ENGINEERING AND DISASTER PREPAREDNESS FOR HERITAGE STRUCTURES

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As defined by Miriam Webster an Emergency is "An unforeseen combination of circumstances or the resulting state that calls for immediate action."(1). The same source defines a Disaster as "A sudden calamitous event bringing great damage, loss, or destruction; broadly: a sudden great misfortune or failure." (2)

During a building's lifetime it will be exposed to many types of emergencies. Most are relatively minor incidents such as a broken pipe, fallen tree limb, or act of vandalism that damages a portion of the building but does not result in permanent or complete loss. However while generally less frequent, emergencies may be severe such as an earthquake, hurricane or tornado that completely destroys the structure.

A disaster is the result of an emergency that is not properly controlled because the designer did not anticipate the emergency event or they did not have adequate design knowledge for the building to survive the event. History is filled with examples of emergencies that became disasters including hurricanes, tornados, floods, fires, and earthquakes. For historic buildings preventing emergencies from becoming disasters is an important part of preservation. Unfortunately emergency preparedness and disaster prevention are often overlooked by preservationists.

One common type of building emergency that may or may not become a disaster is a fire which usually starts as a relatively minor incident such as an overheating electrical cable. If the emergency is detected and suppressed, progress of the event is interrupted; however if it is allowed to progress to an uncontrolled blaze the building may be completely destroyed, which is the disaster. The fire may also spread to involve other buildings creating a larger disaster as was demonstrated by the Great Chicago Fire of 1871.

In some instances one type of emergency can lead to wide spread disaster such as was demonstrated in the 1989 San Francisco earthquake in which natural gas pipes ruptured and a number of fires broke out from the leaking gas. The Midwest floods of 2008 started off as emergencies from snowmelt and rainwater but quickly elevated to a disaster as levees failed and entire swaths of cities and towns were suddenly inundated.

The session on Engineering and Disaster Preparedness for Heritage Structures should define the impact of disasters on humankind's built environment and the role that the engineering community can play to reduce the impact of disasters in historic structures. The session should evaluate how engineers are trained for this work and specifically how a preservation engineering curriculum can fulfill needs that are not currently served. The document is intended to be a basis for the discussion and does not attempt to answer questions, which will be an objective of the emergency/disaster discussion group.

A large portion of preservation engineering discussions focus on structural and seismic issues which is understandable since framing and other structural elements can fatigue and fail over time and are frequent causes of historic building damage. The structural engineer who identifies flaws in an existing building's construction and develops solutions that will maintain building integrity during an earthquake is practicing preservation engineering. Likewise the engineer who realizes that the roof structure on a historic building has been weakened from repeated exposure to category 4 or 5 hurricanes, and presents solutions to withstand future storms is also practicing preservation engineering.

In building design there are several engineering disciplines, in addition to structural, that are a part of the building design process. They include designers of climate management systems (heating, ventilation and air conditioning), electrical and communications systems, and safety and security features. The first objective of the engineering process is to design systems for specific functions but this also includes evaluating potential emergencies caused by the systems and prevention of catastrophe.

Electrical engineers are trained to design power systems that safely provide adequate electrical capacity for the building's use and occupancy. In older historic buildings the cables and circuits are often antiquated and may overheat and fail, resulting in a fire. Is the electrical engineer who recognizes defective electrical circuitry in a historic building and identifies improvements that allow safe electrical use in the building practicing preservation engineering?

Historic buildings often have heating systems that are inefficient and have exceeded their original design life. They may now create building safety hazards including carbon monoxide poisoning and fires. A mechanical engineer can evaluate a system to identify deficiencies and develop solutions that produce a desired comfort level and maintain safety. They can also recognize poor air movement to reduce or eliminate mold or rotting conditions, and design duct systems to control these conditions. Is the mechanical engineer who designs new and safe heating and air conditioning systems for a historic building practicing preservation engineering?

Many historic buildings are / have been lost to fire. A fire protection engineer is trained to evaluate fire hazards and develop methods to reduce the risk of fire. They can also design fire resistance, and fire detection and suppression systems to reduce fire severity. Is the fire protection engineer who identifies risk and designs appropriate protection systems for the building practicing preservation engineering?

One of the roles of the civil engineer is to control water movement and reduce erosion through ground realignment and drainage. Is the civil engineer who recognizes that a historic district is threatened by storm flooding and designs a series of water diversion measures to reduce the threat practicing preservation engineering?

Security engineers evaluate the risk of vandalism, theft, terrorism and other criminal activities. They design features that can make it more difficult for an intruder to access a building, or will increase the chance that the intruder will be apprehended if they enter. Is the security engineer who works with a historic building to reduce the possibility of unauthorized entry and vandalism practicing preservation engineering?

This leads to a fundamental question. Is the preservation engineer a unique specialist engineer who is solely responsible for overseeing all aspects of engineering as it relates to the historic structure? If so, how do they obtain the wide array of knowledge that the various engineering disciplines (electrical, mechanical, fire protection, civil, security) possess to achieve the satisfactory performance objectives of each discipline?

Alternatively is the electrical, mechanical, fire protection, civil or security engineer who works with historic structures a preservation engineer? Depending on the specific type of building and required expertise the answer may be either, leading to a specialist degree in preservation engineering or a preservation engineering certification for practicing engineers

One item to note is that to insure building safety many jurisdictions require building design work to be accomplished by a licensed professional engineer (PE). Licensure which is regulated by state boards exists for electrical, structural, mechanical, civil, and fire protection engineers. However at present time there is not a licensing arrangement for a preservation engineer and therefore to comply with requirements a preservation engineer who designs a system must be licensed in the specific discipline or work in tandem with a licensed engineer.

Engineers use modern codes and standards as their basis of design. These documents usually result after the causes of prominent disasters have been determined and solutions are identified to prevent similar events in the future. Codes and standards and the use of materials that have been validated by an independent testing agency such as Underwriter’s Laboratories (UL) or Factory Mutual (FM) become relatively easy to apply in new building construction. This provides the engineer with confidence that the system, component or feature will result in a safe design.

The greater difficulty is to prove that traditional materials, techniques, or systems installed before the advent of modern testing standards can offer an equivalent level of safety. Without knowledge of expected performance, engineers will frequently follow the conservative known approach and design systems which may conflict with historic preservation objectives. In turn this leads to systems that may not be fully appropriate for the building and disagreements with the preservation community.

Therefore topics that need to be discussed in this colloquium include:

1. What process is appropriate for engineering safety into historic buildings?
2. How should the preservation engineer be trained to implement the process
3. In designing curriculum modules and courses what are the issues that faculty

should consider for process training?

4. Should these be undergraduate or graduate level courses?
5. Is there applicability for both?
6. What potential research funding may be available to develop these modules/courses?

A starting point to consider is the concept of performance-based regulatory systems which are increasingly used for unique and unusual structures that do not conform to standard prescriptive solutions. “Performance-based regulations are about required outcomes rather than about specific solutions and explicitly describe the intent of the code, unambiguously” (3).

One example of a performance-based process is found in National Fire Protection Association (NFPA) #914 *Code for the Protection of Historic Structures* (4). The committee responsible for this code realized that too often modern, prescriptive fire and life safety codes conflict with historic preservation goals, and consequently the components and design techniques used are inappropriate. To address the unique aspects of historic buildings a performance-based section was developed to help the design professional achieve compliance while retaining unique character defining features of the building.

For example a historic door will have some degree of fire-resistance integrity but since it was constructed before the advent of modern testing standards the exact value is unknown. Under a prescriptive approach the building official may not be confident in the door's ability to resist fire for an exact time period (i.e. one-hour) and will require replacement with a contemporary door.   Under the performance approach the designer can evaluate the door to approximate the fire resistance and add either supplemental features that add fire resistance, lower the fuel load in proximity to the door to decrease the amount of time that the door must withstand fire attack, or provide supplemental fire protection such as automatic fire sprinklers to control the fire. The performance-based approach gives the engineer the ability to evaluate options and select appropriate solutions.

The NFPA 914 process begins with documenting the building's character defining features and use, accompanied by a professional evaluation of existing fire safety strengths and deficiencies. It determines probable fire scenarios to objectively define the type of fires that may occur within the structure. This produces a basic understanding of specific building requirements that must be addressed during the fire safety portion of the preservation effort.

The next step establishes performance goals and objectives for both historic preservation and fire safety. For example the code's egress objective may state that all persons must safely evacuate the building in less than two-minutes while the preservation objective may state that existing corridors cannot be altered or enlarged without negatively impacting the historic integrity of the building.

This is followed by evaluating options that determine how each objective may be achieved. In the above example the choices may include limiting occupancy or adding fire safety systems such as early warning fire alarm systems or fire sprinkler systems which increase the time that the egress route will remain viable.

The final task is acceptance of the solutions by each responsible stakeholder which includes owners, design professionals (architects and engineers), regulatory officials (fire, building and insurance), and preservationists. Ultimately this should result in achievement of fire safety using solutions that are technically appropriate without the loss of the historic features that may result from strict adherence to modern codes.

The preservation engineer must possess a number of skills to be effective including:

- Technical expertise. For all buildings, modern and historic, the engineer must have a strong knowledge of their specific building design discipline. If the engineer designs systems for historic buildings they must also have knowledge of preservation issues and understand how to adapt contemporary systems to older buildings. The Association or Preservation Technologists (APT) has proposed a definition for preservation engineer that says "A practicing engineer who through knowledge, training, experience, and skill provides technical services in conformance with established conservation principles" (5).

- Objectivity. Applying contemporary building solutions to a historic building may require excessively invasive or infeasible measures. Therefore the preservation engineer must be able to develop specific performance goals for building safety and apply appropriate solutions.

- Communications. Many safety officials are sensitive to preservation but have the first responsibility to insure public safety. Modern codes and standards present a defined path of safety that officials can be comfortable with and when non-standard issues are presented, as with historic buildings, they may be unsure how to achieve an equivalent safety level. The preservation engineer must possess effective communication skills to present an issue and the rationale for alternative solutions. This engineer must also be able to communicate with preservationists so that the degree of impact of the solution is understood.

In summary:

- Building safety is an aspect of preservation. If the building is destroyed by storms, floods, earthquakes, fires or vandalism then there may be nothing left to preserve.

- Engineers are responsible for designing a number of building systems including heating, air conditioning, electrical, communications, fire protection, security, and civil systems. Evaluating risk and designing safety into each system is a part of the engineering process.

- Engineers are rarely trained in preservation and most learn their skills through experience. A curriculum in preservation engineering may provide the opportunity to train practicing or new engineers who want to focus on historic buildings.

- The preservation engineering curriculum should produce a process that provides engineered safety in all systems – structural, electrical, mechanical, fire safety, security and civil – found in historic buildings.
- The curriculum must train engineers to use the process.

- Engineers who work in preservation must possess skills that include technical expertise, objectivity and communications.

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1. Merriam Webster Online Dictionary, "*Emergency*" www.merriam-webster.com/dictionary/emergency, March 07, 2009

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2. Merriam Webster Online Dictionary, "*Disaster*" www.merriam-webster.com/dictionary/disaster, March 07, 2009

3. Richard W, Bukowski, Vincenzo Nuzzolese. "Performance-based Fire Protection of Historical Structures", Fire Technology, 45, 23-42.

4. National Fire Protection Association, NFPA #914-2007, 1 Batterymarch Park,

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5. Association for Preservation Technologies, “A Philosophy for Preservation Engineering”, http://apti.invisionzone.com/index.php?s=6bc42660914323eb9cac773a82f8a36&showtopic=9, March 06, 2009