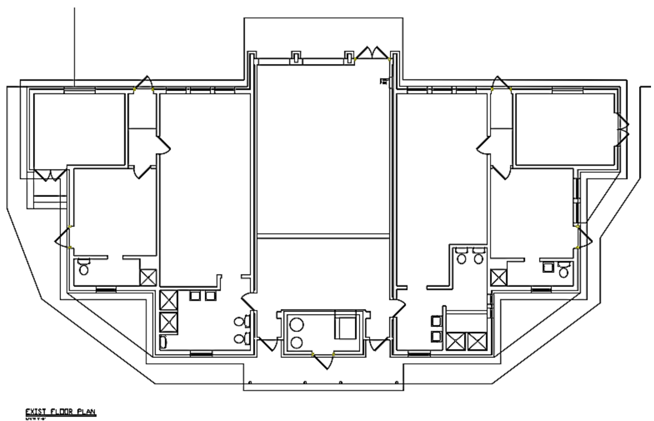
DOCUMENTING EXISTING PLANS AND CREATING ALTERNATE LAYOUTS

As mentioned, it would also be important to document the existing facility, so as to determine the extent of changes needed to make it suitable for alternate uses. The case study shown below was a real life, and very recent, example of exploring such alternate uses for an abandoned and deteriorating building.

The existing structure in this study, sits in a residential zoned district next to a golf course. The building was originally used as a pool house for a large swimming pool behind it, that had been collapsed and filled in years before. The pool house sat empty for many years and was beginning to deteriorate, primarily from water infiltration. Choices being considered were to either tear it down and sell the land, or minimally restore the building to again make it weathertight, then market it for several types of reuse.

Prior to tearing it down, a decision was made to spend the money and effort, exploring whether the building could be used for alternate purposes. That work began by documenting the existing plan and elevations.

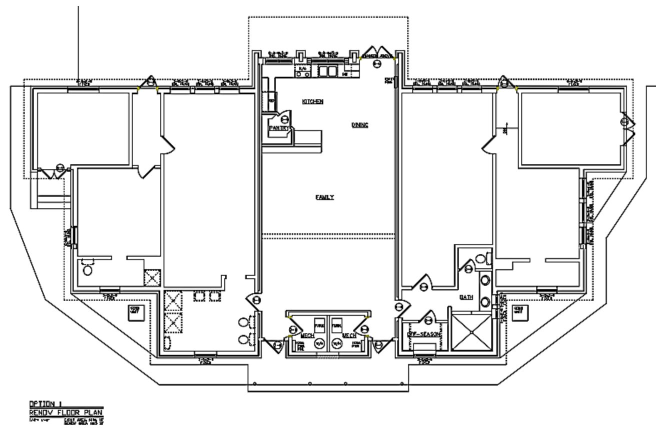


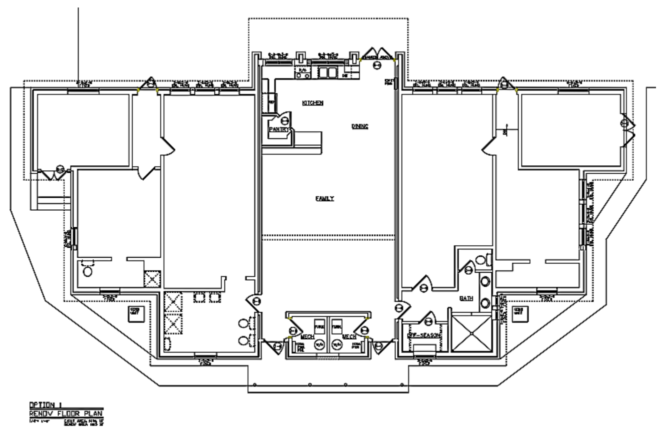


With the existing structure laid out, alternate options for the reuse of the building were explored. All options included a scope of work and common to them all, was the initial need to clean up the exterior and make the building weathertight.

OPTION 1 –

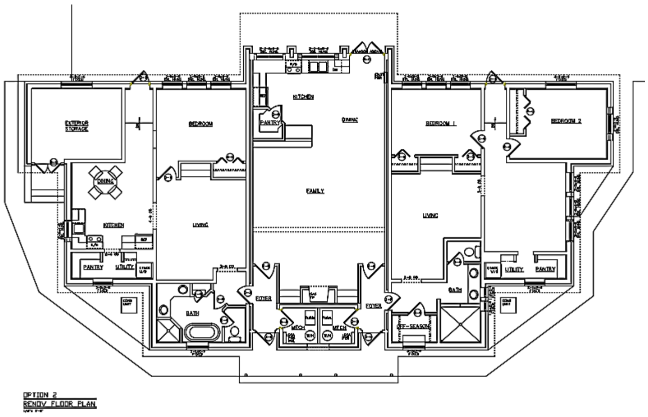
This first option showcased the creation of a useful kitchen and one renovated bathroom, as well as creating separate power panels for each area and two HVAC split systems to allow zoning. These changes made the structure reusable as an office structure with two tenants and a common break area.

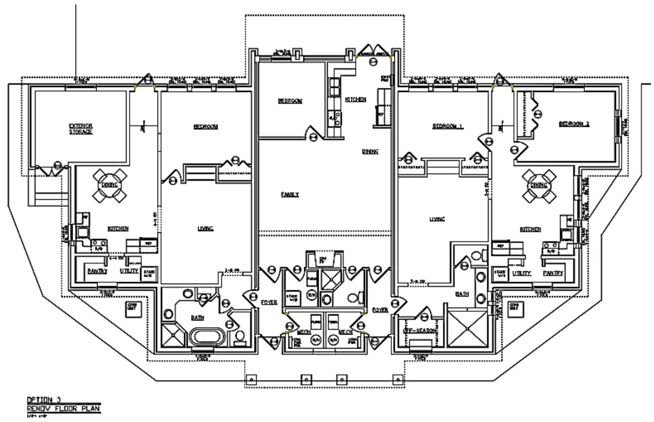


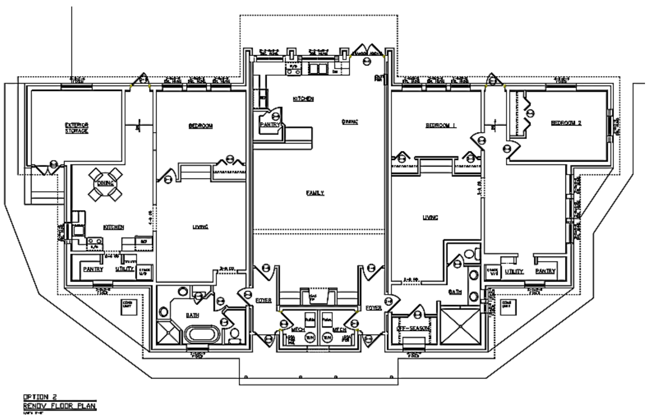


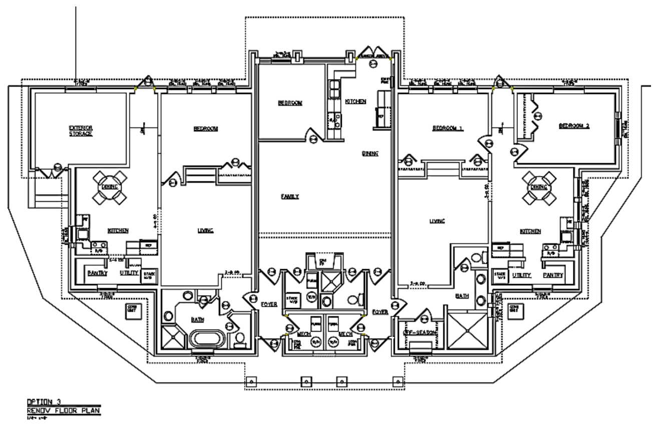
OPTION 2 –
This second option incorporated changes needed to create two separate living units with a central common area. This configuration allowed one unit to be isolated with the central area accessible from just one side, creating two sizes of rental units.

OPTION 3 –
This third option was similar to the previous option, but the central area was turned into a studio living unit, for additional rental. Fire walls would need to be created, but with masonry walls already in place, that would be quite easily accomplished.



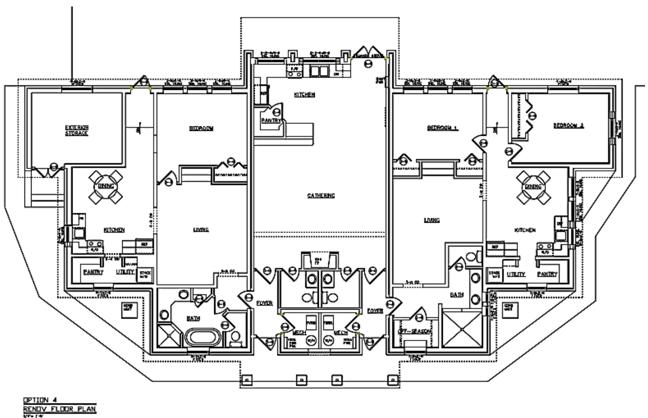


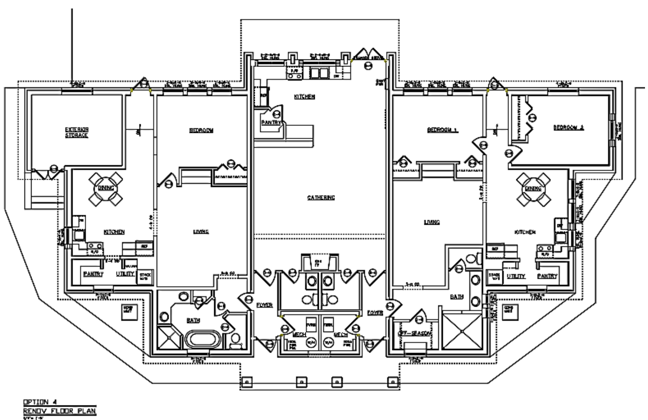




OPTION 4 –

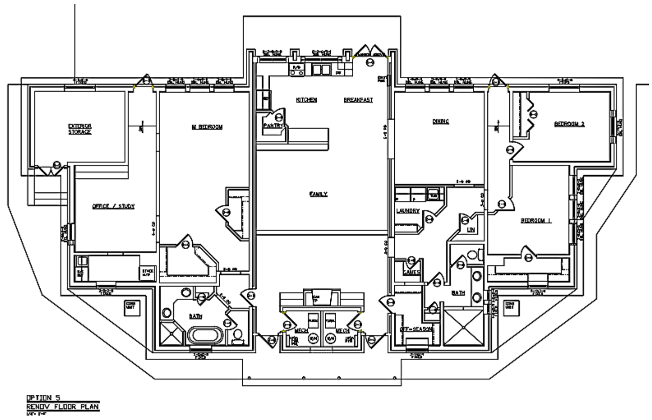
This fourth option created rental units on each side, with the center area remaining usable for receptions, weddings, conference retreats, etc,, with its own bathrooms.

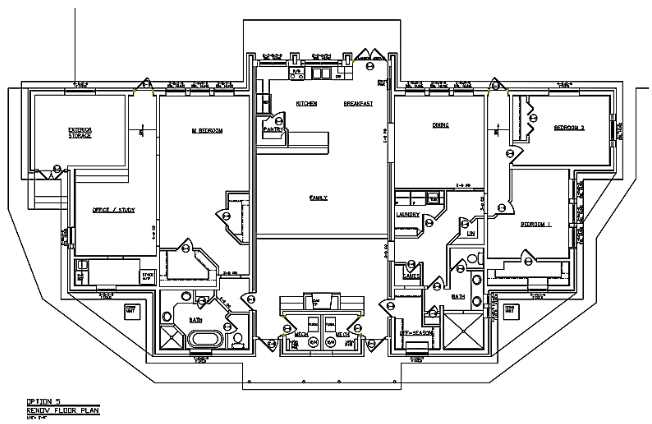




OPTION 5 –

This fifth and last option explored changes needed to convert the pool house into a single residence, one utilizing a split bedroom plan.





I am happy to report that the plans created for the various options were used in marketing and the existing building was successfully sold, just prior to the creation of this course.

STRUCTURING A REALTOR / ARCHITECT COLLABORATION

Before including this section in this course, I spoke about my idea regarding such a collaboration between these professions, with a realtor friend in Fort Wayne, IN. He specializes in rehabilitating and marketing commercial properties. The following are ideas generated from our discussion.

Compensation for work done on the front end by the architectural half could be handled in three ways, two of them problematic. In the first approach, the realtor would pay the architect directly for services to create what would essentially be marketing tools for their use. Since compensation for a realtor doesn't occur unless a sale is made, this approach seems a bit risky for the realtor. The building owner could also pay the architect directly for services to create what would essentially be marketing tools for their business use, then and later. But proposing that an owner incur that cost up front, might separate the realtor in a pretty negative way from other realtors offering to list the building with no initial cost to the owner. In a third scenario, just as the realtor fronts the costs to market it, the architect would also provide their initial services at no cost, chalking it up to marketing for the firm. Then, upon sale of the building, the sales fee would be split between the realtor and the architect, using a percentage agreed upon earlier, possibly up to one half the commission going to each.

What would the advantages of such an arrangement be to the realtor? The availability of such services and an inclusive sales team to building owners, would set that realtor far apart from other commercial realtors competing for the listing. Moreover, having an existing plan and proposed plans available to market to viable market segments, would likely result in a much quicker turn around of the building.

What would the advantages of such an arrangement be to the architect? Upon the sale of the building, as is appropriate with any kind of assumed risk, the fee realized would be a significantly higher return on investment than with the simple provision of building documentation. Moreover, already being familiar with the building and having drawings completed at some level, the architect would be in a strong position to market remaining design services regarding the reuse of the building, to the new owner of the property.

My friend felt such a business arrangement between a realtor and an architect would certainly be of mutual benefit. I do as well.

SUMMARY

Whenever a change of ownership is proposed for a property containing an older building, a decision will need to be made. The existing structure will need to be either reused as is, repaired before reuse, restored to a previous historic condition, repurposed through adaptive reuse or removed and replaced with a newer building or different use. These options are ordered in terms of their probable cost to investors and to society. There are guidelines that help shape such a decision.

The easiest decision to make will be the one with the least cost invested to realize a decent return. If an existing building can be reused, exactly as it sits, for the same purpose for which it was utilized beforehand, the only significant cost would be the purchase price of the building. No extra effort or expense need be expended to restore some level of cash flow.

Market research will determine whether repair and some level of upgrades would be a viable option. If decay or failure of some building component led to its abandonment of use, that will need to be repaired before reuse can happen. In the process, if renovating would yield more return in rental than the cost of the upgrades, it would be a good investment to improve finishes, lighting, appliances, etc. before reopening for business.

Restoring the building to a previous level of historic accuracy is an investment that must be very carefully researched. Doing so is obviously not the least costly option. A truly historic structure will limit a number of potential occupancies. Seeking grants and other forms of financial assistance from historic restoration groups may result in strings attached for future use. But even with non-historic use of the structure, the resulting building will be a source of community and personal pride.

Adaptive reuse is a solid compromise between reuse with upgrades and historic restoration. Restoring the exterior and repurposing the interior touches on the best of both worlds. The pride and identity of the neighborhood can be restored, while maximizing the potential return on investment by making the space inside as modern and rentable as possible.

The last option is to remove or demolish the structure and replace it with another use. This is the most expensive option, facing the most hurdles from regulatory agencies, taking the longest and doing the most damage to the environment. Rebuilding is still preferable to leaving the site empty or reusing it as a parking lot. Unless of course, parking is desperately needed in the area and rental of the spaces can be an equally lucrative return on investment.

The least advantageous use of an existing building is a choice made, not by investors but by municipalities. That is the decision, by placing enough onerous regulations and bureaucratic obstacles in place, that investors and developers would rather pass on an opportunity, letting a building just sit empty and continue to decay. While doing so, it becomes a danger to surrounding properties by becoming structurally unsound or a fire hazard, by attracting criminal activities and by lowering the value of surrounding properties.

Any reuse of older buildings is better than none. Some thought just needs to be put into the options of how to do so, before any decision is made on to the best way to proceed.

REVIEW QUESTION ANSWERS

1. **Unless it has been ____________, land in a community will always have an intrinsic value.**
   a. **Contaminated by hazardous waste**
   (This is the correct answer, taken from the course material. None of the other answers provided change the actual value of the land.)
   b. Obtained under fraudulent means
   (This condition results in no change to the resale value)
   c. Used previously for illegal activities
   (what is done on the land has no association with its worth)
   d. Ceded as part of a previous lawsuit
   (This only affects value if an outstanding judgement or encumbrance remains against the property.)

2. **Thorough inspections of existing buildings should be made by someone ___________ , before a decision is made regarding the building's final disposition.**
   a. Who has not participated in projects nearby
   (The condition of property nearby has little bearing on the physical condition of a subject property.)
   b. Who has participated in the renovation of a nearby building
   (This again has no bearing on the physical condition of any individual building)
   c. Currently serving on the zoning commission controlling use of the property
   (A conflict of interest)
   d. **With no financial or vested interest in the building or repairs**
   (There should be no potential conflict of interest)

3. **Knowing the value of __________, available for reuse in that location and zoning district, will be useful in making decisions.**
   a. A gutted building shell
   (Few would care to purchase a building and pay to just have it gutted, before attempting to resell it.)
   b. Already permitted signage
   (This does have value, but generally not enough to drive a decision on building disposition)
   c. **An empty site**
   (This is especially important when demolition is one of the options being considered)
   d. Neighboring complimentary businesses
   (While the value of nearby buildings can impact the value of a subject property, it will not be the primary driver of a decision regarding final building disposition)

4. **When assessing floor systems, those of older buildings _____________ strong enough to support current loading requirements.**
   a. Are almost never
   (This is not often the case.)
   b. **Are usually**
   (Before the advent of precise engineering programs, the structure of older buildings tended to be oversized, so as to err on the side of caution.)
   c. Are assumed to be
   (Assumptions are dangerous things, especially when life and safety are involved, and should never be made in such instances.)
   d. Are accepted by most codes as
   (Codes make no recognition of the age of a building.)

5. **Ornamentation and significant components can sometimes be removed from _________ areas of a building and reused in more ________ areas.**
   a. **Private, visible**
   (This is a very viable way to preserve the architectural character on the inside of a building, when matching pieces are difficult or impossible to obtain.)
   b. Service, commercial
   (Possibly, but this isn't what is described in the course material)
   c. Exterior, interior
   (These outside probably aren't going to be very appropriate inside.)
   d. Public, rentable
   (Whether a space is rentable or not has no bearing on where ornamentation should be reused.)

6. **__________ will also have major input on whether they wish to finance a restoration, or a removal followed by a rebuild.**
   a. Neighborhood associations
   (Typically not funded by the neighborhood association)
   b. Institutions holding funds in trust
   (Unless the trust has qualifications in place for how funds can be used, these institutions would have no say in how disbursements are used.)
   c. Potential heirs of the developer
   (Until the developer is dead, potential heirs usually have no control over funds.)
   d. **Insurance companies**
   (Without them signing off on a project, funds won't likely be forthcoming.)

7. **It may be necessary to submit proposed changes and repairs to damaged buildings for zoning and planning approvals, if the ________ is expected to change.**
   a. Business name
   (No one really cares, so long as standards of decency are maintained and no trademarks are violated.)
   b. **Occupancy use**
   (This is absolutely true, as life safety requirements are different for each occupancy classification)
   c. Exterior color scheme
   (This would only come into play if there is already a recommended or required color palette for a redevelopment district in which the building sits.)
   d. Perimeter drainage
   (Drainage issues typically come into play only when the area of impervious surfaces on the site will be changed.)

8. **Material prices can be driven up by ___________ .**
   a. The rising costs of mortgage loans
   (These affect overall lifetime costs, but have no effect on material prices)
   b. Increasing scarcity of building sites
   (This has no effect on material prices, just land costs.)
   c. Onerous legislation by regulatory agencies
   (This has no effect on material prices, just quality of life.)
   d. **Natural disasters creating shortages**
   (This problem will definitely affect material prices, as supply suddenly drops below demand.)

9. **In general terms, in order for a building to be considered 'historic,' it needs to be at least _____ old.**
   a. Two hundred years
   (The older I get, the younger this seems, but this is still too many years to match course material.)
   b. Over forty years
   (This is closer, but still doesn't match actual criteria.)
   c. One century
   (The older I get, the younger this seems, but this is still too many years to match course material.)
   d. Fifty years
   (Well, I'm at least considered 'historic' now. Sounds better than decrepit.)

10. **If we are to keep historic structures, then ___________ them becomes important as well.**
   a. Maintaining
   (It does little good to go through the effort of restoration, just to let a building deteriorate again.)
   b. Publicizing
   (Publicity will have little effect on a building's continued existence.)
   c. Designating
   (In a sense this is actually true, though it is not the answer given in the material. Having a building officially designated as 'historic' does put some protections in place and opesn the door to funding opportunities. But it is not a prerequisite to keeping an older structure.)
   d. Subsidizing users of
   (Although many users wish this were true, very few historic building owners or users are subsidized.)

11. **Demolishing buildings of historic or cultural significance can create _______________.**
   a. A void in a historic district
   (Definitely, but this is not the answer given in the material.)
   b. An unprecedented amount of hazardous waste
   (Not unless the building was previously used for hazardous purposes or contained hazardous materials.)
   c. Tremendous societal opposition
   (This can be expected and perhaps rightly so, since buildings with a lot of age also generated a lot of memories.)
   d. Displaced older businesses
   (The age of any displaced businesses has nothing to do with the building age.)

12. **Retrofitting in adaptive reuse is the art of finding value in what others may _________.**
   a. See as liabilities
   (This is straight from the course material and an excellent investment strategy.)
   b. Simply transport to a landfill
   (And what a waste that might be.)
   c. Publicly disparage
   (Opinions are usually worth about exactly what was paid for them.)
   d. Demand be removed
   (Those demanding such are not likely to be the ones suffering financial loss by tearing it down.)

13. **The two biggest hurdles to overcome in complying with building codes during retrofits are ____________ .**
   a. Reattachment of veneers and new copings
   (These are neither specified in the code, nor problems with many retrofit projects.)
   b. Safety and accessibility
   (This is the answer given in the course, the two code areas with which it is most difficult to comply during retrofits.)
   c. Vehicular access and parking
   (These are zoning issues, not building code requirements.)
   d. Material staging and pedestrian safety
   (These are not building code concerns, though OSHA requirements may come into play for the second.)

14. **Older buildings provide a direct link back to a community's _______________.**
   a. Founding fathers
   (Not necessarily true in most cases, unless the building is about as old as the community.)
   b. Scandals about old money
   (How fun, but usually not true.)
   c. Original intentions when founded
   (It would be very difficult to ascertain these with any certainty.)
   d. Heritage and history
   (This is definitely the case. Back to older buildings being sources of old memories.)

15. **At the end, the project must be ____________ or private money will abstain from involvement.**
   a. A source of pride
   (Most investors are far more concerned with a return on investment, than with pride.)
   b. At least break-even
   (Break-even is a terrible investment.)
   c. Profitable
   (And this would be exactly why investors, invest)
   d. Free from regulatory hassles
   (It is probably safe to say that no projects in America are free from regulatory controls any longer)

16. **Which of the following is NOT a building component now deemed to be hazardous.**
   a. Plasticized paints
   (These are the paints, including latexes, most commonly used today.)
   b. Asbestos insulation
   (This is definitely a known health hazard.)
   c. Lead paint
   (This is definitely a known health hazard.)
   d. Flooring containing asbestos
   (This is definitely a known health hazard, especially during removal.)

17. Simply put, successful adaptive reuse often requires some level of cooperation between _______________.

a. Artisans and developers

(Such a partnership is nice, but not a prerequisite for project success.)

b. Community leaders and investors

(Such a partnership is nice, but also not a prerequisite for project success. Often, there is no community participation.)

c. Developers and municipalities

(Unless a municipality is willing to work with developers in terms of compliance with regulations, there are so many rules, adhering to all could make a project untenable.)

d. Lenders and builders

(Such a partnership is nice, but not a prerequisite for project success, since private money may be used.)

18. According to the United States Environmental Protection Agency, it takes _____________ for a new energy-efficient building to save the amount of energy used in demolishing an existing structure.

a. Only eleven months

(If this were true, more existing buildings would be disappearing.)

b. Eleven and one half years

(A little closer to reality, but still way off.)

c. About sixty-five years

(This is the actual number, determined by research by the agency.)

d. A millennium

(Seems that way sometimes, with some investments.)

PDH Academy

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ARCHITECTURE FOR DISASTER RELIEF FINAL EXAM

1. **In a high-wind event, __________ pressures work to pull the parts of the house up.**
   a. Downdraft
   b. Lateral
   c. Uplift
   d. Crosswind

2. **In determining the performance of buildings in hurricanes. ______________ shapes are best.**
   a. Compact
   b. Symmetrical
   c. Simple
   d. All of the above

3. **Prior to European arrival in the Caribbean, most indigenous homes had walls made of __________.**
   a. Adobe
   b. Wattle and daub
   c. Brick
   d. None of the above

4. **______________ are classified as either in-ground, above-ground, or within a basement**
   a. Bunkers
   b. Bomb shelters
   c. Safe rooms
   d. Conservatories

5. **The two types of flood proofing are ________________________.**
   a. Up and down
   b. Wet and dry
   c. Bitumen and polyurethane
   d. None of the above

6. **The ______________is by far the best shape for earthquake and hurricane resistance.**
   a. Triangle
   b. Cube
   c. Dome
   d. Ellipse

7. **When responding to the immediate situation after a disaster it is important that people see _____________.**
   a. Who is in charge
   b. Action as soon as possible
   c. What caused the disaster
   d. Government involvement

8. **______________________ is one of the best natural materials for shingle making.**
   a. Asphalt
   b. Rubber
   c. Birch bark
   d. None of the above

9. **In addition to the obvious physical challenges, there are also ________ needs to be addressed.**
   a. Psychological
   b. Emotional
   c. Social
   d. All of the above

10. **Some disasters that would have previously been attributed to natural causes, are the result of __________.**
    a. Nuclear reactions
    b. Actions of man
    c. Meteorological cycles
    d. None of the above

11. It is important to establish temporary housing in locations that will allow people to ______.

a. Earn a livelihood
b. Be close to ancestral homesites
c. Access infrastructures
d. All of the above

12. Providing adequate ________ is one of the most intractable problems in international humanitarian response.

a. Water
b. Food
c. Healthcare
d. Shelter

13. Due to the _________________Fukushima populations had to go to provisional housing further away.

a. Destruction of infrastructures
b. Radiation
c. Lack of potable water
d. None of the above

14. Haiti's is one of the __________________ countries in the Western Hemisphere.

a. Hottest
b. Windiest
c. Poorest
d. Most humid

15. A significant problem with designing and building in Haiti is the lack of available __________.

a. Electricity
b. Skilled labor
c. Timber
d. Building inspectors

16. Early examples of man-made buildings were most likely fabricated from ________________.

a. Wood
b. Bones
c. Hides
d. All of the above

17. In addition to their network of roads, Rome was also famous for their impressive __________ system.

a. Aqueduct
b. Welfare
c. Horticultural
d. Agricultural

18. When disaster strikes, ______________ is of the essence.

a. Planning
b. Time
c. Construction
d. None of the above

19. When providing emergency shelter, materials should be ___________________.

a. Minimal
b. Inexpensive
c. Able to be on site as soon as possible.
d. All of the above

20. The short-term response phase may last _____________________.

a. Days
b. Weeks
c. Months
d. Years

21. Many designs for houses after the earthquake of 2010 in Haiti were deliberately designed as ____________.

a. Gazebos

b. Cabanas

c. Shacks

d. Tiny houses

22. Approximately______ percent of all the energy released in earthquakes comes from the Circum-Pacific Belt.

a. 20

b. 40

c. 60

d. 80

ARCHITECTURE FOR DISASTER RELIEF

COURSE DESCRIPTION / LEARNING OBJECTIVES / CONTENT

COURSE DESCRIPTION:

This course will investigate the opportunities for architects, designers, and engineers as they address the unique needs and challenges when designing structures and communities in the aftermath of natural disasters.

COURSE OBJECTIVES:

Objective 1: To gain a basic understanding of the loads that natural forces exert on structures in order to design buildings that provide for the physical safety of the victims of disasters.

Objective 2: To gain a sensitivity to the mental and emotion need of people for a home, not just a house.

Objective 3: To gain a knowledge of the essential social need of community for victims of disasters and how architects can plan villages to promote a healthy social environment.

Objective 4: To inspire creativity in the approach and design of architectural solutions to protect and encourage people who find themselves in the dire conditions that natural disasters create.

INTRODUCTION

I remember sitting in a studio jury session when I was in architecture school and realizing that most, if not all, of the students were upper middle class or upper class. It wasn't because of the cost of tuition because it was a state university. It was because each individual had grown up with a certain privilege that allowed not having to worry about the rudimentary essentials of life - what one would wear, and what one would eat, and where one would sleep. It was a situation that allowed one to think about "higher" ideas such as the fine arts – painting, sculpture, theatre, and architecture.

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When one thinks of buildings, they think of them as ART. Whereas others who were less privileged only thought of buildings as shelter.

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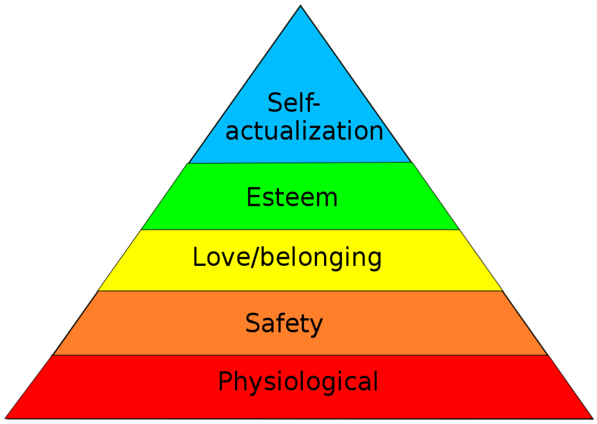
Abraham Maslow explained the situation with his well-known "Hierarchy of Needs". Maslow's idea suggests that the most basic level of needs must be met before the individual will effectively desire (or focus motivation upon) the secondary or higher-level needs. Only when our basic foundational needs are met can we ascend to upper levels of human fulfillment and actualization.

MASLOW'S HIERARCHY OF NEEDS



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For millennia some people have lived and grown accustomed to the "finer things of life." Even the poor today possess more than the above average person had in years gone by. It is not uncommon to see a homeless person in a third world country with a cell phone. Though life may not be abundant for many in the world today, the vicissitudes of extremity have for the most part been held at bay.

But what happens when catastrophic, life changing events happen? What happens when the society to which we are accustomed collapses? What happens when the shopping malls and light rails and highways and restaurants are all gone? What happens when there are no grocery stores or petrol stations or coffee shops? What happens when there is no available electricity or reliable drinking water or functioning toilets. What happens when the buildings we have admired have collapsed, crushing friends and family?

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Then comes a time when even architects must return to square one and think of buildings primarily as shelter. But addressing the primary need for structure does not preclude addressing of psychological, emotional, and social needs as well, and architects are uniquely qualified to do so.

There are many types of disasters that occur, force majeure, some acts of God, some acts of man. In recent times, we recognize that some disasters that would have previously been attributed to God or natural causes, are actually the result of the actions of mankind. It is commonly accepted nowadays that extreme weather events may be due to long term carbon emissions that have been introduced into the atmosphere since the industrial revolution. We still label them as "natural" disasters, but it is a nature that has been influenced, if not abused by mankind, both unwittingly and wittingly. For instance, the perennial wildfires in the western United States have been attributed to the overcontrol of fires that occur from natural causes such as lightning. The Fukushima disaster was a hybrid event, beginning with an earthquake and a tsunami, but ending with a nuclear catastrophe of mankind's making.

This course will not address the more prodigious disasters of our times such as Chernobyl, or Three Mile Island, not because they are unimportant, but because they are extraordinary. We will instead focus on two of the "ordinary" types of disasters: earthquakes and hurricanes (Atlantic) / typhoons (Pacific).

Though there have been many disasters in recent history, this course will consider only three:

- Indonesian tsunami 2004
- Tohoku earthquake and tsunami 2011
- Haiti earthquake 2010

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INDONESIAN TSUNAMI 2004

Tied for 10th place is an apocalyptic magnitude 9.1 earthquake that struck off the west coast of Sumatra, Indonesia, on Dec. 26, 2004. The quake created a catastrophic tsunami that killed approximately 230,000, and displaced nearly 2 million people in 14 South Asian and East African countries. Moving at speeds of 500 mph, the tsunami reached land in 15 to 20 minutes after the quake hit, giving residents little time to flee to higher ground. In some places, the tsunami wave height was over 100 feet high.

Estimated damages from the earthquake and tsunami are estimated at $10 billion dollars. This event is considered the third largest earthquake in the world since 1900, and its tsunami has killed more people than any other tsunami in recorded history. Because of the time of year, many of the people who died, died because of exposure after the disaster for lack of shelter rather than the tsunami itself. The distance between the beach and the hills in some areas meant that the death toll in some villages was as high as 90%. Twenty days after the tsunami occurred, a medical team found people who had been without food or medical assistance apart from one single air drop. Some children were found on their knees without the strength to stand up.

As is the case in all post disaster programs for housing the victims, there are three stages – emergency shelter, such as tents and lean-tos, temporary or transitional houses, such as barracks and camp cabins, and finally, to normal houses in communities with infrastructures, public spaces, and social/cultural facilities.

In the region of Indonesia where the tsunami struck, there were some pre-existing conditions that were important to consider. Firstly, the people's lives were essentially connected to the pre-disaster ancestral location of their homes. Some of this was due to their livelihoods being dependent on coastal living. Originally, the Indonesian government had forbidden rebuilding on the tsunami devastated areas. At the insistence of many of the survivors, the ban was lifted so that the people could return to where they considered to be their home. Secondly, many of the people had previously been forcibly displaced and placed in military camps built for the refugees of the conflict between the separatist Acehnese Freedom Movement and the Indonesian military. This caused them to be frightened by some of the transitional situations from emergency to temporary housing which were often like military styled barracks.

Fortunately, within weeks after the disaster reconstruction was identified as a number one priority for the Indonesian Government and international non-government organizations (INGOs). Within a month of the disaster over 400 international aid organizations had arrived on the scene, with over a quarter of these dedicated to housing reconstruction. Within a period of five years of the disaster more than 125,000 houses had been built in Aceh.

Many of these houses were built from a top-down perspective. They were generally a single plan of minimum standard design established by the BRR (Agency for the Rehabilitation and Reconstruction of Aceh and Nias), which is a $36m^2$ masonry house consisting of one multipurpose room, two bedrooms and one bathroom. Residents had zero input into the design of their house or what their real needs might be.

One development that was originally considered a success was the Indonesia-China Friendship Village usually referred to as the Jackie Chan Village, since the Hong Kong movie star had made a donation to the village and had also visited on one occasion. Originally housing about 2,400 residents that were from several different cultural groups, the population was reduced to half of that in a few years. Even though people liked their new homes, in some cases even better than their pre-tsunami ones, it was just too remote for the residents to find employment. Also lacking were markets, schools, and other amenities needed to successfully support a sustainable community.

Reconstruction in Indonesia after the tsunami is not without real success, however.
The anti-poverty network Uplink Banda Aceh (UBA) maintained that villagers should be able to rebuild where they previously lived. This was at the time when the government had established a "no-build zone." UBA organized protests against the ban and provided temporary shelter and food in coastal villages in the no-build zone. With the help of international funding, they developed resident-driven construction in 23 villages in and around Banda Aceh. They worked directly with community members to plan and rebuild housing and infrastructure, including community centers and houses of worship.

UBA's philosophy was that "outside parties who want to help disaster victims should empower the communities and consider the role of local institutions, so that community rebuilding post-disaster is initiated by the local people themselves."

By the summer after the tsunami, UBA had salvaged enough wood from the tsunami debris to construct 450 temporary shelters across 23 villages. They subsequently worked with Jakarta architect Marco Kusumawijaya and local community members to plan and build more than 3,000 permanent homes by February 2007. While global organizations were still arguing about processes, UBA had already surveyed villages, obtained local buy-in, and had started building homes. UBA did not limit their role to the construction of housing and infrastructure. They organized community programs and social events. They also helped restore income-generating opportunities. For instance, much of the farmland had been damaged by saltwater, so they taught farmers techniques for enhancing agricultural productivity in high-salinity soil. Those who have studied post-tsunami reconstruction in and around Banda Aceh have discovered that houses built with community participation are in better condition than houses that are built "top-down" by outside developers.

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TOHOKU EARTHQUAKE AND TSUNAMI

The 2011 Tōhoku earthquake and tsunami occurred at 14:46 JST (05:46 UTC) on 11 March. The magnitude 9.0–9.1 earthquake had an epicenter in the Pacific Ocean, 45 miles east of the Oshika Peninsula of the Tōhoku region, and lasted approximately six minutes, causing a tsunami. It is sometimes known in Japan as the "Great earthquake disaster of East Japan", The disaster is often referred to in both Japanese and English as simply "3.11"

It was the most powerful earthquake ever recorded in Japan and the fourth most powerful earthquake in the world since modern record-keeping began in 1900. The earthquake triggered powerful tsunami waves that reached heights of up to 133 feet in Miyako in Tōhoku›s Iwate Prefecture, and which, in the Sendai area, traveled at 435 mph and up to 6 miles inland. Residents of Sendai had only eight to ten minutes of warning, and more than a hundred evacuation sites were washed away. The snowfall which accompanied the tsunami, and the freezing temperature greatly hindered the rescue efforts. Ishinomaki, the city with most deaths, was 0°C (32°F) when the tsunami hit. The official figures released in 2021 reported 19,747 deaths, 6,242 injured, and 2,556 people missing, and a report from 2015 indicated 228,863 people were still living away from their home in either temporary housing or due to permanent relocation.

The tsunami caused the Fukushima Daiichi nuclear disaster, primarily the meltdowns of three of its reactors, the discharge of radioactive water in Fukushima and the associated evacuation zones affecting hundreds of thousands of residents. The loss of electrical power halted cooling systems, causing heat to build up. The heat build-up caused the generation of hydrogen gas. Without ventilation, gas accumulated within the reactor containment structures and eventually exploded. Residents within a 12 mile radius of the Fukushima Daiichi Nuclear Power Plant and a 6.2 mile radius of the Fukushima Daini Nuclear Power Plant were evacuated.

Early estimates placed insured losses from the earthquake alone at US $14.5 to $34.6 billion. The Bank of Japan offered ¥15 trillion (US $183 billion) to the banking system on 14 March in an effort to normalize market conditions. The World Bank's estimated economic cost was US $235 billion, making it the costliest natural disaster in history.

THE NEED FOR SHELTER

One of the most pressing consequences of disaster is that a large number of houses are destroyed or rendered uninhabitable, and a large number of people are left without a safe place to live. As a part of disaster management, shelter-after-disaster management attempts to respond to this need during the emergency phase and afterwards during recovery work. In the Humanitarian Emergency Response Review, Paddy Lord Ashdown states that "Providing adequate shelter is one of the most intractable problems in international humanitarian response."

TEMPORARY HOUSING

Temporary or emergency shelter focuses on providing shelter for the period immediately after the catastrophe. The purpose of temporary housing is to support victims during the recovery period allowing victims to begin return to their normal domestic life and daily routines. When people lose their houses they also lose their privacy, their identity, and their apparent dignity as human beings. Temporary housing is intended to provide a space for protection, privacy, and dignity. Temporary housing is also intended to enable family and community life, creating a sense of normalcy in the lives of the affected people.

INDUSTRIALIZED TEMPORARY HOUSING

To address the immediate demand for a large quantity of temporary housing units, industrial construction materials and methods would seem to be "go to" solutions. While such solutions will suffice for a period of time, the dangers of decontextualization leading to dehumanization are very real and this type of temporary housing will soon become counterproductive in the quest for normalization.

TEMPORARY HOUSING IN JAPAN

The post-disaster shelter management model in Japan is distributed along three stages or phases:

- Emergency shelter for immediate response
  Used for days, weeks, or at most months
- Provisional housing for short term response
  Use is variable, from one to five or six years
- Permanent housing for long term response
  Either a return to status quo architecture or new more appropriate designs

DESIGN

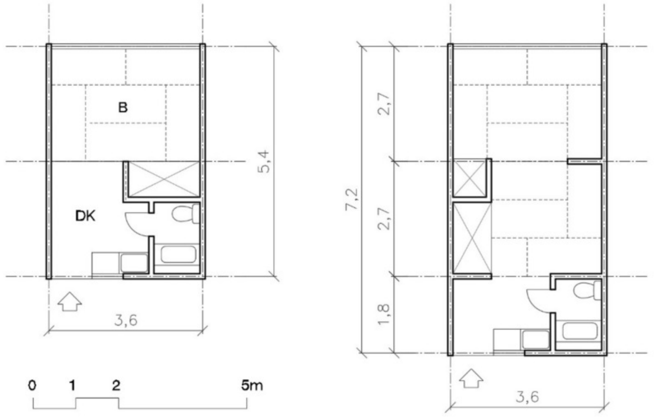
The Japanese temporary housing has followed a single design with very little variation in the last 25 years. The design promotes the social isolation of residents, making recovery from the psychological, emotional, and social problems that obtain after a disaster very difficult.

Efforts were made to improve the social health of residents by moving pre-disaster communities together to the same camp and place temporary housing areas as close as possible to the residents' original neighborhoods. This proved to be of some help, but it was not possible to set up camps in some of the areas of the destroyed neighborhoods.

The architecture and design of the temporary housing areas proved not to be a solution but rather a part of the problem.

Japan's temporary houses used light metallic-structure prefab, over which elevated flooring made of plywood sheets was placed 12 inches above the ground. The ceiling and walls were composed of thin wooden sheets plated by thin galvanized steel. There was no thermal insulation or any type of noise cancellation.

Two models were offered: one bedroom with 215 ft2 and two bedrooms with 280 ft2. The houses were equipped with a prefabricated bathroom and a small kitchen. The rooms were sized using tatami mats ~ (3ft × 6ft), which determined the size of the room: ~ 9ft X ~12ft.



Most of the temporary housing areas could hold 250 to 1000 temporary houses, although some were much more populated, including one camp that had more than 2000 houses. The matrix layout of the houses, all facing the same direction, meant that entry doorways never faced each other and reduced the possibilities of interaction between neighbors. Also, there were no allowances for plazas, courtyards, or any kind of public space. The overall scheme was more that of a concentration camp.

TŌHOKU 2011 CONTINUED...

The extent of the disaster's area, and the specific location of the affected areas due to the radioactive contamination from Fukushima, resulted in different ways in how the temporary housing areas could be managed.

More than 50,000 temporary houses had to be manufactured. Houses were similar to what has been described, however at Tohuko, wooden manufacturing companies built more than 6000 units, 4000 of which for Fukushima. It took approximately two months to manufacture the prefab housing, and the wooden houses a bit more. However, it took several more months for many of the temporary housing areas to become available. In September 2018 seven and a half years after the earthquake, there were still more than 5600 people living in temporary housing areas in Iwate, Miyagi, and Fukushima.

In Tōhoku, it was not possible to locate temporary housing areas near the areas where people formerly lived. Due to the radiation around Fukushima populations had to go to provisional housing further away. Also, in the areas affected by the tsunami it was hard to find suitable land to set up the temporary housing areas, so those affected had to move to areas further away from their original houses.

At least one community center was built for every fifty temporary housing areas to organize activities to improve and encourage relationships between residents. Centers to care for the elderly were also included in some temporary housing areas.

Special initiatives were initiated in the temporary housing areas like the "Do it Yourself" and "Home for All" projects. The "Do it Yourself" project was a collaboration between two private companies, the Royal Home Center Co. Ltd. and Daiwa House Industry. The project provided materials and know-how so residents could improve their houses by building additional features such as benches, awnings, and fences. The "Home for All" project is an initiative of the architect Toyo Ito. The project's main mission is to enable residents to participate in the construction of centers for meetings and celebrations as a community-building strategy.

Because of the huge number of temporary houses that needed to be built and the tight deadlines for assembly, the building quality was very low resulting in complaints from the residents. Some common complaints were the lack of ventilation under the floor, which resulted in mildew, condensation on windows, the oppressive heat in the summer due to insufficient insulation and the lack of privacy because there were no sound deadening measures.

In Tōhoku, in addition to the more industrial metal/wood houses, three prefectures built temporary wooden houses. There was a large variety of types which made for a more human sense of place. The wooden houses were preferred by the residents. They took longer to build but the price was similar to that of the metal/wood prefab houses.

It is disturbing that though many of the problems that obtained after the earthquake/tsunami were architectural in nature, very little was actually contributed by architects to solving the problems. Rather temporary housing units and their arrangement in camps remained status quo even though there were decades of evidence that the approach was not only not working but was in many ways compounding the problems.

Japanese temporary housing units have barely changed in the 25 years since. The houses were intentionally designed to provide autonomous and self-sufficient life inside of it. This would seem to be right thinking providing safety and privacy. But self-sufficiency can be isolating and counterproductive to social health. M.A. Smith compared China and Japan's post-disaster temporary housing areas. The Chinese units differed from the Japanese in that the Chinese units were not autonomous. The Chinese units were simply bedrooms with no running water. All bathing and dining were done in common facilities necessitating daily contact with others in the community increasing socialization and improving the psychological and emotional health of the residents.

Kodokushi, or "lonely death" means death alone without the care or company of another person. In Tōhoku 230 cases of *kodokushi* were recorded in six years (2011 to 2016), according to the National Police Agency, 97 were in the first three years. In contrast to the 230 cases of kodokushi in the Japanese camps, the Chinese had no cases at all.

Not only have there been no architectural improvements to the temporary housing units, but there have also been no urban design improvements either. The matrix layout of the houses, all facing the same direction, meant entry doorways never faced each other and reduced the possibilities of interaction between neighbors. No public spaces were designed into the camps. This is indicative of the prevailing ideology of design that is based on physical production and not human needs.

There is the saying that "a house is not a home," and the adage is key to the misunderstanding that supplying a house is enough to solve the needs of disaster victims. What the victims have lost is not just their houses, but their homes, which includes all their belongings, which provided them with their identity as well as the loss of family members and friends. After a disaster, the relationships that the affected people had with friends, neighbors, and acquaintances in their communities are broken.

Certainly, a physical structure is a major part of restoring what has been lost, but the psychological, emotional, and social aspects of community life are the essential elements of what will successfully provide the victims with new homes.

The philosopher Takashi Uchiyama criticized the Japanese government's management of the Tōhoku disaster. According to Uchiyama, recovery is neither revival economy, nor rebuilding houses, but the rebuilding of relationships between people and between human beings and nature. For architects that means designing villages not just houses. Villages with houses arranged in schemes that will encourage social exchange with neighbors. Villages that will include plazas and parks and marketplaces.

A good starting place for rebuilding community would be public forums, where the members of the [new] community could contribute their ideas and the expression of their needs could be heard. Granted that during the extreme and chaotic times immediately following a disaster, it is difficult to congregate people in any deliberate and organized way, but it is important that the affected people feel that they are part of the solution to the enormous problem they find themselves in. If they feel like they are helpless and at the mercy of the government, NGOs, and charity organizations, rather like children who cannot help themselves, then they will become depressed and lose vision for a future restoration and a return to normal life.

HAITI EARTHQUAKE 2010

A catastrophic magnitude 7.0 earthquake struck Haiti just northwest of Port-au-Prince on Jan. 12, 2010. It ranks as one of the three deadliest quakes of all time. Haiti is one of the poorest countries in the Western Hemisphere. It's limited experience with large earthquakes left Haiti extremely vulnerable to destruction and loss of life. As many as 3 million people were affected by the quake. Death toll estimates range from 230,000 to 316,000 persons.

The earthquake impacted a country whose buildings were not built to any regular engineering standards. Pierre Fouche, at the time, Haiti's only earthquake engineer, said he was saddened by the fact that so many who died were killed because buildings in Haiti were so poorly constructed. Haiti does not have a national building code. Most people in Haiti still live and work in unreinforced buildings, typically constructed of brick, block or concrete. Such buildings are considered to be rigid and lack any of the ductility that is required to be resistant to the kinds of forces of earthquakes exert.

Early promises of building a new Haiti by programs such as those inaugurated by former U.S. Secretary of State Hillary Clinton were supposed to be symbols of the new nation, but the failures of these endeavors only highlighted the intractable housing problem of Haiti. A mere fraction of the permanent houses promised for Haiti have been built, and the quality of the materials used in the homes have been deemed so inferior that USAID officials say they are considering taking legal action against contractors. The Haitian government financed a development called Lumane Casimir Village on the outskirts of Port-au-Prince. Two years after it was started, only 30 percent of the development was completed, and just 477 of 1,280 of the completed homes were occupied.

In a Miami Herald interview., USAID Mission Director John Groarke said that the enormous housing problem Haiti faced could not be resolved just by having donors build houses. Rather he believes the focus should be helping Haitians build their own house as well as assisting the Haitian government in building their own roads and infrastructure. This has become a recurrent conclusion after many failed attempts at top-down solutions to disaster relief around the world.

POST-EARTHQUAKE HAITIAN ARCHITECTURE

A significant problem with designing and building in Haiti is the lack of available timber. This is due to the mass harvesting of trees in the past to produce charcoal. Consequently, current Haitian architecture continues to rely on concrete to build dwellings and other buildings. Most of the concrete used is in the form of blocks which are often combined with traditional stonework. Roofs are generally composed of locally sourced palm thatch. Unfortunately, the roofs are prone to hurricane damage and the walls are vulnerable to earthquake damage.

A great challenge lies in designing and building structures and dwellings that will survive future natural disasters, while being affordable to a nation with such a weak economy.

REVIEW QUESTIONS

1. **The American psychologist who created the Hierarchy of Needs was ____________.**
   a. Abraham Lincoln
   b. Sigmond Freud
   c. Abraham Maslow
   d. Carl Jung

2. **Fukushima was a hybrid disaster with an earthquake, ____________, and a nuclear meltdown.**
   a. Cyclone
   b. Tsunami
   c. Typhoon
   d. Tornado

3. **Many of the people who died in the Indonesian tsunami of 2004, died because of __________.**
   a. Starvation
   b. Dehydration
   c. Drowning
   d. Exposure

4. **The three responses after a disaster are __________, short term, and long term.**
   a. Immediate
   b. Longevity
   c. Brief
   d. Overall

5. **After a disaster people prefer to rebuild________________.**
   a. A different location
   b. On higher ground
   c. The place where they lived before the disaster
   d. Near an escape route

6. **Successful reconstruction is usually done by ________________.**
    a. Experts
    b. General contractors
    c. NGOs
    d. The victims themselves

7. **The Japanese word for "lonely death" is _____________________.**
    a. Hari kari
    b. Kamikaze
    c. Kodokushi
    d. Sudoko

8. **The greatest loss people suffer from disasters is their _____________.**
    a. House
    b. Belongings
    c. Home
    d. Employment

EFFECTS OF DISASTERS

STRUCTURAL DAMAGE

- ***Residential***

There is abundant evidence that ancient humans found shelter in natural formations such as caves and tree hollows, but there is also evidence that early humans also built structures to protect themselves from the natural elements as well as from predators. Some of the earliest examples of man-made buildings were most likely fabricated from wood, animal bones and hides and consequently have not survived. Some current primitive and nomadic societies live in huts and tents that may be very similar to these earliest human architectural endeavors. Mongolian yurts or Native American tepees and wigwams are examples.

Not unlike other animal species, humans are familial and structures that humans have built are primarily residential, shelters to protect themselves from exposure to the elements as well as safe places to eat, sleep, work, and play without fear of predation whether from wild animals or other people.

In addition to supplying the lower level of Maslowian needs of safety and security, residences also provide people with opportunity to express their personalities and sense of aesthetic and pride.

When disasters destroy peoples' residences, they are bereft of their most important physical means of protection and dignity.

STRUCTURAL DAMAGE

- ***Public***

In addition to being familial, humans are also social, congregating and living in close proximity to other families. Both opportunities and problems arise when people live together, and social contracts must be made. These contracts help protect individual freedoms, but also seek to take advantage of human association resulting in laws, commercial enterprises, and public institutions which are beneficial to the individual because they are beneficial to the whole.

Consequently, just as the familial aspects of human life gave rise to residential building, social aspects of human life gave rise to commercial and public buildings - commercial buildings for shops and offices and public buildings for public administration and law enforcement.

When disasters destroy our social and public buildings, order suddenly becomes chaos.

INFRASTRUCTURE DAMAGE

- ***Transportation***
- ***Roads***
- ***Bridges***
- ***Rails***
- ***Shipping Ports***
- ***Airports***

In addition to the residential, commercial, and public buildings that humans built, pathways to move themselves, their livestock, and their goods from one place to another were also developed. Herd paths became trails, which became roads which connected intra-community buildings and highways that connected nearby villages, towns, and cities. Plank roads, stone pavements, and even concrete roads became important infrastructure for human activities. The ancient Roman road system was very sophisticated even by today's standards. The Romans standardized the width of their roads to 4.2 meters (4.6 yards) wide to allow for two-way traffic. They also built their roads with a slight slope to allow water run-off. At the peak of the Roman Empire, over 50,000 miles of highway made it possible to effectively rule the ancient world. Modern interstate and state highways along with bridges, railways, shipping, and airports are essential for the movement of people and goods and the velocity of the economy.

When disasters destroy the arteries of commerce and supply, life essentials are cut off and society risks collapse.

INFRASTRUCTURE DAMAGE

- ***Utilities***
- ***Electical***
- ***Water***
- ***Communications***

In addition to their vast network of roads, Rome was also famous for their impressive aqueduct system bringing needed water from miles away to their citizens for drinking and irrigation.

Modern infrastructures now include more than roads, railways, shipping channels, and airports. Just as important are networks of pipes and wires that distribute water, gas, electricity, and data.

When disasters destroy infrastructures, essential lifelines are severed.

TIMELINE

When disaster strikes, time seems to come to a standstill but actually time becomes of the essence like never before. After a disaster, there are three essential timely responses – immediate, short term and long term.

Disaster ……….. Immediate Response ……….. Short Term Response ……… Long Term Response

IMMEDIATE RESPONSE

Immediately following a disaster, a rapid response is crucial. Medical services are required for bodily injuries, as well as immediate attention to damaged structures to insure some level of safety and security. Often casualties due to exposure after the disaster exceed those caused by the actual disaster event. This was certainly the case with 9.1 earthquake and ensuing tsunami that struck off the west coast of Sumatra, Indonesia, in the middle of winter on Dec. 26, 2004.

Well-intentioned but ill-advised responses like what happened in Haiti after the 2010 earthquake seemed to provide for the immediate need for shelter but were actually recipes for further disaster by erecting windsails and providing potential wooden projectiles.

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Not only were the structures themselves potentially dangerous, but they were also arranged like chicken coops without any regard for the sociological needs of the people. Supplying the more basic Maslowian needs does not preclude considering the higher needs of people.

Architects are uniquely capable of designing solutions to immediate physical needs of people while recognizing the mental, psychological, emotional, and sociological needs as well.

When responding to the immediate situation after a disaster event, it is important that people see action as soon as possible, both for physical protection and safety and for emotional encouragement. Promises with procrastination and inaction cause the people to be discouraged and to distrust those who are trying to help.

Materials should be minimal, inexpensive, and able to be on site as soon as possible. If possible, construction methods should be kept simple, so that the victims of the disaster can perform most, if not all, of the actual construction.

One effective tactic to shelter people from the elements immediately after a disaster event is the employment of survival shelters using natural materials such as tree limbs, branches, and leaves in forested areas. In areas where there are no trees dugouts can be made into the earth. In areas where there is significant snow fall, the snow can be used to build igloos.

SHORT TERM RESPONSE

After the immediate needs are met, an intermediate or short-term response should be planned and executed. This would include both temporary structures as well as a rudimentary community planning including roads, activity specific zoning, and infrastructure easements. The short-term response phase may last for years and should be a large advance forward toward a more permanent and normal build out. It need not be a "familiar" architecture, since the architecture that was familiar is what failed in the disaster event. Social life will not have returned to normal yet, so the community arrangement may still be more of a camp than a village, but if many of the needs of the population are being successfully met, the people will be encouraged and will afford patience toward the next phase of the recovery of normal life.

LONG TERM RESPONSE

Long term response would include analysis and evaluation of historical and traditional building materials and methods as well as consideration of contemporary and futuristic materials and methods. The traditional buildings and infrastructure that have been destroyed may provide a nostalgic desire to return to the past but advances in new materials and methods should not be ignored, since a prime objective for future development will be to prevent or at least to protect as much as possible from a similar disaster.

Architects are also prone to succumbing to trying to recapture the past. Many designs for housing after the earthquake of 2010 in Haiti were deliberately designed as shacks. The argument was that this was the architectural vernacular to which Haitians were accustomed and their culture should be respected. The fault with that argument that is that Haitians were not living in shacks by cultural choice, but because of their poverty.

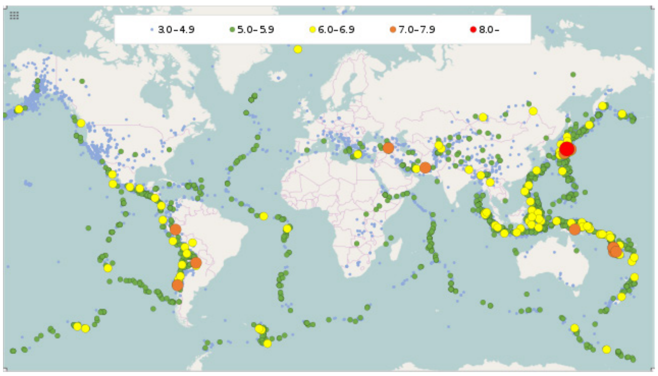
The devastation from the earthquake actually afforded an opportunity to start anew with buildings that would be more appropriate to the conditions of the country. Just as high sloped roofs are common in northern Europe to shed snow and stucco and large overhangs are common to sunny areas in the south, Haitian buildings need to be designed considering the frequent earthquakes and powerful hurricanes that continually plague the country.

EARTHQUAKES, HURRICANES, AND FLOODING

CAUSES OF EARTHQUAKES

The causes of earthquakes are numerous, including underground explosions, movement of magma within volcanoes, and impacts of large objects with the ground. These types of earthquakes usually have low intensity and rarely cause significant damage. However when earthquakes occur because of sudden movements that occur within the earth's crust they can be very dangerous and cause great damage. The earth's crust has a series of large cracks that divide it into a series of very large plates, called tectonic plates. Gravitational forces, forces induced by the earth's rotation, and forces generated by convection within the earth's molten core cause these tectonic plates to be shoved against each other, causing stress and strain energy to build up within each plate and along the boundaries between these plates. These tectonic earthquakes are explained by the so-called elastic rebound theory, formulated by the American geologist Harry Fielding Reid after the San Andreas Fault ruptured in 1906, generating the great San Francisco earthquake. According to the theory, over a period of years, the stresses will accumulate to a point where they exceed the frictional resistance between the plates or the strength of the rocks. When this happens, sudden fracturing results and a rapid shift of the earth's crust will occur, releasing some of the strain energy that has been stored over the years. This energy is released in the form of kinetic energy that radiates outward from the zone where the differential movement occurred. This causes the ground shaking and other geological effects associated with earthquakes.

LOCATIONS OF EARTHQUAKES



An earthquake can occur anywhere, but most earthquakes occur along lines of weakness in the earth's crust, which are termed faults. Faults can often be found along the bases of mountain ranges and hills that were formed by past tectonic activity on these faults. The most important earthquake belt is the Circum-Pacific Belt. It affects many highly populated coastal areas around the Pacific Ocean. Approximately 80 percent of all the energy released in earthquakes comes this belt. Because at many places the Circum-Pacific Belt is associated with volcanic activity, it has been often referred to as the "Pacific Ring of Fire", but there does not appear to be a direct causal link between volcanoes and earthquakes. They are probably only related due to the activity of the same tectonic processes. A second belt, known as the Alpide Belt, passes through the Mediterranean eastward through Asia and joins up with the Circum-Pacific Belt in the East Indies. The energy released in earthquakes from this belt is about 15 percent of the world's total.

SIZE OF EARTHQUAKES

Earthquakes are measured by quantifying the size and severity of an earthquake, respectively termed magnitude and intensity. Magnitude is a measure of the amount of energy released by an earthquake event. C. F. Richter measured magnitude on the basis of how much a standard seismic wave measuring instrument deflected, when located a specified distance from the place where an earthquake occurred. Richter created a logarithmic magnitude scale ranging from 0, for earthquakes that release negligible energy, to 9 or more, for the largest earthquakes that have ever occurred. An increase of 1 unit on the Richter scale represents an increase by approximately 32 times the amount of energy released, so that, a magnitude 6 earthquake releases approximately 32 times more energy than a magnitude 5 earthquake, and a magnitude 7 earthquake releases approximately 1,000 times more energy than a magnitude 5 earthquake.

TSUNAMIS AFTER EARTHQUAKES

Tsunami is a Japanese word for "harbor wave". Following some earthquakes, long-wavelength water waves in oceans or seas sweep inshore. They sometimes come ashore at great heights above mean tide level. Such waves can be extremely destructive. The usual cause of a tsunami is sudden displacement in a seabed sufficient to cause the sudden raising or lowering of a large body of water. The most destructive tsunami ever recorded occurred on December 26, 2004, after an earthquake displaced the seabed off the coast of Sumatra, Indonesia. More than 200,000 people were killed by a series of waves that flooded coasts from Indonesia to Sri Lanka.

REVIEW QUESTIONS

9. Ancient humans found shelter in _________.

a. Caves
b. Hollows of trees
c. Huts
d. All of the above

10. In addition to being familial, humans are also _____________________.

a. Psychological
b. Social
c. Emotional
d. Competitive

11. The Romans standardized the width of their roads for __________.

a. Live stock
b. Chariots
c. Aqueducts
d. Two way traffic

12. Often short term housing solutions are like ____________.

a. Villages
b. Camps
c. Towns
d. Cities

13. The earth's crust is divided into a series of very large plates, called ____________ plates.

a. Tectonic
b. Dental
c. Geological
d. Geographical

14. Most earthquakes occur along lines of weakness in the earth's crust, which are termed__________.

a. Cracks
b. Fissures
c. Faults
d. Crevasses

15. The Circum-Pacific Belt is often referred to _________________.

a. Circle of Death
b. Pacific Ring of Fire
c. Volcano Row
d. Pacific Triangle

16. An increase of 1 unit on the Richter scale represents an increase by approximately ______ times.

a. 2
b. 4
c. 16
d. 32

17. Tsunami is a Japanese word for "________________".

a. Sushi
b. Earth shake
c. Harbor wave
d. Coastal storm

EARTHQUAKE RESISTANCE BUILDING DESIGN

The vertical movement of the earth caused by earthquakes is not responsible for the greatest damage to buildings since all structures are designed to withstand vertical forces, i.e. the force of gravity. It is the rolling horizontal waves of an earthquake that exert the extreme and damaging horizontal forces on structures. These forces cause lateral accelerations. Lateral accelerations are measured as G-forces. A sudden movement to the side creates enormous stresses for a building's structural elements, including beams, columns, roofs, walls, and floors, as well as the connectors that hold these structural elements together. When those stresses are great enough, the building can collapse or suffer extreme damage.

SHAPE

When designing building in seismic areas, it is best to avoid irregular or asymmetrical designs, such as "L" or "T" shaped buildings or split-level structures which are more susceptible to torsion (twisting along longitudinal axes). Keeping buildings symmetrical allows seismic forces to be distributed equally throughout the structure. Limiting cantilevers, decorative elements or anything easily dislodged from a building is also advised.

FOUNDATION

By definition, when an earthquake occurs, the earth "quakes" or moves. It is, therefore, necessary to isolate the foundation from the earth to prevent seismic waves from traveling through a building. This is referred to as "base isolation". There are several strategies to accomplish this.

In typical perimeter wall foundations, instead of using rigid concrete footings, some flexible support should be used. These can be rubber pads or some other shock absorbing material that will vibrate during the shock of the earthquake but will prevent the seismic activity from engaging the building itself allowing it to remain steady. If the building can be saved from experiencing seismic oscillation, structural failure can be prevented.

Another solution involves floating a building above its foundation on a system of bearings, springs or padded cylinders. Engineers often choose lead-rubber bearings, which contain a solid lead core wrapped in alternating layers of rubber and steel. The lead core makes the bearing stiff and strong in the vertical direction, while the rubber and steel bands make the bearing flexible in the horizontal direction. Bearings attach to the building and foundation via steel plates and then, when an earthquake hits, allow the foundation to move without moving the structure above it. As a result, the building's horizontal acceleration is reduced and suffers far less deformation and damage.

Monolithic slab on grade is also an effective seismic resistance foundation. The structure must be effectively attached to the slab. According to the International Residential Code (IRC), anchor bolts should be at least 1/2-inch diameter and should be embedded at least 7 inches into the foundation concrete. They should be spaced no more than 6 feet apart. Any wall section over 24 inches long should have at least two bolts, located at least 3.5 inches but no more than 12 inches from the ends of the sill plate. Every bolt should have a tightened nut and washer.

MATERIALS AND EARTHQUAKES

Steel

It is commonly thought that steel buildings do not do well under the stresses of earthquakes, when in fact, steel buildings have advantages over concrete buildings in earthquakes.

Common sense makes us think that the heavier and more rigid an object is, the stronger it is. We assume that the weight of concrete would help hold a building down, and the stiffness of concrete would resist the swaying under the wind impact. That would be true for loads that are solely lateral, but an earthquake is different than other loads. The earth itself moves, laterally and vertically moving the foundation of the building and the forces involved are of such a magnitude that the weight of the building is inconsequential. In fact, like judo, a building's weight actually works against the structure. The greater the mass of a building being put into motion, the greater the force exerted on the structural elements, and on the connections between those structural elements. A lighter structure undergoes less damaging force because it has less mass – and therefore less force – to damage itself under seismic shaking.

It is especially important for taller buildings, to be made of light and flexible materials such as steel that can flex with the movements that earthquakes create. Multi-story buildings that are fabricated with steel are 60 to 70 percent lighter and 10 times stronger than buildings that are made of concrete of the same size. Because of these attributes, buildings constructed primarily from steel require less earthquake proofing than those made with other materials.

For a building material to resist stress and vibration, it must have high ductility — the ability to undergo large deformations and tension. Buildings that are constructed primarily of steel or other metals are highly ductile and therefore are much better at resisting earthquakes. Steel is much lighter than concrete and more flexible than concrete and other building materials, making it more likely to bend instead of break when experiencing seismic force.

According to the World Steel Association, buildings that are ductile are much safer than stiffer buildings as they dissipate energy from seismic waves. A building will typically have ductile parts that can undergo plastic deformations without complete structural failure during an earthquake

Wood

Wood is the most widely used construction material in the United States, particularly for residential buildings. Census data show that, nationwide, out of 14,000 multi-family buildings completed in 2015, more than 87% were wood frame. Of 648,000 single-family houses completed that year, more than 93% were wood frame. And in the earthquake-prone Western United States, roughly 98% of all existing homes—from modest dwellings to luxurious mansions—are wood frame structures

The aftermath of historical earthquakes around the world has repeatedly proven that wood frame buildings generally perform well during earthquakes. One example is the so-called Gingerbread Houses, a distinctly Haitian architecture which originated in the late-19th century with the Haitian National Palace. It is a style that was inspired by Parisian architecture, although modified for the Caribbean climate and to local cultural aesthetics. Gingerbread Houses were usually built of wood and masonry or stone and clay and had wraparound balconies and featured steep turret roofs which were used to redirect hot air. They were usually designed with louvered shutter windows to take advantage of the breezes and flexible timber frames to withstand earth tremors and storms. Only around 5% of Gingerbread Houses were destroyed or damaged during the 2010 earthquake (compared to around 40% of other structures). These facts have left experts thinking that they could serve as a model for future seismic-resistant architecture.

REVIEW QUESTIONS

18. When designing building in seismic areas, it is best to avoid __________________.

a. Irregular plans
b. Asymmetrical designs
c. Split level structures
d. All of the above

19. To protect from earthquakes, it is necessary to ________ the foundation from the earth.

a. Integrate
b. Isolate
c. Elevate
d. Levitate

20. A lighter structure undergoes ________ damaging force than a heavier one.

a. More
b. Less
c. Equal
d. None of the above

21. For a building material to resist stress and vibration, it must have high ___________.

a. Resilience
b. Compression
c. Ductility
d. Rigidity

22. ____________is the most widely used construction material in the United States.

a. Concrete

b. Steel

c. Aluminum

d. Wood

23. A Haitian architecture which originated in the late-19th century is the_____________ house.

a. Painted lady

b. Gingerbread

c. Victorian

d. Hurricane

Wood-frame buildings can be designed to stand up to high winds and earthquakes given the following characteristics:

- **Inherent Flexibility**

Wood's ability to withstand high loads for short periods of time and retain its elasticity and ultimate strength can be an asset in seismic and high-wind zones.

- **Lightweight**

Forces in an earthquake are proportional to the weight of a structure. Wood-frame buildings typically weigh less than those made of concrete and steel, which are typically seven times as heavy, reducing inertial seismic forces.

- **Ductile Connections**

The ability to yield and displace without fracturing under abrupt lateral or horizontal stresses is an attribute of wood-frame construction, which features typically nailed connections that allow it to respond to seismic and high-wind events without critical failure.

- **Redundant Load Paths**

Wood-frame construction provides numerous load paths through shear walls and diaphragms, which typically have hundreds of structural elements and thousands of nail connections. The numerous fasteners and connectors used in wood-frame construction offer multiple, often redundant, load paths for extreme forces, reducing the chance the structure will collapse if some connections fail as opposed to structures built with heavy frames constructed from non-wood materials having relatively few structural members and connections. The failure of one load path can lead to overloading of adjacent members or joints.

- **Connectivity**

The connection of structural elements to the foundation is essential. Wood-frame construction is easy to secure to the foundation using standard connections and tie-downs manufactured for high-load designs.

- **Strength and Stiffness**

The thickness of mass timber panels and the number and size of nails fastening the assemblies determine each component's stiffness. Heavy bracing for shear walls can resist lateral distortion common in earthquakes. The lateral forces of an earthquake tend to rack (trapezoid) buildings. Shear walls provide racking resistance, and walls and diaphragms (roofs and floors) constructed with panels of plywood or oriented strand board (OSB) over lumber framing have proven to be effective. Strength and stiffness of structural elements is increased by using thicker structural panels and on both sides if necessary and increasing the number of fasteners.

- **Design and Engineering**

The 1994 Northridge Earthquake was a milestone for engineering of wood structures. Most of the structures badly damaged in Loma Prieta earthquake of 1989 were built prior to "modern" codes, however the Northridge earthquake caused damage to structures even though they were built in the era of updated codes. Wood light-frame construction was a significant part of the overall poor structural performance in the Northridge Earthquake. A significant number of people died in the collapses of wood light-frame structures. More than 200 apartment buildings were heavily damaged. In the Reseda area of the San Fernando Valley, some entire neighborhoods were turned into ghost towns as many apartment buildings were condemned and could not be occupied.

Some buildings had weak/soft stories which explained their failures, but some recently constructed multi-family residential buildings with engineered shear wall systems that appeared to conform to recent building code provisions also failed. This led to a revisitation of accepted engineered design and detailing practices.

Historically, wood frame structures have not generally benefited from engineering design because wood construction practices had not been codified uniformly across the country until the 1990s. Seismic design specifications for engineered concrete and steel buildings have been standard for some time, but seismic design provisions for wood frame construction have been less specific.

While the first code addressing the construction of wood frame construction was published in the early 1970s, it was not mandatory nor was it enforced by local building departments. After the Northridge earthquake, a new awareness of wood frame vulnerability initiated subsequent editions of building codes and construction standards for wood frame construction to become mandatory in many jurisdictions throughout the US.

In 2000, the first International Residential Code (IRC) was published by the International Code Council (ICC), the organization that publishes the International Building Code (IBC). The IRC was developed with the specific intention of overseeing the design and construction of detached one- and two-family dwellings and townhouses, as well as other residential occupancies (including dormitories and apartments of fewer than three stories). The IRC was adopted by many state and local governments, and by the end of 2002 the 2000 version of the IRC was adopted by most states. By 2017, the IRC had been adopted by 49 states and the District of Columbia.

Since the adoption of the IRC, building quality has improved dramatically which can be attributed to improved codes and standards resulting in better design, especially with new hold-down systems to resist overturning, and specially manufactured hardware to better control load paths. An anomaly that exists, however, was that in many cases, wood frame buildings constructed in the 1940s and 1950s performed better than those built in the 1960s. Even though the houses were built with inferior practices in the 1940s all the way to 1970s, the houses were built with simpler geometries in both plan and elevation, were smaller in size, had smaller rooms, and had smaller and fewer window and door openings in the exterior walls. All of these factors provide the majority of the lateral support for wood frame buildings. Contemporary architectural features which became popular in the 1960s led to designing homes with fewer solid exterior and fewer interior partition walls. This alone resulted in a significant reduction in the lateral load-carrying capacity of these homes.

In addition to the more "open plan" preferences, many multi-story wood frame buildings are weakened by the "soft story" in which the structural stiffness or strength is much lower on the first floor than other floors because of large openings (such as garage doors or open floor plans), while upper floors have more partitioned rooms. In addition, seismic demand is driven by the combined effects of the frequency content of ground motion and the natural period of buildings. The spectral acceleration experienced by a one-story wood frame building is lower than that of a two-story building during an earthquake. This results in lower seismic forces and reduced damage in one-story buildings.

BASIC DESIGN THEORY FOR WOOD FRAMED STRUCTURES - DIAPHRAGMS AND SHEAR WALLS

Engineered systems are designed to resist earthquake loads. A lateral load path is established, and each element is designed to resist the calculated earthquake force. Roofs and floors are designed as diaphragms and some of the walls are designed to function as shear walls. Diaphragms and shear walls are used to transfer loads and to keep the building from distorting or twisting. Designs require adequate sizing of lumber framing elements and connections between all of the framing elements in the load path. Connections are especially important as this is where most failures occur. Nails and framing anchors are required to connect the diaphragms to shear walls. Hold-down connections are used to hold down the corners of the shear walls and anchor bolts are required to connect shear walls to the foundation.

TRADITIONAL LIGHT-FRAMED WOOD CONSTRUCTION

Most wood construction in the U.S. is currently still light-framed wood systems, and has been like since the mid-1900s. **Light-frame construction** is a system of construction using many small and closely spaced members that can be assembled by nailing. It is the standard for U.S. housing. Early forms of light-frame construction were balloon-frame houses with wood cladding Balloon framing, sometimes called Chicago framing, is a system of framing in which the vertical elements of the exterior walls, i.e. studs, extend the full height of the structure from the soleplate to the roof plate. Floor joists are fastened to the studs either by being nailed or screwed to the sides of the studs or by sitting on a ledger that has been let into the studs. The name comes from the French maison en boulin, boulin being a French term for a horizontal scaffolding support. Invented in Chicago in the 1840s, Balloon framing aided the rapid settlement of the western U.S. Balloon framing was replaced by another form of light-frame construction, platform framing. In platform framing, each floor is framed separately and sits on the story beneath it, as contrasted with balloon framing, in which the studs extend the full height of the building from sole plate to the rafters. Platform framing offers an easier and safer system of construction. Carpenters fabricate each story floor, which is supported by the story beneath it. The floor serves as the working platform on which the stud wall frames are fabricated in sections and then lifted into place. On top of this is placed a second floor or the roof. The roof is formed of rafters (sloping joists) or wood trusses.

Light-frame building consists of dimensional lumber framing and wood panel sheathing, which performs very well in earthquakes from a life-safety standpoint for two main reasons:

- as a natural material, wood is much lighter than steel and concrete and has intrinsic flexibility, making it more resilient to earthquake loading
- the redundancy in light-framed wood building load paths makes it very robust against collapse. Even when most structural components are heavily damaged, the building system can still manage to remain standing by developing alternative load paths.

Major research and engineering projects have made strides in improving light-framed wood building seismic performances, including:

- CUREE-Caltech Wood Frame Project (1995 - 2000) supported by FEMA after the 1994 Northridge Earthquake in California. This was the first systematic investigation into seismic performance of as-built light-framed residential buildings. Wood shear walls were tested in the lab, effects of non-structural finishing materials were assessed, numerical models were developed for earthquake response prediction and large-scale shake table tests on full wood building structures were conducted. The project established a foundation for quantitative understanding of wood building response in earthquakes.
- NEESWood Project (2005 - 2009) supported by the National Science Foundation. This project took learnings from the CUREE project and pushed it to a higher level. The objective was to develop performance-based seismic design methods for mid-rise wood buildings that are not only safe but also have reduced damage during large earthquakes. A direct displacement design (DDD) method was proposed and verified using a full-scale six-story light-framed wood building on the E-Defense shake table in Japan. The project attracted great attention because it was the world's largest building tested on a shake table to date.
- NEESSoft Project (2010 - 2013) supported by the National Science Foundation. The NEESSoft project examined existing wood building retrofit opportunities, focusing on "soft-story buildings". Soft-stories are ones that have large openings on the first floor. A full-scale four-story apartment building was tested to the point of collapse at the end of the project. Effective retrofit techniques were developed in this project and verified in full-scale testing before the collapse.

By 2014, earthquake engineering for light-framed wood buildings developed to a point that:

- multi-story wood buildings up to six stories could be constructed to withstand large earthquakes with limited damage.
- existing soft-story buildings could be retrofitted to withstand large earthquakes without collapse
- a comprehensive set of design and analysis tools for light-framed wood building had been developed and validated through large shake table tests.

Although the size and height limit of wood construction is still limited in the International Code Council's (ICC) International Building Code (IBC), light-frame wood building design has made it possible for wood buildings with the seismic performance levels of typical steel and concrete systems for mid-rise construction.

REVIEW QUESTIONS

24. Wood-frame construction provides numerous _________ paths through shear walls and diaphragms.

a. Load
b. Critical
c. Extreme
d. Resistance

25. The 1994 ______________ Earthquake was a milestone for engineering of wood structures.

a. San Francisco
b. Tacoma
c. Northridge
d. San Andreas

26. In 2000, the first International __________ Code was published by the International Code Council.

a. Building
b. Administrative
c. Electrical
d. Residential

27. Soft-stories have ____________.

a. Large doors
b. Garage doors
c. Large windows
d. All of the above

28. Diaphragms and shear walls are used to transfer______________.

a. Forces
b. Loads
c. Frames
d. Vibrations

29. ______________ construction is a system of construction using many small and closely spaced members.

a. Braced framing
b. Heavy framing
c. Arkansas framing
d. Light framing

30. Balloon framing is sometimes called _____________ framing.

a. New York
b. Boston
c. Chicago
d. Denver

MASS TIMBER AND TALL WOOD

Wood is a surprising ductile material due to its high strength relative to its lightweight structure. Timber already has a good reputation in earthquake-prone regions. Wooden structures often survive and, being strong and light, tend not to collapse heavily and crush their inhabitants in the manner of poorly built concrete homes. This is the reason why traditional housing in San Francisco area is built from wood. Timber is very strong, but it is also very brittle when it fails so ductility for deformation capacity must be supplied by other means. This is usually accomplished using steel rods and brackets. The downside to this is that after an earthquake the rods and brackets must be replaced. One solution is to allow the walls to rock or slide. This is called a rocking wall. The walls are made from cross-laminated timber (CLT) and designed with post-tensioned cables. With this design, the building's core rocks and then re–centers itself in the event of an earthquake while sustaining little to no damage to the primary structure, avoiding any need to demolish the building after an earthquake and making it more easily repaired.

A full-scale validation of new CLT wood building components was completed at the world's largest outdoor shake table, at the University of California San Diego. Katerra, a construction company investing heavily in cross-laminated timber (CLT) construction material, saw its seismic shear wall tested. Katerra's wall system was tested at three different intensities -- medium, large, and extreme. The wall system achieves its seismic resistance through rocking mechanisms placed along the base of each CLT panel, allowing the building to absorb energy and flex horizontally under load.
The results showed that:

- Under medium intensity the system experienced no damage
- Under large and extreme intensity, damage occurred, but only at the connection devices

The CLT performed as well as steel or concrete. However, in the event of an earthquake, Katerra's wall system allows the damaged connection devices on the building to be pulled out and easily replaced. This would not be possible with steel or concrete.

Michael Green is a Canadian architect and an author of books on mass timber construction. The Case for Tall Wood Buildings is a case study on using materials such as cross-laminated timber (CLT) panels and engineered glulam wood beams to build skyscrapers as tall as 30 stories. In 2013, Green gave a TED talk titled "Why we should build Wooden Skyscrapers'. Green's architecture firm Michael Green Architecture designed the seven-story T3 building in Minneapolis, which was built using 3,600 cubic meters of wood, and is intended to sequester about 3,200 tons of carbon for the life of the building.

Cross Laminated Timber (CLT) is an innovative wood product invented in Europe in the 1990s. CLT consists of 3 to 11 wood layers glued together to form solid panels with a thickness normally ranging from 60 to 320 millimeters (2.36 – 12.6 inches). The great benefit of the material is in its intrinsic sustainability, the rapid building process, and great flexibility of use. CLT has been used primarily for low-rise residential, commercial, mixed-use buildings, but recently architects are beginning to propose buildings made in CLT with 6 stories and over, such as the nine-story Stadthaus Building in London and the 10-story Forte Building in Australia. These projects have demonstrated through testing that wood components with large volume (mass timber) can survive fire for extended periods of time, and if layers of protection or sacrificial wood layers are implemented, a mass timber building may survive fire without losing load bearing capacity. Other mass timber buildings that have been constructed or planned in North America include the six-story Wood Innovation Design Centre in Prince George, BC; the 12-story Framework Project in Portland, OR; and the 18-story Brock Commons Tallwood House at University of British Columbia. Worldwide, many more ambitious tall wood building projects have been announced, including conceptual designs pushing for wooden skyscrapers over 30 stories. The tallest CLT building to date is in Mjøstårnet, Brumunddal, Norway. The 85.4-meter-high Mjøstårnet (meaning "The tower of lake Mjøsa" in Norwegian) was completed in 2019. Designed by Norway's Voll Arkitekter, the 18-story mixed-use building contains a restaurant, offices, hotel rooms, and 33 apartments. The structure of Mjøstårnet consists of glulam trusses, columns, and beams, while CLT was used for stiffening elements, and to build the elevator shafts and the staircases. An even taller building is proposed in Japan. The W350 Project is a proposed wooden skyscraper in central Tokyo, Japan, announced in 2018. The skyscraper is set to reach a height of 350 (1148 feet) meters with 70 floors, which upon its completion will make it the tallest wooden skyscraper, as well as Japan's highest, over all, skyscraper. The skyscraper is set to be a mixed-used building including residential, office and retail space. It is supposed to be made of 90% wood. Steel braces will be used to enhance resistance to wind and earthquakes. The project requires 185,000 cubic meters of timber (6.5 million cubic feet) and plans to revitalize forestry and timber demand in Japan. Wooden structures are easier to rebuild or replace than concrete structures if it collapses. Two-thirds of Japan is covered by forest, making it the 2nd most tree-covered country of the OECD (Organization for Economic Cooperation and Development) countries after Finland.

Cross Laminated Timber (CLT)-constructed buildings offers many advantages such as the potential for mass production, prefabrication, speed of construction and sustainability as an environmentally friendly and renewable construction product. Good thermal insulation, acoustic performance, and fire ratings are some additional benefits of the building system.

While CLT is recognized as an engineered wood product in the 2015 National Design Specification for Wood Construction, the seismic design parameters for buildings constructed with a CLT wall still do not exist in the U.S. model building code. For this reason, existing mass timber buildings often utilize steel or concrete lateral systems for earthquake loading.

INNOVATIVE MATERIALS

Scientists and engineers are developing new building materials with even greater shape retention. Innovations like shape memory alloys have the ability to both endure heavy strain and revert to their original shape, while fiber-reinforced plastic wrap — made by a variety of polymers — can be wrapped around columns and provide up to 38% greater strength and ductility.

Engineers are also turning to natural elements. The sticky yet rigid fibers of mussels and the strength-to-size ratio of spider silk have promising capabilities in creating structures. Bamboo and 3D printed materials can also function as lightweight, interlocking structures with limitless forms that can potentially provide even greater resistance for buildings.

Over the years, engineers and scientists have devised techniques to create some effective earthquake-proof buildings. As advanced the technology and materials are today, it is not yet possible for building to completely withstand a powerful earthquake unscathed. Still, if a building is able to allow its occupants to escape without collapsing and saves lives and communities, we can consider that a great success.

DUCTILE MATERIALS

Ductility describes how well a material can tolerate deformation before it fails. Materials with high ductility can absorb large amounts of energy without breaking. Structural steel is one of the most ductile of all materials. On the other hand, masonry and concrete are low-ductility materials, making them vulnerable materials to seismic waves. Unfortunately, unreinforced masonry (URM) is one of the most common types of partition wall systems in many buildings in North America, and many other countries around the world. URM partition walls are mostly brittle and catastrophic during an earthquake shaking. A new material has been developed called eco-friendly ductile cementitious composite. Sprayable Ecofriendly Ductile Cementitious Composites (EDCCs) is a form of fiber reinforced engineered cementitious-based composite material that is similar in nature to steel and when applied to URM walls greatly increases the wall's ductility. Experiments showed applying a 10-millimeter-thick layer to interior walls protected them from damage during a 9.0-magnitude simulated quake.

Another innovative material to reinforce existing URM is carbon fiber. Carbon fiber is the lightest and strongest material known to man. When carbon fiber straps are installed on masonry wall with an industrial-strength epoxy, it creates an unbreakable bond between the carbon fiber material and the wall surface. The result is a wall which is significantly stronger than steel.

STRUCTURAL REINFORCEMENT

There are numerous methods for reinforcing a building's structure against potential earthquakes. Commonly used shear walls and braced frames redirect seismic forces and transfer lateral forces from the floors and roof to the foundation. Diaphragms are rigid horizontal planes that transfer destructive lateral forces to vertical-resistant parts of the building, such as a building's walls or framework. Movement-resistant frames work by making a building frame's joints rigid while letting the other parts of the frame move.

Shear walls are made of panels that help a building maintain its shape during movement by transferring earthquake forces. Shear walls are sometimes supported by diagonal cross braces. There are called braced frames. Generally made of steel, these frames have the ability to support both compression and tension, which helps to counteract the pressure and push forces.

Diaphragms consist of the floors of the building, the roof, and the decks placed over them, and help remove tension from the floor and push the forces to the vertical structures of the building.

Moment-resistant frames allow for more flexibility in a building's design than shear walls do. Shear walls are often solid and do not allow for windows and doors. Moment-resistant frames are open frames that work by ensuring that the joints of the building remain rigid which allows for the columns and beams to bend without compromising the structure.

SEISMIC DAMPERS

Effective earthquake-resistance in buildings often requires shock absorbers or seismic dampers. Seismic dampers absorb destructive energy, protecting the building from sustaining it. Similar to a shock absorber on a vehicle, a piston filled with a hydraulic fluid absorbs the energy of the movement and dissipates it as heat. These are usually placed in the connection of columns to beams.

In the now destroyed World Trade Center, the dampers were made of visco-elastic material, material that was partially viscous, that is, partially flowable like oil, and also elastic, which means they act somewhat like steel, in that after being strained to defprmation they return to their original shape. Construction crews placed the dampers, 11,000 of them in each building, between the bottom of the floor trusses and the columns—two parts of the building that tended to move with respect to each other when the edifice swayed. When it did so, those two parts would shear the visco-elastic dampers. This shearing caused the material to heat up, and that heat was transferred to the building.

PENDULUM POWER

Another damping method used in buildings, especially high-rise structures is the use of pendulums. Typically, a large ball is suspended with steel cables with a system of hydraulics at the top of the building. When the building begins the sway due to wind or seismic activity, the ball acts as a pendulum and moves in the opposite direction to stabilize the direction. The resonant frequency of a building can be calculated, and the pendulum, or tuned mass damper, can be tuned to counteract the building's movement in the event of an earthquake.

SEISMIC INVISIBILITY CLOAK

Instead of just dealing with forces once they enter a building, research is being done with ways buildings can deflect and reroute the energy from earthquakes altogether. Called the "seismic invisibility cloak", this method involves creating a cloak of 100 concentric plastic and concrete rings and burying it at least three feet beneath the foundation of the building.

As seismic waves approach the building, they enter the rings, and are forced to move through to the outer rings in the path of least resistance resulting in rerouting the waves away from the building and dissipated into the ground.

HURRICANES

A hurricane is a storm that occurs in the Atlantic Ocean and northeastern Pacific Ocean. A typhoon occurs in the northwestern Pacific Ocean. A cyclone occurs in the South Pacific Ocean or Indian Ocean. There is no difference in the specifications and dynamics of the storms. The only difference is where they occur. A tornado (twister, whirlwind) is a rotating column of air that is in contact with both the surface of the Earth and a cumulonimbus cloud.

Hurricanes are usually more destructive because of the area they cover, which can range from about 60 miles in diameter up to 1,000 miles. Tornadoes are much smaller in area affected—from 300 to 500 yards wide.

The name hurricane comes from the Mayan storm god Hunraken and the Arawak word hurican, which meant the "devil wind." Over 4,000 tropical storms have occurred in the North Atlantic (including the Caribbean) in the last 500 years, half of which have become hurricanes.

When a hurricane force wind blows against a building, the windward wall tends to block the air, and the air pressure increases. The force can smash doors and windows, collapse walls and support and bracing systems, or completely destroy a building.

Whereas the windward walls suffer from positive pressure, the other surfaces of the building, experience suction. If there is a window or door opening in the windward side, the high pressure can push into a building where it can blow through partitions, and even through the leeward wall. The internal pressure is helped by the external suction on all the surfaces other than the windward wall. Whole roofs can be lifted from their place. If the eye of a hurricane passes over a home, it will be subjected to winds in one direction and after the eye passes, it will be subjected to winds from the opposite direction.

Key to hurricane and tornado resistance is in strengthening the load path. Buildings are always designed to provide a continuous load path to support down-bearing gravity forces, which are compressive, pushing the parts of the house into each other. Every framing member is placed to be supported by another, and each must be strong enough to bear the downward force, which is finally transferred to the earth.

In a high-wind event, the support needs reverse. Uplift pressures work to pull the parts of the house up. These forces usually follow the same load path as for gravity loads. Buildings need to be designed to ensure that tension forces don't pull the connections apart and that shear forces don't sever the horizontal connections such as nails and screws as the framing is pulled upward.

With tornadoes and hurricanes, wind is not the only factor. Rainfall and storm surges as well the flooding that ensues is sometimes more damaging than the wind. Rainfall can damage structures by washing away walls, and by washing under foundations, or just the weight of water itself on flat and low slope roofs.

REVIEW QUESTIONS

31. CLT is an acronym for _______________.

a. Cross lateral torsion
b. Cold loaded transfer
c. Cross laminated timber
d. Class limited terminals

32. Shape memory alloys are able to both endure heavy strain and revert to their ___________ shape.

a. Intended
b. Original
c. Estimated
d. Equivalent

33. Structural steel is one of the most ______________ materials.

a. Ductile
b. Versatile
c. Rigid
d. Durable

34. _______________ is the lightest and strongest material known to man.

a. Diamond

b. Platinum

c. Carbon Fiber

d. Nylon

35. Diaphragms in a building are usually _______________.

a. Floors

b. Roofs

c. Decks

d. All of the above

36. Some buildings use ____________ to absorb destructive energy.

a. Springs

b. Seismic dampers

c. Sponges

d. None of the above

37. Some high-rise buildings use ____________ to dampen sway.

a. Windmills

b. Water tanks

c. Pendulums

d. All of the above

38. A ___________________occurs in the South Pacific Ocean or Indian Ocean.

a. Cyclone

b. Typhoon

c. Hurricane

d. Tornado

DESIGNING FOR HURRICANE RESISTANCE

Some main design considerations for wind resistance are:

LOCATION

The location of the building is important. Of course, it is best to avoid building in high-risk zones at all, but sometimes we have no choice. In such cases, the best we can do is to design and build for the inevitable storm(s) by building a stronger-than-normal house reinforced to resist the forces of wind and rain.

SHAPE

If we don't have choice over location, we still usually do have control over the shape of our buildings and shape is a very important factor in determining the performance of buildings in hurricanes. Simple, compact, symmetrical shapes are best. The square plan is better than the rectangle. The rectangle is better than the L-shaped plan. Even more important than the shape of the plan shape is the geometry of the roof. For lightweight roofs it is best that they be hipped and with a steep pitch, with little or no overhangs at the eaves and with ridge vents.

WINDOWS AND DOORS

Second to roofs, windows and doors require the most attention. Glass windows and doors are vulnerable to flying objects. There are only two solutions. Opening protection can be provided by one of two methods

- An approved impact-resistant covering capable of resisting windborne debris impacts can be installed over an existing, unprotected opening (such as a window or door).
- An approved, impact-resistant product (such as a new window or door assembly) can be installed in place of a product that is not designed to resist such forces or as an alternative to impact-resistant shutters or screens.

For new buildings there is the opportunity to design storm shutters which are integrated into the design of the overall structure. They can also be designed to have another function (e.g. sun shading, burglar proofing, etc.) and to even enhance the appearance of the building.

ROOF AND WALL COVERINGS CAPABLE OF RESISTING HIGH WINDS

Nail roof sheathing with 8d ring-shank or screw-shank nails at 4” o.c. along ends of sheathing and 6” o.c. along intermediate framing.

PROTECTION FOR OPENINGS

(windows, doors, garage doors, soffits, and vents) to resist high winds, windborne debris, and wind-driven rain

Opening protection can be provided by one of two methods

- An approved impact-resistant covering capable of resisting windborne debris impacts can be installed over an existing, unprotected opening (such as a window or door).
- An approved, impact-resistant product (such as a new window or door assembly) can be installed in place of a product that is not designed to resist such forces or as an alternative to impact-resistant shutters or screens.

STRUCTURAL SYSTEMS PROVIDING A CONTINUOUS PATH FOR ALL LOADS

(gravity, uplift, and lateral) to be passed from the building exterior surfaces to the ground through the foundation

Roof to wall connection should be Simpson H1 or equivalent uplift and shear capacity. Connectors should be attached on sheathing side of exterior walls.

Tie gable end trusses to structure with continuous 2” x 4” x 8’ lateral braces at 6’- 0” o.c.. Provide a tie strap attached with (8) 10d common nails at each end.

Continuously sheathe gable end walls with structural panels (plywood or OSB). Nail sheathing with 8d common nails at 4” o.c. along perimeter and 6” o.c. at intermediate framing.

Nail upper story sheathing and lower story sheathing into structural rim board.

Continuously sheathe all walls with wood structural panels (plywood or OSB) including areas around openings for windows and doors. Nail wall sheathing with 8d common nails at 4” o.c. along perimeter and 6” 0.c. at intermediate framing

Extend wall sheathing down to ap sill plate, fasten with 8d common nails at 4” o.c.

Secure post-to-beam connections with Simpson MSTA24 or equivalent

Anchor the sill plate to the foundation by installing 1/2” anchor bolts through 0.229x3”x3” square plate washers, minimum 48” o.c.

In addition to the aforementioned, the following recommendations are particularly appropriate for non-engineered construction and for minimum cost construction:

1. Limit height of buildings to one and two stories.
2. Ensure that lightweight floors and roofs are securely fastened to the walls to improve their performance in hurricanes.
3. The shape of the building should be, as far as possible, symmetrical which would provide a more balanced distribution of forces in the structure.
4. Provide sufficient distance between openings to avoid slender piers. Keep the openings moderate in width to avoid long-span lintels.
5. Link the heads of all walls together by providing a continuous collar or ring beam at floor and roof levels.

6. Lightweight roofs should be not less steep than 20 degrees (generally speaking, the steeper the better up to about 30 degrees) to improve their wind resistance.

7. To improve their wind resistance lightweight roofs should have a hipped shape (sloping in four directions) rather than a gable shape (sloping in two directions) or a mono-pitch shape.

8. Again, to improve their wind resistance, lightweight roofs should have minimum overhangs at the eaves, even to have no overhangs at all. The need to shade windows and doors from sun and rain may be met by separate canopies or awnings that can break away under strong winds conditions.

9. The use of ridge vents reduces internal pressures and therefore help in keeping on lightweight roofs in a hurricane.

WATTLE AND DAUB

Prior to European arrival in the Caribbean, most indigenous homes had low walls frequently made of wattle and daub (wooden strips "daubed" with a stucco-like mixture) with roofs usually constructed of locally harvested thatched palms. These materials were more suitable to the Caribbean climate than those initially tried by the European settlers. Stone, for example, might withstand hurricane-force winds, but it proved problematic in the heat and humidity, as well as during earthquakes, when it could rupture or crumble to the ground. Meanwhile, Wattle and daub houses could withstand hurricanes, and though the roofs might occasionally require replacement following a storm, they could be quickly and easily repaired with local materials.

Wattle and daub is one of the most common infills, easily recognizable by the appearance of irregular and often bulging panels that are normally plastered and painted. It is an arrangement of small timbers (wattle) that form a matrix to support a mud-based daub. The timbers normally fall into two groups, the primary timbers or staves, which are held fast within the frame and the secondary timbers or withies which are nailed or tied to or woven around the staves. Arrangement and sizes of panels vary from area to area as does the orientation of the staves. The daub was applied simultaneously from both sides in 'cats' (damp, workable balls) pressed into and around the wattle to form a homogeneous mass. As the daub dried it was often keyed by scratching or 'pecking' to receive a lime plaster covering. The surface plaster was usually made of lime and sand or some other aggregate reinforced with animal hair or plant fiber. The plaster was finished flush, or in some cases, it would continue across the panels and timbers alike. This would allow less important timbers to be concealed and only principal members to be shown.

Wattle and daub is not a rigid system, but therein lies its benefit. It is able to accommodate structural movement without failure. It actually provides superior support to weaker timbers where other forms of infill might not. Wattle and daub is not lightweight or flimsy. Its weight is similar to the weight of bricks, but its insulation is better and better security since it is more difficult to break through than brick. Under the right conditions a wattle and daub panel should last a very long time. Examples of 700 years old are known to exist.

SAFE ROOMS

The level of occupant protection provided by a safe room is much greater than the protection provided by buildings that comply with the minimum requirements of most building codes According to FEMA, "A safe room is a room or structure specifically designed and constructed to resist wind pressures and wind-borne debris impacts during an extreme-wind event, like tornadoes and hurricanes, for the purpose of providing life-safety protection."

Safe rooms are classified as either in-ground, above-ground, or within a basement. While in-ground safe rooms provide the inherent missile protection afforded by the surrounding soil coverage, above-ground safe rooms are required to be rigorously tested to ensure that they can also provide missile impact protection. All properly constructed safe rooms offer life safety protection when properly designed and constructed.

Safe rooms should not be built where flooding can occur which may have the potential to endanger occupants. Safe rooms with the potential to be flooded should not be occupied during a hurricane or other rain event.

FLOODING

Of course, the best plan to avoid flooding is to avoid building in any area that is vulnerable to flooding. Unfortunately, one third of the entire continental United States is at risk of flooding, so to design and build with the consideration of the potential of flooding the following protective measures should be taken.

ELEVATE THE STRUCTURE ABOVE THE FLOOD LEVEL

The flood level elevation for specific areas can be found online using programs such as the Estimated Base Flood Elevation Viewer run by FEMA. Using this information, architects can calculate how high to raise the building. The most common way of elevating is by building the structure on columns, piers, pilings, or stilts, or a traditional solid foundation can be built higher.

BUILD WITH FLOOD RESISTANT MATERIAL

Flood resistant materials are those which can last in contact with flood waters for at least 72 hours without 'significant damage.' 'Significant damage' is defined by any damage requiring more work that just cleaning or low-cost cosmetic repair, such as painting. Flood resistant materials should be durable and resistant to extreme humidity.

FLOODPROOFING

There are two types of floodproofing: dry and wet. Dry floodproofing prevents flood waters from ever even entering the structure. Wet floodproofing allows flood waters to enter the building, but in such a way as to prevent damage to the structure. Dry floodproofing is achieved by the uses of coatings, membranes, sealants, and other waterproof barriers. A waterproof barrier can consist of a layer of masonry sealed with a waterproof membrane, protecting the exterior walls against water penetration. Wet Floodproofing includes permanent or contingent measures applied to a structure or its contents that prevent or provide resistance to damage from flooding while allowing floodwaters to enter the structure. This includes securely anchoring the structure, using flood resistant materials below the Base Flood Elevation (BFE), protection of mechanical and utility equipment, and use of openings or breakaway walls. According to FEMA, application of wet floodproofing as a flood protection technique under the National Flood Insurance Program (NFIP) is limited to enclosures below elevated residential and non-residential structures and to accessory and agricultural structures that have been issued variances by the community.

RAISE HVAC EQUIPMENT AND MECHANICAL, PLUMBING, AND ELECTRICAL SYSTEM COMPONENTS

Service equipment may be protected from damage from flooding, by the use of waterproof enclosures, barriers, protective coatings, or other means, but all of these methods are prone to failure. The best way to protect flood damage is to locate the service equipment above the flood protection level. Such equipment includes heating, ventilating, air conditioning, plumbing appliances, plumbing fixtures, duct systems, and electrical equipment including service panels, meters, switches, and outlets. If any of these components are exposed to floodwater, they can become severely damaged and in the case of electrical equipment, there is the potential risk of fire if short circuited

ANCHOR FUEL TANKS

Unmoored fuel tanks float and are easily moved by flood waters. Once afloat, tanks can crash into to other objects damaging the object and the tank itself. A damaged petroleum tank could contaminate flood waters and create a potential medium for fire. A damaged LP tank could risk a devastating explosion. Even buried tanks can be pushed to the surface due to buoyancy. Therefore, all fuel tanks should be anchored, either by attaching them to concrete anchors that are heavy enough to resist flood water forces, or strapping them to ground anchors.

CONSTRUCT PERMANENT BARRIERS

A permanent barrier that is placed around a building can prevent flood waters from reaching it. Such barriers should be constructed using a floodwall made of concrete or masonry, or by using a levee made of compacted layers of soil with an impervious core. Both floodwalls and levees require extensive maintenance.

INSTALL SEWER BACKFLOW VALVES

Sewer backflow valves prevent flooded sewage systems from backing up into a home. In certain flood-prone areas, this issue is common, and can cause damage that is both difficult to repair and hazardous to occupants' health. Generally, gate valves are preferred over flap valves because they provide a better seal against flood pressure.

GRADE THE LAWN AWAY FROM THE HOUSE

Sloping the grade away from the building should be done in every case. It is not only a deterrent to flooding, but it prevents surface water from becoming ground water which can exert significant hydrostatic pressure against foundations and basements. As a minimum the angle of slope should be 1" per 1'-0 away from the building.

TYPES OF DISASTER SHELTERS AND STRUCTURES

DOMES

The dome is by far the best shape for earthquake and hurricane resistance.

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Footings

Depending on soil bearing capacity, geotechnical reports and any optional subgrade reclaim tunnels, a continuous circular ringbeam foundation is engineered and constructed. When complete, all material and equipment needed for the monolithic dome construction are moved into position inside the foundation.

A custom fabricated waterproof exterior roofing membrane is attached to the footings and inflated. Depending on the size of the dome, this process takes minutes to a couple hours.

Insulate

Once inflated, the monolithic dome construction process is completed from inside the dome, avoiding costly weather delays. The polyurethane foam insulation applied provides initial rigidity and a thermal barrier from the outside elements protecting the concrete and dry bulk storage product from extreme freeze-thaw cycles and condensation.

Rebar

Rebar is attached to the foam providing additional rigidity and a skeleton structure for the concrete. Additional layers will be placed in the dome depending on the engineering specifications.

Shotcrete

With the first mat of rebar hung, shotcreting begins. Shotcrete is applied in thin concentric layers intermittently with the installation of additional cages of rebar and until depth gauges are covered.

IMMEDIATE RESPONSE SHELTERS

"Pop-up" Structures

When responding to the immediate situation after a disaster event, it is important that people see action as soon as possible, both for physical protection and safety and for emotional encouragement. Promises with procrastination and inaction cause the people to be discouraged and to distrust those who are trying to help.

Materials should be minimal, inexpensive, and able to be on site as soon as possible. If possible, construction methods should be kept simple, so that the victims of the disaster can perform most, if not all, of the actual construction themselves.

SURVIVAL STRUCTURES – LOW TECH

Following is a list of some of the simplest forms of shelters.

Body-Heat Shelters

Shelter can be described as a shell that traps a pocket of dead air warmed by body heat.

- **Debris Hut** – Mound of decomposed leaf litter and other organic debris with an excavated pocket that is large enough to crawl into.

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- **Quinzhee Hut** – it is made of snow and should be made tall enough so you can sit up

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Open Shelters

Structures that reflect a fire's warmth are the most important shelters to know how to build. They can be erected without tools in an hour provided you are in an area with downed timber

- **Pole and Bough Lean-to** – Considered to be one of the most ancient shelters, the lean-to will serve as a windbreak, fire reflector, and overhead shelter.

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- **A-Frame** – Offers the most protection against the wind and can be heated by a fire at the entrance.

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Enclosed Shelters

Take longer to build than open shelters and can be warmed by a small fire

- **Wickiup** is like a tipi made from poles, brush, and vegetation.

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- **Wigwam** – A dome dwelling built with long, limber poles. This is a semi-permanent structure with curved surfaces making it an ideal shelter for all kinds of conditions.

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- **Salish Subterranean Shelter** – These shelters are not the most practical solution because of the necessity of digging a 3 foot in depth pit; but they offer a higher level of protection from extreme temperatures, both cold and hot.

This Photo by Unknown Author is licensed under

You can learn more about building these structures at the following website: *https://www.fieldandstream.com/photos/gallery/survival/shelter/2006/10/seven-primitive-survival-shelters-could-save-your-life/*

SURVIVAL STRUCTURES – HIGH TECH

An example of a higher tech survival structure is a temporary relocatable shelter that is a modular, lightweight, rugged, sometimes insulated, and easy to set up space. This type of structure usually comes as a complete kit and many times requires the use of one or two tools. These shelters typically are long-lasting and have a surprising amount of usable space with a minimal footprint. Each component is lightweight making it easy for anyone to be able to set it up. Whether in snow or sun, these provide shelter and relief from the elements.

CASE STUDY: HAITI 2010 EARTHQUAKE

The population of Haiti is about 11,603,684 as of Tuesday, December 14, 2021. The ethnic groups of the population are 93.8% African descent, 5.4% Mulatto and 0.8% other. There is also an Asian minority and Arabs. Haiti has a total area of 27,750 km2; most of it is in the western third of the Hispaniola island and the rest are smaller islands that are near the Haitian coast, such as Gonâve, Île de la Tortue, Les Cayemites, Île-à- Vache and La Navase.

There are many mountains in Haiti, with only some coastal plains and few valleys; the largest valley is the Cul-de-Sac, where Port-au-Prince is found on its western end. The main Haitian river is the Artibonite, which is also the longest on the Hispaniola Island. The biggest city is Port-au-Prince with more than 3 million in the metropolitan area; the second largest city is Cap-Haïtien. The rain season is from April to June and from October to November. Tropical cyclones and hurricanes are common during the summer months and they have resulted in tremendous human suffering.

Haiti is currently the least developed country in the Americas. Even before the devastating earthquake, the country was among the world's poorest and least developed. There are certain economic indicators that can be calculated to compare the social and economic situation of different countries. Some of these indicators show that Haiti has fallen behind other low-income developing countries since the 1980s. In 2006, Haiti ranked 146th of 177 countries in the United Nations Human Development Index (2006). About 80% of the population was estimated to be llving in poverty in 2003. Haiti is the only country in the Americas on the United Nations list of Least Developed Countries.

About 66% of all Haitians work in the agricultural sector. Most of them do small-scale subsistence farming, but this activity makes up only 30% of the GDP. In the last ten years, very few jobs were created, but the informal economy is growing. Mangoes and coffee are two of Haiti's most important exports. Haiti has consistently ranked among the most corrupt countries in the world on the Corruption Perceptions Index.

Foreign aid makes up approximately 30%-40% of the national government's budget. The largest donor is the United States followed by Canada, and the European Union. Venezuela and Cuba also make various contributions to Haiti's economy, especially after alliances were renewed in 2006 and 2007.

EARTHQUAKE IMPACT

The earthquake on 12 January 2010 struck Haiti at the heart of its capital, Port-au-Prince, as well as in the Villages of Léogâne, Jacmel and Petit-Goâve. The damage and losses, which grew every day, are estimated to be nearly 8 billion USD according to the most recent assessment of losses and damages.

IMPACT ON HUMAN LIFE

The human impact is immense. Roughly 1.5 million people, i.e. 15 percent of the national population, were directly affected. According to the official Haitian Government estimates, more than 300,000 died and as many were injured. About 1.3 million people are still living in temporary shelters in the Port-au-Prince metropolitan area. Over 600,000 people have left the affected areas to seek shelter elsewhere in the country. Existing problems in providing access to food and basic services have been exacerbated. By striking at the very heart of the Haitian economy and administration, the earthquake had a severe effect on human and institutional capacities, both the public and the private sectors, as well as international technical and financial partners and some non-governmental organizations (NGOs).

IMPACT ON INFRASTRUCTURE

The destruction of infrastructure is colossal. About 105,000 homes were totally destroyed and over 208,000 were damaged. More than 1,300 educational institutions and more than 50 hospitals and health centers have collapsed or are unusable. The country's main port has been greatly disabled. The Presidential Palace, Parliament, law courts, and most ministerial and public administration buildings have been destroyed.

IMPACT ON THE ENVIRONMENT

Although environmental indicators were already at warning levels, the earthquake has put further pressure on the environment and natural resources, thus increasing the extreme vulnerability of the Haitian people.

OTHER FACTORS CONTRIBUTING TO THE EARTHQUAKE DEVASTATION

Very soon after the earthquake it was obvious that such a toll could not be the outcome of just the force of the tremor. It is also due to an excessively dense population in urban areas, a lack of adequate building standards, the disastrous state of the environment, disorganized land use, and an unbalanced division of economic activity. The capital city, Port-au-Prince, accounts for more than

65 percent of the country's economic activity and 85 percent of Haiti's tax revenue.

OVERALL DAMAGES AND LOSSES CAUSED BY EARTHQUAKE

Overall damage and losses caused by the earthquake on 12 January 2010 are estimated to be USD 7.9 billion, which is just over 120 percent of the country's GDP in 2009. In fact, since the common-global method for estimating damage and losses was first devised 35 years ago, this is the first time that the cost of a disaster is so high in relation to the country's economy.

Most damage and losses were felt by the private sector (USD 5.5 billion, i.e. 70 percent), whereas there was USD 2.4 billion of damage and losses in the public sector (i.e. 30 percent of the total).

The value of destroyed physical assets, including housing units, schools, hospitals, buildings, roads, bridges, ports, and airports, is estimated to be USD 4.3 billion (55 percent of the overall cost of the disaster). The effect on economic flows (production losses, reduction of turnover, loss of employment and wages, increase in production costs, etc.) was USD 3.6 billion (equivalent to 45 percent of total).

According to the Haitian government, after the earthquake of January 12, 2010, "there were 1.2 million people in 460 spontaneously organized camps. Of these, 250,000 people were living in 21 of these camps presenting major risks for the well-being and safety of their inhabitants." [1]

1 Section 4.3.1 of the action plan for national recovery and development of Haiti - key initiatives for the future (March 2010)

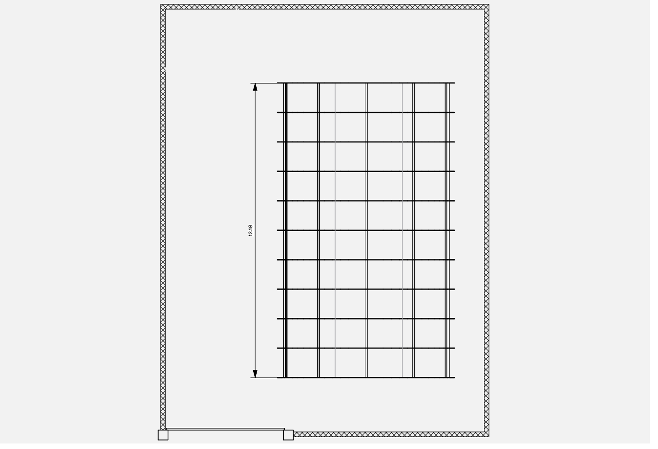
Since Haiti is vulnerable to hurricanes, it was important to establish shelter for these people that was quickly accessible, affordable, and resistant to the natural elements that threatened them. In addition to the obvious physical challenges, there were also social needs to be addressed. Structures that gave the displaced people of Haiti personal dignity and planning that made communities possible and manageable were also matters of high priority.

The proposed design that follows is an attempt to address those needs.

IMMEDIATE RESPONSE

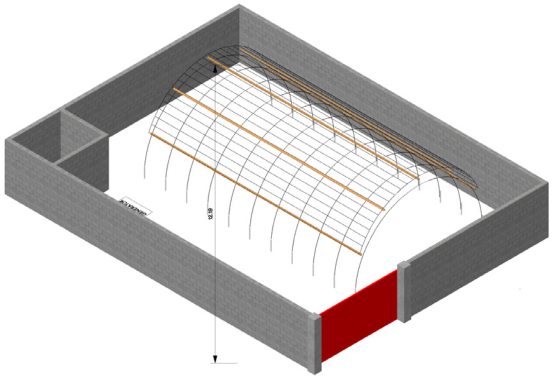
A "Pop Up" Pavilion

The environment of Haiti is year-round heat and because the forests were harvested years ago to produce charcoal, there is very little vegetation. The goals are simple – get people off the ground and out of the sun. Complete enclosure is not important, in fact, in many cases, it is not even desirable.



The site was a roughly 43' X 57' walled lot in the village of Titanyen, Cabaret, Haiti, with a dug-out latrine in the corner.

The materials used were 14' X 48' billboard "vinyls" that had been rejected due to copy issues such as misspellings or color defects. Since they were to be discarded, the cost was zero. They were imported to the site from the US by Americans flying on commercial aircraft carrying military style duffle bags.



The framework was 2-1/2” PVC electrical conduit bent into semi-circular arches. The arches were formed by inserting the ends of the conduit into chain link fence terminal posts that had been driven into the ground.

The ribs of the frame were held in position with ropes that maintained the spacing and stabilized by guying to posts driven into the ground.

The billboard vinyls were stretched over the frame and lashed to the arches for the roof. Other vinyls were used as ground cloths, spread and spiked to the ground for a finished floor.

Under the direction of the designer, the entire building was erected in a single day using only the citizens of the village as labor.

The elderly women of the village brought their folding chairs into the shade of the space immediately upon completion and began socializing with one another.

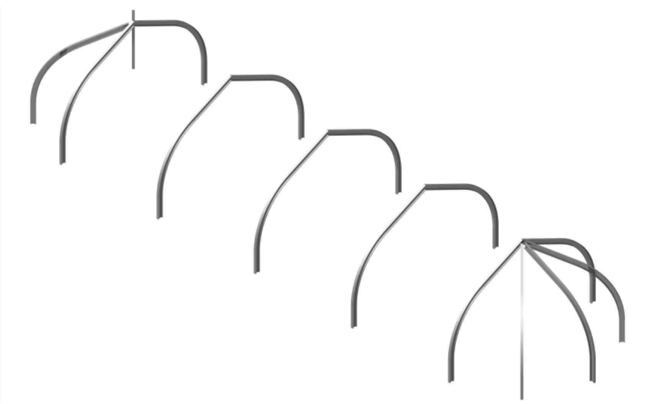
The next morning the women and children of the village decorated the pavilion with flowers and streamers and five couples were married in a combined wedding ceremony in the afternoon.

In less than 72 hours responders had left the United States with materials, the pavilion was constructed, and utilized for community socialization and ceremonial purposes.

In a very short period of time, a group of people who were down and dejected were encouraged and proud of the job they had done to meet the needs of their community.

SHORT TERM RESPONSE

Stressed Membrane Structures



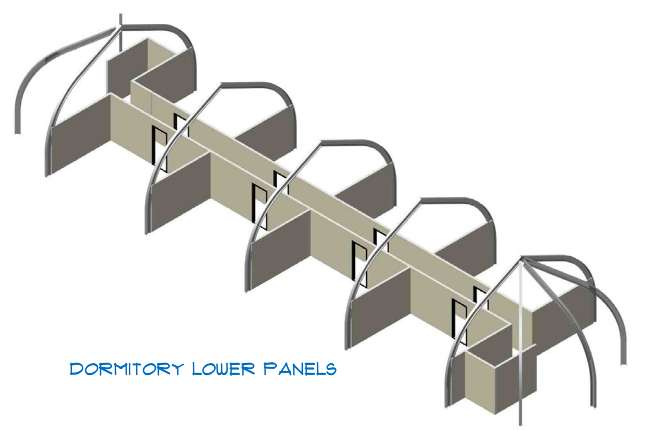
Similar in some respects to the pop-up pavilion constructed with conduit and billboards, stress membrane structures are fabric membranes stretched between aluminum ribs. They can be bolted to concrete slabs or secured to the ground with earth anchors.

There are many advantages to using stressed membrane structures for disaster relief. Because of their relative light weight and small parts, they are easily shipped and transported to sites, even remote and sites that are difficult to assess. Assembly of the arches and erection is speedy and can be accomplished with local workers, both skilled and unskilled. The aluminum frames can be bolted to monolithic slabs or secured to natural grades with earth anchors. Spans up to 200' wide and unlimited lengths can be accomplished.

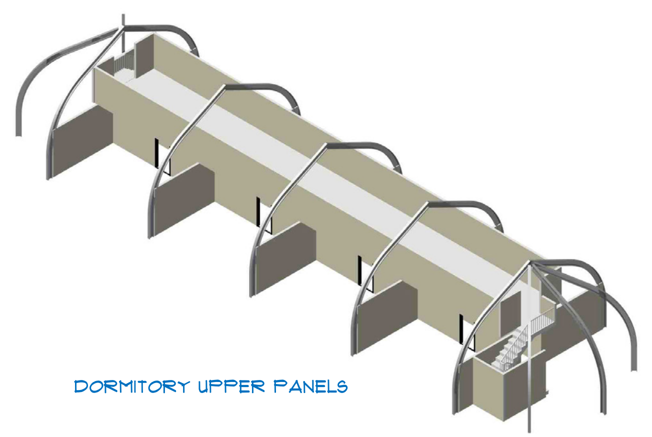
Insulated structures are extremely efficient to heat and cool due to the minimal thermal bridging in the frame. Depending on the climate, stressed membrane structures can last decades and can also be dismantled and relocated. They are also uniquely resistant to hurricanes and tornadoes. The Missile Defense System integrated architecture at Fluor Alaska Inc., located in Shemya, Alaska, is engineered to withstand wind loads of 120 mph. The Warwick Le Lagon Resort in Vanuata in the southwest Pacific was used as a storm shelter on March 13, 2015, during Cyclone Pam, a category 5 cyclone.

Stressed membrane building manufacturers generally supply a technician that can supervise a crew of unskilled workers to erect the structures, providing the disaster victims employment and a sense of pride and accomplishment.

Interior configurations can be for any purpose or occupancy. This configuration is for a dormitory.

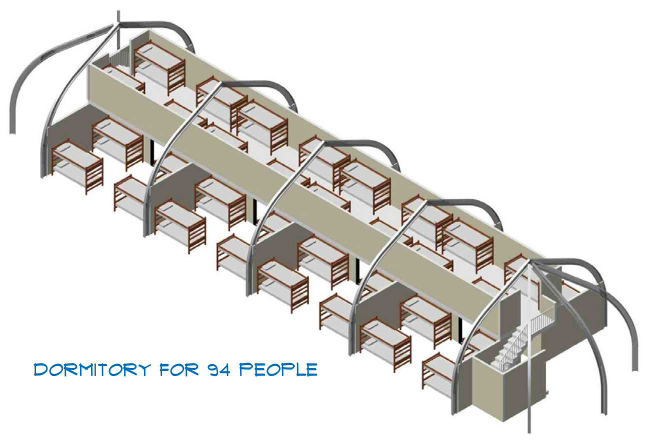


These are the walls for the ground floor.



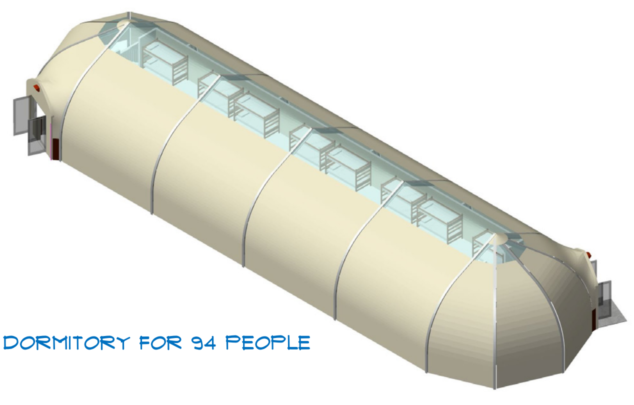
DORMITORY UPPER PANELS

These walls are for the upper floor.



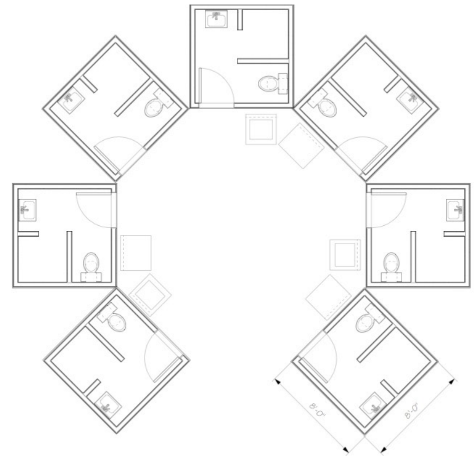
DORMITORY FOR 94 PEOPLE

Each room downstairs sleeps 8 occupants, while the upper level sleeps 32 for a total of 96 people.



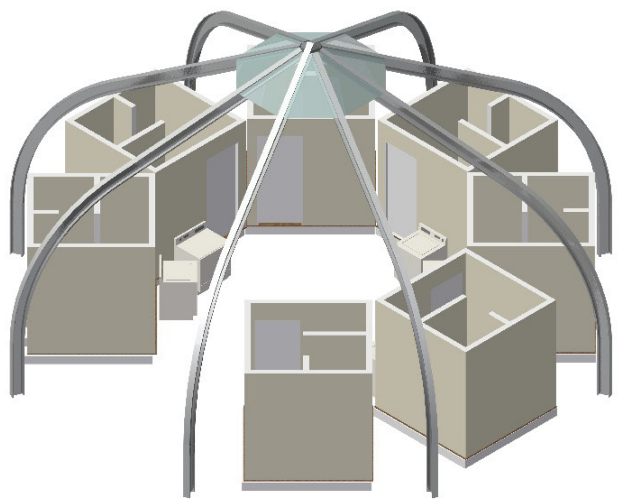
DORMITORY FOR 94 PEOPLE

Finished dormitory with stressed membrane and translucent skylight panels.



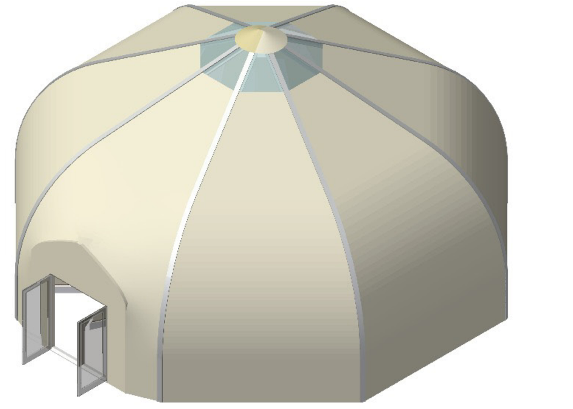
TOILET / SHOWER / LAUNDRY POD PLAN

Since this particular dormitory configuration does not include toilet/lavatory/shower rooms, a separate dedicated structure with bathrooms and laundry facilities must be supplied.

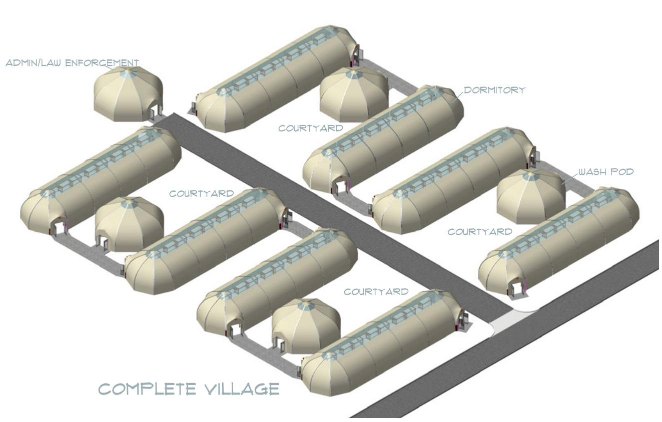


TOILET / SHOWER / LAUNDRY POD

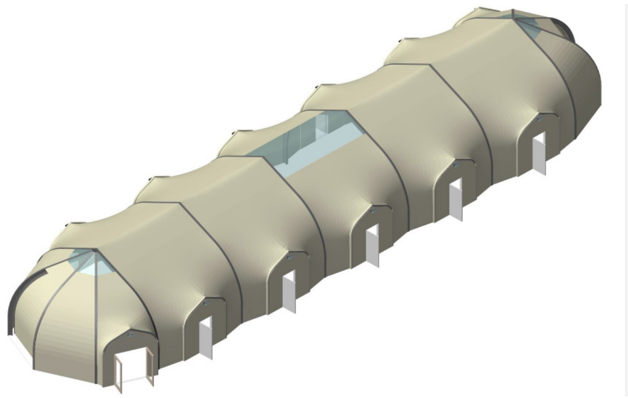
The frame and walls for a seven-unit bathroom facility with two washers and dryers.



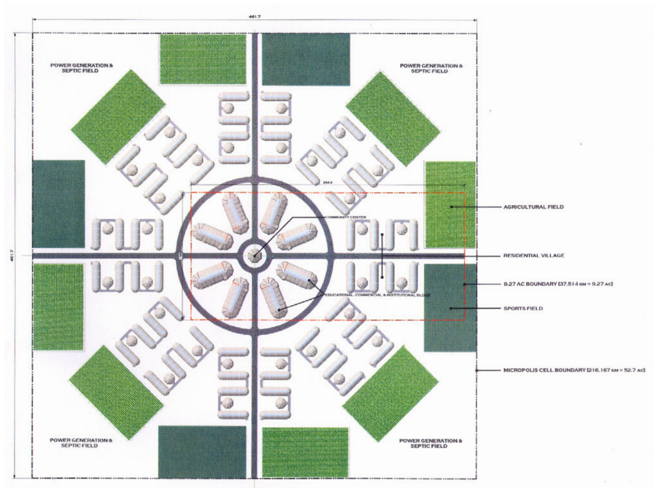
The completed toilet/shower/laundry pod.



Each village would be anchored with an administration and law enforcement pod.

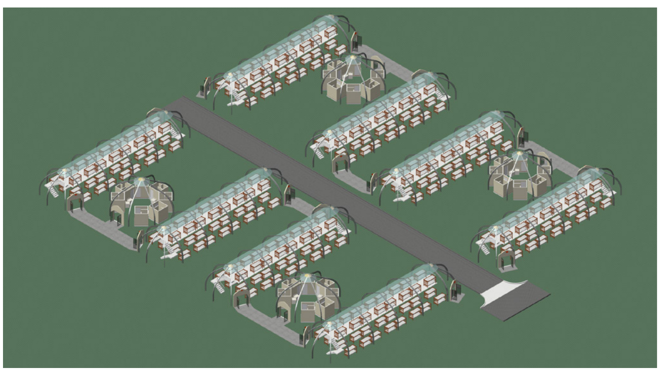


Whereas the dormitory configuration is suitable for single adults and teenagers, this configuration is for family units with separate apartments with exterior entrances and a central bathhouse.

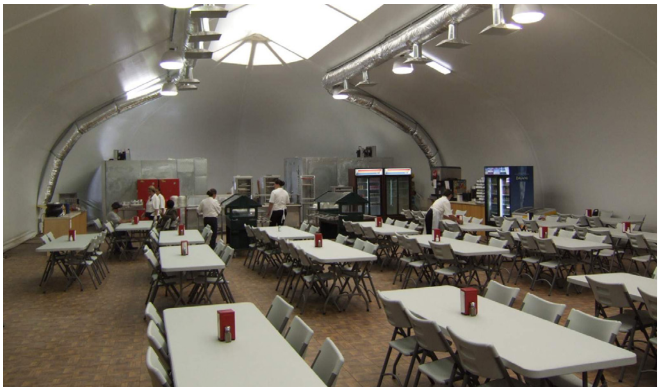


Multiple villages can be arranged around institutional, education, and commercial zones creating a micropolis cell.

This 53 acre micropolis cell would have a population of 6,400 people providing housing, commercial, educational, and administrative buildings. Each quadrant would also have areas for recreation and agriculture.



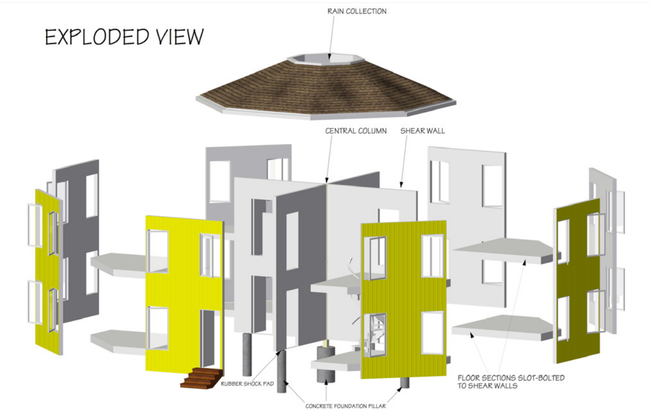
Dormitory and family housing buildings are paired with a shared bath/laundry pod and arranged to create courtyards for outdoor cooking and social congregation. This is the normal way Haitians congregate.



In addition to the examples demonstrated here, the buildings can be used effectively for other applications including, but not limited to health care facilities, schools, and civic and governmental facilities.

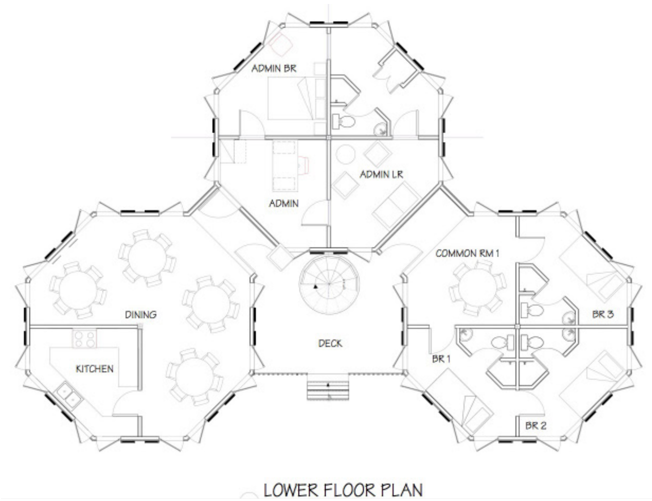
SHORT TERM RESPONSE

Safehouse Modules



The Safe House™ module is designed on the structural principle of a plant. Rather than the building being supported on structural perimeter walls, the building is supported on a central stalk. Sheer walls hang on the central column and the floors sections are connected with bolts that can shift within slots to accommodate seismic and wind forces. Exterior wall panels are attached to the floor sections.

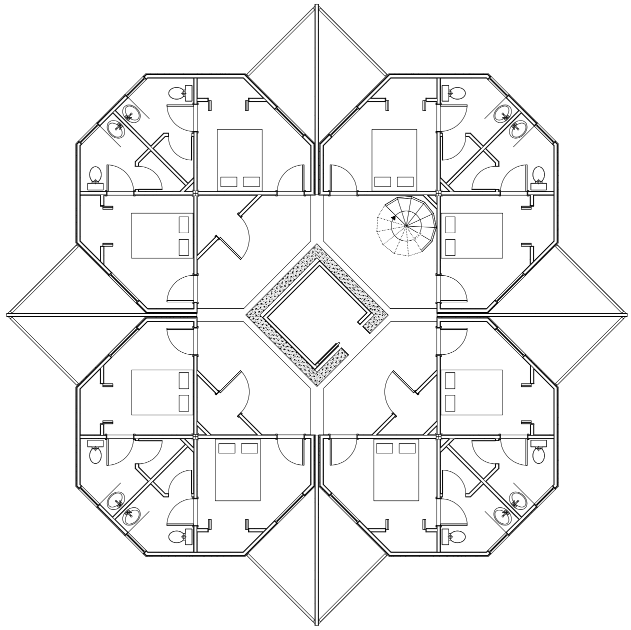
The plan is octagonal to minimize corners so that winds will more easily flow around the structure. There is no perimeter foundation that could be washed away with flooding and the house is elevated to allow flood waters to flow unobstructed under the building. Roof overhangs are breakaway so that they will not contribute to roof uplift. The roof is built to collect rainwater in a tank that can be used for washing. Rinse water is collected in a gray water tank. The gray water can subsequently be used to flush toilets.

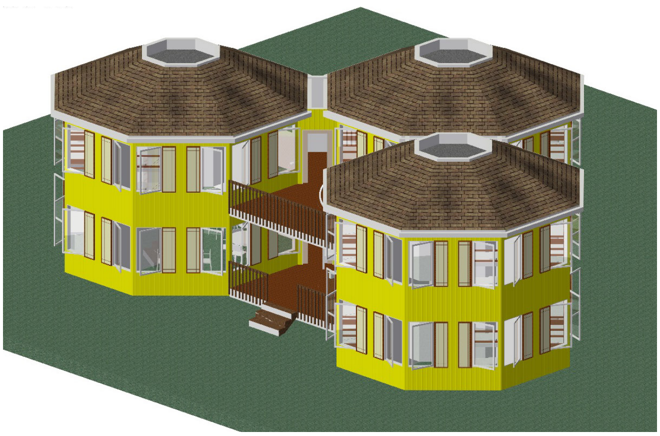


The plan of the modules can be configured to suit its occupancy and the modules can be arranged like cells in a honeycomb to create complexes from the individual modules.

This plan and configuration is for a twenty-four resident orphanage.

A TYPICAL 8 ROOM FLOOR FOR A SAFEHOUSE™ HOTEL





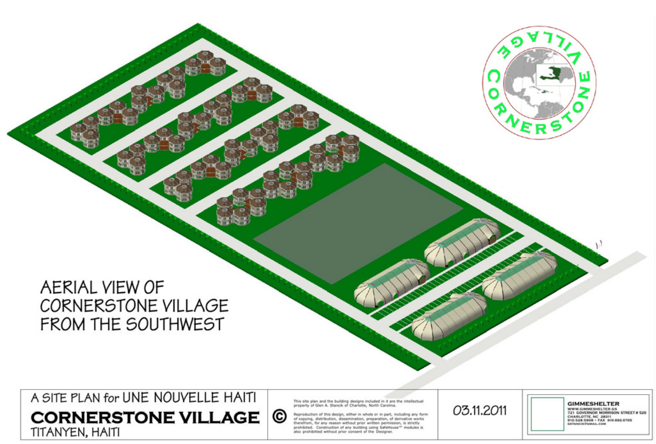
This plan and configuration is for an apartment building.

This plan and configuration is for a high rise hotel.

This site plan was for a development to be built near the village of Lafiteau on Port-au-Prince Bay 19 km northwest of Port-au-Prince. It utilizes Safe House™ construction as well as stressed membrane structures for public spaces. Lafiteau is a port town and home to notable processing plants, including the Caribbean Mills Processing Plant and the Grain Processing Plant. The residences were intended for employees of the processing plants.

The earthquake of 2010 left many children orphaned, so the care for orphans is a regular part of Haitian community life. Twenty-five percent of the population of this development would be orphans.

Victims of the Haitian presidents Papa Doc and Baby Doc Duvalier were buried in mass graves in Lafiteau, as were 100,000 victims of the 2010 earthquake.



An aerial view of the development from the southwest.

SHORT TERM RESPONSE USING ISO CONTAINERS

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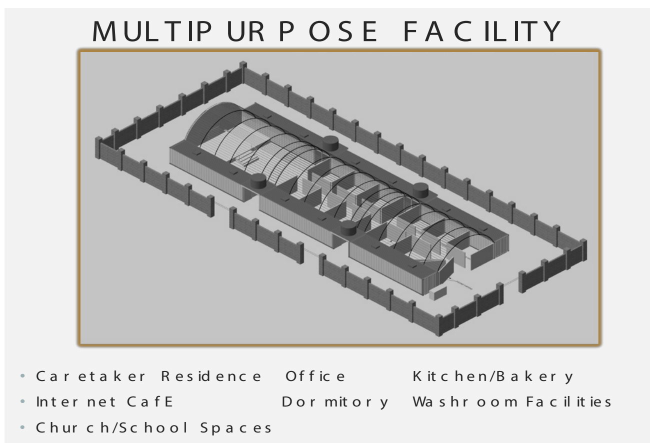
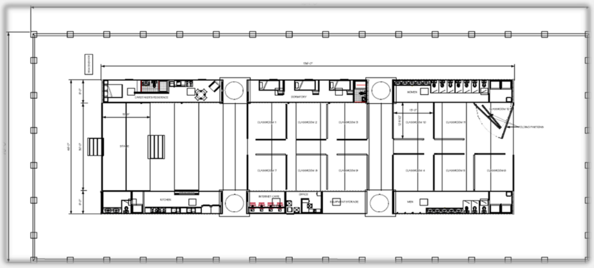
The use of ISO shipping containers for purposes other than their intended purpose has become popular. ISO or Intermodal Containers are large, standardized shipping containers, designed and built for intermodal freight transport, meaning these containers can be used across different modes of transport – from ship to rail to truck – without unloading and reloading their cargo. They are essentially modular storage "rooms". They are built to withstand extreme environments. There are currently over 17 million shipping containers in circulation globally. Used containers for purchase can cost anywhere between $1,400-$2,600, depending on the size and condition of the container, making them an affordable option for disaster relief applications. They are also ideal for transporting, even to remote locations.



This multipurpose facility is constructed using six 40' containers separated by a 30' space which serves as a common agora which can be used a marketplace on market days, an assembly space for religious services or civic meetings. This space is roofed using greenhouse hoops which can be covered with a membrane or OSB and EPDM of TPO single ply membrane. Hinged panels secured to the sides of the containers can be used to divide the courtyard into classrooms for weekday school classes.

MULTIPURPOSE FACILITY



- Caretaker Residence
- Office
- Kitchen/Bakery
- Internet CafE
- Dormitory
- Washroom Facilities
- Church/School Spaces

LONG TERM RESPONSE USING DOMES

Leogane

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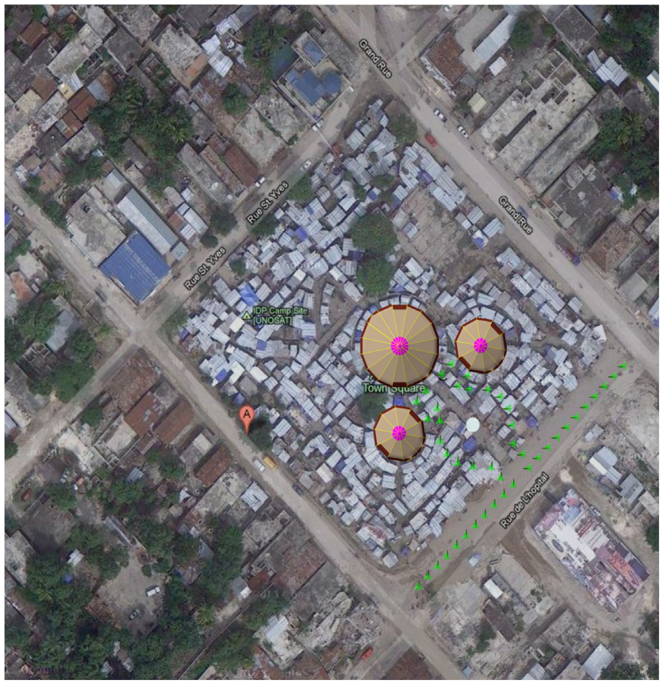
Leogane was the epicenter of the 2011 earthquake in Haiti. 80-90% of all the buildings were destroyed. As the municipal buildings were all destroyed, the city hall was moved to a telecommunication building for temporary location.

Upon request by the mayor of Leogane, I made a proposal to establish a new city center for the town. Before I visited the site, I examined satellite photos of the city. I noticed an unusual grouping of three circles in the main square of the town. A shanty town had been established on the grounds, but the circles had somehow been respected. The best I could ascertain was that the ancient stone circles were the ruins of a central city plaza or perhaps they were cisterns or fountains associated with a fabled 500-year-old church to the city's patron saint, *Sainte Rose de Lima.*

The shapes and the adjacencies of the circles seemed to be an ideal template for a site plan for a new town hall.



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The first proposed structures would be stressed membrane structures (SMS) which could be erected quickly. The projected use of the SMS buildings would be 5-10 years. The main structures would be the town hall for the office of mayor and administrative departments. The outlying buildings would house law enforcement including a jail and a civic center for community functions and events.

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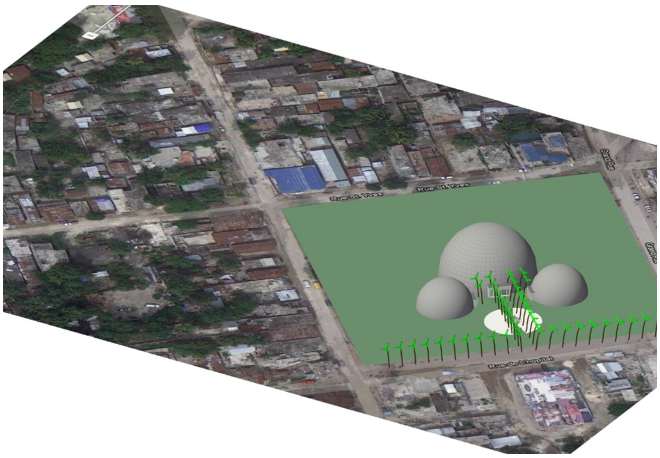

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The more permanent solution would be to replace the SMS buildings with concrete domes. The dismantled SMS buildings could be relocated and repurposed for other uses.

Since Leogane was particularly vulnerable to earthquakes (the first total destruction of Leogane by an earthquake was in 1770), it was appropriate that dome architecture be the prevailing type of building for the area.

SUMMARY

Natural disasters like hurricanes, floods, tornadoes, earthquakes and wildfires happen every year. According to an American Institute of CPAs survey conducted by The Harris Poll in the fall of 2019, six in ten Americans believe they are likely to be personally impacted by a natural disaster in the next three to five years.

When disasters strike, people's lives are overturned by the loss of lives and property. Houses and other buildings are accounted as some of the greatest losses. Without buildings, people find themselves without shelter, privacy, security, and a sense of identity. Architects are uniquely gifted and trained to design the buildings that disaster victims need. It is both a privilege and a responsibility to do so.

Designing in the aftermath of a disaster is no different than any other situation, except that the parameters of limitation are very different. The need for shelter is the same. So is the need for a dignified design that respects the humanity of those that will inhabit our designs. Time and costs parameters will, however, be drastically different. The environmental and site conditions will also be quite different. Some conditions will be so unique they are almost unimaginable.

After a disaster, there are three essential timely responses – immediate, short term and long term.

IMMEDIATE

When responding to the immediate situation after a disaster event, it is important that people see action as soon as possible, both for physical protection and safety and for emotional encouragement. Materials should be minimal, inexpensive, and able to be on site as soon as possible. If possible, construction methods should be kept simple, so that the victims of the disaster can perform most, if not all, of the actual construction.

SHORT TERM

After the immediate needs are met, an intermediate or short-term response should be planned and executed. This would include both temporary structures as well as a rudimentary community planning including roads, activity specific zoning, and infrastructure easements.

LONG TERM

Long term response would include analysis and evaluation of historical and traditional building materials and methods as well as consideration of contemporary and futuristic materials and methods. The traditional buildings and infrastructure that has been destroyed may provide a nostalgic desire to return to the past but advances in new materials and methods should not be ignored, since a prime objective for future development will be to prevent or at least to protect as much as possible from a similar disaster.

A primary consideration to post-disaster designs is what caused the disaster. Any effective design must account for the earthquake, wind, or flood forces that may obtain in the future. Once emergency problems have been solved, there exists an opportunity to design houses, buildings, and cities that in the future will provide not only physical protection, but psychological, emotional, and aesthetic satisfaction as well.

REVIEW QUESTIONS ANSWER KEY

1. **The American psychologist who created the Hierarchy of Needs was ___________.**
   a. Abraham Lincoln
   b. Sigmond Freud
   c. Abraham Maslow
   d. Carl Jung
   a. is an American, but not a psychologist. b. and c. are psychologists but not American. C. is correct answer.

2. **Fukushima was a hybrid disaster with an earthquake, _____________,and a nuclear meltdown.**
   a. Cyclone
   b. Tsunami
   c. Typhoon
   d. Tornado
   a., c., and d. are types of storms. b. is a tidal wave caused by an earthquake.

3. **Many of the people who died in the Indonesian tsunami of 2004, died because of ________________.**
   a. Starvation
   b. Dehydration
   c. Drowning
   d. Exposure
   d. is correct answer because the tsunami occurred in December causing many to die of exposure.

4. **The three responses after a disaster are ___________, short term, and long term.**
   a. Immediate
   b. Longevity
   c. Brief
   d. Overall
   The responses are points on a timeline; therefore a. is the correct answer.

5. **After a disaster people prefer to rebuild_______________.**
   a. A different location
   b. On higher ground
   c. The place where they lived before the disaster
   d. Near an escape route
   c. is the correct answer because people are attached to their locations and want to resume life where they are familiar.

6. **Successful reconstruction is usually done by ___________.**
   a. Experts
   b. General contractors
   c. NGOs
   d. The victims themselves
   Even though experts, general contractors, and NGOs can be effective at reconstruction, successful reconstruction is best done by those who have suffered the loss.

7. **The Japanese word for "lonely death" is ___________________.**
   a. Hari kari
   b. Kamikaze
   c. Kodokushi
   d. Sudoku
   a. is honorable suicide, b. is intentional suicidal airplane crash, and c. is a number game. d. is the correct answer.

8. **The greatest loss people suffer from disasters is their ____________.**
   a. House
   b. Belongings
   c. Home
   d. Employment
   a., b., and d. are all specific important physical losses, c. includes mental and emotional aspects.

9. **Ancient humans found shelter in ___________.**
   a. Caves
   b. Hollows of trees
   c. Huts
   d. All of the above
   While a., b., and c. are not comprehensive, the list is inclusive.

10. **In addition to being familial, humans are also ___________.**
    a. Psychological
    b. Social
    c. Emotional
    d. Competitive
    Social is familial writ large.

11. **The Romans standardized the width of their roads for _________.**
    a. Livestock
    b. Chariots
    c. Aqueducts
    d. Two-way traffic
    Livestock and chariots could navigate narrower roads, but two-way traffic required wider and standardized roads.

12. **Often short term housing solutions are like _____________.**
    a. Villages
    b. Camps
    c. Towns
    d. Cities
    a., c., and d. are natural, organic social organizations of human living and activity. Camps are quickly put together but often inhuman.

13. **The earth's crust is divided into a series of very large plates, called ___________ plates.**
    a. Tectonic
    b. Dental
    c. Geological
    d. Geographical
    c. and d. refer to the earth, but not the plates. B. is facetious.

14. **Most earthquakes occur along lines of weakness in the earth's crust, which are termed _________.**
    a. Cracks
    b. Fissures
    c. Faults
    d. Crevasses
    a., b., and d. occur in many places on the earth's surface, but are not necessarily associated with earthquakes.

15. The Circum-Pacific Belt is often referred to ________________.

a. Circle of Death
b. Pacific Ring of Fire
c. Volcano Row
d. Pacific Triangle

The terms "circum" and "Pacific" are obvious clues.

16. An increase of 1 unit on the Richter scale represents an increase by approximately _______times.

a. 2
b. 4
c. 16
d. 32

Because the scale is logarithmic, in terms of energy, each whole number increase corresponds to an increase of about 31.6 times the amount of energy released.

17. Tsunami is a Japanese word for "________________".

a. Sushi
b. Earth shake
c. Harbor wave
d. Coastal storm

A tsunami is a wave caused by an earthquake. C. is the only answer that includes a wave.

18. When designing building in seismic areas, it is best to avoid __________________.

a. Irregular plans
b. Asymmetrical designs
c. Split level structures
d. All of the above

While a., b., and c. are not comprehensive, the list is inclusive.

19. To protect from earthquakes, it is necessary to ____________ the foundation from the earth.

a. Integrate
b. Isolate
c. Elevate
d. Levitate

Since damage to buildings by earthquakes is caused by forces coursing through the structure, the best tactic is to isolate the building from the earth.

20. A lighter structure undergoes ________________damaging force than a heavier one.

a. More
b. Less
c. Equal
d. None of the above

Once dynamic forces act on a building, heavier buildings will generate stronger forces.

21. For a building material to resist stress and vibration, it must have high _______________.

a. Resilience
b. Compression
c. Ductility
d. Rigidity

Ductility is the ability of a material to change shape without losing strength.

22. ________________is the most widely used construction material in the United States.

a. Concrete
b. Steel
c. Aluminum
d. Wood

Due to its availability, ease of use, and relative price advantage, wood is widely used in the US

23. A Haitian architecture which originated in the late-19th century is the______________ house.

a. Painted lady
b. Gingerbread
c. Victorian
d. Hurricane

While a. and c. were late 19th century styles of houses, they were not used in Haiti. Gingerbread houses were designed to accommodate the conditions of Caribbean weather conditions.

24. Wood-frame construction provides numerous _________ paths through shear walls and diaphragms.

a. Load
b. Critical
c. Extreme
d. Resistance

Shear walls and diaphragms are load bearing components; therefore a. is the correct answer.

25. The 1994 ______________ Earthquake was a milestone for engineering of wood structures.

a. San Francisco
b. Tacoma
c. Northridge
d. San Andreas

The last San Francisco earthquake was 1989. An earthquake occurred near Tacoma in 2001. San Andreas is a major fault line. The Northridge quake occurred in 1994.

26. In 2000, the first International __________________ Code was published by the International Code Council.

a. Building
b. Administrative
c. Electrical
d. Residential

All choices are codes, but a. is the code published by the ICC in 2000.

27. Soft-stories have ____________________.

a. Large doors
b. Garage doors
c. Large windows
d. All of the above

Soft stories are considered "soft" because of their vulnerability due to large openings.

28. Diaphragms and shear walls are used to transfer_________________.

a. Forces
b. Loads
c. Frames
d. Vibrations

Shear walls and diaphragms are load bearing components; therefore b. is the correct answer.

29. **______________ construction is a system of construction using many small and closely spaced members.**
    a. Braced framing
    b. Heavy framing
    c. Arkansas framing
    d. Light framing
    a. and b. are framing systems that use heavy members, c. is a system using widely spaced members. D. is the correct answer.

30. **Balloon framing is sometimes called ___________ framing.**
    a. New York
    b. Boston
    c. Chicago
    d. Denver
    Balloon framing was invented in the 1830s in Chicago.

31. **CLT is an acronym for ____________________.**
    a. Cross lateral torsion
    b. Cold loaded transfer
    c. Cross laminated timber
    d. Class limited terminals
    No explanation needed.

32. **Shape memory alloys have the ability to both endure heavy strain and revert to their _________shape.**
    a. Intended
    b. Original
    c. Estimated
    d. Equivalent
    Since the shape of members is designed to withstand the loads it must resist, it is necessary to return to the originally designed shape.

33. **Structural steel is one of the most ____________ materials.**
    a. Ductile
    b. Versatile
    c. Rigid
    d. Durable
    Of all the properties steel is known for, ductility is the main property.

34. **_________________ is the lightest and strongest material known to man.**
    a. Diamond
    b. Platinum
    c. Carbon Fiber
    d. Nylon
    Developed in 1860 to be used in light bulbs, carbon fiber was developed in 1958 to be used a structural material.

35. **Diaphragms in a building are usually ________________.**
    a. Floors
    b. Roofs
    c. Decks
    d. All of the above
    While a., b., and c. are not comprehensive, the list is inclusive.

36. **Some buildings use _________ to absorb destructive energy.**
    a. Springs
    b. Seismic dampers
    c. Sponges
    d. None of the above
    Seismic vibrations from earthquakes become destructive energy in buildings and must be dampened.

37. **Some high-rise buildings use ___________ to dampen sway.**
    a. Windmills
    b. Water tanks
    c. Pendulums
    d. All of the above
    Pendulums counteract the tendency for buildings to sway due to wind or earthquake forces.

38. **A _________________occurs in the South Pacific Ocean or Indian Ocean.**
    a. Cyclone
    b. Typhoon
    c. Hurricane
    d. Tornado
    A tropical system in the Atlantic and northeast Pacific is called a hurricane. In the south Pacific and northern Indian ocean, they're called cyclones. A tropical system in the northwest Pacific is called a typhoon.

Accessible Restroom Design

AIAPDH229

2 HSW/LU

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RESTROOM ACCESSIBILITY FINAL EXAM

1. **Which of the designs below require an ambulatory accessible toilet compartment in addition to a wheelchair accessible toilet compartment?**
    a. A men's restroom that has three urinals and two water closets
    b. A women's restroom that has two water closets
    c. A men's restroom that has three urinals and three water closets
    d. A women's restroom that has two lavatories and four water closets

2. **Which statement is true?**
    a. Americans with Disabilities Act (ADA) was signed into law more than 30 years ago.
    b. Americans with Disabilities Act (ADA) was signed into law more than 20 years ago.
    c. Americans with Disabilities Act (ADA) was signed into law more than 10 years ago.
    d. Americans with Disabilities Act is not a law. It is a recommendation.

3. **If accessing a door from the front, how much clearance beyond the latch side of the door is needed on the push side if it has a latch but not a closer?**
    a. 0 inches
    b. 18 inches
    c. 22 inches
    d. 24 inches

4. **What is the maximum height a shelf can be mounted in a restroom?**
    a. 30 inches
    b. 36 inches
    c. 40 inches
    d. 48 inches

5. **Which of the following is a requirement for water closets in a new building?**
    a. The water closet must be placed so that its centerline is 18 inches from the side wall or partition
    b. Per *ADA*, a vertical grab bar is required in addition to the two horizontal grab bars
    c. An ambulatory accessible water closet is required if a restroom has six or more water closets (toilets) or a combination of six or more urinals and water closets
    d. An ambulatory accessible water closet is required if the water closets in the women's and men's restrooms combined total six or more

6. **If a newly constructed men's restroom has one urinal and one water closet, which of the following statements is true?**
    a. Both the urinal and the water closet must be accessible.
    b. Neither the urinal nor the water closet need to be accessible.
    c. The urinal needs to be accessible, but the water closet does not.
    d. The urinal does not need to be accessible, but the water closet does need to be accessible.

7. **What is ISA referencing in this course?**
    a. International Society for Accessibility
    b. Intercultural Systems of Accessibility
    c. International Symbol of Accessibility
    d. Internal Systems of Automation

8. What is the seat height for an accessible toilet?

a. 16 inches to 18 inches

b. 17 inches to 19 inches

c. 18 inches to 20 inches

d. 19 inches to 21 inches

9. Doors can swing into the required clear floor space for a fixture in a single user restroom if a _____________is located beyond the arc of the door.

a. 60 inch turning circle

b. 60 inch T-shaped turning space

c. 48 inch x 60 inch clear floor space

d. 30 inch x 48 inch clear floor space

10. What is the required depth of an ambulatory toilet compartment?

a. 56 inches

b. 59 inches

c. 60 inches

d. 66 inches

11. What of the following is not a requirement of a sign, if provided, for a non-accessible restroom?

a. International Symbol of Accessibility

b. A directional sign to the nearest accessible restroom

c. Braille

d. Visual characters

12. What is the maximum height for a threshold at a roll-in shower?

a. 1/4 inch

b. 1/2 inch

c. 3/4 inch

d. 1 inch

13. Which of the following is an acceptable height for the top of a shower seat to be located in an accessible shower?

a. 16 inches above the shower floor

b. 16 inches above the bathing room floor

c. 18 inches above the shower floor

d. 18 inches above the bathing room floor

14. What is the clear floor space required on the pull side of an accessible door into a restroom with both a latch and a closer for frontal approach?

a. 12 inches

b. 16 inches

c. 18 inches

d. 24 inches

15. What is the maximum allowable slope for an accessible shower floor?

a. 1:12

b. 1:20

c. 1:28

d. 1:48

16. What is the clear floor space required on the push side of a door into a restroom with only a closer?

a. 0 inches

b. 12 inches

c. 18 inches

d. 24 inches

17. Which of the following toilet rooms must be accessible?

a. A newly constructed toilet room in an office building

b. A toilet room currently being renovated in a public high school

c. A restroom in a shopping mall that was constructed in 1998.

d. All of the above

18. If a classroom is being renovated in a middle school, which of the following statements is true.

a. It is not necessary to renovate the non-accessible student restrooms adjacent to the classroom because the project scope only includes the classroom.

b. It is only necessary to renovate the non-accessible restrooms if the classroom being renovated is being done so for a student who is in a wheelchair.

c. The non-accessible restrooms only need to be renovated with the classroom renovation if they were constructed after January 26, 1992.

d. The non-accessible restrooms must be renovated because they support the classroom that is being renovated.

19. If a custodial closet is being renovated in a public office building, which of the following is true regarding the restrooms adjacent to the custodial closet?

a. They must be renovated with the custodial closet if they are not accessible.

b. They do not have to be renovated with the custodial closet if they are not accessible.

c. Only the entrance into the restrooms needs to be made accessible.

d. The restrooms do not need to be renovated because their cost exceeds 20% of the cost of the custodial closet renovation.

20. For new construction, which accessibility standards must be followed (unless modified by an administrative authority with the local governing authority?

a. *2010 ADA Standards for Accessible Design*

b. *2012 ADA Standards for Accessible Design*

c. *1991 ADA Standards for Accessible Design*

d. Either the *1991 ADA Standards for Accessible Design* or *the 2010 ADA Standards for Accessible Design* (designer/owner's choice)

ACCESSIBLE RESTROOMS

COURSE DESCRIPTION

Designing and constructing accessible restrooms can be challenging. This course will consolidate and summarize the restroom requirements from the *2010 ADA Standards for Accessible Design*.

LEARNING OBJECTIVES

Learning objectives include the following.

1. Understand when a restroom is required to be accessible.
2. Recognize the elements within a restroom that must be accessible.
3. Know how to design and install those elements so that they are accessible.
4. Learn tips along the way for designing accessible restrooms.

ACCESSIBLE RESTROOMS

Even though the Americans with Disabilities Act (ADA) was signed into law over thirty years ago (in 1990), design professionals, owners, and contractors still struggle to fully comply with the *ADA Standards for Accessible Design*. A revised version of the standards was adopted in 2010 and went into effect on March 15, 2012. Over ten years later, there remains a lack of knowledge among design professionals of these standards. They are lengthy. It takes time and experience to be able to digest and fully understand them. New college graduates enter the design profession every year who have almost no knowledge of the regulations because, oftentimes, those teaching the students have no experience implementing them, and the ADA is not included in the curriculum. Even if a designer prepares a set of fully compliant construction documents, contractors are relied upon to coordinate and provide the necessary care to construct the built environment in compliance.

There is one room that almost every building has, yet it can be one of the more challenging accessible spaces to design, the restroom. This course will outline the requirements for restroom accessibility, go over some of the most common mistakes made in designing, constructing, and furnishing accessible restrooms, and provide tips on how to avoid these mistakes. This course is based on the *2010 ADA Standards for Accessible Design*, or *ADA Standards* for short. The *italic* numbers in parenthesis are the referenced *ADA Standards* section numbers. Dimensions are for adult accessibility. Reference the *ADA Standards* for children's dimensions. All images are taken from the *2010 ADA Standards for Accessible Design*. A free downloadable version may be found at www.ada.gov. Keep in mind that the Administrative Authority for local jurisdictions can modify the provisions and interpretations, so always check with the local governing authority for their specific requirements.

When is a restroom required to be accessible?

1. Was it built or renovated after January 26, 1992?
2. Is it being constructed by, on behalf of, or for the use of a public entity?

If you answered 'yes' to both questions, it is required to be accessible. If the restroom was constructed before that date, it does not mean that you can discriminate against those with disabilities. Barriers must be removed when readily achievable. Refer to the *Americans with Disabilities Act Regulations* for more information.

If you are renovating or altering an area of a building that could affect the usability of or access to an area that contains a primary function (a major activity for which the facility is intended), then the restrooms serving that area must be accessible or be made accessible. There is an exception if the cost and scope of those specific alterations (path of travel including restrooms, telephones, and drinking fountains) are disproportionate to the cost of the overall alteration (exceeds 20% of the cost of the alteration to the primary function). (*202.4*) There are provisions for historic buildings yet only when the renovations would compromise the historic significance of the building. (*202.5*)

General exceptions for providing restroom accessibility include if the restroom is in a construction trailer (*203.2*), a common use area of a detention or correctional facility that is only used by detainees and security personnel (*203.7*), or the common use area of a residential facility that does not serve dwelling units required to provide specific mobility features (*203.8*). If it is technically infeasible to comply in alterations, a unisex toilet room can be provided if located in the same area as the existing inaccessible restrooms. Only 5 percent of portable units in a single location are required to comply. 50 percent of single user toilet rooms within a cluster of multiple single user toilet rooms need to comply. (*213.2*)

TIP: Even if not required, consider including a universal toilet room in your design. They can accommodate any occupant. Parents appreciate them when they need to bring their young children to the restroom in public. Care givers of adults who require assistance can do so discreetly. If you go a step further and provide an adult changing station, the person requiring assistance no longer needs to be placed on the floor to receive assistance.

Which elements pertaining to a restroom must comply for the restroom to be fully accessible? There is no point in having an accessible restroom if there is not an accessible route to get you there (*206.2.4*) and an accessible entrance (*206.4*). Once you are there, at least one of each of the following must comply, if provided: toilet compartment, water closet, urinal, lavatory, mirror, bathtub OR shower, coat hooks and shelves. Additional common building elements that must comply (if provided): fire alarm system (215), signs (216), and 5 percent of each type of locker (225.2.1).

ACCESSIBLE ELEMENTS

The Entrance

Signs are generally provided to identify the men's, women's, or universal restrooms in a public building. If they are provided, they must comply with the requirements outlined in Section 703 of the *ADA Standards*. The specific requirements are too extensive to cover in this course; however, there are general requirements for restroom signage. If there are existing restrooms in a building that are not accessible, directional signs with the International Symbol of Accessibility (ISA) indicating the location of the nearest restrooms that are accessible must be provided. If every restroom in the facility is not accessible, the ones that are accessible must have a sign with the ISA on it. (*216.8*) Signs must be installed on the latch side of the door and at a height so that the bottom of the lowest row of letters on the sign is no lower than 48 inches above the finish floor and the bottom of the highest letter is no higher than 60 inches above the finish floor. An 18 inch by 18 inch clear floor space is needed in front of the sign. (*703.4*) Braille is required below the text. (*216.2*, *703.3*)

Depending on the use of the facility, there is oftentimes a change in floor materials at the entrance into the restroom. If there is a difference in material height of more than 1/2 inch, the change in height must be beveled; the overall height cannot exceed 1/2 inch. (*303*) For an alteration, the threshold in a doorway is allowed to be as high as 3/4 inch if it has beveled edges on each side with a 1:2 maximum slope. (*404.2.5*)

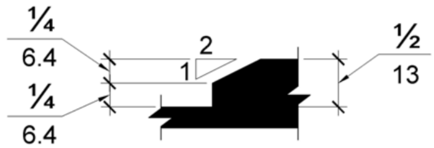

Figure 303.3
Beveled Change in Level

If the entrance into the restroom has a door, it must provide a clear width of 32 inches when the door is open 90 degrees unless the door is included in an alteration. Then, a projection of 5/8 inch on the latch side of the door is allowed. (*404.2.3*)

TIP: Offset hinges may be used to assist with obtaining the required clearance for doors in renovation projects where the doors are less than 36 inches wide.

The door must also have the required minimum maneuvering clearances shown on Table 404.2.4.1. Drawings detailing these clearances may be found on Figure 404.2.4.1 (not shown below) of the *ADA STANDARDS*. If the door is recessed more than 8 inches, the maneuvering clearances for forward approach are required. (*404.2.4.3*)

Installing push button electric door operators is oftentimes a welcome addition, especially at exterior doors that have a greater opening force. However, they are NOT a requirement of ADA STANDARDS. They may not act as a substitute for providing the required clearances. (*404.3.2*) This is unlike the 1990 ADA standards that had a provision for this.

A door has its own required maneuvering clearances, but elements within a restroom have required clearances, as well. A door cannot swing into the required clear floor space for any fixture, but they may swing into the required turning space. There are a couple of exceptions to that rule, but both exceptions are for single occupant restrooms. Doors may also not swing into the required width of an accessible route. (*603.2.3*) (The required width may be based on your local jurisdiction's adopted life safety codes, such as the International Building Code.)

Table 404.2.4.1 Maneuvering Clearances at Manual Swinging Doors and Gates

Type of Use		Minimum Maneuvering Clearance	
Approach Direction	Door or Gate Side	Perpendicular to Doorway	Parallel to Doorway (beyond latch side unless noted)
From front	Pull	60 inches (1525 mm)	18 inches (455 mm)
From front	Push	48 inches (1220 mm)	0 inches (0 mm)[1]
From hinge side	Pull	60 inches (1525 mm)	36 inches (915 mm)
From hinge side	Pull	54 inches (1370 mm)	42 inches (1065 mm)
From hinge side	Push	42 inches (1065 mm)[2]	22 inches (560 mm)[3]
From latch side	Pull	48 inches (1220 mm)[4]	24 inches (610 mm)
From latch side	Push	42 inches (1065 mm)[4]	24 inches (610 mm)

1. Add 12 inches (305 mm) if closer and latch are provided.
2. Add 6 inches (150 mm) if closer and latch are provided.
3. Beyond hinge side.
4. Add 6 inches (150 mm) if closer is provided.

TIP: No clearance is required beyond the latch side of the door for forward approach if the door does not have BOTH a latch AND a closer.

There are a few additional requirements for accessible doors. The hardware cannot require tight grasping, pinching, or twisting of the wrist (*309.4*). Most lever handles meet this requirement; knobs do not. The hardware must be mounted between 34 and 48 inches above the finish floor (*404.2.7*). If the door is provided with a closer, it needs to be programmed so at least 5 seconds are provided for the door to reach 12 degrees from the latch from the open position. (*404.2.8*) More than 5 pounds of force cannot be required to open interior restroom doors (*404.2.9*).

If the restroom is designed without a door like those at most airports, there are specific minimum maneuvering clearances that must be maintained. A clear path of at least 36 inches is required. (403.5.1) At the doorway, that distance can be reduced to 32 inches. If the route into the restroom requires a 180 degree turn around an element that is less than 48 inches wide, the clear width must be increased to 42 inches. The 42-inch clearance is not required if the width at the turn is at least 60 inches. (*403.5.2*) See Figure 403.5.2.

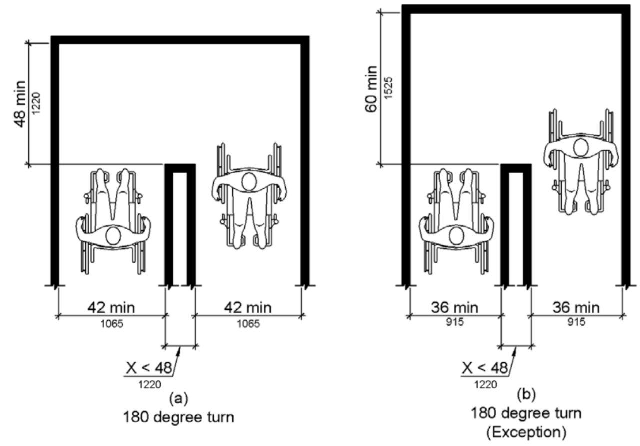

Figure 403.5.2
Clear Width at Turn

Once you get inside the restroom, a circular turning space is required that is at least 60 inches in diameter, or a T-shaped space per Figure 304.3.2 is required.

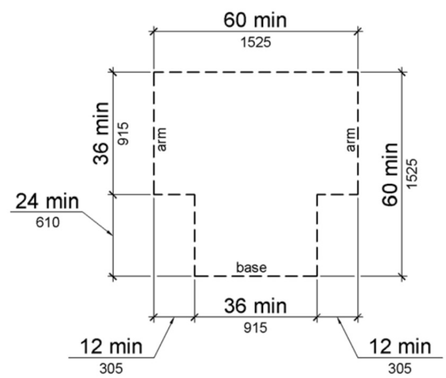

Figure 304.3.2
T-Shaped Turning Space

Mirrors

If mirrors are provided above the sink, lavatory, or countertop in a restroom, the accessible one needs to be mounted so that the bottom edge of the *reflecting* surface (NOT the frame) is no more than 40 inches above the finish floor. (603.3)

TIP: Installing a full-length mirror in lieu of mirrors over sinks accommodates more people, can reduce the amount of time someone spends at the sink, and it can address site-line issues created by mirrors reflecting toilet stalls or urinals when the sinks are on the wall opposite the stalls and urinals.

Coat Hooks and Shelves

Coat hooks must be located between 15 and 48 inches above the finish floor for an unobstructed forward or side reach. If they are located over an obstruction that is between 20 and 25 inches deep, such as a countertop or shelf, they should be mounted no higher than 44 inches above the finish floor for a forward reach. See Figure 308.2.2(b). For an obstructed side reach between 10 and 24 inches, they should be mounted no higher than 46 inches. See Figure 308.3.2(b) (*308*) Shelves must be located between 40 and 48 inches above the finish floor. If located in a circulation path, they cannot stick out beyond the wall more than 4 inches unless their leading edge is 27 inches or lower. (*603.4 and 604.8.3*)

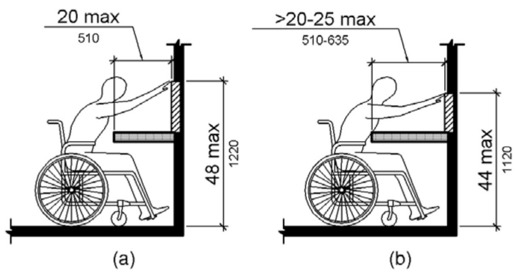

Figure 308.2.2
Obstructed High Forward Reach

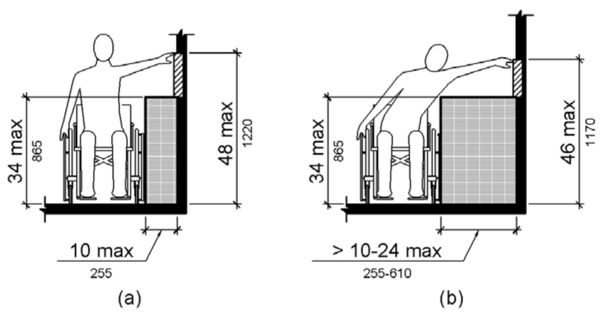

Figure 308.3.2
Obstructed High Side Reach

TIP: Provide recessed shelves or shelves less than 4 inches deep if they need to be located along a circulation path.

Please note that other toilet accessories, such as paper towel dispensers and soap dispensers, cannot protrude from the wall more than 4 inches, as well, if they are in a circulation path unless cane detection lower than 27 inches is also provided. Many manufacturers now sell accessories that are less than 4 inches deep to prevent them from becoming protruding objects.

TIP: Dimensions provided are for adults. See Advisory 308.1 for child-specific reach ranges.

REVIEW QUESTIONS:

1. **What height do accessible mirrors need to be mounted if they are located above a sink, lavatory, or countertop in a restroom?**
   a. The middle of the mirror should be at 60 inches above the finished floor (AFF)
   b. The bottom of the reflecting surface should be 40 inches or less AFF
   c. The bottom of the frame should be 40 inches or less AFF
   d. Mirrors are not required to be accessible

2. **Which restroom described below must be fully accessible?**
   a. A restroom in a private residence
   b. A pair of restrooms in a public building constructed in 1990 that has never been renovated
   c. A restroom in a construction trailer
   d. A public restroom in a new school

3. **What is the required clear width for an accessible door?**
   a. 30”
   b. 32”
   c. 34”
   d. 36”

4. Regarding accessible doors, which statement is true?

a. Push button electric door operators may substitute providing the maneuvering clearances at doors

b. If a door is recessed only 9”, the maneuvering clearances for parallel approach are acceptable

c. Push button electric door operators are a requirement for restroom doors in public schools

d. Doors cannot swing into the clear floor space for any fixture in a multi-user public restroom

5. How much clearance beyond the latch side of the door is needed on the push side if it has both a latch and a closer?

a. 0 inches

b. 12 inches

c. 18 inches

d. 24 inches

6. Which of the following is true of permanent restroom accessible signs?

a. They should be mounted on the latch side of the door

b. They should be mounted so the centerline is at 60 inches above the finish floor

c. They do not need to contain Braille

d. A 24 inch by 24 inch clear floor space is required in front of it

Baby Changing Stations

Baby changing stations are considered work surfaces, so at least 5%, but no less than one, must be accessible. (*Advisory 902.1*) The top needs to be 28 and 34 inches above the finish floor when down. (*902.3*) Knee and toe clearances (detailed in the lavatory section below) are required. The operating mechanism (handle) also needs to be in an allowable reach range as described in the section above. They cannot be a protruding object when they are stowed (per the U.S. Access Board’s *Guide to the ADA Standards*). The stations can only be located in an accessible toilet stall if they do not obstruct the minimum space required for the water closet. (*Advisory 604.8.1.1*) The clear floor space for the baby changing station can overlap the clear floor space for another fixture. However, the baby changing station cannot overlap the clear floor space required for another fixture.

TIP: Some jurisdictions consider baby changing stations as protruding objects when they protrude more than 4 inches into a path of travel if they are in the open/down position because some users will leave them down. This would be a hazard for those with visual impairments. Check with your local jurisdiction for their specific requirements.

Water Closets

For a wheelchair accessible restroom or stall (compartment), the water closet needs to be placed so that its centerline is between 16 and 18 inches from the side wall or partition. For an ambulatory accessible water closet, that dimension is between 17 and 19 inches. (*604.2*) If there are six or more toilets (or combination of toilets and urinals) in a restroom, an ambulatory accessible compartment is required in addition to the wheelchair accessible compartment. (*213.3.*)

TIP: The thickness of the finish materials needs to be considered when planning accessible restrooms.

A 60 inch wide by 56 inch deep clearance is required around the water closet. This is inside a single-user restroom or within a wheelchair accessible stall. The depth needs to be increased to 59 inches inside a wheelchair accessible stall if the water closet is floor mounted instead of wall mounted. (*604.8*) The only items that can be installed inside this clearance other than the water closet are grab bars, dispensers, sanitary napkin disposal units, coat hooks, and shelves. (*604.3.2*) The clear floor space for the water closet can overlap the clear floor space for other fixtures and the turning space. It cannot overlap other fixtures, though. (*603.2.2*) There is an exception for residential dwelling units.

The seat for a water closet must be installed between 17 and 19 inches above the finish floor unless it is inside a restroom accessed through a single office or within a residential dwelling unit. (*604.4*)

Grab bars are required to be provided on the rear wall above the water closet and the side wall closest to the water closet unless one of the three exceptions apply (single-user restroom accessed through a private office, residential dwelling unit, or detention/correction facilities). The rear wall grab bar needs to be a minimum of 36 inches long. From the centerline of the toilet, it must measure no less than 12 inches in one direction (towards the side wall) and 24 inches in the other direction. The grab bar located on the side wall must be a minimum of 42 inches long. It cannot be located more than 12 inches nor extend more than 54 inches from the rear wall. (*604.5*) The tops of both grab bars need to be installed between 33 and 36 inches above the finish floor. (*609.4*)

TIP: Specify and install longer grab bars than those required, so they do not have to be installed to the exact minimum and exact maximum dimensions listed in the standards to comply.

Circular grab bars can measure between 1-1/4 inches and 2 inches in diameter. Non-circular grab bars can be up to 2 inches across with a perimeter dimension between 4 and 4.8 inches. The distance between the wall and grab bar must be 1-1/2 inches. If a toilet accessory, such as a paper towel dispenser, is mounted below the grab bar, there needs to be 1-1/2 inches of clearance between the accessory and the grab bar. For items mounted above the grab bar, 12 inches of clearance are required. (*609*)

The grab bars need to withstand 250 pounds of force. To achieve this, plan ahead by putting blocking in the walls where grab bars are designed, so the grab bars can be adequately anchored to the wall. (*609.8*)

One of the most common errors at accessible water closets is the location of the flush controls. They must be located on the open side of the stall (except those at ambulatory water closets). (*604.6*)

The centerline of the toilet paper dispensers must measure between 7 and 9 inches in front of the water closet. The exiting paper should be located between 15 and 48 inches above the finish floor, and it cannot be placed behind the grab bars. Even though it may assist with expense and waste, the dispensers cannot have delivery controls that disallow continuous flow of paper. (*604.7*)

Toilet stall doors have the same requirements as standard swinging doors (Table 404.2.4.1), except only 42 inches of clearance is required in front of a toilet stall door if the approach is from the latch side, and they must be self-closing. The door opening needs to be at least 32 inches wide and be located in the front partition, side wall, or partitions farthest from the water closet. It also cannot swing into the required stall area. The door opening is required to be less than 4 inches from the adjacent partition that is perpendicular to the partition in which the door is located. See Figure 604.8.1.2. (*604.8.1.2*)

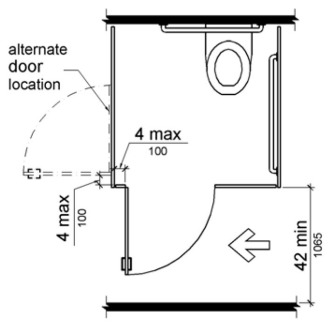

Figure 604.8.1.2
Wheelchair Accessible Toilet Compartment Doors

Ambulatory accessible stalls need to measure between 35 and 37 inches wide and be no less than 60 inches deep. This is 4 inches deeper than a wheelchair accessible stall with wall-mounted water closets. Side-wall grab bars must be installed on both sides of the stall. They have the same dimensional requirements as the side-wall bars for the wheelchair accessible stalls. Also like the wheelchair accessible stalls, the doors cannot swing into the required area and must be self-closing. 42 inches of clearance is required in front of an ambulatory stall if approaching from the latch side. (*604.8.2*)

A common overlooked error at both wheelchair and ambulatory accessible stall doors is that door pulls must be installed on both sides of the door near the latch between a height of 34 and 48 inches above the finish floor. (*604.8.1.2*)

TIP: Information provided is for adult restrooms. See 604.9 for the water closet standards specific for children's use.

REVIEW QUESTIONS:

7. What does the depth of a wheelchair accessible stall (toilet compartment) need to be if it has a wall mounted water closet?

a. 56 inches

b. 59 inches

c. 60 inches

d. 66 inches

8. Which of the following statements is true?

a. The rear wall grab bar located at an accessible water closet should be no less than 42 inches long

b. The side wall grab bar located at an accessible water closet should be no less than 42 inches long

c. Grab bars are not required at ambulatory accessible toilet compartments

d. The side wall grab bar located at an accessible water closet should be no less than 36 inches long

9. When is an ambulatory accessible toilet compartment/stall required?

a. If the number of stalls in the men's and women's restrooms combined is 6 or more.

b. If the number of stalls in a restroom is 6 or more or the total number of urinals and water closets in a restroom is 6 or more

c. If the stalls are located in a hospital

d. If a wheelchair accessible stall is not feasible

10. Which of the following is not allowed to overlap the required clearance around a water closet?

a. Shelves

b. Seat cover dispensers

c. Clear floor space for other fixtures

d. Door

11. In an accessible toilet compartment, how long does a side grab bar need to be?

a. 36 inches

b. 42 inches

c. 48 inches

d. 54 inches

12. In a toilet compartment, how long does the rear wall grab bar need to be?

a. 36 inches

b. 42 inches

c. 48 inches

d. 54 inches

13. What is the required clear width of an accessible toilet compartment door?

a. 30 inches

b. 32 inches

c. 34 inches

d. 36 inches

14. What is the maximum distance a toilet compartment door can be from the adjacent wall or partition?

a. 2 inches

b. 3 inches

c. 4 inches

d. 6 inches

15. What is the required clear floor space for a urinal that is within a 25 inch deep alcove?

a. 30 inches x 48 inches

b. 36 inches x 48 inches

c. 36 inches x 60 inches

d. 60 inches x 60 inches

16. Which of the following is NOT accessible?

a. A lavatory is installed so that the centerline of it is 19 inches off of the adjacent wall

b. A water closet in a wheelchair accessible stall is installed so that the centerline of it is 19 inches off of the adjacent wall

c. A lavatory is installed so that the centerline of it is 17 inches off of the adjacent wall

d. A water closet is installed so that the centerline of it is 17 inches off of the adjacent wall

17. What is the required depth of a toilet compartment with a floor mount water closet?

a. 56 inches

b. 59 inches

c. 60 inches

d. 66 inches

Urinals

Stall-type and wall-hung type urinals can be accessible if the rims are no more than 17 inches above the finish floor and are no less than 13-1/2 inches deep. A 30 inch wide by 48 inch deep clear floor space is required in front of the accessible urinals. If the urinal is located in an alcove that is deeper than 24 inches, a width of at least 36 inches needs to be provided. (*305 and 605*)

TIP: An accessible urinal is only required in restrooms with more than one urinal. (213.3.3)

Lavatories (Sinks in a Toilet Room)

A 30 inch by 48 inch clear floor space is required in front of accessible lavatories. If the lavatory is located in an alcove that is deeper than 24 inches, the width must be increased to 36 inches. Space under the lavatory is included in the clear floor space; therefore, knee and toe clearances are required. Toe clearance should be provided between the floor and 9 inches above the finish floor and extend horizontally under the lavatory for a distance between 17 to 25 inches. See Figure 306.2. The space under the lavatory should be clear of obstructions for the knees between 9 and 27 inches above the finish floor. The clearance needs to be 11 inches deep at the height of 9 inches above the finish floor and at least 27 inches above the finish floor for a depth of 8 inches. This knee clearance can be reduced at a rate of 1 inch depth for every 6 inches of height between 9 inches and 27 inches above the finish floor. See Figure 306.3. (*306.2, 306.3, and 606*)

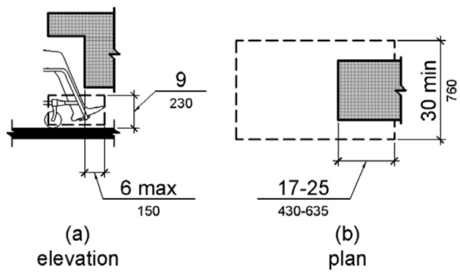

Figure 306.2
Toe Clearance

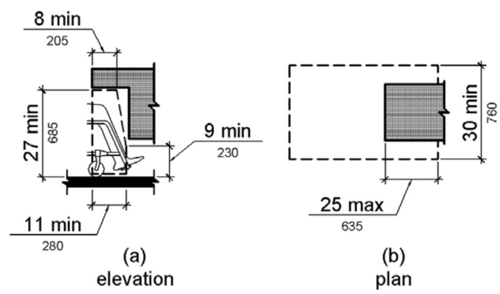

Figure 306.3
Knee Clearance

There are exceptions to a front approach clear floor space requirement for restrooms accessed through a private office, in residential dwelling units, and those used primarily by children. Only one bowl of a multi-bowl sink needs to have the required clear floor space. The dip of the overflow pipe below the lavatory does not have to be considered when providing the required knee and toe clearances because one's knees can go on either side of the pipe. (*606.2*)

A common mistake with sink installations is where to take the maximum height measurement. The top of the sink or counter can be no higher than 34 inches above the finish floor unless it is a sink in a unisex restroom accessed from a single private office or within a residential dwelling unit. The 34 inch maximum measurement is to whichever is higher, the front of the sink rim OR counter surface. Drop-in sinks, oftentimes, stick up above the counter, so the top or the sink should be installed no higher than 34 inches above the finish floor, NOT the top of the counter. (*606.3*)

Faucets cannot require tight grasping, pinching, or twisting of the wrist in order to operate. Therefore, faucets with knob handles do not comply with the ADA STANDARDS. Typically, lever handle controls are installed at accessible sinks. (*309 and 606.4*)

The pipes under the sink must be insulated or covered to prevent contact. (*606.5*)

The accessible sink may not be placed within the accessible toilet stall. (*213.3.4*)

TIP: Do not position a lavatory in a circulation path unless there is cane detection, such as the side of a counter or wall, at the leading edge at a height 27 inches or lower. The bottom of an accessible lavatory cannot be mounted below 27 inches, or it impedes on the required knee clearance.

Bathtubs

Accessible bathtubs need a minimum of a 30 inch wide clear floor space that is along the entire length of the bathtub. An accessible lavatory can be in this required clearance if it is on the same end as the controls. If a permanent seat is provided at the head end wall, the side clear floor space needs to extend another 12 inches beyond the head end wall. See Figure 607.2.b.

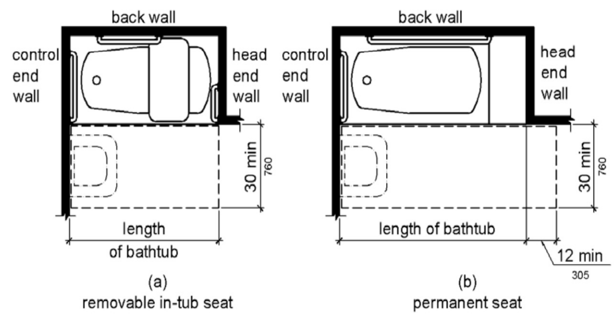

Figure 607.2
Clearance for Bathtubs

A seat is required at the head end of the bathtub. It may be permanent or removable. The top of the seat must be between 17 and 19 inches above the bathroom finish floor (not the bathtub finish floor). The depth of the seat should be 15 to 16 inches. It must be securely placed. Permanent seats may only be placed at the head end of the bathtub. Their depth must be 15 inches or greater. They need to extend the entire width of the bathtub to the back wall. They can extend beyond the outer edge of the bathtub. (*610.2*)

Grab bars are also required unless the bath is located in a bathroom accessed through a single private office or residential dwelling unit. Even if one of the exceptions applies, reinforcement (or blocking) must be installed in the walls so that grab bars can be easily installed in the future if the need arises. Grab bars at bathtubs need to have the same cross section as those listed above at water closets.

The placement of the grab bars depends on if the bathtub seat is permanent or removable. For permanent seats, two grab bars must be placed on the back wall. One should be mounted between 33 and 36 inches above the finish floor. The other one needs to be installed between 8 and 10 inches above the rim of the bathtub. Both grab bars must be installed no more than 15 inches from the head end wall and a maximum of 12 inches from the control end wall. Another grab bar is required on the control end wall at a height between 33 and 36 inches above the finish floor. It should have a minimum length of 24 inches and placed close to the front edge of the bathtub. See Figure 607.4.1.

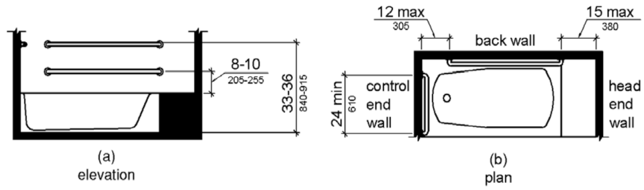

Figure 607.4.1
Grab Bars for Bathtubs with Permanent Seats

If the bathtub seat is permanent, two grab bars are still required on the back wall. They will be installed at the same heights as those without permanent seats. The only difference is that they should be a minimum of 24 inches in length and installed no more than 24 inches from the head end wall and 12 inches from the control end wall. A grab bar should also be installed on the control wall in the same manner and size as the one for non-permanent seats. A fourth grab bar must be installed on the head end wall at the front edge of the bathtub at the standard height between 33 and 36 inches with a minimum length of 12 inches. See Figure 607.4.2.

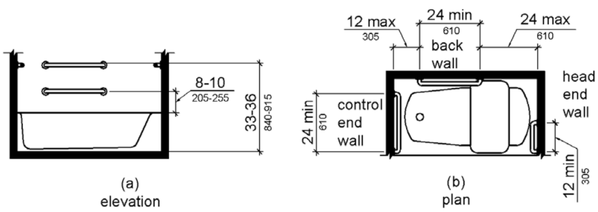

Figure 607.4.2
Grab Bars for Bathtubs with Removable In-Tub Seats

The controls need to be positioned on an end wall between the bathtub rim and grab bar. They should also be located within the front half of the open side of the bathtub. As with faucets, lever controls should be installed. (*607.5*)

Tempered water no warmer than 120 degrees needs to be provided from a shower spray unit. This unit must have a hose that is at least 59 inches long and can be fixed or held during use. An on/off control with a non-positive shut-off is needed so that the water is kept at about the same temperature while in the off position until one is ready to rinse off. Adjustable-height shower heads on vertical bars allow for even more flexibility; however, they need to be installed so that do not interfere with the use of the grab bars. (*607.6*)

If there is a bathtub enclosure, they cannot obstruct controls, faucets, shower and spray units. They also cannot get in the way of someone transferring from a wheelchair into the bathtub or onto the seat. Tracks for the enclosure are not allowed. This should not be an issue as they are generally not the preferred choice for enclosures due to their difficult cleaning and maintenance.

Shower Compartments

Transfer Type

There are three types of accessible shower compartments: transfer type, standard roll-in type and alternate roll-in type. Each has their own requirements for size, grab bars, seats, and controls. *Transfer* type showers are required to be 36 inches wide by 36 inches deep. These dimensions are the clear inside dimensions from center points of opposing sides and are not minimum or maximum dimensions. The clear floor space along the shower can be no less than 36 inches wide by 48 inches long. The dimension is taken from the control wall to beyond the seat wall. (*608.2.1*)

Grab bars mounted between 33 and 36 inches above the finish floor are required across the control wall and around the corner on the back wall to a point 18 inches from the control wall. See Figure 608.2.1. There are exceptions to this requirement for private offices and residential dwelling units. (*608.3.1*)

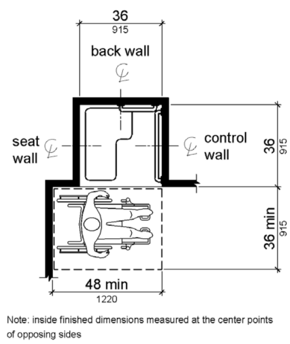

Figure 608.2.1
Transfer Type Shower Compartment Size and Clearance

A seat is required in a transfer type shower. It can be folding or non-folding. Transient lodging guest rooms that are required to be accessible need folding seats. In residential dwelling units, the seats do not have to be installed, but the wall reinforcement must be installed. (*608.4*) The seat must extend the width of the side wall and stop no more than 3” from the shower entry. The top of the seat is required to be no less than 17 inches and no higher than 19 inches from the bathroom (NOT shower) finish floor. (*610.3*)

As with other plumbing fixtures, the controls cannot have knobs; they need to have lever handles. The faucets, shower spray unit, and the controls should be mounted on the side wall that is opposite the seat at a height between 38 and 48 inches above the finish floor. They should be located horizontally no more than 15 inches from the centerline of the seat toward the shower opening. See Figure 608.5.1. (*608.5.1*)

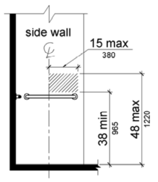

Figure 608.5.1
Transfer Type Shower Compartment Control Location

Standard Type

The minimum inside clear dimensions measured at center points of opposing sides for a *standard* roll-in type shower compartment must be a minimum of 30 inches wide by 60 inches deep. The clear floor space adjacent to the shower cannot be less than 30 inches wide by 60 inches along the entry face of the compartment. The only element that can be located inside this clear floor space is an accessible lavatory if it is not adjacent to the controls or shower seat. See Figure 608.2.2. (*608.2.2*)

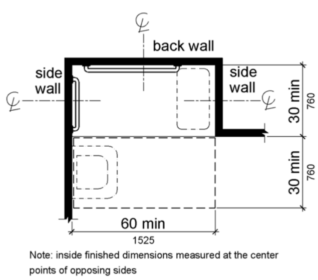

Figure 608.2.2
Standard Roll-In Type Shower Compartment Size and Clearance

In a standard roll-in type shower compartment with a seat, provide grab bars on the back wall and side wall opposite the seat. Grab bars should not be installed over the seat on the side wall or back wall. If there is not a seat in the standard shower, grab bars are needed on all three walls. Each grab bar within a single shower needs to be mounted at the same height between 33 and 36 inches above the finish floor. They should be installed no more than 6 inches from adjacent walls. See Figure 608.3.2. (*608.3.2*) Continuous grab bars may also be installed.

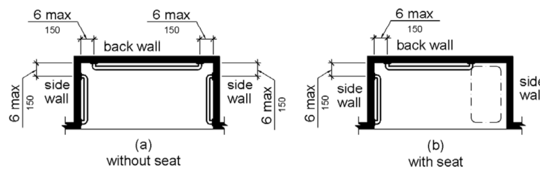

Figure 608.3.2
Grab Bars for Standard Roll-In Type Showers

The controls, faucets, and shower spray unit in a standard roll-in type shower compartment *without* a seat can be mounted on any of the three walls above the grab bar as long as they are no higher than 48 inches above the shower floor. The controls, faucets, and shower spray unit in a standard roll-in shower compartment *with* a seat need to be installed on the back wall adjacent to the seat within 27 inches of the seat wall. See Figure 608.5.2. (*608.5.2*)

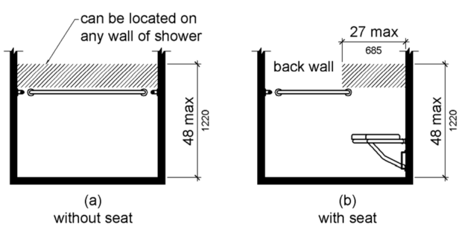

Figure 608.5.2
Standard Roll-In Type Shower Compartment Control Location

If seats are provided in standard roll-in type shower compartments, they must be the folding type. They also need to be installed on the side wall that is adjacent to the controls and should be as wide as the side wall, itself. The seat can stop no more than 3 inches from the shower entry. As with the transfer style seats, the top of the seat is required to be installed between 17 and 19 inches from the bathroom (NOT shower) finish floor. (*610.3*)

Alternate Type

The dimensions for an *alternate* roll-in type shower compartment are 36 inches wide by 60 inches deep.

Unlike the standard roll-in type shower, the entry side is not completely open. There is a 36 inch wide opening provided at one end of the long side. See Figure 608.2.3. (*608.2.3*)

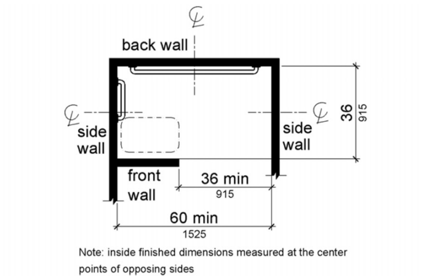

Figure 608.2.3
Alternate Roll-In Type Shower Compartment Size and Clearance

At alternate roll-in showers, the back wall and the side wall furthest from the compartment entry are required to have grab bars mounted between 33 and 36 inches. As with the standard shower, do NOT place grab bars above shower seats, more than 6 inches from adjacent walls, or at varying heights. (*608.3.3*)

The controls, faucets, and shower spray units in the alternate roll-in shower compartments *without* seats can be placed no higher than 48 inches above the shower floor only on the side wall farthest from the shower entry. In alternate showers *with* a seat, they must be positioned on the side wall adjacent to the seat and can be no more than 27 inches from the side wall that is behind the seat. They could also be placed on the back wall opposite the seat no more than 15 inches from the centerline of the seat. See Figure 608.5.3. (*608.5.3*)

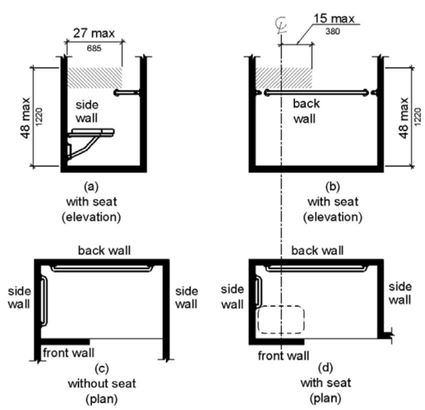

Figure 608.5.3
Alternate Roll-In Type Shower Compartment Control Location

If a seat is provided in an alternate roll-in type shower compartment, it also needs to be the folding type. It can only be installed on the front wall opposite the back wall. It needs to extend across the entire front wall, stopping just shy of 3 inches from the entry into the shower. (See Figure 608.5.3(d).) Like the other shower seats, the top of the seat must be positioned between 17 and 19 inches above the bathroom finish floor. (*610.3*)

All Accessible Shower Types

The seats installed, if any, in each of the three types of showers can be one of two types, rectangular shaped or L-shaped. Both types have individual guidelines as to size and how far from the wall they can be installed. Those requirements are shown in Figures 610.3.1 (rectangular) and 610.3.2 (L-shaped). The seats and their components must sustain vertical and horizontal forces of 250 pounds. (*610.4*)

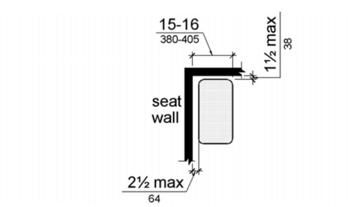

Figure 610.3.1
Rectangular Shower Seat

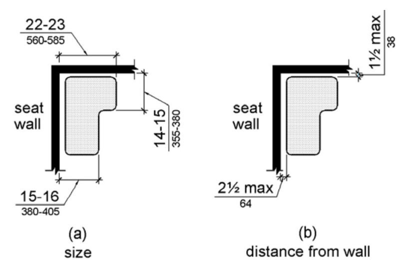

Figure 610.3.2
L-Shaped Shower Seat

All three shower types have the same requirements as bathtubs for shower spray units and water. However, there is an exception for shower heads if they are NOT at medical care facilities, long-term care facilities, transient lodging guest rooms, or residential dwelling units. They may be fixed if the shower head is located no more than 48 inches above the shower floor. (*608.6*)

The thresholds in roll-in type showers cannot be higher than 1/2 inch; they need to be beveled for the top ¼ inch of height. The shower floors may slope to drains, but the slope may not exceed 1:48. (*304.2*) For transfer type showers, the thresholds can be up to 1/2 inch high with beveled, rounded, or vertical edges. Existing facilities can have 2 inch high thresholds in transfer-type shower compartments if a 1/2 inch high threshold would interfere with the structural reinforcement of the floor slab. (*608.7*)

Like bathtubs, the shower enclosures cannot obstruct the controls, faucets, and shower spray units or obstruct the transfer onto the shower seats from wheelchairs. (*608.8*)

TIP: If both showers and bathtubs are provided, only one bathtub OR one shower must be accessible. (213.3.6)

CONCLUSION

The *2010 ADA Standards for Accessible Design* provides very detailed requirements for accessible restrooms and washrooms. It can be a confusing set of regulations to understand and remember, even for experienced designers and contractors. We hope this course consolidated the requirements in such a way that you have a better understanding of what needs to be accessible, when it needs to be accessible, and how to accomplish accessibility within restrooms and washrooms.

REVIEW QUESTIONS:

18. What is the required clear floor space for a lavatory?

a. 30 inches by 48 inches

b. 32 inches by 60 inches

c. 36 inches by 48 inches.

d. 30 inches by 60 inches

19. Per the ADA Standards, what is the minimum clear floor space required within a standard roll-in shower?

a. 30 inches by 48 inches

b. 36 inches by 48 inches

c. 30 inches by 60 inches

d. 36 inches by 60 inches

References:

ADA.gov – ADA Standards for Accessible Design

REVIEW QUESTION ANSWERS

1. **What height do accessible mirrors need to be mounted if they are located above a sink, lavatory, or countertop in a restroom?**
   a. The middle of the mirror should be at 60 inches above the finished floor (AFF); incorrect, the bottom of reflecting surface should be 40 inches or less.
   b. The bottom of the reflecting surface should be 40 inches or less AFF: Correct
   c. The bottom of the frame should be 40 inches or less AFF; Incorrect, the bottom of the reflecting surface should be 40 inches or less AFF
   d. Mirrors are not required to be accessible; incorrect, mirrors do need to be accessible.

2. **Which restroom described below must be fully accessible?**
   a. A restroom in a private residence; incorrect accessibility compliance applies to public restrooms
   b. A pair of restrooms in a public building constructed in 1990 that has never been renovated; incorrect if the building has not been renovated and was built prior to January 26, 1992, it is not required to be accessible.
   c. A restroom in a construction trailer; incorrect this is an exception to the rule
   d. A public restroom in a new school; Correct, any public restroom built after January 26, 1992 needs to meet accessibility requirements.

3. **What is the required clear width for an accessible door?**
   a. 30”; incorrect, width is 32 inches
   b. 32”; correct
   c. 34”; incorrect, width is 32 inches
   d. 36”; incorrect, width is 32 inches

4. **Regarding accessible doors, which statement is true?**
   a. Push button electric door operators may substitute providing the maneuvering clearances at doors; incorrect push button electric door operators are NOT a requirement of ADA Standards and do not fulfill/replace other standards.
   b. If a door is recessed only 9”, the maneuvering clearances for parallel approach are acceptable; incorrect there are minimum maneuvering clearances that must be maintained, Table 404.2.4.1 goes over these Maneuvering Clearances
   c. Push button electric door operators are a requirement for restroom doors in public schools; incorrect push buttons are not a requirement of ADA standards
   d. Doors cannot swing into the clear floor space for any fixture in a multi-user public restroom; correct

5. **How much clearance beyond the latch side of the door is needed on the push side if it has both a latch and a closer?**
   a. 0 inches; incorrect, clearance needs to be 12 inches
   b. 12 inches; correct
   c. 18 inches; incorrect, clearance needs to be 12 inches
   d. 24 inches; incorrect, clearance needs to be 12 inches

6. **Which of the following is true of permanent restroom accessible signs?**
   a. They should be mounted on the latch side of the door; correct
   b. They should be mounted so the centerline is at 60 inches above the finish floor; incorrect, the bottom of the highest letter should be no higher than 60 inches above the finished floor.
   c. They do not need to contain Braille; incorrect, Braille is required to go below the text
   d. A 24 inch by 24 inch clear floor space is required in front of it; incorrect this does not relate to signs

7. **What does the depth of a wheelchair accessible stall (toilet compartment) need to be if it has a wall mounted water closet?**
   a. 56 inches; correct the depth of the stall should be 56 inches
   b. 59 inches; incorrect the depth of the stall should be 56 inches
   c. 60 inches; incorrect the depth of the stall should be 56 inches
   d. 66 inches; incorrect the depth of the stall should be 56 inches

8. **Which of the following statements is true?**
   a. The rear wall grab bar located at an accessible water closet should be no less than 42 inches long; incorrect this grab bar should be a minimum of 36 inches long.
   b. The side wall grab bar located at an accessible water closet should be no less than 42 inches long; correct, the grab bar located on the side wall needs to be a minimum of 42 inches long.
   c. Grab bars are not required at ambulatory accessible toilet compartments; incorrect, an ambulatory accessible toilet compartment is a narrower toilet compartment that is useful for those that need support on two sides, they are equipped with 2 parallel grab bars.
   d. The side wall grab bar located at an accessible water closet should be no less than 36 inches long; incorrect the side wall should be no less then 42 inches long.

9. **When is an ambulatory accessible toilet compartment/stall required?**
   a. If the number of stalls in the men’s and women’s restrooms combined is 6 or more; incorrect, it goes by number of stalls in a single restroom, not by total number in building.
   b. If the number of stalls in a restroom is 6 or more or the total number of urinals and water closets in a restroom is 6 or more; correct
   c. If the stalls are located in a hospital; incorrect, a hospital is not the only public entity
   d. If a wheelchair accessible stall is not feasible; incorrect, an ambulatory is required along with a wheelchair accessible stall if there is a total number of 6 or more stalls within one restroom.

10. **Which of the following is not allowed to overlap the required clearance around a water closet?**
    a. Shelves; incorrect, these can be installed inside this clearance
    b. Seat cover dispensers; incorrect, these can be installed inside this clearance
    c. Clear floor space for other fixtures; incorrect, the clear floor space for the water closet can overlap the clear floor space for other fixtures and turning spaces.
    d. Door; correct, this is not allowed to overlap the required clearance around a water closet

11. **In an accessible toilet compartment, how long does a side grab bar need to be?**
    a. 36 inches; incorrect, the side grab bar needs to be a minimum of 42 inches
    b. 42 inches; correct
    c. 48 inches; incorrect, the side grab bar needs to be a minimum of 42 inches
    d. 54 inches; incorrect, the side grab bar needs to be a minimum of 42 inches

12. **In a toilet compartment, how long does the rear wall grab bar need to be?**
    a. 36 inches; correct
    b. 42 inches; incorrect, the rear wall grab bar needs to be a minimum of 36 inches
    c. 48 inches; incorrect, the rear wall grab bar needs to be a minimum of 36 inches
    d. 54 inches; incorrect, the rear wall grab bar needs to be a minimum of 36 inches

13. **What is the required clear width of an accessible toilet compartment door?**
    a. 30 inches; incorrect, clear width of toilet compartment door needs to be 32 inches
    b. 32 inches; correct
    c. 34 inches; incorrect, clear width of toilet compartment door needs to be 32 inches
    d. 36 inches; incorrect, clear width of toilet compartment door needs to be 32 inches

14. **What is the maximum distance a toilet compartment door can be from the adjacent wall or partition?**
    a. 2 inches; incorrect, maximum distance can be 4 inches
    b. 3 inches; incorrect, maximum distance can be 4 inches
    c. 4 inches; correct
    d. 6 inches; incorrect, maximum distance can be 4 inches

15. **What is the required clear floor space for a urinal that is within a 25 inch deep alcove?**
    a. 30 inches x 48 inches; incorrect, the required floor space is 36 inches x 48 inches
    b. 36 inches x 48 inches; correct
    c. 36 inches x 60 inches; incorrect, the required floor space is 36 inches x 48 inches
    d. 60 inches x 60 inches; incorrect, the required floor space is 36 inches x 48 inches

16. **Which of the following is NOT accessible?**
    a. A lavatory is installed so that the centerline of it is 19 inches off of the adjacent wall; incorrect, this meets the requirements and is accessible
    b. A water closet in a wheelchair accessible stall is installed so that the centerline of it is 19 inches off of the adjacent wall; correct, this is NOT accessible, the water closet needs to be placed so that its centerline is between 16 and 18 inches from the side wall or partition.
    c. A lavatory is installed so that the centerline of it is 17 inches off of the adjacent wall; incorrect, this meets the requirements and is accessible
    d. A water closet is installed so that the centerline of it is 17 inches off of the adjacent wall; incorrect, this meets the requirements and is accessible

17. **What is the required depth of a toilet compartment with a floor mount water closet?**
    a. 56 inches; incorrect, required depth of a toilet compartment with a floor mount water closet is 59 inches
    b. 59 inches; correct, this is the required depth
    c. 60 inches; incorrect, required depth of a toilet compartment with a floor mount water closet is 59 inches
    d. 66 inches; incorrect, required depth of a toilet compartment with a floor mount water closet is 59 inches

18. **What is the required clear floor space for a lavatory?**
    a. 30 inches by 48 inches; correct
    b. 32 inches by 60 inches; incorrect, clear floor space in a lavatory should be 32 inches x 60 inches
    c. 36 inches by 48 inches ; incorrect, clear floor space in a lavatory should be 32 inches x 60 inches
    d. 30 inches by 60 inches; incorrect, clear floor space in a lavatory should be 32 inches x 60 inches

19. **Per the ADA Standards, what is the minimum clear floor space required within a standard roll-in shower?**
    a. 30 inches by 48 inches; incorrect, the minimum clear floor space required within a standard roll-in is 30 inches by 60 inches.
    b. 36 inches by 48 inches; incorrect, the minimum clear floor space required within a standard roll-in is 30 inches by 60 inches.
    c. 30 inches by 60 inches; correct
    d. 36 inches by 60 inches; incorrect, the minimum clear floor space required within a standard roll-in is 30 inches by 60 inches.

PDH Academy

Blast Resistant Design
A Primer for Architects

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FINAL EXAM
BLAST RESISTANT DESIGN

1. A "blast" event refers to:

a. An entertainment event that gets beyond the capability of the building where it is being held

b. Any type of force that causes a building to move

c. A shockwave of compressed air that spreads outwards from an explosion

d. A military action using live ammunition

2. For Blast buildings that are used in forward military positions, which one of the following is an important characteristic?

a. Air conditioning

b. Easily transported and erected

c. Must be yellow and red in color

d. Use solar energy for power

3. Which of the following types of Architecture have potential for requiring blast resistant design:

a. Industrial buildings

b. Strategically symbolic buildings

c. Transportation hubs

d. All of the above

4. Many military building installations have a degree of blast design consideration. How many broad categories do these buildings typically fall into?

a. 2

b. 3

c. 4

d. 5

5. The most frequently occurring blast events happen in which type of building?

a. Military

b. Industrial Plants

c. Federal facility

d. Residential Buildings

6. An effective BR design team is composed of which of the following professionals?

a. Architect

a. Structural Engineer

a. Building Owner

a. All of the above

7. The secondary layer of the BR design team consists of which of the following professionals:

a. Owner & their QRA/security consultant

b. Structural engineer and Contractor

c. MEP consultants and material vendors and manufacturers

d. Regulators and Association Managers

8. "Side-On" over pressure is also called:

a. Reflected pressure

b. A force that strikes only the side of a building or structure

c. Free field overpressure

d. Low volatility over pressure

9. The blast "duration" is measured in:

a. Impulse units

b. milliseconds

c. seconds

d. hours

10. Deflagration explosions are created by low explosive forces and move at speeds _______ the speed of sound (sub-sonic).

a. Equal

b. Above

c. Below

d. None of the above

11. ______________ results in supersonic (faster than the speed of sound) explosions created by high explosives.

a. A Vapor Cloud

b. Detonation

c. Shock Wave

d. Deflagration

12. Which type of explosion occurs when a cloud of flammable vapor, gas or mist ignites.

a. Shock wave

a. Deflagration

a. Vapor Cloud

a. Thermal Radiation

13. Which of the following terms comes from the military and is used in reference to attacks from the air, specifically for damage that can be caused by bombs that are designed to explode above a target?

a. HOB (Height of Burst)

b. Stand-Off Distance

c. Building Damage Levels

d. Progressive Collapse

14. Increasing the "Stand-Off Distance" does which of the following?

a. Increases the impact of the blast

b. Eliminates the blast wave

c. Creates an observation point for monitoring blasts

d. Reduces the damage risk from a blast

15. This type of overpressure is on the side "facing" the blast when a blast wave propagates in a rigid surface. This type of overpressure is always higher than the pressures on the other faces.

a. Reflected Overpressure

b. Incident Overpressure

c. Back face Overpressure

d. All of the above

16. This type of overpressure is sometimes called the "free field" overpressure and is the undisturbed blast wave pressure that impacts the overall building.

a. Reflected Overpressure

a. Incident Overpressure

a. Back Face Overpressure

a. Impulse Pressure

17. Per ASCE, how many Building damage levels are there?

a. 3

b. 4

c. 5

d. 6

18. When a building is designed to a Low BDL, which of the following is not true:

a. Building is usable after an event

b. Only minor repairs are needed

c. Cost of repairs approaches replacement cost of the building

d. Building design is robust and repair costs are moderate.

19. Who sets the BR design criteria?

a. The Architect

b. IBC codes

c. The structural engineer

d. The Owner and their QRA consultant

20. On a typical Overpressure / Impulse curve, low pressure and low impulse values mean?

a. Nothing

b. Less damage

c. More damage

d. A region of negative impulse

21. Which of the following are relevant BR design issues that need to be addressed during the building programming?

a. Does the Building need to be designed for BR?

b. Who will determine BR design criteria?

c. Should the design team hold or proceed on an assumed basis as directed by Owner?

d. All of the above

22. When designing for BR, Architects have primary responsibility for all of following except:

a. Exterior wall components and details.

b. Foundation design

c. Exterior doors and hardware.

d. Window systems and glazing.

23. Which of the following are favorable characteristics of prefabricated BR buildings?

a. Speed of transport and erection

b. Standardization

c. Deployment in remote areas

d. All of the above

24. If structural strengthening of a building is not feasible or insufficient to address blast impact, what is a technique that can mitigate the shockwave?

a. Employ slopes, or berms around the building

b. The use of “blast walls”

c. The use of heavy blast rated fabric and similar tensile structures

d. All of the above

25. Buildings designed for ___________ psi require specialized components.

a. <1

b. 3-7

c. 8-10

d. None of the above

Blast Resistant Design - A Primer for Architects

The course on Blast resistant Design is a three-part course broken down as follows:

PART 1 – Introduction to Blast Resistant Design

PART 2 – Technical Issues and Considerations

PART 3 – Implications for Blast Resistant Design for Architects

PART 1 – INTRODUCTION TO BLAST RESISTANT DESIGN

In an age of mega industrial and commercial projects and evolving threats of urban terrorism, requirements for and responses to designing buildings for varying degrees of blast resistance have become more relevant for Architects across the design spectrum. For many the terminology and science involved can seem overwhelming. This course will demystify the terms and concepts to enable participants to create better design responses and interact with their consulting engineers and clients with greater confidence.

The objectives of the course are 3-fold:

1. Provide Architects an understanding of the emerging trends in Blast Resistant (BR) Design as these requirements enter into mainstream design.
2. Explain the science behind BR design and lift the veil from the complex sounding terminology and remove common misunderstandings that lead to inhibitive design responses. By demystifying the concepts, architects will be better positioned to work with their structural engineers and clients. The course will address terms such as Blast-Proof vs Blast Resistant; Overpressures and impulses; 3-part curves; Blast contours; Inherent protective properties of common construction systems and active vs passive responses.
3. Share rules of thumb and experience-based guidelines from the perspectives of Architect and Owner. These will provide valuable concept takeaways without being burdened by the math.

LEARNING OBJECTIVES

- Relevance of Blast Resistant (BR) design to Architects
- Explain the key terms in Blast Resistant Design
- Understand the principles of Blast Resistant design
- Impact of factors such as building shape, profile, geography
- Explain what a QRA approach to building design is
- Is Blast Resistant design inherently Ugly?
- How BR design implications are going beyond industrial, military and offshore settings

Disclaimer Notice:

This course is intended to provide information as an educational benefit for architects and design professionals. The author has attempted to present a summation of the concepts and published data in a manner that intended to clarify these for architects. While the Information contained in this course has been reviewed and presented with all due care, the author does not warrant or represent that the Information is free from errors or omission. The author accepts no liability whatsoever for, or in respect of any use or reliance upon this publication by any party. Author: Muhammad Siddiqui.

WHAT IS BLAST RESISTANT DESIGN?

A “blast” in the context of Blast Resistant (BR) design refers to a shockwave of highly compressed air that spreads outwards from an explosion source. When that wave strikes a building, the building experiences tremendous pressures, measured in psi, but for very short durations, measured in milliseconds. It is this characteristic of blast impacts that requires specialized treatment of building structures and envelopes beyond the types of protection that are more common, such as wind forces or seismic considerations. Those are more sustained in duration and impose different forces on a structure.

Blast Resistant design, as addressed in this course, involves design requirements to be considered to enable a building to provide the required level of protection to an anticipated blast event. The “event” trigger can be an accidental explosion due to a chemical process in an industrial setting, some form of terrorist attack using explosives or any number of accidental explosion scenarios which can occur in an increasingly urbanized society with its complex infrastructure demands.

It is not practical to plan for all accidental scenarios but where there is some likelihood of a potentially predictable explosion based on either the arrangement of an industrial plant or the strategic vulnerability of a facility (as in a potential target for a terrorist attack), then the buildings in these settings have to be designed to mitigate the impacts of the potential threat. This design response is executed using Blast Resistant design concepts.

BRIEF HISTORICAL BACKGROUND

Awareness of the threat that explosive blasts pose to structures has been around from the time explosives were invented and used in warfare. As such it was in the military realm that design of buildings to resist blast impacts was first developed. The early responses were derived from the impact resistance philosophies of earlier warfare. Basically, this meant resistance through brute strength – the bunker approach. While this can be an effective solution, it is generally very expensive and very limited in function. This solution was, and continues to be, a valid consideration in specific military situations. It is also a baseline approach to nuclear facility design.

However, following the industrial revolution and the proliferation of factories, pipelines and complex chemical process plants and increased use of hydrocarbon-based processes, the non-military threat of accidental industrial blasts became an ever-growing real possibility. These fears were brought to realization in several smaller scale accidents in Europe and the United States in the early part of the 20th century. As the awareness and potential consequences of these processes became more understood, engineers began to analyze the forces created by different types of blasts and then develop responses to mitigate these to protect people and critical equipment. Almost in parallel, the invention of dynamite in 1867, unleashed a new era of the use of high explosives, initially for mining, but quickly into the arena of weaponry. The use of explosives for military purposes generated a series of powerful threats and this led to an awareness that infrastructure and buildings needed to be protected from the effects of these new forces. The US War Department had started to investigate the science of blast impacts on buildings prior to World War 2 but it was the development of nuclear weapons that triggered highly focused and detailed study of the impact of blast forces on structures. Much of the foundational research for blast resistant design was done in the 1940s and 1950s by the US Department of Defense as part of the nuclear weapons program. (NOTE: This course is not intended to cover design for nuclear facilities as these are designed to respond to different criteria and conditions than industrial explosions or terrorism attacks.)

Below is a timeline of some notable blast events, their magnitude and resulting loss as measured in fatalities:

[It is worth noting that when losses are discussed in the context of blast resistant design, the unit of measure is generally human fatalities. It is difficult to ascertain why this has become so, but one possibility is that while material costs and zone of destruction can vary enormously based on the location and type of facility damaged, the purpose of blast resistant design is, first and foremost, to protect as much human life as possible, followed by the most critical operating infrastructure. Hence, it follows that the success or failure of blast resistance be measured in how many lives are saved or lost. By extension, human fatalities can be inferred as a measure of the severity of a blast on society.]

Date	Event / Location	Cause	Explosive Force (TNT equivalent)*	Fatalities
1917	Maritime Accident: Halifax Canada	French Steamer Mont Blanc carrying explosives collided with Norwegian ship Imo	2,900 tons	Over 1,750
1921	Industrial Explosion: Oppau, Germany	Explosion at an ammonium sulfate and nitrate plant	1,000 tons	500 – 600
1947	Industrial Accident: Texas City, USA	Explosion 1: On April 16, 2,300 tons of ammonium nitrate exploded aboard SS Grandcamp; Explosion 2: On April 17, 960 tons of ammonium nitrate exploded on the SS High Flyer	Exp 1: 690 tons Exp 2: 288 tons	Estimates to 567

1974	Industrial Explosion: Flixborough, UK	Chemical explosion following the ignition of a vapor cloud.	unavailable	28
1986	Nuclear Accident: Chernobyl, Ukraine	Melt down and explosion at No 4 reactor during a safety test.	10 tons	Estimates range upwards of 4,000 due to long term effects
1995	Truck Bombing: Oklahoma City, USA	Terrorist attack on a federal building in Oklahoma using ammonium nitrate and other substances.	2.5 tons	168
2013	Industrial Explosion: West, Texas, USA	Ammonium nitrate explosion at fertilizer plant	12.5 tons	15
2015	Industrial Accident: Tianjin, China	A series of explosions at a container storage facility where chemicals were stored.	21 tons	173
2020	Industrial Explosion: Beirut, Lebanon.	Chemicals stored at the Port of Beirut exploded.	300 – 400 tons	218

Source: Wikipedia / Reuters

**** For comparison: The GBU-43B (nicknamed MOAB – Mother of All Bombs), the most powerful non-nuclear bomb in the US arsenal has explosive power of 11 tons. A Tomahawk missile is 0.5 tons and the "Little Boy" (The nuclear bomb dropped on Hiroshima Japan) was about 15,000 tons.***

BLAST RESISTANCE VS BLAST PROOF

If you have ever noticed that many watches will note they are "water resistant" and then specify a depth to which that resistance is applicable. There was a time when the term "waterproof" was used but that is no longer the case. The reason is that "something proof" implies that it provides complete protection from whatever it is "proofing" from. That is an absolute condition that is not practical in real world scenarios. Protection from moisture intrusion can be resisted to a certain depth based on the design but at some level, the pressure will exceed the level of design protection and damage will occur. Hence the term resistance is used, and its limits identified. The concept of protection for buildings from blasts follows the watch analogy. To blast "proof" a building, it would have to emerge completely unscathed after being subjected to any blast. The military comes closest to creating bunkers that are sometimes called blast proof. But even these brutes have a limit beyond which they cannot resist. For example, a bunker that can resist a 500 lb. bomb impact will not escape damage from a 2,000 lb. bomb. In most industrial, commercial, or public facilities where blast impacts are a concern for designers, a level of blast resistance is determined by a detailed QRA (Quantitative Risk Assessment) performed by specialized engineering and Risk consultancy firms. The QRA study will analyze the types of blast threats, among other risks, to a facility and provide a guide to designers about the levels of blast impact and the likelihood of their occurrence. Based on this information, a facility owner determines the level of risk and mitigation they want. That establishes the level of blast resistance for which the building is to be designed. In all cases, the blast design, no matter how heavy or light, represents a level of Resistance to a specified blast magnitude. In no cases can a building be termed completely blast proof. Blast Proof and Blast Resistant are not interchangeable terms. Architects need to be wary if a client asks for a "blast proof" design. This is generally the result of either lack of familiarity with the concepts of BR design or simply a common confusion of the terms. Regardless, it is important to ensure that any contractual language or Scope of Work clearly define the term as "Blast Resistance" rather than "Blast Proof". In addition, is advisable to state the limits and criteria of the Blast Resistance. If this is not known at the time, language stating an assumed criteria should be stated with the condition that these limits of BR design will be updated when specific information is provided by the Owner. Since that timing may be an unknown, there should be a clause to allow for adjustment in design fees to accommodate the BR design effort if it exceeds a minimum level stated in the Scope of Work.

WHY SHOULD ARCHITECTS CARE ABOUT THIS?

For most architects, concern for Blast Resistant design is not a routine consideration and it is not even a category in building codes such as the IBC.

This area of design has generally been relegated to a highly specialized niche of architects who practice within the military or industrial domain. However, due to the rise in urban terrorism from the 1980s onwards, the advent of car and truck bombings targeting pubic and politically symbolic buildings has become a sad but real concern. It is also not an issue that we can ignore as a threat in far away locations. In 1995 the bombing of the Alfred P. Murrah Federal Building in Oklahoma City using an explosive laden truck brought the reality of such events to the United States heartland. Since then, credible threats to various buildings of high visibility within and outside the United States have caused many facilities to actively incorporate blast resistant design into their requirements. As a result, more and more architects and engineers involved with mainstream commercial, institutional and public architecture are having to consider elements of blast resistance. While the structural integrity of the design is a role that structural engineers fulfill using complex dynamic analyses, architects must be knowledgeable about the constraints on their design freedom and the costs of mitigation. In addition, all building connection details, exterior doors, glazing, penetrations and overall envelope design are affected to some degree depending on the Blast design criteria. Architects who become familiar with the terminology and reasons for the limitations are better positioned to collaborate with their engineers and owners to offer workable designs that do not have to be "Bunkeresque". In commercial and public settings this knowledge becomes invaluable in designing effective blast resistant buildings that can otherwise look "normal".

WHERE DOES BR DESIGN HAVE RELEVANCE? – BUILDING TYPES, LOCATIONS, INDUSTRIES, ENVIRONMENTS

As has been mentioned, blast resistant buildings are now being developed in almost all typologies. Still, the main areas where this is a key programming question are:

a) **Military**: Many military installations have a degree of blast design consideration. The Department of Defense (DoD) in the US has very detailed criteria for buildings and blast responses based on the use, location and criticality of the building. Typically, the buildings fall into two broad categories:

   I. Those located in permanent bases and installations. These are more conventional buildings with levels of protection dictated by DoD protocols.

   II. Those located in forward military positions or bases. These involve an element of mobility to the buildings, requiring them to be modular and flexible in terms of erection, removal, and transportation.

b) **Industrial Plants**: The examples in the Historical Background section above cited many industrial accidents. These remain the most frequently occurring events and as such the use of blast resistant design is an essential part of the programming for these facilities. In recent years, with better siting and the use of more BR buildings, the number of fatalities is declining. While improved processes and greater focus on safe work practices are contributors, when an accident does happen, the resistance of the building is the last measure of protection. Often it is the difference between life and death.

c) **Politically or Strategically Sensitive Facilities:** In current times, with the proliferation of technology and availability of explosives, the ability of a few disaffected individuals to cause great damage is a real risk. To protect the users and make these facilities as accessible as possible to the public in a free society, considerations for blast resistance are an increasing priority. In these cases, there are two elements: Passive and Active design. The passive protection involves perimeter protections such as bollards, walls, hardscape elements with the aim of deterring approach of potential threats from getting close enough to the building to cause real damage. The protection of structures by hardening or designing for Blast resistance is another element of passive measures. Active measures involve security monitoring, guards, preemptive surveillance and similar techniques. The challenge for architects is to facilitate both objectives in a way that does not create a brutal design or convey a sense of siege or fear. An excellent case study to understand how this balance can be achieved is in the enhancements made around the National Mall in Washington DC in the years after 2001. Many of the protective measures are imperceptible to visitors but some, such as the retaining wall around the Washington Monument are very visible but beautifully integrated into the landscape such that it becomes a welcoming feature rather than an intimidating symbol of fear. It is such integration of soft and hard landscape, urban space planning and surveillance technology that come together as part of a cohesive design response to safeguard sensitive symbolic facilities without creating an overtly oppressive feel. Of course, there are some governmental and sensitive scientific facilities where a measured degree of "in your face" intimidation in the design is part of the "stay away" message that the design deliberately conveys. But even here, the while the scare factor succeeds in deterring the casual threat, other, more discreet, and robust design measures have to be taken to protect from the more serious dangers.

d) **Public Facilities:** Beyond the likely political or military targets, we must recognize the unfortunate reality that terrorists around the world target many public buildings. For this reason, new facilities such as schools, museums, sports and entertainment venues, transportation hubs and other places of assembly are increasingly adopting some of these principles. In all cases, the likelihood risks and costs are weighed and a balance regarding the level of protection is determined. These become the design criteria for the design team. Just as for the politically or nationally symbolic structures, public facilities also need to strike a balance between the degree of visible "protection" that conveys security against design measures that border on penal architecture. Here too, landscape and careful traffic circulation plays a significant part in softening the public face of the blast protection elements.

e) **Federal Facilities:** This category can be considered part of both Public Facilities and Politically or Strategically Sensitive facilities. However, this deserves a special mention and unique category because all Federal facilities are now subject to some level of protective design consideration that includes a level Blast Resistance. This requirement also includes any existing facilities that are expanded or undergo a major renovation. For all these Federal building categories, the General Services Administration (GSA) of the US Federal government establishes design guidelines that are de-facto codes.

f) **Residential:** This may seem an odd category but there is an emerging trend among many prominent people (whether due to fame or wealth) to seek protective design elements for their residences. In some ways, this is no different from other times in history when feudal lords, aristocrats and others from the ruling classes took measures in the design of their homes (castles) to create a protective barrier from not only external attack but also from rebellious elements within their own domains. It is just that in current times, the class of prominent targets and their potential enemies is more numerous, and the types of threats are more sophisticated and deadly when explosives are used. The most challenging of these can be homes built in urban areas. The design considerations remain the same, but applications differ depending on the circumstances. For example, the protection of a home set in a sub-urban lot with surrounding acreage will be different from the response to protect a penthouse apartment in a high-rise tower. The application of BR design for private residences is a very specialized category where the schemes are often unique and coordinated with security consultants. The details of tactics applied are, understandably, kept confidential and rarely, if ever, published.

WHO MAKES UP AN EFFECTIVE BR DESIGN TEAM? – ARCHITECT, STRUCTURAL ENGINEER, OWNER, REGULATORS:

To arrive at the optimal blast protection level for a facility, it has to be a collaboration between the Owner, QRA assessment consultants, architect, structural engineer, and in the case of public or commercial settings, the landscape designers. Since there are no adopted building codes that provide mandated requirements for blast design, it is the owner and the QRA / security consultant who determine the criteria for the design. This lays out the level of threat (risk) that they want to mitigate. These criteria provide the structural engineer the basis to determine the forces for which they need to design the foundation and structure. The Architect uses the criteria to detail the connections and exterior envelope of the building. The electrical and MEP engineers have to ensure protection of their service feeds and penetrations of conduits and pipes into the building. They also must consider their design for recirculating air if the exterior air intakes are damaged and provide contingency for power failures using UPS (Uninterrupted Power Supply) and backup generator systems. The degree to which any of these considerations are implemented is based on the level of building functionality and redundancy that the Owner wants to retain following a blast event.

In addition to the above, there is an increasing role that governmental regulators are starting to play in influencing BR design. In some industries such as nuclear or military, there are now established design regulations (effectively codes) that govern most aspects of BR design. However, in commercial, industrial, and public settings, a body of opinions and guidelines are emerging from various academic and industry groups. Similarly, more and more lessons and consequent recommendations emerge from investigations of accidents or near misses that occur. So, while there are currently no BR building codes, it is likely that at some point in the future some requirements will be adopted as the demand for BR protection becomes more prevalent. For this reason, even architects who may not actively practice in BR design, may find it useful to at least be versed in the terminology and basic concepts just as most architects are generally familiar with the basics of seismic or wind design even if they do not practice in an earthquake or hurricane prone region. Sometimes, it is mistakenly assumed that seismic design is the same as BR design. In part 2 of the course, the relationship between wind, seismic and BR will be explored.

One emerging group in the BR design space is the multitude of manufacturers and construction trade groups who have recognized the growth of BR design applications across multiple building types. These vendors and trade groups have, over the last decade (2010s) taken initiatives to test, research and innovate solutions for BR design. While the primary objectives have been commercial, the benefits of these actions have encouraged competitors to also join the band wagon. The result has been that there are now many studies, white papers and new products that provide designers with many options and supporting data and testing validation for their design components. Industry groups and trade associations also sponsor academic research that further advances BR design flexibility. Some trade associations such as the PCI (Pre-Cast Concrete Institute) have published not only research data but also provide extensive construction detail guidance for architects and engineers. Similarly, the AISC (American Institute of Steel Construction) publishes a Steel Design Guide for the Design of Blast Resistant Structures. Other manufacturers from prefabricated building BRB (Blast Resistant Building) vendors like Hunter and Red Guard to companies like *Roxtec* that specialize in protecting BR penetrations and numerous door, window and hardware suppliers are all now sources of products and design information.

Based on the above discussion, it should be evident that a good BR design team starts with a knowledgeable Owner and their QRA / security consultant who understand their industry and the project's societal risk exposure. On that basis they can provide the appropriate design criteria. The next group is the design team. This includes a primary and secondary layer. The primary layer is the Architect and Structural engineer. They jointly establish the tactical design response for the building, establishing the structural frame type and building envelope materials and construction type. The secondary layer of the design team consists of the MEP consultants and material vendors and manufacturers whose engagement and infusion of information for timely design decisions helps to ensure an integrated design and avoids re-work which can lead to gaps in design integrity. Lastly, depending on the project, there may be regulatory requirements or even official design "rules" that must be followed. While these regulators are separate from the design and Owner team, a good practice is to engage them early and consider them and their guidelines as consultative de-facto team members. This is similar to the way architects approach building code officials. One can choose to see them as adversaries or as guides. It should not be expected that they will necessarily go easy due to early engagement, but it is certain that upfront coordination will reveal any critical areas of concern soon enough to maintain design pace and avoid late inconvenient adjustments.

This concludes Part 1 of the course. Part 2 will focus on technical terms, considerations and design responses.

SECTION 1 REVIEW QUESTIONS:

1. **In non-military situations, which types of buildings are most frequently impacted by blasts**
   a. Tall skyscrapers
   b. Residential subdivisions
   c. Industrial facilities
   d. Schools

2. **QRA is the acronym for:**
   a. Quality Research Analysis
   b. Quotient of Risk Assessment
   c. Qualitative Review Approach
   d. Quantitative Risk Assessment

3. **Which of the following codes has extensive guidelines for Blast Resistant Buildings?**
   a. IBC 2009
   b. NFPA 101
   c. UBC
   d. None of the above

4. **In developing a house for a famous client with security concerns, who would advise the architect on the criteria for any blast resistant design requirements?**
   a. The owner's security consultants
   b. The local building official
   c. The Department of Defense
   d. The structural engineer

5. **Which of the following are building elements affected by BR design?**
   a. Exterior doors & hardware
   b. Wall and roof penetrations
   c. Exterior Windows
   d. All of the above

PART 2 – BLAST RESISTANT DESIGN – TECHNICAL CONSIDERATIONS

Part 1 of this course covered a basic introduction to Blast Resistant (BR) design, some fundamental concepts, and its applicability and relevance for Architects.

This part will review the main technical terms and considerations that Architects should be familiar with if their project requires a BR design. In this part we will address the following items:

4. Blast Resistant technological development
5. Technical terms explained
   - Overpressure
   - Deflagration vs Detonation
   - Impulse & Duration
   - Positive and Negative phases
   - HOB
   - Stand-Off distance
   - "psi" rating
   - Building Damage Levels
   - Progressive Collapse
   - Ductile and Robust structures
   - Frequency / Risk Analysis
6. Pressure Impulse Curves
7. "Blast Radius" and "Blast Contour"
8. Seismic vs Blast Resistant design
9. BR Building components
10. Blast Design Tools

BLAST RESISTANT DESIGN TECHNOLOGY

Over the past century the technology to support and enhance Blast Resistant (BR) design has developed significantly to a point where it is now possible to design almost any style of building and still meet the BR requirements for most applications. Of course, the more architecturally sophisticated the design, the higher the cost to provide BR features. The point is that while in decades past, technology was a limitation, it is not so much anymore. Budgets and functionality are now the main drivers.

The initial technological developments for BR design started to take shape based on the analyses conducted during the development of the US atomic bomb program. As part of this program, extensive studies were undertaken to understand the impact of blasts on structures. Based on the reaction of the buildings to blast forces, a science of Blast Resistant design started to emerge. Forces were better understood and categorized, and the resistance of structural and other building elements was documented. This provided engineers with the knowledge and criteria to design and reinforce structures to withstand the forces. Beyond the structure, building cladding, doors, windows, roofs, and all exposed elements started to be studied and manufacturers began to develop, test and market products to support these designs. Initially, the limited applications meant that very few vendors supported BR design and when these products were offered, the price tags were very high. Much of this was due to expensive testing to prove the BR capabilities. Over time, especially after security concerns like terrorism, urban threats and industrial accidents made BR responses more mainstream, product manufacturers were able to increase the variety and capabilities of many affected architectural products. By the mid-2010s, BR variants for most types of architectural building products could be found or existing products upgraded. It should be noted that this is true for the lower-level BR requirements. The reason is that it was determined that all products and building systems have an inherent blast resistance to a certain level of impact simply by virtue of their design characteristics such as wind loading, and other design forces routinely applied due to building codes. By testing existing products for varying levels of blast conditions, many products could be used “as is” and some needed only minor modifications. In other situations, depending on application, entirely new products were developed.

With the constant advances in building technology, development of lighter and stronger materials and more refined, flexible engineered connections and virtual testing, more and better design options are becoming available for architects.

BR DESIGN TERMINOLOGY

There are some common terms used in the context of BR design. Most of these have specialized engineering depth. However, it is useful for Architects in general but especially those involved with BR design to be familiar with the terms and what they conceptually mean. This allows an Architect to have more meaningful discussions with their structural and MEP engineers, product vendors and clients.

- **Explosion**

According to Merriman-Webster dictionary, an explosion means “ to burst forth with sudden violence or noise from internal energy: *such as : to undergo a rapid chemical or nuclear reaction with the production of noise, heat, and violent expansion of gases dynamite explodes.”* In technical terms, as relevant to BR design, an explosion is a “*is a rapid expansion in volume associated with an extremely vigorous outward release of energy, usually with the generation of high temperatures and release of high-pressure gases” [Wikipedia].* This is accompanied with a bright flash and an audible blast. Depending on where the explosion happens, the portion of the energy is released as part of the flash that is characteristic of explosions. This is the result of the thermal radiation. Some more of the energy is absorbed into the soil and results in ground shock. Most of the remaining energy releases through the air as a shock wave. Both the ground and air shock waves expand radially from the explosion epicenter.

- **Deflagration and Detonation**

Explosions that are created by low explosive forces and move at speeds below the speed of sound (sub-sonic) are called deflagration. Examples would be an open fuel fire or the burning of gasoline in a car engine. Detonation results in supersonic (faster than the speed of sound) explosions created by high explosives. These travel through shock waves. It is these types of explosions resulting from detonations (or industrial accidents that are in effect unintended detonations) that BR design deals with. A point of note here is that explosions of one type can morph into the other. For example, a vapor cloud explosion (starts as a detonation) followed by a fire is one of the worst-case scenarios for a petrochemical plant. Conversely, when a deflagration escalates into a detonation, the rapid increase in speed and the resulting shock wave can have consequences that several fold more dangerous than a deflagration only events.

[TIP: To see examples of the various types of explosions listed here, there are many samples of actual videos or animations on YouTube that can illustrate the force and rapidity with which these events can unfold]

- **Vapor Cloud**

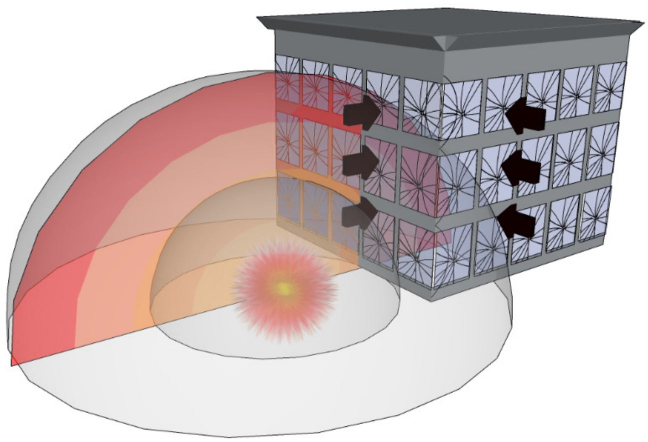
This is an explosion that results when a cloud of flammable vapor, gas or mist ignites. These types of explosions generate very high over pressures and cause catastrophic damage. This type of risk is very high in industrial settings where flammable gasses are used, and a risk of leakage is present along with potential ignition sources. Buildings that are built within potential risk zones are always designed for Blast Resistance.

- **Shock Wave**

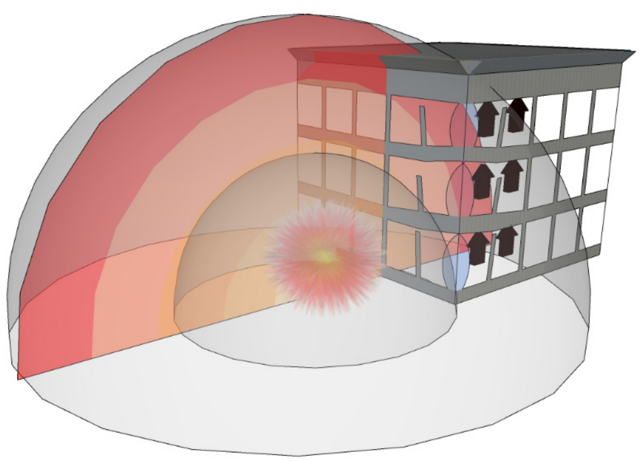
This is the compression wave resulting from an explosion that travels through the air, dissipating the energy released by the explosion. The pressure in the front of the wave is called the "Peak Pressure" and this decreases as the wave moves out from the origin of the explosion. The part of the wave front where the pressure is greater than the atmospheric (normal) pressure is called the "Positive Phase". This is followed immediately by a portion of the wave where the pressure is actually drops lower than atmospheric pressure. This is called the "Negative Phase" (see Figure 2.2). It tends to have a "suction" effect. This dynamic of a powerful high-pressure impact on a building, immediately followed by a negative pressure suction force is critical to understanding how the structure and building components should be designed so they can address both forces. It's like designing to mitigate effects of whiplash on a building.

The effects of a blast wave on a building are illustrated below:

1. Blast wave breaks windows, exterior walls are blown in and columns may sustain damage. (*Figure 2.0a*)



2. Blast wave forces floors upwards. Structure buckles. (*Figure 2.0b*)



3. Blast wave surrounds structure, there is downward pressure on the roof and inward

pressure on all sides. Structural members fail with risk of progressive collapse. (*Figure 2.0c*)

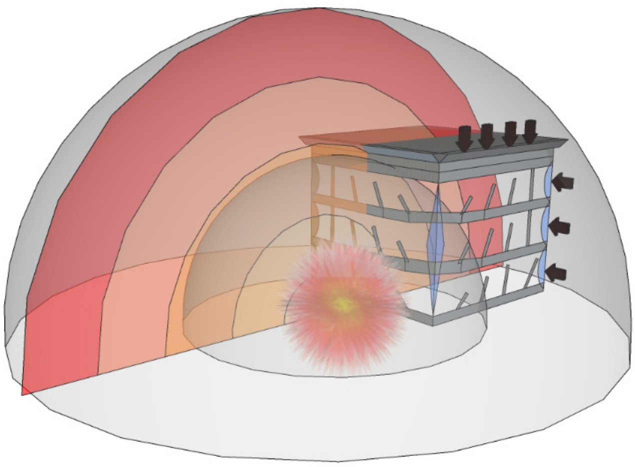


Figure 2.0: Blast Pressure Effects on a Structure

Source: Adapted from Naval Facilities Engineering Center, "User's Guide on Protection Against Terrorist Vehicle Bombs," May 1998. Graphics modified by Author

- **Overpressure**

For the purpose of building design, this is the pressure that impacts the building and is measured in psi (metric = bars). The higher the value the more potential damage will be caused. Since blast shockwaves tend to be spherical in nature, the overpressures do not only impact the façade where they strike, but also the sides and top of the building. As has been noted, the shockwave also has a negative phase and as such the rear façade is also impacted. There are three major types of overpressures impacts to a building.
(See Figure 2.1):

- ○ Reflected over pressure is on the side "facing" the blast when a blast wave propagates into a rigid surface. The "reflected" overpressure is always higher than the pressures on the other faces (The incident pressures). This enhanced "reflected" overpressure can be about twice the incident pressure for incident pressures under 15 psi but can increase to over 12 X the pressure for stronger values.
- ○ Incident, or "Side-On", also sometimes called the "free field" overpressure is the undisturbed blast wave pressure that impacts the overall building. Simplistically, these are the pressures on all sides that are not "facing" the blast wave.
- ○ Back (Rear) face overpressure is the pressure on the façade of the building on the back side of the shockwave facing façade. Often this is treated the same as the other incident side-on facades for the purpose of design. It is noted only to emphasize that all facades of a building experience some level of impact from a blast wave and so have to be considered in BR design, even if the risk is unidirectional.

After considering the above, engineers design for the reflected pressure which is higher than the side-on pressure.

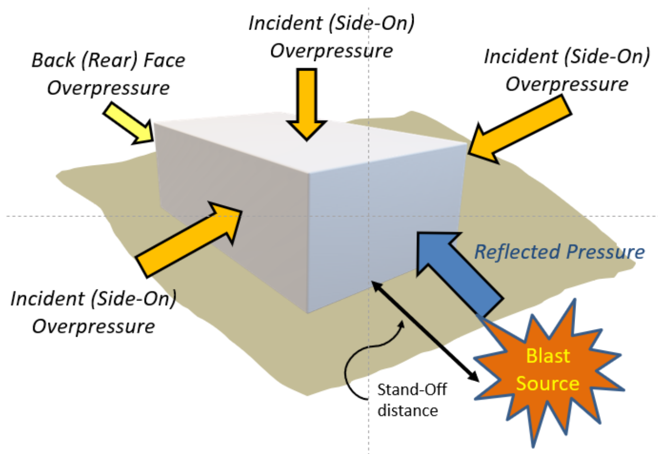


Figure 2.1 – Reflected & Incident (Side On) Overpressure (Simplified). Source: (c) muhammad a. siddiqui.

- **Impulse & Duration**

While over-pressure defines the magnitude of the blast impact, the duration is the length of time the blast wave acts on the building. Unlike hurricanes, earthquakes, or even tornadoes, that can act on a building for several seconds, minutes or longer, blast waves are very rapid and literally pass in the blink of an eye. They are measured in milliseconds since blasts tend to be very powerful impacts for a very brief time. As a result, the true impact of a blast wave on a building is a function of both the overpressure and the duration that the blast acts on the building.

Many times, impulse and duration get used interchangeably but they are not the same. Put simplistically, duration is time and impulse is a result of force applied over a period of time, i.e: change in momentum. For BR design, it is the impulse that is used by engineers. It is represented by the area under the pressure/duration curve. See Figure 2.2. This also illustrated how the blast wave creates a positive and negative impulse. Generally, the negative phase is ignored for design response because it has a smaller effect of the building design response required than the effects of the positive impulse phase.

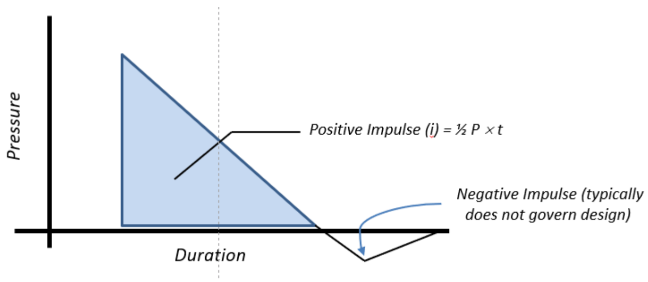


Figure 2.2 – Pressure / Duration Curve and Impulse (Simplified). Source: Author

- **HOB (Height of Burst)**

The term HOB comes from the military in terms of attacks from the air, specifically for damage that can be caused by bombs that are designed to explode above a target. By exploding above a target, the level of damage caused can be much greater than an impact explosion. This is because the blast wave coverage is expanded. Weapon designers develop the optimum heights for detonation based on maximizing the destructive consequences. A non-military application from this concept is in assessing the blast impacts from aerial vapor cloud explosions where the expected elevation of leaked gases can be modelled, and the resulting explosions simulated similar to the way the military evaluates impacts of bombs. In this case, the roof of the building bears the brunt of the reflected overpressure.

- **Stand-Off Distance**

The term stand-off distance comes from security and is the distance between the source of an explosion threat and the potential target building. This distance is adjusted to minimize damage level depending on the risk-based assessment of the level of threat. This distance is determined interactively by law enforcement, building owners and engineers for a given threat type and risk. Architects then use the established distance to create physical elements around the building to restrict access within the standoff distance. This is done in conjunction with other security and control measures. There are no civilian code-based guidelines for stand-off distances. However, FEMA, in its Reference manual to Mitigate Potential Terrorist Attacks (publication FEMA 426) provides guidelines and charts that define incident overpressures in psi as a function of stand-off distance and explosive force based on pounds of TNT. The FEMA charts illustrate that the stand off distance can range from less than 100 feet for a small car bomb of less that 100 lbs. of TNT to 2,000 feet for a large truck bomb with tens of thousands of pounds of TNT.

- **"psi" Rating**

It is common to hear many people using the term "psi rating" to describe a BR building. This refers to the peak overpressure for which the building is being designed. While it is a convenient way to understand how much one BR building may be more or less resistant than another, it is important to understand that overpressure is NOT the sole determining factor on the degree to which a building must be reinforced. The impulse and duration are equally important. A building with a low psi rating but a long duration may require more design enhancement than a building with a higher psi impact but a very short duration. So, while a "psi rating" may be used in layman discussions, there is no such standard within the engineering community. That said, it should be noted that while there is no "rating", the overpressure psi is a valid and widely used measure as a starting point for evaluating various design elements, guidelines and products. The final selection for the building BR structural design must include the impulse factor.

- **Building Damage Levels**

Once a criterion for the expected threat level is defined, the next step is to determine the response that the building design must provide. This can range from the ability to completely withstand the blast to only maintaining sufficient structural integrity to allow occupants to survive while the building may sustain irreparable damage. This is a very important consideration since designing a building to withstand a blast unscathed can be a very expensive proposition. According to the

ASCE (American Society of Civil Engineers) there are three Building Damage Levels (BDL) – High Medium and Low. For most projects, owners tend to set design response to the Medium level. This means that the designers must design a building to a level that after an event it only suffers damage to the medium level – repairable for reuse at a lower cost than replacement. See table below:

Building Damage Level	Description
High	Key components may have lost structural integrity; building may collapse due to environmental conditions (i.e. wind, rain, snow); and total cost of repairs approaches replacement cost of building.
Medium	Significant repairs needed from widespread building damage; building cannot be used until repaired; and cost of repairs is likely significant.
Low	Minor repairs from damage needed but building can be used; and cost of repairs may be moderate to low.

Table 2.1. Source: ASCE

The US Department of Defense (DoD) provides a table that correlates conventional construction without any blast resistant hardening against incident pressures.

Level of Protection	Incident Pressure (psi)
High	1.1
Medium	1.8
Low	2.3

Table 2.2. Correlation of DoD level of Protection to Incident Pressure. Source: DoD

This is a useful proxy for what some call "inherent" level of BR protection for conventional construction. However, design professionals should be cautious in how they use the above information. The term "conventional" construction is very broad and likely to vary from location to location and building type. It is always necessary to evaluate the design with the structural engineers to validate whether a proposed design without special BR consideration is adequate for the required BR pressures and impulse. If the pressures are low enough, it is possible that no further modifications may be necessary.

In considering damage levels and levels of protection, Architects are often asked about how much damage occurs for a given "psi" blast for a "normal" building. There is a widely used table that provides a useful response to this question. The table is compiled from a combination of studies and is provided below:

Damage	Incident Pressure (psi)
Typical window glass breakage	0.15 – 0.22
Minor damage to some buildings	0.5 – 1.1
Panels of sheet metal buckled	0.1 – 1.8
Failure of concrete block walls	1.8 – 2.9
Collapse of wood framed buildings	Over 5.0
Serious damage to steel framed buildings	4 – 7
Severe damage to reinforced concrete structures	6 – 9
Probable total destruction of most buildings	10 – 12

Table 2.3. Damage Approximations Due to Blast. Source: EXPLOSIVE SHOCKS IN AIR, Kinney & Graham, 1985; FACILITY DAMAGE AND PERSONNEL INJURY FROM EXPLOSIVE BLAST, Montgomery & Ward, 1993; THE EFFECTS OF NUCLEAR WEAPONS, 3rd EDITION, Glasstone & Dolan, 1977.

A caveat in using the above table is that the studies from which it is compiled, are quite dated. For broad based discussion the information is valid. However, while many basics have stayed the same, there have been significant changes in many materials and construction techniques during the intervening decades which should be considered before passing final judgement. If an Owner is asking for an opinion on an existing building's capabilities, the table may start the discussion, but a proper analysis should be done before drawing a conclusion.

- **Progressive Collapse**

When a primary structural element of a building structure fails and there is resulting failure of adjoining structural elements, the result is a progressive collapse. This can result from accidents like fires that weaken structures or the result of impacts from blasts that "take out" main structural members. One of the most dramatic examples of a progressive collapse was the destruction of the Alfred P. Murrah Federal Building in Oklahoma City. A deliberate use of progressive collapse is employed in the demolition of large or tall buildings through use of controlled detonations resulting in an implosion of the structure.

- **Ductile and Robust Structures**

Two of the techniques to provide resistance to blasts are to make the buildings robust and / or make them ductile. As a principle, the greater the ductility of the structure, the greater its ability to resist failure. This is the "bend but not break" philosophy. The structure is designed to provide an elastic response. Steel frames are effective in providing this property. On the other hand, the robustness of a building is its strength in resisting excessive loads. This is the brutish approach. Usually, materials such as concrete are used but a steel frame with redundant members can also be robust. In fact, redundancy of structural members is used to provide additional strength to older buildings where concern for additional threats is identified. However, it should be noted that adding redundancy or strengthening existing buildings is an expensive and complicated endeavor that is frequently not worth the economic investment.

- **Frequency / Risk Analysis**

In part 1 of the course, the concept of a QRA (Quantitative Risk Analysis) was introduced. The application of this methodology to BR design results in a recommendation from the QRA consultant (in concert with the building owner) for the design overpressures and durations for the buildings in the project based on their location relative to the threat source. The analysis involves extensive scenario modelling. The analytical tools and models are almost always proprietary to the QRA firms. The models evaluate the likelihood and frequency of an event occurring. The building owner and the QRA consultant determine the risk level that the owner is willing to accept for a given frequency of the threat. These are evaluated in terms of the statistical chances of an event occurring and represented by values such as 1 x 10-6 (meaning that at the given location, there is a once in a million chance of the overpressure exceeding the modeled value). In some cases, the results are presented in terms of the number of fatalities resulting from an event.

In industrial settings, the owners often set the acceptable risk levels in coordination with their insurance carriers. In public and governmental projects, the levels are set by guidelines published by agencies (such as GSA, FEMA, DoD, DoE and others) as there are currently no building codes that establish BR design criteria. The division of risk responsibilities are illustrated below:

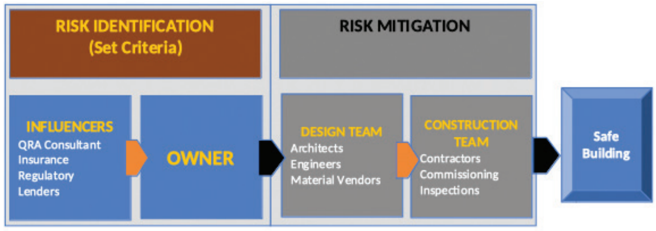


Figure 2.3 – Risk Identification & Mitigation. Source: Author

STAKEHOLDER LEVELS OF ENGAGEMENT

In the absence of established codes for BR design, the defining of the need, extent of BR required, and the level of architectural design are all either given by the Owner or determined by a collaborative consensus between the Owner, QRA consultant, engineers and architects. The level of engagement is particularly high on the part of the owners who must set the criteria and assume the risks resulting from those decisions. The owners are aided in this effort by the QRA consultants who identify the types of risks and their likelihood. In non-industrial settings where security is the driver for BR design, the owners consult with law enforcement and federal agencies to help establish design criteria. For governmental buildings, the relevant agencies establish the criteria and provide design guidelines or requirements.

Once the criteria are established, the architects and engineers (structural, HVAC and electrical) work collaboratively to develop a design that meets the owner's functional and BR design requirements.

OVERPRESSURE / IMPULSE CURVES

Given the strong relationship between overpressure and impulse in influencing BR design, it is useful for Architects to have a high-level understanding of what the Overpressure / Impulse curves look like and what they mean.

An Overpressure / Impulse curve plots the pressure on the Y axis and the impulse of the blast on the X axis. The curves for constant Building Damage Levels for a given blast scenario are then plotted.

The building design characteristics and location criteria are then modeled, and the resulting response is plotted. It will show where a design falls on the curve. The design can then be modified until it is in the region that has been established as acceptable to the project team.

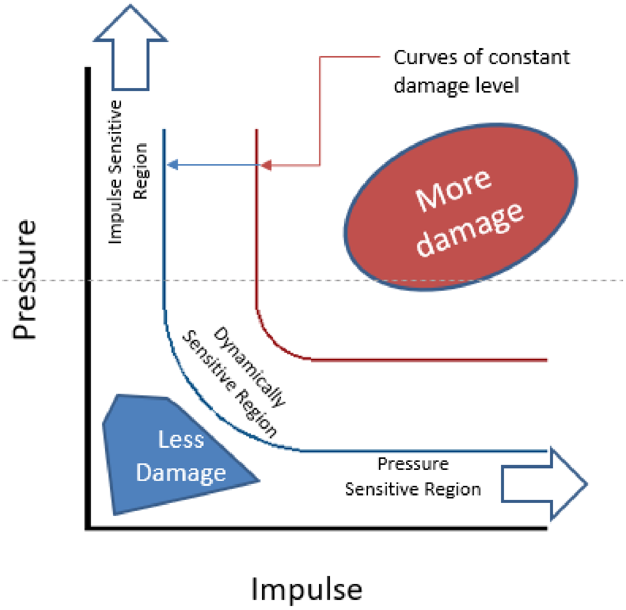


Figure 2.4 – Pressure / Impulse curve showing damage level and sensitivity zones. Source: Author

BLAST RADIUS AND BLAST CONTOURS

Another term that designers encounter from QRA consultants is the "Blast Radius" or "Blast Contours". These are simply modeled points of equal blast pressure radiating from the point of the explosion. Like map contours that represent points of equal elevation, these "blast contours" do the same for blast pressure. The contours closer to the origin of the explosion represent higher pressures and lines further out represent lower pressures. By plotting the location of the proposed building, a target overpressure design basis can be developed. The term "Blast radius" is more commonly used when the blast wave is more likely to be uniform (circular). The term "Blast contour" is used when the blast dissipation is more likely to be irregular. In concept and application, they are used the same way. The example below shows a sample of blast contours.

Figure 2.5 – "Blast Contours"; Source: Author (Not a real location or situation but for illustrative purposes only)

SEISMIC VS BLAST RESISTANT DESIGN

It is tempting to equate Blast Resistant design with Seismic design. But the two involve different types of forces acting differently on a structure. Hence, the responses are also different. An earthquake causes ground movements in wanes that shake the building from the foundation upwards. As we have discussed, a blast generates a shockwave that primarily hits the building through the air, although there is a ground component to the blast wave as well that is similar to an earthquake, but it is much lower in intensity. The other major difference is the time involved. Blasts have durations of milliseconds whereas an earthquake can last for several seconds and minutes. Other differences that affect buildings are that earthquakes are almost always followed by multiple aftershocks of diminishing intensity. Earthquakes also tend to affect the entire building at the foundation fairly uniformly and the shaking causes the upper structure to respond. Blasts do not affect the structure uniformly. They are most severe on the façade and elements closest to the path of the blast wave. So, while the theory of addressing seismic and blast resistance have common roots, the tactical applications and responses are different and diverge depending on the severity of each threat.

BR BUILDING COMPONENTS

A common misconception among design professionals is that BR design only affects the building structure and exterior walls. While those are indeed the most sensitive areas, there are several other components of a building that must be addressed to provide a BR design. The following are the major components that are affected:

- **Foundations**

Foundations are inherently part of the building structure, but they are listed separately here to emphasize that BR design is not solely a function of lateral design. The miniscule time that the severe blast overpressures impact a building place very powerful stresses on the building foundation and the connections between the foundation and the superstructure.

- **Exterior Doors and Hardware**

Depending on the expected overpressure and BDL criteria, specialized doors have to be used. The frames and hardware are similarly specialized. For lower ratings, many available heavy-duty doors and hardware provide adequate resistance, but this should always be verified. Some Owners will specifically require "blast rated" components (meaning they have been tested and certified). Blast rated doors are not usually readily available "stock" items. They are fabricated for each project so lead times must be factored. Similarly, the availability and lead times for blast rated hardware should also be a consideration for early specification and procurement.

- **Exterior Windows**

Until relatively recently, BR window systems were generally unavailable, and the use of bullet resistant vision panels was the closest substitute. However, there are now BR window systems and glazing options that can provide both large surface and high-pressure resistance. Laminated annealed glass with structural sealant at the inside perimeter is generally the preferred option. In industrial settings, windows are avoided but this is not generally feasible be in civilian or government facilities. As a result, FEMA, in its publication FEMA 427 has provided performance conditions for windows that provide a useful basis for BR design:

Performance Condition	Protection Level	Hazard Level	Description of Window Glazing
1	Safe	None	Glazing does not break. No visible damage to glazing or frame.
2	Very High	None	Glazing cracks but is retained by the frame. Dusting or very small fragments near sill or on floor acceptable.
3a	High	Very Low	Glass cracks. Fragments enter space and land on floor no further than 1 meter (3.3 feet) from window.
3b	High	Low	Glazing cracks. Fragments enter space and land on floor no further than 3 meters (10 feet) from the window.
4	Medium	Medium	Glazing cracks. Fragments enter space and land on floor and impact a vertical witness panel at a distance of no more than 3 m (10 feet) from the window at a height no greater than 2 feet above the floor.
5	Low	High	Glazing cracks and window system fails catastrophically. Fragments enter space impacting a vertical witness panel at a distance of no more than 3 meters (10 feet) from the window at a height greater than 0.6 meters (2 feet) above the floor.

Table 2.4. Performance Conditions for Windows. Source: Primer for Design of Commercial Buildings to Mitigate Terrorist Attacks, FEMA 427

As with all guidelines, these serve as a baseline and must be validated for the project's applications. In the case of windows, architects should consult with their structural engineers to make sure the openings and frame anchoring systems are integrated into the design. For glazing, the manufacturer of the framing and glass should be actively consulted and testing data for their products meets the project criteria.

Finally, it should be noted that for BR design, the costs increase exponentially as the window size and/or the overpressures increase.

- **Interior Studs and Wall / Roof Connections**

Even though the blast impacts the exterior of the building, the impact, even if for a few milliseconds, causes a momentary shift in the building. Therefore, all connections to the exterior envelope have to be flexible to withstand the movements. This is similar in concept to earthquake design. Current engineering advances allow structures to be more dynamic (less bunker like) and that increases movement. That in turn requires all connecting elements to be similarly designed.

- **Penetrations**

Any element that penetrates the exterior envelope of a BR building should be designed to meet the movement criteria of the BR design. These include electrical, mechanical and other types of penetrations. Generally, it is advisable to minimize through-wall or through-roof penetrations but that is not always practical. In these cases, there are special sleeves designed specifically to address BR needs. All the engineering disciplines involved should have familiarity with BR design options for their own area of specialty.

The above capture the most common technical elements that require special focus. The main point to emphasize is that when it comes to BR design, all connections and treatment of the building envelope and its skeleton have to be evaluated. Depending on the risk level and design parameters, the number of items requiring special design and the relationships between the components can be relatively common if the BR requirements are low but as these increase in intensity, the design can get complex.

BR DESIGN TOOLS

The analysis of blast impacts for a given set of criteria is a complex process, the most important and sophisticated of which are the structural predictions for how the structure is likely to behave. Physical testing is expensive and most often not practical. The analysis of a design response to a blast event requires it to be time dependent and non-linear. The techniques involve complex dynamic modeling techniques that evolved from those used for advanced seismic analyses. The elaboration of these is beyond the scope of this course and is really a structural engineering specialization. It is, however, beneficial for Architects to know that their structural engineers have experience using dynamic analysis and employ software that is capable of performing the required calculation. Some of the available computer software programs (per FEMA) are:

- AT Planner (U.S. Army Engineer Research and Development Center)
- BEEM (Technical Support Working Group)
- BLASTFX (Federal Aviation Administration)

In addition to the above, structural engineers use other, sometimes proprietary, software to perform the calculations. There is presently (2022) no specialized software for Architects for blast resistant design.

SECTION 2 REVIEW QUESTIONS

6. **On Blast Contour maps, the irregular concentric "contours" represent:**
   a. Lines of equal pressure
   b. Zones established by FEMA and DoD
   c. Blast duration
   d. All of the above

7. **Which of the following are building elements affected by BR design?**
   a. Exterior doors & hardware
   b. Wall and roof penetrations
   c. Exterior Windows
   d. All of the above

8. **According to some published data as tabulated in this course, collapse of wood framed buildings can occur in blasts over:**
   a. 0.5 psi
   b. 10 psi
   c. 5.0 psi
   d. 1.8 psi

9. The destruction of the Alfred P. Murrah building in Oklahoma City is a dramatic example of what kind of damage:

a. Tornado hit

b. Bunker busting bomb

c. Seismic failure

d. Progressive collapse

10. Which FEMA publication provides performance conditions for windows??

a. FEMA 426

b. FEMA 427

c. FEMA 429

d. FEMA does not provide such a guideline

11. Which of the following is NOT a software that addresses or supports blast design analysis :

a. BEEM

b. AT Planner

c. BLASTFX

d. REVIT

12. What types of pressure impact a building as a result of a blast shockwave?

a. Side-on pressure

b. Reflected pressure

c. Back (Rear) face pressure

d. All of the above

13. The government agency that establishes design guidelines for Federal building categories:

a. GSA

b. FEMA

c. The Department of Defense

d. NSA

PART 3 – BLAST RESISTANT DESIGN – IMPLICATIONS FOR ARCHITECTS

Part 1 of this course covered a basic introduction to Blast Resistant (BR) design, some fundamental concepts, and its applicability and relevance for Architects. Part 2 focused on technical definitions and considerations.

In this last part the following will be examined:

- Programming for BR design – interaction between architects, clients, engineers and vendors
- What Architects need to specify for BR
- Choosing prefabricated, pre-engineered or site built
- Choice of BR forms
- Do BR buildings have to be inherently "ugly" bunkers?
- BR design codes
- Rules of Thumb for Architects

PROGRAMMING FOR BR DESIGN

The need for a BR designed building is not always an upfront "given". In most cases the need for the requirements is extracted during the programming stage of the building. If the question is not raised early, the design impact can be significant. For Architects who work with building types or in industries where BR design is a routine occurrence, the programming questions are standard. However, as has been explained, BR requirements, or at least considerations, are entering into many non-traditional applications. So, it is generally a good idea to ask the question and establish whether BR design will apply or not. In cases where BR design is required, the following are the key elements that need to be addressed during programming:

- Ask the question "Does the Building need to be designed for BR or considerations for blast threats?"
- If so, are the design criteria available?

- If not, who will provide these – QRA consultant or Owner?
- What is the timing to receive the information?
- Should the design team hold or proceed on an assumed or "placeholder" basis as directed by Owner?

The process is illustrated in a flow chart in Figure 3.1.

Blast Resistant (BR) Building Design Programming Flow Chart

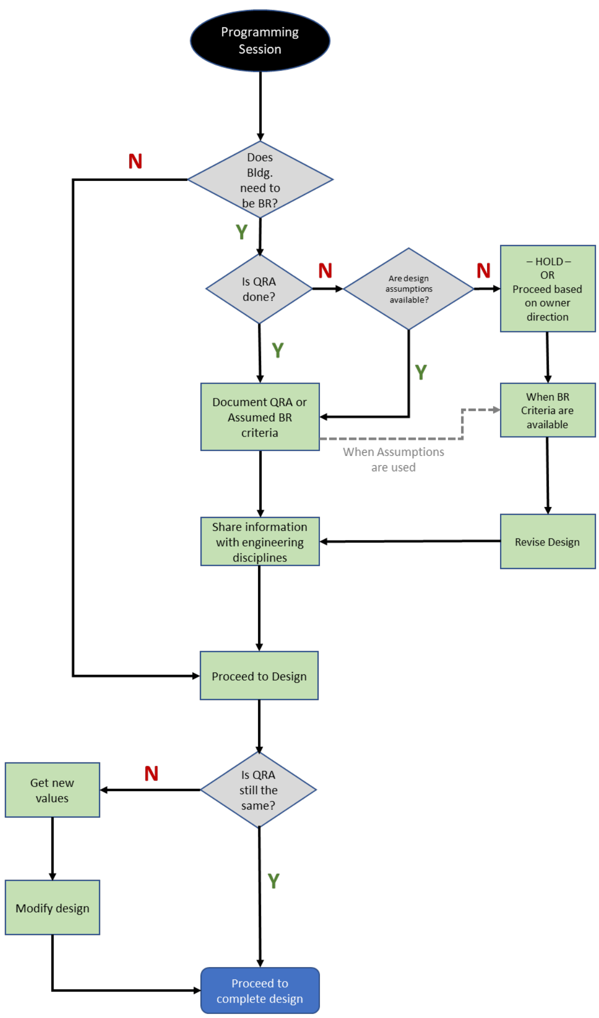


Figure 3.1 – BR Design Programming Flow Chart
Source: Author

WHAT ARCHITECTS NEED TO SPECIFY FOR BR

The typical elements of a BR building which architects have a primary responsibility to specify are:

- Exterior wall components and details.
- Exterior doors and hardware.
- Window systems and glazing.
- Roofing systems.
- Interior wall systems – to have flexibility.
- All connection details between interior building elements and the exterior envelope

In specifying BR "rated" systems and components, architects need to ensure that their specifications state the overpressure requirements that the building is designed for. In cases where the likely source of the blast is known, making the blast direction predictable, there may be different blast resistance requirements for the surfaces with reflected (blast facing side) and side-on (other faces) pressures. In these cases, architects should work closely with structural engineers to ensure the right resistance criteria are applied uniformly across each surface. In practice, generally all sides are designed to the highest value. This helps with uniformity of materials. When products are specified, it is important to request credible testing data from manufacturers. The test reports should specify the criteria for which the test was conducted.

For detailing connections, it is worth checking various industry associations that have published go-byes to assist architects. For example, precast concrete is a popular system for industrial blast resistant building facades. In recognition of this, the Precast Concrete Institute (PCI) has published several blast resistance connection details in the PCI Designer's Notebook series. Another source of good information is the Whole Building Design Guide (WBDG.org) developed by the National Institute of Building Sciences that includes participation from the leading federal agencies involved with BR design (DoD, DoE, GSA, Dept. of Homeland Security, NASA, State Department, Dept. of Veterans Affairs). When using standard details, recommended connections, or other suggested solutions from industry of government sources, architects should always check to see if the solution is prescriptive or a useful starting point. Most are of the latter type, meaning that they need to be adapted to the project specifics. This is not any different from any standard detail application but in the case of BR design, due to the potential consequences of failure, extra care and diligence should be applied.

CHOOSING PREFABRICATED, PRE-ENGINEERED OR SITE BUILT

Depending on the function and location for the BRB (Blast Resistant Building), architects have a variety of choices to address the client's needs. The options include three distinct approaches:

- **Prefabricated BR Buildings**

As demand for BR buildings has increased, much of the need is in industrial settings where functionality and speed are the key drivers. For these applications, many mobile building fabricators have developed prefabricated BR buildings that can be quickly transported and erected on locations. Most of these systems are modularized based on the size of a container for truck transport. The BRBs can be a single container for small applications such as local control rooms or instrument enclosures in industrial applications where quick installation is needed or where access to the site is physically restricted. For uses where more space is needed, multiple modules can be combined to create larger BR complexes.

The main advantages of the prefabricated BRB options are speed, standardization, ability to be deployed in remote areas, and the outfitting of equipment, finishes, and utilities at the shop. These buildings can also be erected in remote and challenging site locations with minimal labor and erection time (if a setting pad or foundation is available with the required service utilities). Prefabricated buildings also tend be lower cost per SF than a field constructed building. The drawbacks are that these solutions offer limited configuration options and are best suited for smaller unit sizes. They are also not very attractive for public buildings or facilities outside of industrial or military settings.

- **Pre-Engineered BR Buildings**

A Pre-Engineered Building (PEB) differs from a Prefabricated (Prefab) building in that a Prefab building is wholly designed and built in a factory and shipped to site (in whole or in sections that are re-assembled at site) whereas a PEB mainly refers to a steel building whose configuration is determined before building components are manufactured. Pre-engineered buildings are often designed to allow greater flexibility by using a prefabricated skeleton to create a framework for the new building.

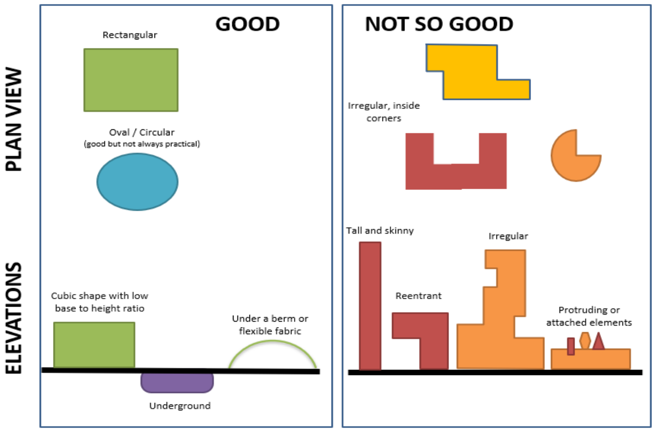
The pre-engineered building industry now has a sizeable footprint the BR design field. These buildings offer more flexibility of size and form, but they only provide the BR structural frame and, in some cases, the exterior cladding and even doors and hardware. However, as the blast "rating" increases, these systems start to get more complicated, and they lose some of their economic advantages. Unlike prefabricated buildings, the pre-engineered approach is more of a building block approach where components, rather than entire building sections are shipped to site and erected. PEBs also do not facilitate the incorporation of utilities and finishes in the fabrication shop. The most efficient application seems to be the use of these systems to provide a pre-engineered structural frame, thus reducing field time compared to constructing a more traditional steel frame.

- **Site Built BR Buildings**

In many situations, a prefabricated building is not the right solution either due to the functional uniqueness, complexity, or aesthetic requirements for the building. In these situations, the building design follows a conventional design process with BR as an added requirement. This is seen commonly in industrial buildings that fall in a relatively high (over 3 psi) blast risk zone, but their functionality precludes the use of prefabricate buildings. In this case, if there is no significant architectural aesthetics involved, a combination of pre-engineered components and site construction can be employed. In other cases where the building has a special public function (like embassies, schools, public buildings), the buildings are always site constructed in a conventional manner but often with unconventional materials and methods.

CHOICE OF BR FORMS

Blast Resistant building now come in a variety of architectural styles, especially for public and commercial uses. However, there are some basic rules of physics that make some types of shapes and forms more suited to BR design. The most efficient and cost-effective building shapes are those that are regular, preferably rectangular or circular. Other shapes can be made blast resistant but with each irregularity and complexity, the structural design gets complicated, and costs increase rapidly. As a generic guideline, the following shape are a good go by:



© muhammad a siddiqui

Figure 3.2 – BR building forms Source: Author

The diagrammatic representation (Fig. 3.2) illustrates how simplicity and regularity are prime objectives for selection. A few points to note are that shapes that can trap a blast wave (like "U" shapes or inside "reentrant corners) create major design challenges and are best avoided. This applies to both plan and elevations. In the use of underground structures, these are very effective for the airborne portion of a shockwave but are affected by the subsurface portion of the blast wave and so that must be considered by the structural response.

If structural strengthening of the building is not feasible or insufficient to address blast impact, there are techniques that can mitigate the shockwave. One option is to employ slopes, or berms around the building that can be used to shield buildings by absorbing and deflecting the wave. Another frequently used solution is the use of "blast walls" that can be used to block or deflect the impact of a blast, thereby protecting the structure. These types of walls are most commonly used to protect critical equipment in industrial settings where a likely direction of the blast risk is predictable. This is a more cost-effective option than housing the equipment is a fully blast resistant building. It is also a viable consideration when the threat to an existing non-BR building is identified, and modification of the building is not practical. Another popular BR option, often used in temporary BR structures, is the use of heavy blast rated fabric and similar tensile structures, usually inflatable, as these can "bend" with blast waves and quickly regain shape. In the event of failure and collapse, these structures have soft components so are less deadly.

DO BR BUILDINGS HAVE TO BE INHERENTLY "UGLY" BUNKERS?

If one simply does an internet search using the phrase "blast resistant buildings" and looks at the images that show up, there would be no blame in thinking that all BR buildings are container looking, uninviting and "ugly". The reason for that is the most marketed, and hence most tagged websites are those of prefabricated BR building manufacturers. These, as described earlier, tend to be standardized for shipping, modularization, and cost effectiveness, resulting in their bleak and harsh looks. Some vendors try to soften the appearance by using bright colors and/or applying graphics and stripes.

If, however, the internet the search is modified to look for "Blast Resistant Embassies" or "Blast Resistant Courthouses", an entirely different set of buildings can be seen. Even though the sample of photographs is limited because many of these facilities are not publicized for obvious security reasons, the architectural diversity of form and materials is evident. The point is that BR buildings do not need to be inherently "ugly" and "lifeless". That reputation is the result of historical industrial and military use that is entirely driven by cost and "fit for purpose" mentality, not aesthetics or even user comfort. When public image, user friendliness and human factors are factored, more appealing designs are realized – no doubt with a premium cost. One design element that gets special attention is windows. As a rule, BR buildings avoid the use of windows and any type of exterior (and even interior) glazing. However, as discussed in Part 2 of the course, there are glazing products out there that can be used but these can get bulky and expensive. For most uses, it is true to say that windows are discouraged. However, there are creative solutions to liven up windowless spaces. One very successful option is the use of high-resolution display panels framed as windows. These can be either fed live video feeds of the exterior to mimic a true window or they can be used with recorded scenes that create a "mood" for the occupants. This technique, originally developed for underground spaces and medical facilities is seeing more applications in BR buildings.

BR DESIGN CODES

As far as civilian building and life safety codes like the IBC or NFPA are concerned, there are currently (2022) no requirements for BR buildings. These, as has been stated, are owner determined requirements derived by a risk analysis. However, that is not to say that there are no regulatory or scientific based guideline available. Industries such as petrochemicals and several government agencies have published studies, guidelines and even mandatory rules that govern BR buildings. These range from the extreme of the Nuclear Regulatory Commission (NRC) for nuclear plants and associated functional buildings to FEMA guidelines for anti-terrorism across all types of public facilities. Some useful references are:

- ASCE "Design of Blast Resistant Buildings in Petrochemical Facilities" Second Edition,
- UNIFIED FACILITIES CRITERIA (UFC) – UFC 3-340-02 (TM5 -1300) "Structures to resist the effects of accidental explosions".
- US Army Corp of Engineers – PDC-TR-06-08 Rev 1 – "Protective Design Center Technical Report".
- FEMA publications FEMA 426 (Ch., ch.4), FEMA 427, FEMA 428 (ch.4), FEMA 429
- Dept of Defense publications for blast resistant structures.

Even though there are no current building codes addressing BR design, it is likely that at some point in the future, as the scope of BR design expands, codes will take up the subject and it will become more standardized. The road to codification of BR standards is likely to take the following steps, as noted in FEMA 429, Chapter 4:

- Federal preemption
- State mandate or preemption
- Local prerogative
- Model code and voluntary standards

The Federal step is already underway as evidenced by the many agencies that have developed and implemented BR standards, guidelines or mandates. Voluntary standards are limited to some industries like petrochemicals, although to date there is not one universally industry wide set of rules.

The factors that will most affect any broad adoption of a BR design code will depend on the types of mandates proposed and their cost impact relative to the perceived safety benefits for the public at large.

THE "ELEPHANT IN THE ROOM" – COST IMPLICATIONS OF BR DESIGN

As with any aspect of building design, owners always want to know the costs. Architects dealing with BR design are frequently asked what the BR "premium" is. There is, of course, no fixed rule because the "premium" varies wildly depending on the level of protection, building type, and the combination of measures to be taken. The exception to this is when an architect has a history of several similar projects, the delta for BR design can be extrapolated over time and, on that basis, a good estimate can be projected. For example, an architect involved with several similar industrial BR buildings was able to determine that the "premium" for that building type ranged from 20% to 50% depending on the design overpressure. Companies regularly involved with BR buildings have similar data on the cost factors for their designs and building types. This information is usually company confidential and very little is published.

For a new project, cost factors to be considered for BR design fall into the following categories:

- **Level of threat:**

This is the overpressure that the building is to be designed for. This results in enhancements to the building that include:

- ○ The strengthening of the structure.
- ○ Structural measures to prevent progressive collapse in the building is more than one level.
- ○ Utilizing strengthened building envelope elements – walls, roof and any exterior attachments that are not sacrificial.
- ○ Upgrading doors, windows, and hardware to meet the BR design criteria.

- **Location of the building:**

If the location of the building makes it susceptible to the blast threat, mitigation steps can include the following:

- ○ Consider stand-off distance if the threat is from a deliberate attack. This will incur costs in terms of land dedicated to landscape – hard and softscape elements like bollards, retaining walls and planters within the stand-off distance.
- ○ Where stand-off distance is not achievable, blast wave deflection or blocking measures like blast walls or berms can be utilized.
- ○ If the above are not feasible or too costly, relocating the facility may have to be considered.

Finally, the amount an owner is willing to pay for a specific level of BR protection comes down to the degree of damage and loss that is deemed acceptable in the event of an "incident". Depending on the likelihood of the event occurring, an owner may elect to take no measures if the odds are so small as to make it near improbable.

RULES OF THUMB FOR ARCHITECTS

This is the concluding section of the course, and the best take away would be to provide some basic "Rules of Thumb" for Architects that could be applied for BR designs. Ten rules are listed. Not because there are only ten but, in the spirit of the late comedian and philosopher, George Carlin, "Ten sounds official."

(The list below is not in any particular order of precedence)

1. Blast Resistance is NOT Blast Proof. There are resistance limits to every design.
2. Regular, "boring" forms are preferrable to exotic or irregular shapes for BR buildings.
3. For structural frames, moment frames are considered a better choice than braced frames.
4. Avoid windows. If not possible, have a generous budget.
5. A building's "psi" rating is an informal layperson term to describe the relative level of blast threat. (Generally referring to the peak reflected overpressure)
6. Most buildings are designed to achieve a Medium Damage Level. Always confirm with the Owner.
7. Keep Architect and engineering roles clear. Architects are responsible for the BR building envelope and all details that connect to it. Structural engineers design the foundations and the building frame. MEP engineers address all utilities, penetrations, and any emergency backup systems.
8. Buildings designed for <1 psi generally require minimal strengthening beyond the code-based wind loads. Buildings up to 3 psi range can be designed using many commercially available materials. Buildings 3-7 psi require specialized components. Buildings over 8 and 10 psi require significant specialized detailing and customized components. Always confirm with structural consultant.
9. Architects do NOT interpret QRA reports or determine blast resistance criteria. The Owner and QRA consultant provide the design criteria, over pressure and duration values which the design team uses, including any exceptions or variances.
10. Do not attach items to BR buildings and keep roofs clear of equipment and minimize penetrations.

SECTION 3 REVIEW QUESTIONS

14. If a QRA analysis is not available, the design team asks which question?

a. Stop all work?

b. Which version of IBC should we use?

c. Are design assumptions available?

d. None of the above

15. Which of the following is NOT a characteristic of Pre-engineered BR buildings?

a. Entirely fabricated in the sop and transported to site.

b. Offer flexibility of size and form.

c. Reduce construction time compared with site-built construction.

d. Generally, do not include utilities installed at the shop.

16. Windows in BR buildings can be ____________:

a. provided, but at a premium cost

b. can never be used.

c. easily adapted from any commercial manufacturer.

d. only used above 20 feet.

17. Which of the following provide BR design guidelines for specific situations?

a. IBC

b. NFPA / BOCA

c. FEMA publications FEMA 426 (ch.3, ch.4), FEMA 427, FEMA 428 (ch.4), FEMA 429

d. Institute of Blast Resistant Building Design.

18. PDC-TR-06-08 Rev 1 – "Protective Design Center Technical Report" is issued by _________?

a. FEMA

b. US Coast Guard

c. US Army Corps of Engineers

d. Dept. of Defense

19. Which of the following are some Rules of Thumbs for Architects doing BR design?

a. Regular, "boring" forms are preferrable to exotic or irregular shapes for BR buildings.

b. Avoid windows.

c. Architects do NOT determine Blast resistance criteria. That must come from the owner.

d. All of the above

20. The road to codification of Blast resistance standards is likely to include which of the following steps?

a. Federal Preemption

b. Local Prerogative

c. State mandate or preemption

d. All of the above

RESOURCES & ADDITIONAL READING

"Design of Blast resistant Buildings in Petrochemical Facilities," ASCE task Committee on Blast Resistant Design, 1997

"Blast Considerations," Precast Concrete Institute Designer's Notebook DN-14

"*Building Security Through Design: A Primer for Architects, Design professionals and their Clients,"* November 2001, The American Institute of Architects, Washington, DC.

"Security Design Criteria for New Federal Office Buildings and Major Modernization Projects," Interagency Security Committee ISC (executive agent – GSA), Washington, DC, May 2001

"Structures to Resist the Effects of Accidental Explosions," U.S. Departments of the Army, Navy and Air Force, November 1990

"Blast Resistant design with Structural Steel," Anatole Longinow, PhD and Farid Alfawakhiri, PhD, Modern Steel Construction, October 2003

"Earthquake-Resistant Design Concepts," FEMA P-749, Washington, DC, December 2010

"Reference Manual to Mitigate Potential Terrorist Attacks Against Buildings," FEMA 426, Washington, DC, December 2003

"Primer for Design of Commercial Buildings to Mitigate Terrorist Attacks," FEMA 427, Washington, DC, December 2003

"Insurance, Finance, And Regulation Primer for Terrorism Risk Management In Buildings," FEMA 429, Washington, DC, December 2003

"P100 facilities Standards for the Public Buildings Service," GSA, Washington, DC, October 2021

"The Risk management Process - An Interagency Security Committee Standard," U.S. Department of Homeland security, Cybersecurity and Infrastructure Security Agency, 2021 Edition

REVIEW QUESTION ANSWERS

Section 1

1. **In non-military situations, which types of buildings are most frequently impacted by blasts**
   a. Tall skyscrapers; incorrect, industrial plants have more frequent events then skyscrapers
   b. Residential subdivisions; incorrect, however, interesting enough there is a trend for more protective design elements being applied to residential house plans.
   c. Industrial facilities; Correct, these remain the most frequently occurring events and as such the use of blast resistant design is an essential part of the programming for these facilities
   d. Schools; incorrect, these are not the most frequently impacted by blasts but this is a public place that is increasingly adopting some of the blast resistant design principles do to some current events in history.

2. **QRA is the acronym for:**
   a. Quality Research Analysis; incorrect
   b. Quotient of Risk Assessment; incorrect
   c. Qualitative Review Approach; incorrect
   d. Quantitative Risk Assessment; correct levels of blast resistance are determined by these assessments performed by specialized engineering and Risk consultancy firms

3. **Which of the following codes has extensive guidelines for Blast Resistant Buildings?**
   a. IBC 2009; incorrect
   b. NFPA 101; incorrect
   c. UBC; incorrect
   d. None of the above; correct, As far as civilian building and life safety codes like the IBC or NFPA are concerned, there are currently (2022) no requirements for BR buildings.

4. **In developing a house for a famous client with security concerns, who would advise the architect on the criteria for any blast resistant design requirements?**
   a. The owner's security consultants; correct, The application of BR design for private residences is a very specialized category where the schemes are often unique and coordinated with security consultants.
   b. The local building official; incorrect, they would generally not have the expertise for BR design
   c. The Department of Defense; incorrect, residential is not their focus
   d. The structural engineer; incorrect they generally will not work with home owners about security concerns.

5. **Which of the following are building elements affected by BR design?**
   a. Exterior doors & hardware
   b. Wall and roof penetrations
   c. Exterior Windows
   d. All of the above

Section 2

6. **On Blast Contour maps, the irregular concentric "contours" represent:**
   a. Lines of equal pressure; correct; these model points of equal blast pressure radiating from the point of the explosion.
   b. Zones established by FEMA and DoD; incorrect, these zones do not show on blast contour maps;
   c. Blast duration; incorrect, these contours deal with blast pressure
   d. All of the above; incorrect

7. **Which of the following are building elements affected by BR design?**
   a. Exterior doors & hardware; correct, this is a building element affected by BR design
   b. Wall and roof penetrations; correct, this is a building element affected by BR design
   c. Exterior Windows; correct, this is a building element affected by BR design
   d. All of the above; correct all answers above are correct

8. **According to some published data as tabulated in this course, collapse of wood framed buildings can occur in blasts over:**
   a. 0.5 psi; incorrect, this would typically cause minor damage to buildings
   b. 10 psi; incorrect, this is probable total destruction of most buildings
   c. 5.0 psi; correct, this incident pressure would cause collapse of wood framed buildings
   d. 1.8 psi; incorrect, this would cause panels of sheet metal to buckle

9. **The destruction of the Alfred P. Murrah building in Oklahoma City is a dramatic example of what kind of damage:**
   a. Tornado hit; incorrect, this did not affect the Alfred P. Murrah building in Oklahome City
   b. Bunker busting bomb; incorrect
   c. Seismic failure; incorrect, this is not what caused the destruction of the Alfred P Murrah building.
   d. Progressive collapse; the destruction of the Alred P. Murrah building was one of the most dramatic examples of progressive collapse. The primary structural element of the building structure failed and there was resulting failure of adjoining structural elements.

10. **Which FEMA publication provides performance conditions for windows??**
    a. FEMA 426; incorrect, this provides guidelines and charts that define incident overpressures in psi as a function of stand-off distance and explosive force based on pounds of TNT.
    b. FEMA 427; correct this publication has provided performance conditions for windows that provide useful basis for BR design
    c. FEMA 429; incorrect, this covers steps that will need to be taken to the codification of BR standards, as there are no current building codes addressing BR design at this time.
    d. FEMA does not provide such a guideline; incorrect, they are in FEMA 427

11. **Which of the following is NOT a software that addresses or supports blast design analysis :**
    a. BEEM; incorrect, this is a software that addresses or supports blast design analysis
    b. AT Planner; incorrect, this is a software that addresses or supports blast design analysis
    c. BLASTFX; incorrect, this is a software that addresses or supports blast design analysis
    d. REVIT; correct, this is NOT a software that addresses or support blast design analysis

12. **What types of pressure impact a building as a result of a blast shockwave?**
    a. Side-on pressure; correct
    b. Reflected pressure; correct
    c. Back (Rear) face pressure; correct
    d. All of the above; correct all above are types of pressure impact as a result of a blast shockwave.

13. **The government agency that establishes design guidelines for Federal building categories:**
    a. GSA; correct, the General Services Administration (GSA) of the US Federal government establishes design guidelines that are de-facto codes.
    b. FEMA; incorrect, FEMA does not provide such a guideline
    c. The Department of Defense; incorrect, this department does not provide such a guideline
    d. NSA; incorrect, the National Security Agency does not provide such a guideline

Section 3

14. **If a QRA analysis is not available, the design team asks which question?**
    a. Stop all work?; incorrect, stopping not necessary at this point
    b. Which version of IBC should we use?; incorrect,
    c. Are design assumptions available?; correct, according to Figure 3.1 this is the next step in the Programming Flow Chart
    d. None of the above: incorrect, according to Figure 3.1

15. **Which of the following is NOT a characteristic of Pre-engineered BR buildings?**
    a. Entirely fabricated in the sop and transported to site.; correct, this description fits a pre-fabricated building not a pre-engineered BR building
    b. Offer flexibility of size and form.; incorrect, this does describe a Pre-engineered BR building
    c. Reduce construction time compared with site-built construction.; incorrect, this does describe a Pre-engineered BR building
    d. Generally, do not include utilities installed at the shop.; incorrect, this does describe a Pre-engineered BR building

16. **Windows in BR buildings can be ____________:**
    a. provided, but at a premium cost; correct, BR buildings try to avoid the use of windows, however there are glazing products out there that can get bulky and expensive bur are an option.
    b. can never be used.; incorrect, windows can be used but are expensive
    c. easily adapted from any commercial manufacturer.; incorrect, these windows are specially made
    d. only used above 20 feet.; incorrect, windows are generally discouraged but can be used if willing to pay a premium for a special type of bulky glazing product.

17. **Which of the following provide BR design guidelines for specific situations?**
    a. IBC; incorrect, not the correct guidelines for BR design and specific situations
    b. NFPA / BOCA; incorrect, not the correct guidelines for BR design and specific situations
    c. FEMA publications FEMA 426 (ch.3, ch.4), FEMA 427, FEMA 428 (ch.4), FEMA 429 incorrect, not the correct guidelines for BR design and specific situations
    d. Institute of Blast Resistant Building Design; correct, this does provide BR design guidelines for specific situations

18. **PDC-TR-06-08 Rev 1 – "Protective Design Center Technical Report" is issued by _________?**
    a. FEMA; incorrect FEMA does not issue this report
    b. US Coast Guard; incorrect, FEMA does not issue this report
    c. US Army Corps of Engineers; incorrect, FEMA does not issue this report
    d. Dept. of Defense; correct, this is a report issued by the Dept. of Defense

19. **Which of the following are some Rules of Thumbs for Architects doing BR design?**
    a. Regular, "boring" forms are preferrable to exotic or irregular shapes for BR buildings.; correct
    b. Avoid windows.; correct
    c. Architects do NOT determine Blast resistance criteria. That must come from the owner.; correct
    d. All of the above; correct, all of the above answers are Rules of Thumb for Architects doing BR design.

20. **The road to codification of Blast resistance standards is likely to include which of the following steps?**
    a. Federal Preemption; correct; correct
    b. Local Prerogative; correct
    c. State mandate or preemption; correct
    d. All of the above; correct, all these steps to codification of Blast resistance will likely happen.

PDH Academy

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Thank you for completing this evaluation. We want to ensure that our training sessions are as meaningful as possible and appreciate your feedback. Please mail your completed forms to:

PDH Academy, PO Box 449, Pewaukee, WI 53072

If you would like to offer feedback on this course to AIA CES, please visit www.aia.org/CESFeedback

Date:____________________

SPEAKING OF OLDER BUILDINGS

Course Number: AIAPDH225

Using a scale from 1 to 5 where 1 is "Poor" and 5 is "Excellent," please evaluate the course in the following areas: (circle one number per question)

	Poor				Excellent
1. Overall satisfaction with this course	1	2	3	4	5
2. Course learning objectives clearly stated and met:	1	2	3	4	5
3. Satisfaction with the format of this course:	1	2	3	4	5
4. Met overall personal objectives for attending:	1	2	3	4	5
5. Quality of course content:	1	2	3	4	5
6. Applicability/value of new knowledge, ideas or information:	1	2	3	4	5

ARCHITECTURE FOR DISASTER RELIEF

Course Number: AIAPDH226

Using a scale from 1 to 5 where 1 is "Poor" and 5 is "Excellent," please evaluate the course in the following areas: (circle one number per question)

	Poor				Excellent
1. Overall satisfaction with this course	1	2	3	4	5
2. Course learning objectives clearly stated and met:	1	2	3	4	5
3. Satisfaction with the format of this course:	1	2	3	4	5
4. Met overall personal objectives for attending:	1	2	3	4	5
5. Quality of course content:	1	2	3	4	5
6. Applicability/value of new knowledge, ideas or information:	1	2	3	4	5

continued on next page

ACCESSIBLE RESTROOM DESIGN

Course Number: AIAPDH229

Using a scale from 1 to 5 where 1 is "Poor" and 5 is "Excellent," please evaluate the course in the following areas: (circle one number per question)

	Poor				Excellent
1. Overall satisfaction with this course	1	2	3	4	5
2. Course learning objectives clearly stated and met:	1	2	3	4	5
3. Satisfaction with the format of this course:	1	2	3	4	5
4. Met overall personal objectives for attending:	1	2	3	4	5
5. Quality of course content:	1	2	3	4	5
6. Applicability/value of new knowledge, ideas or information:	1	2	3	4	5

BLAST RESISTANT DESIGN

Course Number: AIAPDH230

Using a scale from 1 to 5 where 1 is "Poor" and 5 is "Excellent," please evaluate the course in the following areas: (circle one number per question)

	Poor				Excellent
1. Overall satisfaction with this course	1	2	3	4	5
2. Course learning objectives clearly stated and met:	1	2	3	4	5
3. Satisfaction with the format of this course:	1	2	3	4	5
4. Met overall personal objectives for attending:	1	2	3	4	5
5. Quality of course content:	1	2	3	4	5
6. Applicability/value of new knowledge, ideas or information:	1	2	3	4	5

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