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Proceedings of the MCEER Workshop for Seismic Hazard Mitigation of Health Care Facilities

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16. Abstract (limit 200 Words)

The workshop was convened to examine how to ensure continued functionality of health care facilities during and after earthquakes. The workshop was arranged to reflect the key elements that lead to post-earthquake functionality: 1) structural behavior; 2) nonstructural components; 3) emergency management issues; and 4) social and economic issues. Participants focused on defining and identifying subsystems; the features and performance requirements of health care facilities; how practices in the eastern US differ from those in the western US; and how California's experience can be modified and applied in the eastern US. This report summarizes the deliberations and conclusions that resulted from the workshop. The discussions of each group (or integrated group) are summarized. Each chapter contains a brief description of the tasks of each group as well as a short summary of the conclusions. A general summary is presented at the end of the report. The appendices contain the workshop agenda, a list of participants, presentation materials used by the participants, a comprehensive list of nonstructural components that pertain to health care facilities, and a social/economic statement. (Abstract adapted from text).

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Executive Summary

The purpose of the *MCEER Workshop for Seismic Hazard Mitigation of Health Care Facilities* was to develop and consider the possible scope and emphases for MCEER's hospital project. The hospital project is part of a larger research endeavor that focuses on the rehabilitation of critical infrastructure facilities that society will need and expect to be operational following an earthquake.

The workshop brought representatives from academia, industry, government and emergency management together to discuss issues and identify barriers to seismic rehabilitation. The major observations and recommendations are:

1. The need to establish a unified guideline for mitigation of seismic hazards for health care facilities in the eastern U.S.,
2. Emphasize the protection of buildings as well as contents by using advanced technologies,
3. Integrate mitigation and emergency response consistent with MCEER's overall vision, and
4. Coordinate with the current FEMA project carried out at the University of Southern California that concentrates only on nonstructural hospital elements.

The expected outcome of this workshop is the development of a guideline to identify requirements of seismic mitigation efforts for health care facilities in the eastern U.S.

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Section 1
Workshop Summary

The purpose of the *MCEER Workshop for Seismic Hazard Mitigation of Health Care Facilities* was to formulate an action plan to develop retrofit strategies/guidelines for hospitals. The workshop focused on defining and identifying subsystems, features and performance requirements of health care facilities, how eastern practices differ from those in California, and how California's experience can be modified and applied in the east.

A roundtable discussion format was adopted by the organizers to provide the group with the opportunity to explore this important topic in the context of their respective backgrounds. End users and researchers were able to express their concerns to each other so that a comprehensive plan could eventually be developed that considers health care facilities from a holistic viewpoint. Four technical areas were discussed: structural, nonstructural, social/economic/political, and emergency management.

The workshop attendees were selected from four different professional categories. They represented academia, industry, government officials and emergency management officials. In order to achieve balanced enrollment, the number of participants from each category was chosen to be about the same. Table 1-1 presents the distribution of workshop participants and assignments for roundtable discussions. A participants list in included in Appendix A.

Table 1-1 Distribution of Workshop Participants[1]
Assignment to Roundtable Groups

	Academia	Industry	Official/Policy	Total	Room[2]
Nonstructural Systems	Grigoriu, Lee, Singh	Paxton[3]	Hollenbach, Mallen	**5+1**	**A (Main)**
Structural Systems	Lee, Tong	Hart, Mehrain, Shah, Ettouney	Haraga	**6+1**	**B (Civil Division)**
Social/Economic/ Political	Corbett, Lee, Nigg	Glover, Isenberg	Benson, Rossberg	**6+1**	**D (Applied Science Division)**
Emergency Management	Bourque, Lee	Tweedy	Delaney, Hauer, Kuhr, Meyers	**6+1**	**C (Structures Division)**
Total	**7**	**8**	**9**	**24**	

[1] Dr. George Lee will participate in the four roundtable discussions, as needed.
[2] The room name is internal to Weidlinger Associates offices in New York City.
[3] Did not attend the workshop

1.1 Workshop Organization

The workshop was convened to address how to insure continued functionality of health care facilities during and after earthquake events. Figure 1-1 illustrates the key elements leading to post earthquake functionality. They can be categorized into four major keys:

1. Sound structural behavior.
2. Continued functioning of nonstructural components.
3. Emergency management issues.
4. Social and economic issues.

Most importantly, figure 1-1 indicates the nature of interaction and integration among all these key functional elements.

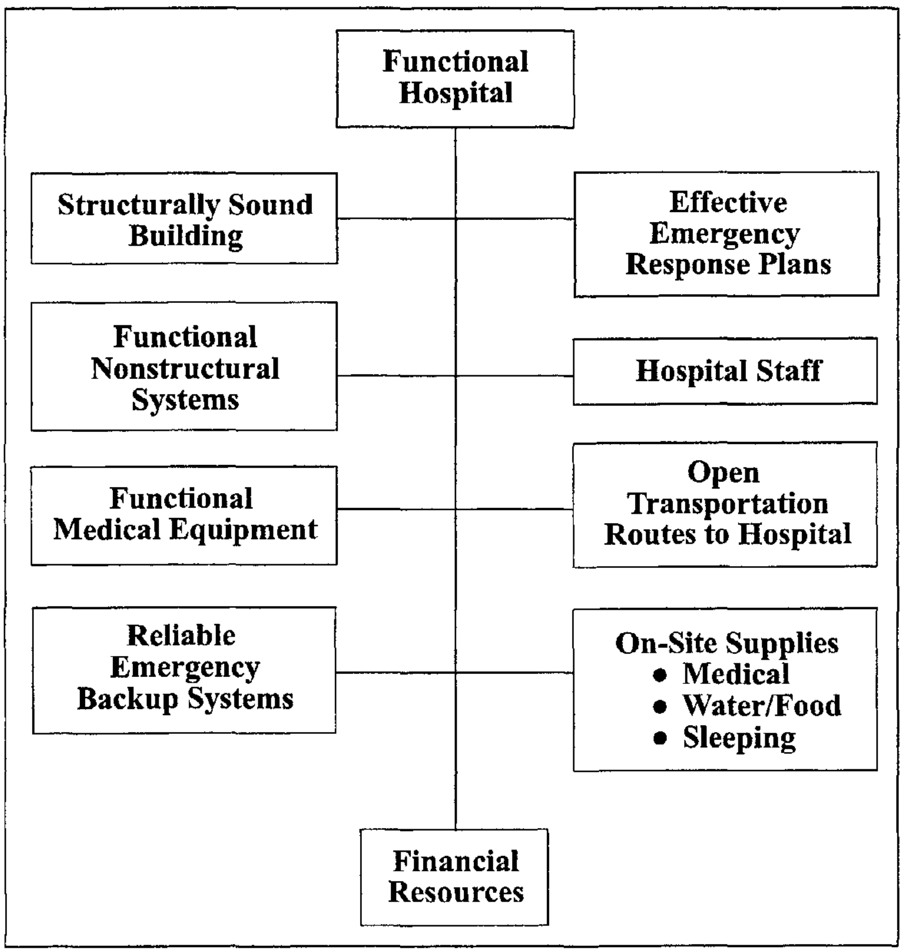

Figure 1-1 Key Elements Leading to Post-earthquake Functionality

The workshop was arranged to reflect these key functional groups. First, several presentations covering the four functional key elements were given to all attendees. Next, the workshop was subdivided into four working groups. Each group was tasked to deliberate one of the specific key elements. After that, the four groups were integrated to two integrated groups. The first group combined the structural and the nonstructural groups. The second group combined the emergency management group and the social/economic group. The deliberations of these two integrated groups concentrated on the integration and interaction between the functionality of the two underlying groups. Finally, all workshop participants were assembled to discuss all the issues, with special emphasis on integration and interaction parameters between all groups. Figure 1-2 shows the workshop plan. The agenda of the workshop is included in Appendix A.

1.2 Organization of Workshop Proceedings

This report summarizes the deliberations and conclusions of the workshop. First, the discussions of each group, or integrated group, are summarized. Each chapter contains a brief description of the tasks of each group as well as a short summary of the conclusions. A general summary chapter is presented at the end of the report. The appendices contain the workshop agenda and participants, presentations materials used by the participants, a comprehensive listing of nonstructural components that pertain to health care facilities that was gathered by Prof. Mircea Grigoriu, and an important social/economic statement by Prof. Joanne Nigg.

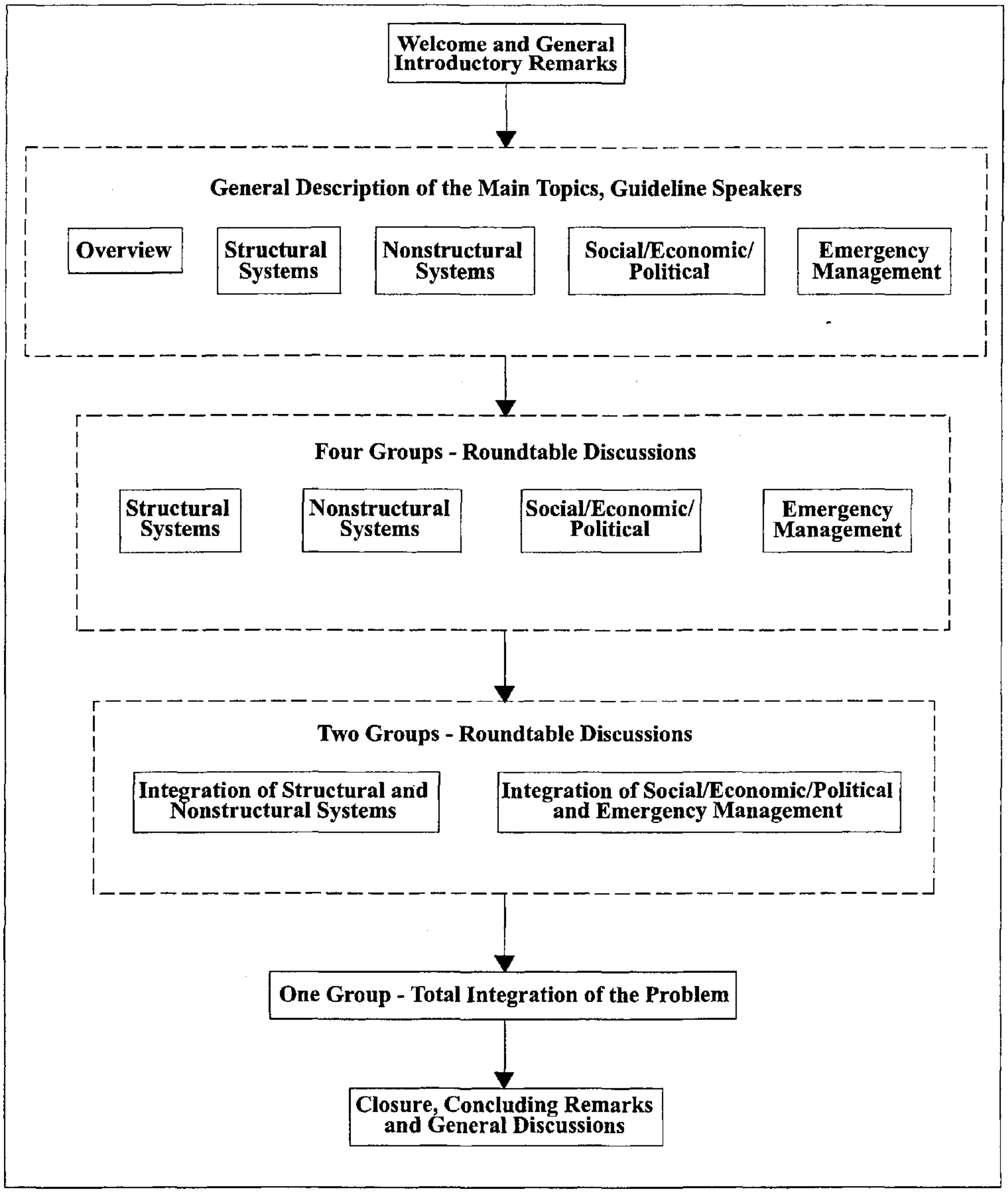

Figure 1-2 General Outline of the Workshop

Section 2
Nonstructural Systems Roundtable

The nonstructural components group of the workshop met to discuss issues that relate to the seismic mitigation problem of health care structures. The composition of the group is shown in table 1-1. Among the issues that were discussed by the group are:

1. Needed research/information in seismic mitigation efforts that can be applied directly to health care facilities.
2. Available west coast information and experiences that can be utilized in the east coast in seismic mitigation efforts.
3. Role of MCEER in promoting cooperation and integration of research and information in the seismic mitigation fields.
4. Specific nonstructural component requirements for health care facilities.
5. Specific nonstructural component requirements for eastern U.S. zones.

The group recognized that perhaps the most important issue in seismic mitigation efforts for health care facilities is the nonstructural components issue. The discussions were focused on the following items:

1. The selection of a few nonstructural systems in health care facilities that are vulnerable to earthquake,
2. The determination of the information required to evaluate the seismic performance of these systems and to develop rehabilitation strategies, and
3. The use of fragility curves[1] to evaluate the seismic performance of nonstructural systems.

The details of these deliberations follow.

2.1 Survey of Nonstructural Systems

Nonstructural systems in hospitals have been surveyed and divided into four main groups. The following is a list of the groups and the components of each group (more details are provided in Appendix C):

Architectural Components

Exterior wall elements
Partitions
Interior veneers
Ceilings

[1] Fragility curves are a measure of the probability that a certain damage state will be exceeded as a function of some parameter representing the intensity of the ground motion; for example Peak Ground Acceleration (PGA). Fragility curves may be developed for structural or nonstructural components, structural systems, or class of structures. Field data or numerical simulations can be used to generate fragility curves. Fragility curves can be used for cost-benefit analysis, policy planning, and rehabilitation.

Parapets and appendages
Canopies and marquees
Chimneys and stacks
Stairs

Mechanical and Plumbing Components
Mechanical equipment
Storage vessels and water heaters
High pressure piping
Fire suppression piping
Hazardous material
Ductwork

Electrical and Communications Components
Transformers
Switchgear

Furniture and Interior Equipment
Storage racks
Bookcases
Computer access floors
Hazardous materials storage
Computer and communication racks
Elevators
Conveyors

2.2 Selected Nonstructural Systems

The selection of nonstructural systems was based on two criteria: the importance of the system for the functionality of the hospital after an earthquake, and the feasibility of conducting seismic analysis of the selected systems within the available resources. The following systems have been chosen:

2.2.1 Elevator Systems

In a typical hospital, there are several elevators that serve different floors and medical units. The functionality of this and any other hospital is highly dependent on uninterrupted vertical transportation of people and supplies in the hospital from one floor to another. The purpose of this study is to evaluate these vertical transportation systems for the seismic disturbances expected to occur in the New York city area, and then to propose advanced technologies that could be implemented to improve the performance of these systems during an earthquake.

The study will provide seismic fragility data for each elevator systems for the two situations: (1) current systems and (2) improved systems retrofitted with advanced technologies. This information will provide a part of data required for the seismic performance assessment of the entire hospital system exposed to the east coast seismic environment.

There are two ways one can estimate this fragility information:

1. From the observed behavior of the elevator systems during a large number of seismic events, or
2. By analysis of the system for a large number of expected earthquake induced ground motions.

Since there are no observed data available on the seismic performance of the elevators in the eastern United States, we will adopt an analytical approach for quantification of the elevator system fragility, and based on this information suggest possible improvements that can be made to these systems.

An elevator system consists of several components that can possibly malfunction during a seismic event, and thus impair the performance of the entire system. From the observations made in past earthquakes in the western United States, the counterweight systems have been observed to be the most vulnerable components, primarily because they are the heaviest components of elevators. As a result, they generate high inertial forces that damage the guide rails, eventually leading to a derailment of the counterweights and complete interruption of the elevator function. Besides these, there are also other components that could possibly affect the performance of an elevator system. Thus, the seismic fragility of an elevator system depends on the fragility of its constituent components, some contributing more to its seismic vulnerability than others. This study will evaluate the performance of each such component when subjected to dynamic seismic forces.

2.2.2 Medical Components

To assess the seismic vulnerability of isolated medical components such as CAT Scan systems, MRI systems, and X-ray systems, it will be assumed that the functionality of the internal components of these systems for high levels of seismic activity has been verified by experiment. Therefore, here we will only assess the vulnerability of the support of these systems to the building.

These systems may be rigidly connected to the building floors and wall or they may be unattached for their possible relocation. If they are rigidly connected to the building system, then this study will examine the adequacy of such connections with regard to their ability to withstand seismic forces. However, if it is required that they not be attached, then this study will examine the possibility of their dislocation during a given intensity earthquake. Suitable removable anchoring arrangements will also be developed.

2.2.3 Water Supply and Fire Protection Systems

Water supply and fire protection are complex systems involving a relatively large number of components, alternative paths for supplying water, several water sources, and a variety of anchors to the supporting structure. Moreover, the preservation of the design function of these systems depends essentially on the state of other nonstructural systems, such as the electric supply system.

Preliminary studies on the seismic performance of fire protection systems for high rise buildings in California have been performed at Cornell University. The essential ingredients of the study are the fragility curves of the individual components and the system topology characterizing the way in which the components are connected. The component connectivity provides information on the available paths of water supply and has been accounted for in the assessment of the overall seismic performance of fire protection systems in California. The calculations were based on fragility curves of individual system components estimated from the extensive set of data available in California on the seismic performance of a relatively large number of nonstructural components. On the east Cost of the U.S., fragility curves of individual components need to be calculated because of the lack of statistical data.

2.3 Information Required for Seismic Analysis

The following is a description of the information required for each system to achieve the seismic study:

2.3.1 Elevator Systems

The following information on the physical and mechanical characteristics of the elevator systems and on seismic input motion characteristics will be required.

Physical and mechanical characteristics of elevator components
Most of the information requested below will be available from the engineering drawings of the elevator. Based on the type and make of the elevator system used, the manufacturer and installer can provide this information more completely.

Elevator Counterweights:

- Physical Characteristics of the counterweight assembly: Size and weight of counterweight frame, position of the weights in the frame
- Number of ropes and their attachment configuration on the counterweight frame
- Guide wheel assembly: Size of the wheels, thickness of the rubber tires on the wheels, force in the preloaded spring in the guide wheel assembly during normal operation, and other physical dimensions of the guide-wheel assembly.
- Guide rail size
- Structural characteristics of the guide rail attachment supports to the building, e.g., support spacing along the rails, details of the structural characteristics of the support hardware (size of members, bolts, welds, etc.)

Elevator Car:

- Physical dimensions of the car, and its structural frame
- Payload
- Details of guide wheel assembly (similar to those required for the counterweights)
- Guide rail dimensions
- Structural characteristics of guide rail attachments on the building (similar to those requested for the counterweights)

Hoist system details:

- Weight of the motor
- Location of motor attachments to the elevator shaft in the building
- Structural details of the attachment
- Hoist wheel arrangements and their attachments

Seismic Motion Characteristics
The motion experienced by an elevator system during a seismic event is the ground motion filtered through the supporting building. To analyze an elevator system, we will require the input motions at all the supports of the guide rails on the building. This information will be obtained from dynamic analysis of the building for the ground motions expected at the site. In its most complete form, this information can be defined in terms of acceleration time histories at the elevator system supports. To estimate the fragility of the elevator components and the whole system, an ensemble of these motions should be available for each level of ground motion intensity.

2.3.2 Medical Components

To assess the adequacy or inadequacy of the supporting arrangements for each medical component, we will need information about their location in the hospital, weight, physical configurations (dimensions and layout) of the components, and the structural details of their supports. We will also need a description of the seismic motion at the supports of these components, usually in terms of the floor motion. This information will be available from a dynamic analysis of the hospital building structure.

2.3.3 Water Supply and Fire Protection Systems

The preliminary information we need to begin the seismic evaluation of the performance of the water supply and fire protection systems includes water sources, water distribution systems, sprinklers, connections to the supporting structure, and water pumps. We need information on the following items.

Water supply
It seems that there are two sources of water at most hospitals, three roof tanks and the city water supply. We need information on both water supplies including:

- Roof tanks: capacity, location on the roof, type, mechanical characteristics such as tank dimensions, wall thickness, etc., details on the roof anchors.

- City water: available water flow rate, location and capacity of the water pumps used to transport the city water to various locations in the hospital, characteristics of the auxiliary electric generator, such as mechanical characteristics of attachments to the structure and details about its function (for example, does the generator provides power automatically to the water pumps if the city supply stops?)
- Water pumps: capacity, number of pumps and their location, connection to the water distribution system, alternative sources of electric power.
- Piping system: typical pipe diameter, strength, and details of attachments to the structure.

Water distribution system

The water supply available from the roof tanks and city is transported to various consumption points in the hospital by a network of pipelines anchored to the structure. In the first phase of the study, it would be sufficient to focus on part of the water distribution system in the hospital, for example, the fire protection system in one of the most critical section of the hospital. We need detailed information on:

- A critical section of the hospital for which even small fires may have severe consequences
- A detailed description of the water distribution system for fire protection in the selected section of the hospital. The description should include all pipelines, pipelines diameters and geometry, hydrants, attachments to the supporting structure, type of joints. For example, the type of connection to the roof tanks and the city water supply are particularly important.

Sprinklers

The type, attachments to the supporting structure connections to the water supply systems, and any additional information if available.

2.4 Conclusions

- Three nonstructural systems will be analyzed seismically. These systems are: elevator systems, medical components, and water supply and fire protection systems.
- There is a need to obtain adequate information of the mechanical properties of the components of the selected systems. The gathering of this information may require survey of the structure of the hospital on hand.
- The seismic evaluation will be based on fragility curves.

Section 3
Structural Roundtable

The structural group of the workshop met to discuss structural engineering issues that relate to the seismic mitigation problem of health care structures. The composition of the group is shown in table 1-1. Among the issues that were discussed by the group are:

1. Needed research/information in seismic mitigation efforts that can be applied directly to health care facilities.
2. Available west coast information and experiences that can be utilized in the east coast in the seismic mitigation efforts.
3. Role of MCEER in promoting cooperation and integration of research and information in the seismic mitigation fields.
4. Specific structural engineering requirements for health care facilities.
5. Specific structural engineering requirements for eastern U.S. zones.

Several of the above items were discussed and many specific conclusions were reached among the group members. Among the important recommended points were the importance of defining analysis levels (simple or advanced) and its compatibility with the type of project. This analysis level was an issue of disagreement between two sides in the group (the more practical side, which favors simplified analytical technique and the theoretical side which favors more analytically involved approach). The need and current lack of health care-specific guidelines were also discussed. The details of all the discussion items are presented in the next section.

3.1 Detailed Discussion

The cost of retrofitting any project for seismic mitigation is a major concern. This becomes even more evident in the case of voluntary retrofits, as might be needed in northeast U.S. hospitals where earthquakes are not a common occurrence. One way of reducing these retrofit costs is to rely heavily on high-tech solutions for retrofitting. Recent experiences have shown that two promising fields of seismic retrofit schemes are a) using column wrapping to improve reinforced concrete confinement and b) use of active/passive control systems.

A distinction must be made between generalized rules/design codes, e.g., UBC, which are meant for all building types. These codes can't address all specific requirements for special purpose systems, such as health care facilities. Specific sets of rules, guidelines or codes are needed for health care facilities. These specialized guidelines would be specific also to the needs and special features of the eastern U.S. One of the most prevalent construction materials in the eastern U.S. is masonry. Use of masonry, especially URM that is coupled with advanced materials technology should be researched. Braced systems with dissipated energy are also a promising retrofit scheme. To encourage retrofitting in the health care facilities in the eastern U.S., less than optimum performance might be acceptable.

Recent California experiences where federal (e.g. FEMA) and local authorities (Seismic Bond Program in LA) financed the research, monitoring and retrofit efforts were highly successful should be studied. Some of these experiences and models can be used for the seismic mitigation efforts in the eastern U.S. Existing design codes might be used for these retrofit efforts, yet some eastern U.S. specific guidelines might be needed. One possibility of addressing essential facilities, e.g. health care facilities is by increasing safety factors.

In order to address the question of special needs of health care facilities, we have to first define earthquake hazards. By investigating some of the implicit assumptions in the conventional definitions and methodologies of earthquake hazards, we might be able to isolate and improve on the specifics of earthquake hazards for essential facilities, such as health care facilities. Another important factor in seismic mitigation is the need to focus on computational analysis of buildings.

What differentiates health care facilities from other systems from a structural engineering viewpoint? One possible way to define the answer is by studying past performance of essential facilities, with special emphasis on hospitals, during recent earthquakes and drawing the proper conclusions. Some facilities fared better than others, and the question is "why did that happen?"

One of the main requirements in a health care facility is that the "down time[2]" is kept to a minimum. One way of keeping down time to a minimum is using performance based design codes.

Some panel participants suggested an approach for assessing the built-in strength of health care facilities. This involves analyzing and designing the structure for an abnormal, but plausible event in the eastern U.S., loading condition, such as hurricane condition. After the building is designed, the behavior of this structure during earthquake conditions can be investigated. This multi-hazards approach can help in justifying the costs of retrofits for seismic mitigation. The panel members agreed that in a medium-to-low seismic zones, such as in the eastern U.S., comparing different loading requirements with those of seismic requirements could be of importance. A detailed understanding of the comparative loading requirements should be available to owners and professionals.

Division of opinions between panel members with respect to analysis level surfaced. Some panel members observed the need for very detailed and advanced analysis for health care facilities. Other panel members questioned the validity of such an approach. They opined that the available resources should be devoted to improving simplified analysis techniques, as well as improving the accuracy of earthquake inputs.

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[2] Down time is the time in which the hospital cannot perform its primary functions.

The correlation between theoretical damage levels and controlled laboratory testing, when subjected to eastern U.S. type seismic motions needs to be investigated further. It was observed that most of the available data on this subject pertains to western U.S. type earthquakes.

In a building-congested environment, such as most eastern U.S. cities (NYC is a perfect example), a need for analytical modeling of building separation requirements is needed. A balance between social/economic cost of buildings and adjacent buildings impacting each other during earthquakes must be obtained.

The panel did not have a consensus on the type of health care facility that should be studied by MCEER. Some panel members felt that focusing on larger health care units is the most efficient approach. Others felt that the trends in the health care industry are toward smaller and more specialized health care units. A two pronged approach seems to be the best.

The panel observed that stressing the use of high-tech methodologies in retrofitting health care units is particularly attractive if/when the health care unit changes its functionality at some future date. Current trends in health care systems, where advances in medical care systems occur in a rapid manner, reinforces this observation.

3.2 Conclusions

The panel ended its discussions by making the following observations/recommendations:

1. Use of the vast design and analysis tools, which were developed by MCEER in the past, will help the project immensely. Mechanisms to transfer such a wealth of information/tools to the practitioners are needed.
2. Focusing on NYC buildings can be of help, due to the size and population of the city.
3. Some advanced technological tools/materials that proved to be successful are Fiber Reinforced Plastics (FRP), passive dampers and base isolation tools.

Section 4
Social, Economic and Political Roundtable

The social, economic and political group deliberated social/economic issues in relation to seismic mitigation for health care facilities in the eastern U.S. Different factors affecting the functionality of the health care facilities, and the success of mitigation efforts were discussed, and several important questions were raised. Some of these questions can serve as the basis for future research efforts by MCEER. The composition of the group is shown in table 1-1.

4.1 Detailed Discussion

The focus of this discussion was on the social, economic and political factors that could affect the likelihood that health care facilities–especially hospitals–in the greater New York City area would voluntarily strengthen or rehabilitate their structures and systems to be able to sustain some (unspecified) level of seismic shaking.

The principle assumption of those involved in the roundtable was that most of these critical facilities had not been built to include seismic design considerations, either for structural or nonstructural systems. Most of these structures are reinforced concrete and/or steel frame; many are also built on piles. Because of these construction issues, the rehabilitation of existing health care facilities in New York City would require significant financial resources, in part due to the large number of these types of facilities.

It was also discussed that critical facilities, like hospitals, face other significant risks that they must address, many of which are perceived to be more pressing than earthquakes. Some of these other threats include: terrorist attacks; attacks using weapons of mass destruction; hurricanes and other severe storms; mass casualty incidents (such as airplane or train crashes); lifeline failures (due to an aging infrastructure); and facility closure due to other structural problems (many associated with deferred maintenance).

The overriding question that was discussed by the group was: Do New York City hospitals really have an earthquake problem; and, if so, how significant is it? It was expressed that New Yorkers have the perception that an earthquake problem does not exist in the City and, therefore, that nothing needs to be done to seismically rehabilitate hospital facilities. If this perception is to be overcome, several questions will need to be addressed:

1. What is the magnitude of the problem?
2. What is the probability that an earthquake of a damaging magnitude will strike the New York City area?
3. What is the vulnerability expected (that is, the levels and types of damage anticipated)?

4. What are the expectations of acceptable performance levels in New York City for different probability earthquakes?
5. How much would certain mitigation efforts cost?
6. Can renovations be done without interrupting service?

In order to begin to address these questions, it would first be necessary to establish the existence of an earthquake "problem" for the area. Some research would need to be conducted to determine how an earthquake problem could be "sold," both to key decision makers as well as to the general public. It was also felt that seismic maps (for example, those developed by the U.S. Geological Survey) would need to be more "user-friendly" in order to be used in general public education efforts. It was also stated that earthquake rehabilitation must be linked to other issues that already had some level of importance to the public. For example, a multi-hazard approach–including willful and accidental events–would be one approach that could be used to address common problems. Also, the key role of hospitals as community resources, both in normal times and disaster situations, should be stressed in order to reframe the ways in which the importance of these facilities and the need to ensure their functionality under a variety of conditions are perceived.

For such an effort to be successful, it was felt that key audiences must be included in the dialogue about the earthquake problem and what approaches to solving it should be taken. The three key audiences included: elected city officials; hospital and HMO administrators; and Health Departments at different levels of government.

Section 5
Emergency Management Roundtable

The emergency management group addressed two major questions. First, would hospitals be affected and, if so, how? And second, did the hospital selected for the case study represent a good approximation of the issues that needed to be addressed? The composition of the group is shown in table 1-1.

5.1 Detailed Discussion

During the deliberations of this group, a slight distinction between hospitals and other health care providers were recognized. This distinction is discussed as follows.

5.1.1 Hospitals

Hospitals clearly will be affected should there be an earthquake in the New York City area. Furthermore, in considering the role of hospitals during and after an earthquake, consideration much be on a regional basis and not on an individual hospital basis. One of the first things that must be addressed is whether the structural performance of the hospital should be designed to a life safety or building survival level. The group assumed that none of the current hospitals in Manhattan and the surrounding boroughs would be able to function at all after an emergency and that there were real questions about their ability to protect the lives of their patients and staff personnel. At best it was concluded that hospitals might be brought to the level of life safety but that in selecting this level of performance substantial public education needs to be directed at decision makers and the public. Experience from California suggests that the public generally do not understand the distinction between life safety and building preservation and that, when understood, often do not accept performance to a life safety standard.

Standards for hospitals need to be more stringent than they are for other buildings under city codes.

Beyond building structure, there are many nonstructural issues that must be considered. These include the integrity of the various utility systems, preservation and protection of equipment either by bolting or other methods, preservation of medications, file systems, computer systems, etc. Fire protection and back-up generators are a major concern. Fire systems need to be retrofitted. Systems for hazmat and biohazard containment need discussion and action. Shut-off valves must be installed for gases, with a decision about the threshold at which such valves engage.

Hospitals need to develop plans for evacuation and guidelines for when evacuation should occur. This necessitates the development of receiver-donor links with other institutions both within and outside of the potential area of impact.

Section 6
Joint Structural and Nonstructural Roundtable

There are several commonalties between the structural engineering issues and the nonstructural components issues. At times, the distinction between the two issues can be difficult to define. Recognizing this, an integrated group which comprises both the structural engineering group and nonstructural components group were formed. This group discussed integration and interaction issues between the two fields. Also, this joint roundtable's discussion focused on identifying short- and long-term research efforts that would need to be undertaken in order motivate seismic rehabilitation efforts in New York City health care facilities.

6.1 Detailed Discussion

The joint panel discussed different possible nonstructural components that are health care specific. The most obvious is different medical equipment. Special needs, specifications and performance levels have to be accounted for in any seismic mitigation plans.

Of special importance are water storage tanks. It was observed by some panel members that in eastern U.S. cities, such as New York City, rooftop water tanks are the norm. This is a result of fire regulations. Vulnerabilities of health care units to the seismic behavior of rooftop water tanks is a subject worthy of study.

The panel deliberated on the relevance/importance issue vs. ease of analysis/design issue. This is most important when transferring research results and recommendations into practical engineering practice. Guidance from MCEER is needed to ease transformation of research products into practical needs.

The panel discussed the demonstration projects issue. Two viewpoints emerged. One viewpoint is that one or two large demonstration projects can cover the majority of important issues in the structural and nonstructural component fields. Proponents of this approach opined that it is impossible to cover all aspects of the engineering problems even with many more demonstration projects. Another opinion emerged that a generalized demonstration project would not be realistic. Several smaller studies that cover as much as possible of the different important engineering issues are preferred. No clear resolution on this issue was developed.

One important agreement within the panel members was that it is prudent to identify and differentiate between long-term and medium-term issues concerning the MCEER health care project.

The joint meeting between the structural and nonstructural panels started by emphasizing the nonstructural community's need for information. Among some of the needed items are the building motions at the point of contacts with the underlying structure, the properties of the nonstructural components and the possible interaction with the underlying building. Complete knowledge of the underlying building analytical model was argued to be of importance to the nonstructural evaluation team. This fact applies independently from the level of analysis (simple or sophisticated) and the type of analysis (equivalent static or dynamic).

The panel observed that the level and type of information needed for the proper evaluation of structural/nonstructural behavior and interaction depends to a great deal on the type of the nonstructural component. For example: elevators would require different information and approaches from fire support system or medical equipment such as cat-scans.

The issue of analysis levels of both structural and nonstructural components was discussed at length. It was agreed that some consistency of analysis levels between both structural and nonstructural components, especially in sensitive facilities, such as health care facilities is essential. Some panel members argued that for health care units, a more accurate/refined analytical approach than the FEMA 273/274 approach is needed for nonstructural components. This is one major differentiating point between the health care facilities and other types of buildings.

The joint panel addressed the issue of observed behavior vs. analysis and design requirements. A correlated study is needed. This study would emphasis both health care facilities and preferably medium earthquakes (which would have closer bearing to NYC area).

One of the important issues that was deliberated was the need for each of the two communities (structural and nonstructural) to gain closer knowledge of each other's needs and methods. An example of the space needs in a particular health care unit was presented to the panel. There was a space requirement conflict between architectural/structural and mechanical systems. The reason for the conflict is that the designers of both systems prepared their designs independently from each other. The final design was compromised after spending unnecessary time and effort. MCEER can play major role in bringing the two communities together.

The level of the analysis that is currently required by design codes for nonstructural components was discussed. It was argued that for research purposes, a much more detailed analysis is needed. Again, the importance of the structural-nonstructural interaction effects was emphasized. It was noted that such interaction effects are not addressed by any current design code.

The need for risk level definitions that are specific to health care facilities (both structural and nonstructural) was observed by some panel members. In addition, a prioritization system for nonstructural components, and the resulting levels of analysis/designs are needed.

The experiences of the west coast in addressing different aspects of earthquake mitigation were discussed. For example, emergency power supplies, communications (both within and outside of the health care unit), fire suppression equipment and the issue of medical gas are all issues that are addressed in different west coast codes. A suitable counterpart for these issues, and others, is needed for the east coast.

Detailed discussions of several structural and nonstructural topics revealed the need for more robust knowledge of design earthquake motions (as time histories). The importance of lifelines to the continued operations of health care facilities was underscored. It was observed that most of the new technology applications are fitted for improving the structural performance after it is built. Based on this, it was suggested by the panel to encourage MCEER to investigate the use of new technologies during the construction and/or retrofit phase.

The linkage between research results and practicing engineers is of importance to professionals. One possible idea was to place some of the recommendations of engineering research following patterns of practicing structural engineers. This could help in speeding the adoption of such research. It would also help in focusing the research efforts into directions which have more significance to practitioners.

The issue of fragility curves was discussed. Since these curves are directly dependent on the seismicity of the region, and since the seismicity of the east and west coasts are different, it is expected that the two sets of fragility curves would be different. It was mentioned that fragility curves are available for the west coast. Unfortunately, such curves do not exist for the eastern U.S. Producing such curves that are east coast specific is needed.

6.2 Summary

The panel then summarized important issues. Each member of the panel summarized his/her view in the fields of analysis and advanced technologies. These summarized views follows:

6.2.1 Analysis

1. Importance of coupled vs. uncoupled systems (structural and nonstructural)
2. Improving simplified analysis.
3. Improved construction specifications.
4. Develop health care-specific design and acceptance criteria.
5. Reconcile analysis and observations, with special emphasis on the east coast experience.
6. With the improvements in computational capabilities, testing on computers should be employed more often.
7. Integration of nonstructural components and structures: need to use time history and possibly nonlinear analysis.
8. Use of probability and extending it to design codes

9. Better definitions of performance measure for health care units. The purpose is the reduction of down time to an absolute minimum.
10. Simple description of earthquakes, especially for time history analysis.

6.2.2 Advanced Technologies

The following advanced technologies were mentioned by the panel as promising for use:

1. Base isolation.
2. Viscous dampers.
3. FRP wrapping and gluing.
4. The question of available data and possible better use of it.
5. New and better details. Slotted connections.
6. New specs for new anchoring
7. Need for simplicity
8. Simple tying down systems
9. Adoption of smart materials
10. Passive control for larger systems
11. Development of simulation and computations to develop simpler analysis and design methods
12. Computation of, and possible linkage of structural and reliability analyses

Section 7
Joint Social/Economic/Political and Emergency Management Roundtable

There are several commonalties between the social/economic issue and the emergency management issue. Recognizing this, an integrated group which comprise both social/economic group and emergency management groups was formed. This group discussed integration issues between the two fields. Also, this joint roundtable's discussion focused on identifying short- and long-term research efforts that would need to be undertaken in order motivate seismic rehabilitation efforts in New York City health care facilities.

7.1 Short-term Research Needs

It was strongly suggested that hospitals should be the initial focus of short-term research efforts. The totality of health care facilities is too broad and diversified for initial attention since they would include facilities, such as:

1. Major public hospitals covering all types of medical care; specialty hospitals (e.g., eye clinics);
2. Imaging and radiological facilities; rehabilitation centers for short-term medical conditions; nursing homes for extended in-patient care;
3. Medical laboratories; and
4. Surgical centers.

The first study that should be undertaken would be a study of the policy environment that regulates and oversees hospital operation. What local, state and national organizations require hospital facilities to meet certain standards or follow specific guidelines related to operational safety of the facility? Which organizations establish guidelines for hospital disaster plans? Are there any federal regulations that would apply to hospitals that establish structural or nonstructural seismic criteria for hospitals in general or for certain types of hospitals?

One of the discussants provided an example of how influences from the policy environment affect hospitals. The Joint Commission on Accreditation of Health Organizations (AHO) requires hospitals to have formal disaster plans. However, these plans are quite varied in their detail and comprehensiveness. AHO exercises no direct regulatory control over hospitals; but these facilities need to be accredited to qualify for Medicare and Medicaid reimbursements, which is a major financial incentive for hospitals to comply with this disaster planning guideline. General hospital disaster plans may often contain the following components to deal with specific problems: a utility failure plan; staffing issues; communication systems; procedures for dealing with the presentation of injuries; and the need to reprovision medicines and supplies.

In addition, this study should look at the types of societal changes that are affecting the ways in which hospitals are functioning today. Many previously non-profit hospitals are being purchased by for-profit health care companies, which is reorganizing the facilities to be more efficient and cost-effective. Within this type of climate, what level of concern is being placed on the long-term physical infrastructure of the facility if the corporation intends to sell it within a short period of time.

7.2 Long-term Efforts

Two longer-term efforts were identified as necessary. First, guidelines and methodologies should be developed for conducting vulnerability assessments of hospitals. To date, no comprehensive approach to risk assessment, much less vulnerability assessment, exists for such facilities. This would be necessary in order for both facility administrators as well as community decision makers to understand the magnitude of the problem they will face if a damaging earthquake event strikes the New York City area.

Second, an educational campaign strategy and materials needs to be developed in order to make hospital administrators aware of the problems they could face in an earthquake situation, both within their own facilities and to fulfill community needs for medical care. It was recommended that this effort should be done in conjunction with studies of how to link earthquake loss reduction measures to other types of hazards, thereby gaining collateral benefits as an incentive for hospital administrators to consider undertaking rehabilitation efforts.

Section 8
Joint Meeting of All Participants

At the conclusion of the workshop, all the workshop participants attended a general session where items of importance to everyone were discussed. Among the issues were integration and interaction issues between all key fields. The central role of MCEER in guiding the research effort was also discussed. Also, the general workshop body discussed short- and long-term research efforts that would need to be undertaken in order motivate seismic rehabilitation efforts in New York City health care facilities.

8.1 Detailed Discussion

At the conclusion of the workshop, each of the participants was asked to make a short concluding remark about his/her observations and recommendations concerning seismic hazard mitigation for health care facilities in the eastern U.S. Each of the following paragraphs contains the viewpoint of participants.

- One of the most important issues in the seismic mitigation of health care facilities is the communications issue. Communication between the health care unit itself and the outside world is essential to maintain during an emergency. In addition, coordination between local and federal emergency services has to be maintained. Communications within the health care unit itself is important. In order to keep these lines of communications open and efficient, well-defined organizational hierarchies have to be designed and rehearsed.

- Well-defined scenarios of the problem have to be established. After that, it has to be communicated to all concerned. These include officials as well as the public at large. Seismic mitigation for health care facilities needs special definition of levels of performance. These levels of performance will include the answer to health care specific questions such as "do all health care units need to have the same performance levels?" Special needs for fire protection and sprinkler quality control have to be addressed. Finally, enhanced training of all involved is needed.

- The magnitude of vulnerability of different health care units should be quantified. The emphasis will be on health care units in the eastern U.S. Available analytical and experimental tools should be employed to achieve such task.

- Identify solutions that will improve functionality both in normal and abnormal operational modes of health care units. Emphasize the common solutions for improved efficiency and cost reductions.

- Continuing from the above paragraph, plan for a multi-hazard approach to achieve safety while reducing costs.

- A clear need was established for developing more accurate approach(s) to investigate performance of health care-based nonstructural components during earthquakes.

- Education of the public about earthquake hazards will help MCEER in its efforts. In addition, Fire and EMD units need guidance from experts (MCEER) in their preparations and training.

- Acceptable performance levels, especially for nonstructural components are needed. Health care specific performance levels need to be emphasized.

- Several important observations can be made: a) political process on many levels should be pursued; b) convincing the public of seismic vulnerabilities is essential; c) varying or conflicting requirements of unique buildings vs. public buildings should be reconciled; d) importance of infrastructures (non-structures) especially for health care units; and e) force integration of social/economic issues with emergency management issues.

- Importance of uninterrupted water supplies. Fire protection measures are of highest priority. The continued functionality of nonstructural components are more important for health care units. Allocation of funds needs continued efforts by all, under the guidance of MCEER.

- We should strive for finding low cost solutions to different problems. Low cost solutions will be easier to accept, especially in moderate earthquake regions. Programs to establish quality assurance and certification of health care facilities for hazard (seismic) worthiness need to be launched.

- There is a clear need for an advisory committee with members who have different backgrounds to help MCEER in charting and continuing its efforts in seismic mitigation for health care units in the eastern U.S.

Section 9
Summary and Conclusions

The following important conclusions and recommendations may be stated based on the discussions of the workshop:

1. Earthquake preparedness in general and health care facilities in particular in urban centers in eastern U.S. is an important issue. Because of the low frequency of occurrence, earthquake hazard mitigation and response is typically not considered a high priority item for utilizing human and fiscal resources by policy makers, emergency response organizations and stakeholders. Therefore, proper communication to the professionals, stakeholders and the public-at-large is among the most important activities.

2. In the eastern U.S., an integrated consideration for multiple-hazard mitigation and response should be considered.

3. The medical service functions and required performance levels of health care facilities are significantly determined by the nonstructural components as well as the structural responses.

4. MCEER should coordinate its hospital project with the on-going FEMA sponsored project at the University of Southern California which deals with evaluation and design approaches to retrofit nonstructural components in hospitals.

5. For the eastern U.S., retrofit strategies for hospitals and nonstructural components should especially emphasize low-cost solutions

6. An advisory panel for the MCEER project should be established including end-users and professionals of various backgrounds.

Appendix A
Workshop Information

Workshop Agenda

List of Participants

MCEER Workshop on Use of Innovative Technologies for Seismic Hazard Mitigation of Health Care Facilities in the Eastern and Central U.S.

October 27-28, 1998

WORKSHOP AGENDA

Tuesday October 27

1:00 - 1:15 pm	Registration	
1:15 - 2:45 pm	Plenary Session	
	Welcome and Overview	*George Lee*
	• Social - Economic Issues	*Joanne Nigg*
	• Emergency Management	*Jerome Hauer*
	• Structural Engineering	*Mohammed Ettouney*
	• Non-Structural Requirements	*Mircea Grigoriu*
	• Practical Considerations: Structures	*Gary Hart*
	• Practical Considerations: Sensitive Systems	*James Mallen*
2:45 - 3:00 pm	Break	
3:00 - 5:00 pm	4 Groups for round table discussions	
	• Structural	*Group leader Ettouney plus recorder*
	• Non-Structural	*Group leader Grigoriu plus recorder*
	• Social - Economic	*Group leader Nigg plus recorder*
	• Emergency Management	*Group leader Hauer plus recorder*
5:00 - 5:45 pm	Meeting of group leaders and recorders	
	Dinner on own	

Wednesday October 28

8:30 - 9:45 am	Plenary Session	*Chair: George Lee*
	• Report of group leaders on group issues and ideas	
	• Assignment of two new groups, primarily based on	
	- Structural / Non-Structural	
	- Social - Economic / Emergency management	
9:45 - 10:00 am	Break	
10:00 - 12:00 pm	Round table discussions of 2 groups	*Leaders: Ettouney, Nigg*
	• Possible conflicts of needs	
	• Possible integration ideas	
	• Skeleton of a position paper as an outcome of the discussion	
12:00 - 1:30 pm	Lunch Break	
1:30 - 3:00 pm	Plenary Session	*Co-Chairs: Ettouney, Nigg*
	• Presentation of discussion results by the two groups	
	• Systems Integration	
	• Shaping of the final report	
3:00 - 3:15 pm	Break	
3:15 - 4:00 pm	Continue the Plenary Session, with an emphasis on the completion of the workshop final report	
4:00 - 4:30 pm	Closure	*George Lee*

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Appendix B
Workshop Presentations

Overview
by George C. Lee

Nonstructural Systems Issues
by Mircea Grigoriu

Structural Systems Issues
by Mohammed Ettouney

Social, Economic and Political Issues
by Jerome Hauer

Emergency Management Issues
by Joanne Nigg

Overview

by George C. Lee

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Outline

- Introduction of MCEER
- Demonstration Project
- Workshop Objectives
- Workshop Focus
  - Research / Discipline matrix
- Workshop Format

Demonstration Project

- Develop Retrofit Strategies for a Critical Facility in NYC
  - A Hospital Complex
- Apply MCEER Research (advanced and emerging technologies) and Approach (systems integration)

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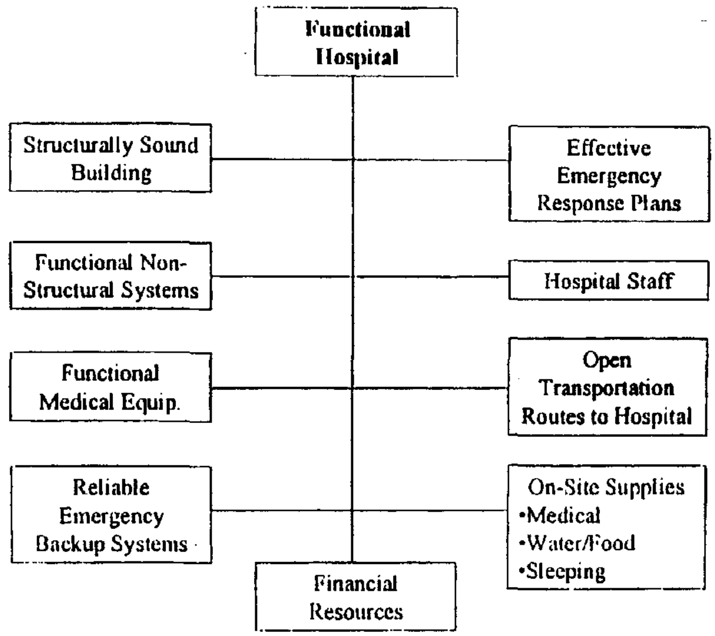
Workshop Objectives

- Develop an Action Plan
- Near term (3-4 years)
  - Road map for the Hospital Demonstration Project
- Long term
  - Blue print for Developing Guidelines for earthquake hazard mitigation of healthcare facilities

Workshop Focus

- Health care Facilities
  - Identify subsystems, their features and performance requirements
- Eastern United States
  - Use experience of California, and modify it for the Eastern US Application

Key Elements leading to Post-Earthquake Functionality



Potential Applications of Advanced Technologies

	Computation, Analysis, Simulation	Structural Control	Materials	Non-Destructive Evaluation	Decision Support Systems
Structural	H	H	H	H	M
Non-Structural	H	H	H	M	M
Social/Economic	M	L	L	L	H
Emergency Mgt.	M	L	L	L	H

L - Low potential for Application; M - Medium potential; H - High potential

Research Priorities

- Focus on those technologies that have a "high" potential for application.
- Early efforts should concentrate on quantifying the expected costs and benefits from these applications.
- Industry partnerships should be encouraged in several areas: a) technology developers, b) other research organizations, architects/engineers, and c) end-users.

Workshop Format

- 4 Groups:
  - Structural
  - Nonstructural
  - Social / Economic / Policy
  - Emergency Management
- Integration
  - The integration of activities

Nonstructural Systems Issues

by Mircea Grigoriu

Discipline: Nonstructural

- Role of Nonstructural Components
- Demonstration Project
- Special Features of Eastern U.S.
- Use of Innovative Technology
- Integration "hooks"
- Outcome

What Are Nonstructural Components?

- Not designed to contribute to structural strength
- Designed for specified features of facilities

Role of Nonstructural

- Importance of Continued Operations of Nonstructural Components
  - Architectural
  - Mechanical
  - Electrical
  - Operational (specific to health care)
  - Miscellaneous
- Performance Levels-Interaction with Structural Performance Levels
- Cost of Retrofit for Existing Facilities

Objectives of Demonstration Project

- Identification of Critical Nonstructural Components/Systems
  - Health Care Facilities (General)
  - Hospital
- Seismic Guidelines for Health Care Facilities
  - Design
  - Rehabilitation
- Case Study Hospital

Inventories of Nonstructural Components

- Nonstructural Components, Hospital
  - Architectural
  - Mechanical
  - Electrical
  - Furniture/Interior Equipment
- Other Nonstructural Components of Health Care Facilities
  - Operational
  - Miscellaneous

Vulnerability/Importance Matrix

Component Importance	Seismic Vulnerability		
	L (low)	M (medium)	H (high)
L			
M			
H			

Seismic Performance of Nonstructural Systems

- Fragility Information on Components
- System Configuration (Redundancy)
- Sensitivity of System Performance to
  - Seismic Vulnerability of Components
  - System Configuration
- Human Error
  - Analysis
  - Design

Demonstration Project

- Hospital
  - Generic Features as a Health Care Unit
  - Specific Features
- Other Needed Features
  - Other Types of Health Care Facilities
- Examples of Essential Units
  - Emergency
  - Surgery
  - Intensive Care

Special Features of Eastern U.S.

- Seismicity Issues
- Relative Adherence to a Seismic Provision
  - Nonstructural components, in general, do not / did not adhere to a seismic provision
- State of Mind

Use of Innovative Technologies

- Computational / Analysis / Simulation
  - Database Methods
  - Reliability Issues
    - Monte Carlo Simulation
    - Fragility Analysis
    - System Reliability
    - Sensitivity Analysis
- Control
  - Passive: Isolation Systems
  - Active

- Materials
- Non Destructive Evaluation
- Decision Support System
  - Types of equipment used

Integration Hooks

- Hooks with Structural
- Hooks with Other Nonstructural Components
- Hooks with Social / Economics
- Hooks with Emergency Management

Outcome

- Use of Specific Technologies
- Different Requirements for Healthcare Facilities
  - General Methods
  - Specific Design Solutions for the Hospital

Handout for Nonstructural Components

- Demonstration Project - Or Hypothetical Situation
- Round Table - Discussions
- Round Table - Integration "hooks"
- Round Table - Resolutions

Demonstration Project

- Description of the Hospital
  - Main features: Structural, nonstructural, social / economic and emergency
  - Specific features, if any
    - Being a hospital?
- Other needed Features to make the Workshop General?
  - Discuss with panel

What Are Nonstructural Components?

- Not designed to contribute to structural strength
- Designed for specified features of facilities

Nonstructural Components in the Hospital

- Architectural Components
  - Exterior wall elements
  - Partitions
  - Interior veneers
  - Ceilings
  - Parapets and appendages
  - Canopies and marquees
  - Chimneys and stacks

Nonstructural Components in the Hospital (cont.)

- Mechanical and Plumbing Components
  - Mechanical equipment
  - Storage vessels and water heaters
  - High pressure piping
  - Fire suppression piping
  - Hazardous material
  - Ductwork

Nonstructural Components in the Hospital (cont.)

- Electrical and Communications Components
- Furniture and Interior Equipment
  - Storage racks
  - Bookcases
  - Computer access floors
  - Hazardous materials storage
  - Computer and communication racks
  - Elevators
  - Conveyors

Other Nonstructural Components in Health Care Facilities

Round Table Discussions - General

- If you are responsible for mitigation of seismic hazards, given:
  - Eastern US, and
  - the five technological fields of MCEER,

- ***What would you like to do for this project?***

Instruction to the table moderator:

- Give the previous question, and the two next template pages to each member in the table, and ask them to think about it for 15 minutes, and fill the two next pages

Ideas of each table member - 1

- Specifics of Eastern US
- New Technologies for Nonstructural Components in Hospitals
- System Reliability

Ideas of each table member - 2

- Type of Research
- Type of Management
- Applicability of New Technologies
- Implementation of New Technologies
- Possible Conflicts / Impediments
- Research Topics Prioritization

Vulnerability/Importance Matrix

Component Importance	Seismic Vulnerability		
	L (low)	M (medium)	H (high)
L			
M			
H			

Round Table Discussions - Integration

- How would you envision the different integration avenues with other disciplines?
- What would you like to see done to improve this integration?

Instruction to the table moderator:

- Give the previous question, and the next template page to each member in the table, and ask them to think about it for 10 minutes, and fill the next page

Ideas of each table member

- Integration with *Structures*
- Integration with other *Nonstructural Components*
- Integration with *Social / Economic*
- Integration with *Emergency Management*

Round Table Discussions - Resolution

- How would you envision the long term road map for healthcare seismic mitigation guideline?

Instruction to the table moderator:

- Give the previous question, and the next template page to each member in the table, and ask them to think about it for 10 minutes, and fill the next page
- Consider the two templates as a starting point for discussions. Add, correct, modify, etc. the items of this template

Ideas of each table member

- Scope
- Enforcement
- Users
- Importance / Necessity

Structural Systems Issues

by Mohammed Ettouney

Discipline: Structural Engineering

- Role of Structural Engineering
- Demonstration Project
- Special Features of Eastern U.S.
- Use of Innovative Technology
- Integration "hooks"
- Outcome

Role of Structural Engineering

- Importance of "safe" structural system
- Performance levels
- Cost of retrofit

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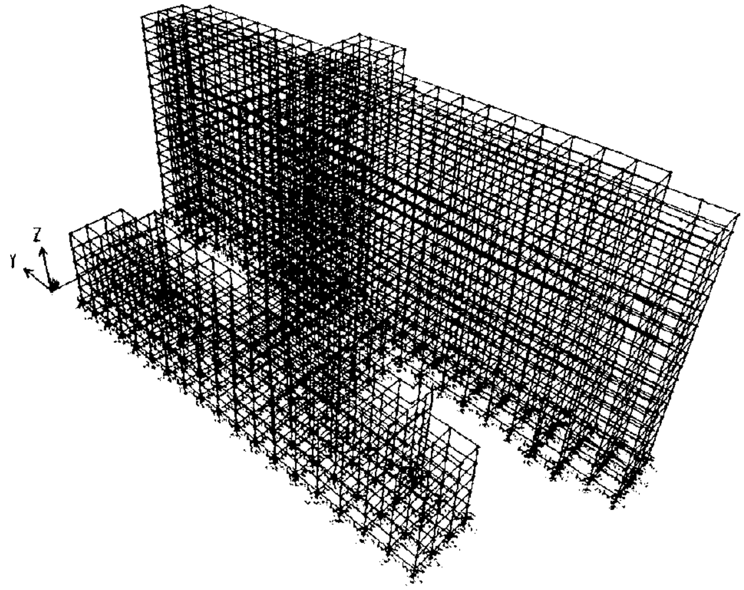
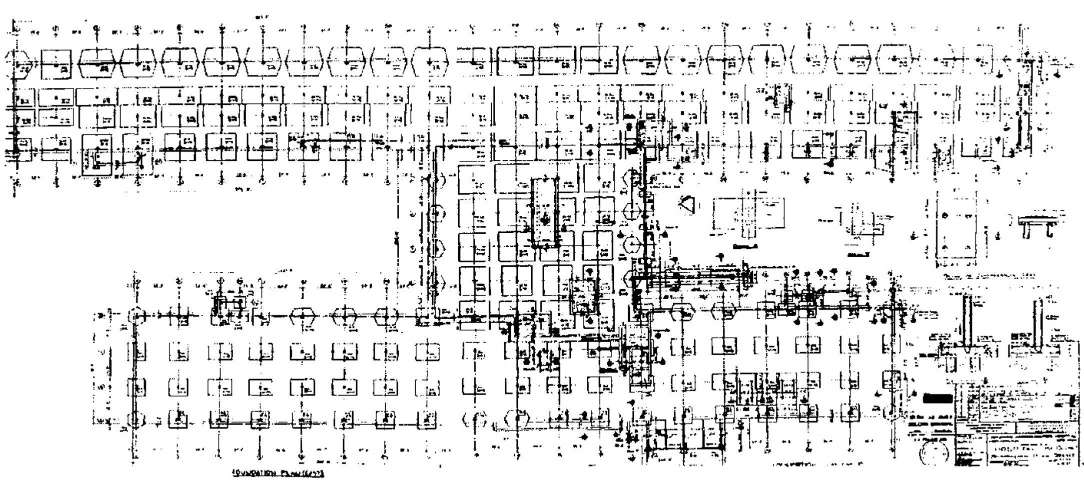
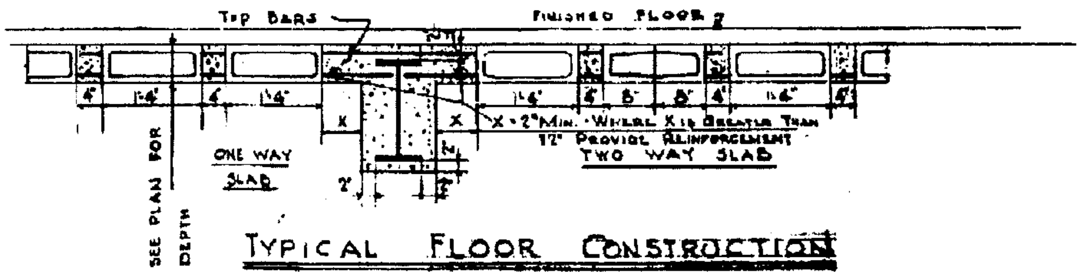


Isometric View of Analytical Model



Pile Cap Detail



Special Features of Eastern U.S.

- Seismicity issues

Use of innovative Technologies 1/2

- Computational / Analysis / Simulation
  - Advanced nonlinear analysis
  - Reliability issues
  - etc
- Control
  - Passive: isolation systems
  - Active

Use of innovative Technologies 2/2

- Materials
  - Fiber Reinforced Plastics (FRP)
- Non Destructive Evaluation
  - Damage detection
- Decision Support System

Integration Hooks

- Hooks with nonstructural
- Hooks with Social / Economics
- Hooks with Emergency Management

Outcome

- Short Term
  - Use of specific technologies
  - Different requirements for healthcare facilities
- Long Term
  - Design charter specific for healthcare facilities?

Structural Engineering Group

- Main items for discussions
  - Demonstration Project Discussions
  - Round Table - Location / Technology
  - Round Table - Integration "hooks"
  - Round Table - Resolutions
- Any other important items?

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Demonstration Project - 1

- VA Hospital - Brooklyn NYC
  - Built around 1947
  - Steel moment resisting Frame
  - about 20 stories - Long natural period
  - Pile foundations
  - In-fill walls
  - Interaction with non-structural components
  - Code application experiences

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Demonstration Project - 2

- Other needed Features to make the Workshop / Case study General?
  - Materials?
  - Structural Systems?
  - Other?

- Discuss important and healthcare specific structural engineering features

Demonstration Project - 3

- Important Healthcare Structural Engineering Features

- Any other important points/thoughts?

Round Table Discussions - Location / Technology

- If you are responsible for mitigation of seismic hazards, given:
  - Eastern US, and
  - the five technological fields of MCEER,
- What would you like to do for this project (Case study and/or added/needed features)?
- Keep in mind specific needs for healthcare facilities

10/27,28/1998 MCEER Workshop - Structural Engineering Group

Instruction to the table moderator:

- Give the previous question, and the two next template pages to each member in the table, and ask them to think about it for 15 minutes, and fill the two next pages

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Ideas of each table member - 1

- Specifics of Eastern US
  - Healthcare facilities specific?
- New Technologies use for Hospital

Ideas of each table member - 2

- Type of research
- Type of Management
- Applicability of new technologies
- Implementation of new Technologies
- Possible conflicts / Impediments
- Research topics prioritization

MCEER Technological Matrix

- Identify possible entries in the matrix

Discipline	Computations Analysis Simulation	Control: Active / Passive	Exotic / New Materials	Non Destructive Evaluation	Decision Support System
Structural					
Non-Structural					
Social / Economic					
Emergency Management					
Integration of Disciplines					

Round Table Discussions - Integration

- How would you envision the different integration avenues with other disciplines?

- What would you like to see done to improve this integration?

Instruction to the table moderator:

- Give the previous question, and the next template page to each member in the tabel, and ask them to think about it for 10 minutes, and fill the next page

Ideas of each table member

- Integration with *nonstructural components*
  - Possible Conflicts
- Integration with *Social / Economic*
  - Performance measures
  - Performance levels
  - Other
- Integration with *Emergency Management*
  - Redundancy of systems?

Round Table Discussions - Resolution

- How would you envision the long term road map for healthcare seismic mitigation guideline?

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Instruction to the table moderator:

- Give the previous question, and the next template page to each member in the tabel, and ask them to think about it for 10 minutes, and fill the next page

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Ideas of each table member

- Scope
- Enforcement
- Users
- Importance / Necessity

Social, Economic and Political Issues

by Jerome Hauer

Workshop on the use of Innovative Technologies for Seismic Hazard Mitigation of Health Care Facilities in the Northeast U.S.

October 27,1998

Mayor's Office of Emergency Management

Rudolph W. Giuliani, Mayor

Jerome M. Hauer, Director

Health Care Facilities

Definition

- *hospitals*
- *clinics*
- *H.M.O.s*
- *nursing homes*
- *skilled nursing facilities*
- *dialysis centers*
- *pharmacies*
- *physicians' offices*
- *EMS stations*
  - *city*
  - *hospital*
  - *commercial*
  - *volunteer*

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Hospitals

Key to the Health Care System

Hospitals

- 78 Hospitals
  - *59 "911 Receiving Hospitals"*
- Well-known to community
- Provide the widest variety of services
- Legally and morally required to treat everyone who presents for treatment

Hospitals
The Challenges

- Complicated facilities
  - single hospital may have multiple buildings of varying ages and construction types
- Complicated Infrastructure
  - medical gases
  - pneumatic tube systems
  - specialized equipment, *e.g.* cardiac telemetry

Hospitals
The Challenges

- Special Hazards
  - large amounts of chemicals
  - biological hazards
  - radiation hazards
  - compressed gases
    - *air*
    - *oxygen*
    - *nitrous oxide*

Hospitals

3 Objectives post-event

#1

Maintain service to current in-patients

- Hospitals can not abandon their patients and must continue to provide care
- Hospital may need to arrange for a safe, orderly evacuation

Hospitals

3 Objectives post-event

#2

Provide Emergency treatment for incident victims

- Hospitals are required to provide care to all who present for emergency care
- Hospitals will not have time to recoup: victims will soon begin to show-up

Hospitals

3 Objectives post-event

#3

Provide supportive care for chronic medical conditions

- Private physicians, clinics, and pharmacies may not be available
- Patients will present to hospitals for assistance with non-emergencies

Emergency Management

Emergency Management

- The principles of Emergency Management can be used by hospitals to limit the impact of a seismic event
- Emergency Management is more concerned with the process than "the toys"
  - new technologies, while useful, are not the most important answer
  - planning, mitigation, preparedness, exercises, *etc.*

Emergency Management

Assessment

- What are the critical systems of a hospital?
  - structural
  - non-structural/support services
    - laboratories, telecommunications, computers, materials management, laundry, food, *etc.*
- What would be the effects of a seismic event?
  - can the systems withstand the event?
  - can the systems quickly recover?
  - would the systems fail? If so, what then?

Emergency Management

New York City Initiatives

- Terrorism preparedness
  - generally improves disaster response
- Coastal Storm planning
  - specifically examined regional health care coordination
- Expanded Health and Medical role in the new Emergency Operations Center (EOC)

Conclusions

- Many types of Health Care Facilities
- Hospitals are the focus of health care
- Hospitals may be the only health care providers functional after a seismic event
- Emergency Management is more interested in the process rather than specific items

Emergency Management Issues

by Joanne Nigg

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ROUNDTABLE DISCUSSIONS:
SOCIAL, ECONOMIC, AND POLICY PERSPECTIVES

ASSUMPTIONS:

- YOU ARE RESPONSIBLE FOR A HEALTH CARE FACILITY OR THE COMMUNITY IN WHICH SUCH FACILITIES EXIST
- THIS FACILITY IS IN THE EASTERN U.S.
- YOU ARE AWARE OF THE SEISMIC HAZARD IN THE AREA

TASK:

- HOW WOULD YOU BEGIN TO APPROACH THIS ISSUE?

ADOPTION/IMPLEMENTATION QUESTIONS

1. WHAT INFORMATION DO YOU NEED ABOUT:

- THE HAZARD/RISK IN THIS AREA?
- RETROFIT TECHNIQUES - STRUCTURAL AND NONSTRUCTURAL?
- DESIRED PERFORMANCE LEVELS?
- COSTS ASSOCIATED WITH ALTERNATIVES?

2. WHAT CONSTITUENCIES MIGHT SUPPORT OR OPPOSE THIS MEASURES?

3. WHAT LEGAL OR REGULATORY IMPEDIMENTS/INCENTIVES FOR TAKING SUCH ACTIONS NOW EXIST? COULD EXIST?

4. WHAT FINANCIAL IMPEDIMENTS/INCENTIVES FOR TAKING SUCH ACTIONS NOW EXIST? COULD EXIST?

5. WHAT TYPES OF NEW OR EMERGENCY TECHNOLOGIES OR APPROACHES COULD BE APPLIED TO LESSENING EARTHQUAKE VULNERABILITY IN HEALTH CARE FACILITIES?

RESEARCH QUESTIONS

GENERAL QUESTION:

WHAT TYPE OF RESEARCH DO WE NEED TO BE ABLE TO LESSEN THE VULNERABILITY OF HEALTH CARE FACILITIES IN THE EASTERN U.S.?

SOCIAL RESEARCH NEEDS:

ECONOMIC RESEARCH NEEDS:

POLICY RESEARCH NEEDS:

ROUNDTABLE DISCUSSION ON INTEGRATION

GENERAL QUESTIONS:

- WHAT MECHANISMS EXIST TO INTEGRATE THE FOUR DIFFERENT MCEER EMPHASES FOR THIS PROJECT - STRUCTURAL ENGINEERING, NONSTRUCTURAL ENGINEERING, SOCIAL/ECONOMIC/POLICY SCIENCES, AND EMERGENCY MANAGEMENT?
- WHAT IMPROVEMENTS COULD BE MADE TO THE INTEGRATION PROCESS?

FROM THE PERSPECTIVE OF THE SOCIAL/ECONOMIC/POLICY SCIENCES, HOW CAN INTEGRATION TAKE PLACE WITH:

- STRUCTURAL ENGINEERING?
- NONSTRUCTURAL ENGINEERING?
- EMERGENCY MANAGEMENT?

ROUNDTABLE DISCUSSION ON FUTURE DIRECTIONS FOR MCEER

GENERAL QUESTION:

WHAT LONG-TERM STRATEGIES OR RESEARCH AGENDAS SHOULD GUIDE MCEER'S EFFORTS ON SEISMIC VULNERABILITY REDUCTION FOR HEALTH CARE FACILITIES?

SPECIFIC QUESTIONS:

- WHAT SHOULD BE THE MAJOR DIMENSIONS OF THE MCEER PROGRAM BE?
- WHO IS (ARE) THE PRIMARY AUDIENCE (OR AUDIENCES) IF UTILIZATION AND IMPLEMENTATION OF EARTHQUAKE RISK AND LOSS REDUCTION STRATEGIES ARE TO BE TAKEN?
- WHAT TOOLS/TECHNIQUES/TECHNOLOGIES/STRATEGIES/ APPROACHES SEEM TO BE MOST IMPORTANT IF THIS EFFORT IS TO SUCCEED?

Appendix C

Survey of Nonstructural Elements in Hospitals

by Mircea Grigoriu

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Survey of Nonstructural Elements in Hospital Buildings

Mircea Grigoriu
Cornell University

C.1 Architectural Components

The architectural components can be divided into eight categories as follows: exterior wall elements, partitions, interior veneers, ceilings, parapets and appendages, canopies and marquees, chimneys and stacks, and stairs and enclosures.

Exterior Wall Elements: A typical building might have three types of exterior wall elements. The exterior façade is called glazed brick and is within the category of anchored veneer. Anchored veneer includes masonry or stone units that are attached to the supporting structure by mechanical means. The façade is not in good condition as cracks have formed in the parapets.

The building has sunshades to lessen the heat directed on the windows. These shades are prefabricated panels. Prefabricated panels should be installed with adequate structural strength within themselves and their connections to resist wind, seismic, and other forces. The sunshades are not in good condition as they have already begun to fail.

The main entrance to the hospital is structural glazing. This falls under the category of glazing systems which consist of assemblies of walls that are made up from structural sub-frames attached to the main structure. The dimensions of the structural glazing are 70 feet wide by about 30 feet high. It begins at the second floor level and extends upward the 30 feet from there.

Partitions: The second category of the architectural components is partitions. Partitions are vertical, non-load-bearing interior elements that provide space division. The hospital has partitions that can be classified as either heavy or light. Heavy partitions are constructed of masonry materials while light partitions are constructed of metal or wood studs surfaced with lath and plaster and are less than five pounds per square foot.

All of the building's interior corridors have heavy partitions made of glazed block, which is at least 6" thick, up to four feet and then plaster. The core area walls are metal panels on the passenger elevator side and glazed block on the service elevator side. The plaza corridor walls are also glazed block. All of the replacement walls, which account for 20~25% of the total, are sheet rock.

The light partitions are located between rooms. Half of them are metal frame and half are plaster.

Interior Veneers: The third category of the architectural components is interior veneers. Interior veneers are thin decorative-finish materials applied to interior walls and partitions. The bathrooms, soil utility rooms, and clean utility rooms all have ceramic tile on the walls. The main lobby has a 4000 square foot terrazzo (marble) floor. Note that the *Guidelines* requirements apply only to veneers mounted 4 feet or more above the floor.

Ceilings: Ceilings can be broken down into four categories as specified by *Guidelines*.

Parapets and Appendages: Parapets and appendages include exterior nonstructural features that project above or away from a building. The hospital has parapets on the entire roof, none of which is in good condition. They are cracked at the corners and have deteriorated bricks. The sunshades that were mentioned above could also be placed in this category.

Canopies and Marquees: The building does not have any marquees, or freestanding structures. It does have aluminum canopies that were added to the back of the building. The sunshades that were mentioned above could also be placed in this category.

Chimneys and Stacks: The building does not have any chimneys, but there are exhaust stacks on top of the existing fans at the ends of the tower and the center of the core. There are 30 fans throughout the building, 80% of which are without a stack. The stacks are 10 feet high, constructed from aluminum, and are in good condition. They are currently strapped with cables and are accessible.

Stairs: The building has four outside staircases and two inside staircases. The inside staircases are located on the north and south sides of the core surrounded by concrete block walls. The stairs have concrete steps and are in good condition.

C.2 Mechanical and Plumbing Components

The mechanical and plumbing components can be divided into six categories as follows: mechanical equipment, storage vessels and water heaters, high pressure piping, fire suppression piping, hazardous materials, and ductwork.

Mechanical Equipment: The mechanical equipment consists of boilers, furnaces, and the HVAC system equipment. The boilers and furnaces are not located inside the building and are therefore not applicable for this analysis. The HVAC system equipment can be divided into vibration isolated, non-vibration isolated, and mounted in-line with the ductwork.

All of the HVAC system equipment within the building can be classified as vibration isolated or mounted in-line with the ductwork. The building has 30 exhaust fans and 30 air handling units that are designated as vibration-isolated. They sit on a concrete pad measuring 4'-6" in thickness. Neoprene and occasionally springs are also positioned under the machines. The fans are located on the 17^{th} floor attic in the south and on the 5^{th} floor in the north. The weight of the units varies from 1000 lbs. to 10000 lbs. They can all be considered to be in good condition.

The building also has three return fans that are mounted in-line with the ductwork. They are located on the 2nd and 3rd floors in the south and weigh approximately 150~200 lbs. each.

Storage Vessels and Water Heaters: Vessels that contain fluids used for building operation can be classified in one of two categories. Legs support category 1 vessels, while category 2 vessels have a flat bottom and are supported by the floor, roof, or a structural platform.

Two hot water tanks in the basement of the south side fall into category 1. They are sitting on a preformed concrete base. The tanks are 10' long and measure 6' in diameter and hold between 2000~3000 gallons of water. One 500-gallon steam flash tank also fits in this category. The tank is 4' long and measures 3' in diameter.

Three steel water tanks encased in brick structures, which are located at the very top of the building, are classified as category 2 vessels. Two of the tanks hold 22,000 gallons of water, while the last one holds 18,000 gallons. All of the vessels are 6.5' high.

High Pressure Piping: This category includes all piping that carries fluids which, in their vapor stage, exhibit a pressure of 15 psi, gauge, or higher. This does not include fire suppression piping. The building has steam and water pipes that fall under this category.

Steam piping, with a pressure of 120 psi, is carried from outside of the building to the basement on the north and south sides through a 6" pipe. The length of the pipes is equal to the length of the building (800'). The pipes are suspended 3' below the ceiling and are supported every 15'. The steam pipes also have an expansion joint.

The water pipe also comes from outside of the building. It is an 8" pipe with a length equal to the height of the building plus 200'. The pipe is mounted with clamps to the plumber shaft.

Fire Suppression Piping: Fire suppression piping includes fire sprinkler piping consisting of main risers and laterals. The main risers are 6" in the main core of the building and 4" in the stairs. They are pressurized to 120 lbs. The laterals are 3"~4". The piping is suspended 1' @ 15' span.

Hazardous Material: The building contains piping that carries oxygen. Oxygen falls under the heading of hazardous material because it is extremely flammable. The pipes are 2 $^{1}/_{2}$" in diameter and made out of copper. They have silver slotted (or soldered) joints.

Ductwork: Ductwork is located in central corridors throughout the building. There is approximately 2~3 ducts in each corridor. They have a square cross section of 30" wide by 18" deep. They are located 12" from the ceilings and are supported by metal rods @ 20'.

C.3 Electrical and Communications Components

The only electrical components of note in the building are the transformers and switch-gear. These components are mostly located in the basement. The transformers are 1500 lbs. each. They are sitting in the basement and are on slab on grade without any pads. The switch-gear is sitting on a raised floor and is also 1500 lbs. There are also 12~15 panels that weigh 1000 lbs. each.

C.4 Furniture and Interior Equipment

These include, but not limited to

- Storage racks
- Bookcases
- Computer Access Floors
- Hazardous Materials Storage
- Computer and Communication Racks
- Elevators
- Conveyors

Surveying these items is not available at this time

Appendix D

Social, Economic and Policy Issues Associated with Health Care Facilities

by Joanne Nigg

Social, Economic and Policy Issues Associated with Health Care Facilities

Joanne M. Nigg
Disaster Research Center
University of Delaware

Health care facilities, especially hospitals and their emergency departments, are very critical community resources during and immediately following disaster events. The ability of hospitals to continue to function in such situations is crucial for reducing life loss and shortening periods of convalescence for the injured. Surprisingly, there has been very little social science research on the preparedness of health care facilities for disasters or on how the operations of such facilities are affected by disaster events. To date, almost no research has been undertaken on how hospital administrators make decisions about strengthening or rehabilitating their facilities to withstand disaster impacts. When earthquake events are considered as a subset of the disaster field, these studies are even fewer in number.

This presentation focuses on the types of research issues social scientists have addressed concerning health care facilities (particularly hospitals); and suggests issues that should be considered in the development of a research strategy for the rehabilitation of a New York hospital, one of MCEER's demonstration projects.

D.1 Research Issues Studied

The social science research of health care facilities can be categorized in three areas – non-damaged hospitals as resources in community disaster response; problems in disaster-impacted hospitals; and hospital disaster planning.

D.1.1 Non-damaged Hospitals as Community Resources

Research has been undertaken both at the system level–that is, at a multi-hospital response in a disaster-impacted community–and at the organizational level–that is, at a single hospital's role in disaster response. Issues studied in relation to how several hospitals respond to the same event include: an analysis of the delivery of emergency medical services (EMS) throughout an affected community or region; modes of casualty transportation; how communication and coordination between hospitals and other community response organizations was organized; and how new technologies (e.g., GIS) have been used to track the distribution of hospital resources and casualties. In the few cases that a single case study was conducted of a specific hospital's response to a disaster, five issues have been investigated: decisions on locating emergency intake; the development of triage systems; various staffing problems that arose (e.g., the convergence of volunteers, both trained and untrained, and the utilization of off-duty personnel); decision making criteria for discharging existing patients to accommodate disaster victims; and an inventory of the types of injuries presented at emergency departments.

D.1.2 Problems in Damaged Hospitals

Research of disaster-impacted hospitals has almost exclusively focused on the types of problems damaged hospitals confronted and the strategies they employed to overcome these problems. Four of the research topics addressed include: problems resulting from and adaptations to the loss of electrical power; decisions concerning the release and/or transport of patients to other facilities; evacuation strategies; and social psychological issues that arose when staff and patients had to be evacuated.

D.1.3 Disaster Planning

Although disaster planning is prevalent in hospitals across the country, very little research has been done to assess the types of planning that have taken place and to evaluate the success of these plans when hospitals experience a disaster. Most of the work to date has been prescriptive, providing information of how to prepare health care facilities for a disaster, with very little analysis of what this planning process has yielded.

D.1.4 Limitations of the Research

The limitations of the topics studied are many, especially when considering earthquake impacts on hospitals. First, there has been a dearth of research in this area; there have been no replications or longitudinal studies on hospitals in disaster situations. Second, the topics reviewed above are for all types of disaster agents, not just earthquakes. Third, what earthquake research has been conducted on health care facilities has taken place in California. Fourth, there has been no research on the social economic or policy issues related to pre-disaster mitigation of health care facilities; all work to date has concentrated on the response period (and, to a much lesser extent, on preparedness).

D.2 Social Science Issues Related to the Hospital Demonstration Project

D.2.1 A Federal Hospital vs. a Community-Based Hospital

It has been proposed that MCEER focus its demonstration project efforts on a Veterans' Administration facility in the New York area. Good access had been developed to a structural seismic engineering analysis of such a facility; and it was hoped that sufficient rapport could be developed with the hospital's administration to allow for further analytic work to take place on the nonstructural systems of the facility, thereby providing a facility for which new technologies, materials, and designs could be tested to strengthen the structure's seismic resistance.

From a social science perspective, however, a federal hospital has limited generalizability, as an organization, to other types of hospitals. Primarily, a hospital constitutes a vital element of a community's infrastructure resources, both during normal times as well as in a disaster situation. While both a publicly owned hospital as well as a private or community hospital may both perform similar types of functions during routine times, they do not in a disaster. For example, both types of hospitals may provide primary and secondary medical care, include specialty departments (e.g., oncology units), have a teaching or research function, provide out-patient services and non-acute are, and have extended care facilities. In many cases, publicly owned hospitals also have special services that few other community-based hospitals support such as: surgical ambulatory care centers; geriatric evaluations units; behavioral health management units; home-based primary care units; and homeless outreach services. While both may even have emergency departments, a VA hospital would not routinely provide assistance to disaster victims from the local area, as would a community-based hospital with an emergency department. A publicly owned hospital has a specific mission to provide medical care to veterans and their families, not to be a primary medical resources for other citizens.

Publicly owned hospitals are not profit-motivated as are some community-based hospitals, but must operate within Congressional budget limitations. publicly owned hospitals, as federal facilities, are like any other type of federal building and must comply with the Presidential Executive Order that requires all federally owned or leased buildings to incorporate seismic design techniques appropriate for the regional hazard, a requirement that other hospitals may not have to meet (depending on the state and local building codes in their communities).

From a social science perspective, federal health care facilities do not perform the same disaster functions nor do they have to comply with similar federal requirements as community-based hospitals. They do not have the same relationship to local emergency management planning efforts; they do not have the same need to coordinate with EMS resources; and they fall under different regulatory requirements with respect to seismic design. Therefore, while such facilities would be an interesting subset of hospital facilities to investigate, community-based hospitals with disaster responsibilities constitute a wider category of medical facilities with broader implications for community disaster planning.

D.2.2 Differences from California Hospitals

Most of the earthquake research on hospitals has been conducted in California since this is where the vast majority of recent damaging earthquakes in the United States has occurred.. However, a New York-based facility would be an extremely challenging research focus because of the difference in the earthquake "climate" in the two states.
A repeated theme in this workshop has been that perceptions of the earthquake threat are low in New York. This is not only true among the general public, but among key decisionmakers as well: facility owners and managers; engineers; and elected and appointed public officials. Perhaps because of a lack of direct experience with earthquake events in the state, building codes for health care facilities in the state (and, by extension, in any major cities) have not included seismic provisions.

Even in California which has had a great deal of recent experience with damaging earthquakes, it is difficult to encourage seismic retrofit and rehabilitation because the benefits of loss reduction efforts are often not clear or well understood. In jurisdictions, such as New York City, these benefits might be even more illusive since the City has had relatively little experience with large-scale disasters of any type in the recent past. However, the high density of the City–both in terms of people and structures–increases the vulnerability of the City to any type of disaster.

A decision to focus exclusively on a hospital in New York is extremely challenging because of the perception that an earthquake, especially a damaging one, is highly unlikely. Given this situation, it might be advisable for social scientists to study community-based hospitals in areas exposed to different levels of seismic hazard and risk. Given this approach, the objective of the research would be to identify the factors that constituted both barriers and incentives to hospital administrators to consider and to implement rehabilitation efforts in their facilities.

D.3 Factors Affecting a Decision to Undertake Seismic Rehabilitation

There is almost no literature on the decisionmaking process of facility owners/managers/ administrators to undertake rehabilitation strategies (regardless of the type of facility). A preliminary review of the existing literature on the more general topic of mitigation decisionmaking identified some categories of factors that might be included in a study of hospital administrators regarding rehabilitation decisionmaking.

Four **social factors** include: perceived need (that is, a threat exists and something needs to be done); anticipated collateral benefits (that is, by undertaking rehabilitation, the facility will benefit in other ways); the local capability of design professionals and the construction trades in seismic design; and the existence of local "champions" (someone who will advocate socially and politically for seismic mitigation).

Economic factors have been largely unexplored. However, it is fairly clear that without an emergency or regulatory requirement, costs for rehabilitation must be perceived as "acceptable" for a desired level of post-impact performance. The whole area of performance- based design posits that different levels of functionality can be attained, but costs will increase for higher levels of desired performance. Empirically, however, there has been no research on what acceptable costs are for the different levels of functionality; nor on what elements of a facility are perceived by a hospital administrator to be critical to a hospital's functioning.

Five **policy factors** will also be important to investigate: the identification of the linkage of seismic mitigation to other social needs and issues (the so-called "collateral benefits" for the facility as a community resource); the perception, held by key elected and appointed officials, of the public's belief in the local seismic risk and the need to reduce it; whether voluntary or mandatory compliance provide a better (or more socially acceptable) mechanism for reducing vulnerability; the identification of creative revenue sources for mitigation; and the identification of governmental incentives (not necessarily just financial) for mitigation.

These factors will need to be further refined and others may need to be added before a study can be undertaken to understand how social, economic, and policy factors actually influence the adoption of seismic retrofit/rehabilitation measures for private, public, and non-profit hospitals, especially those that are not in California.

However, it will be crucial for social scientists and engineering researchers to work cooperatively, in a coordinated fashion for this objective to be achieved. Engineers must identify the new technologies, materials, and design approaches that could lead to the reduction of seismic vulnerability in hospitals; but this can not be done in a vacuum. Engineers must know what nonstructural systems or what units in a hospital are critical to the functionality of the facility and what level of performance administrators expect before they can develop cost-effective strategies for these facilities. And, the types of strategies, may very well be related to factors that engineers typically do not address–patterns in the health care industry that are driving certain cost-saving measures; strategic planning outcomes; local seismic hazard levels; other, more pressing, hazard concerns (such as terrorist attacks); or public expectations of availability of medical care. From this perspective, the hospital demonstration project provides a good vehicle for a multi-disciplinary effort to address rehabilitation issues associated with a critical community facility.

Multidisciplinary Center for Earthquake Engineering Research
List of Technical Reports

The Multidisciplinary Center for Earthquake Engineering Research (MCEER) publishes technical reports on a variety of subjects related to earthquake engineering written by authors funded through MCEER. These reports are available from both MCEER Publications and the National Technical Information Service (NTIS). Requests for reports should be directed to MCEER Publications, Multidisciplinary Center for Earthquake Engineering Research, State University of New York at Buffalo, Red Jacket Quadrangle, Buffalo, New York 14261. Reports can also be requested through NTIS, 5285 Port Royal Road, Springfield, Virginia 22161. NTIS accession numbers are shown in parenthesis, if available.

NCEER-87-0001 "First-Year Program in Research, Education and Technology Transfer," 3/5/87, (PB88-134275, A04, MF-A01).

NCEER-87-0002 "Experimental Evaluation of Instantaneous Optimal Algorithms for Structural Control," by R.C. Lin, T.T. Soong and A.M. Reinhorn, 4/20/87, (PB88-134341, A04, MF-A01).

NCEER-87-0003 "Experimentation Using the Earthquake Simulation Facilities at University at Buffalo," by A.M. Reinhorn and R.L. Ketter, to be published.

NCEER-87-0004 "The System Characteristics and Performance of a Shaking Table," by J.S. Hwang, K.C. Chang and G.C. Lee, 6/1/87, (PB88-134259, A03, MF-A01). This report is available only through NTIS (see address given above).

NCEER-87-0005 "A Finite Element Formulation for Nonlinear Viscoplastic Material Using a Q Model," by O. Gyebi and G. Dasgupta, 11/2/87, (PB88-213764, A08, MF-A01).

NCEER-87-0006 "Symbolic Manipulation Program (SMP) - Algebraic Codes for Two and Three Dimensional Finite Element Formulations," by X. Lee and G. Dasgupta, 11/9/87, (PB88-218522, A05, MF-A01).

NCEER-87-0007 "Instantaneous Optimal Control Laws for Tall Buildings Under Seismic Excitations," by J.N. Yang, A. Akbarpour and P. Ghaemmaghami, 6/10/87, (PB88-134333, A06, MF-A01). This report is only available through NTIS (see address given above).

NCEER-87-0008 "IDARC: Inelastic Damage Analysis of Reinforced Concrete Frame - Shear-Wall Structures," by Y.J. Park, A.M. Reinhorn and S.K. Kunnath, 7/20/87, (PB88-134325, A09, MF-A01). This report is only available through NTIS (see address given above).

NCEER-87-0009 "Liquefaction Potential for New York State: A Preliminary Report on Sites in Manhattan and Buffalo," by M. Budhu, V. Vijayakumar, R.F. Giese and L. Baumgras, 8/31/87, (PB88-163704, A03, MF-A01). This report is available only through NTIS (see address given above).

NCEER-87-0010 "Vertical and Torsional Vibration of Foundations in Inhomogeneous Media," by A.S. Veletsos and K.W. Dotson, 6/1/87, (PB88-134291, A03, MF-A01). This report is only available through NTIS (see address given above).

NCEER-87-0011 "Seismic Probabilistic Risk Assessment and Seismic Margins Studies for Nuclear Power Plants," by Howard H.M. Hwang, 6/15/87, (PB88-134267, A03, MF-A01). This report is only available through NTIS (see address given above).

NCEER-87-0012 "Parametric Studies of Frequency Response of Secondary Systems Under Ground-Acceleration Excitations," by Y. Yong and Y.K. Lin, 6/10/87, (PB88-134309, A03, MF-A01). This report is only available through NTIS (see address given above).

NCEER-87-0013 "Frequency Response of Secondary Systems Under Seismic Excitation," by J.A. HoLung, J. Cai and Y.K. Lin, 7/31/87, (PB88-134317, A05, MF-A01). This report is only available through NTIS (see address given above).

NCEER-87-0014 "Modelling Earthquake Ground Motions in Seismically Active Regions Using Parametric Time Series Methods," by G.W. Ellis and A.S. Cakmak, 8/25/87, (PB88-134283, A08, MF-A01). This report is only available through NTIS (see address given above).

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