



SMIS-EERI WORKSHOP ON SAFE HOSPITAL UNDER NATURAL HAZARDS

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ABSTRACT

Hospitals are highly vulnerable to the action of destructive natural phenomena. A hospital facility is a highly complex system that requires a sound structural system, and undamaged non-structural systems and contents to remain operational. Because the highly complex and refined operation of a hospital demands safety and order, the design of healthcare facilities demands careful consideration of the seismic performance of all their subsystems. This paper presents a summary of the proceedings of the first SMIS-EERI Workshop on Safe Hospital under Natural Hazards. Many of the issues found relevant by a multidisciplinary panel to achieve the concept of Safe Hospital are discussed. There are many challenges that need to be met before the concept of Safe Hospital is achievable. Although some of these challenges are technical in nature, many of them have significant social and economical connotation, so that a multidisciplinary effort is needed to address them. International cooperation provides an ideal setting to achieve progress in this direction.

Background

The *Sociedad Mexicana de Ingeniería Sísmica* (SMIS) and the *Earthquake Engineering Research Institute* (EERI) agreed, during the 100th Anniversary Earthquake Conference Commemorating the 1906 San Francisco Earthquake (April, 2006), to interact through joint research projects and activities that are focused on reducing the levels of seismic risk in Mexico and the U.S. As a first step, both professional associations agreed to co-organize a multidisciplinary workshop on the topic of healthcare facilities. The objectives were to identify opportunities for cooperation, and to establish a common agenda for the reduction of the vulnerability of the health infrastructure in both countries.

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The main objective of the workshop was to discuss, within a multidisciplinary setting, the actual safety of healthcare facilities during the occurrence of natural hazards, such as earthquakes and hurricanes, in order to formulate a common research agenda that can lead to short and long-term mitigation measures on both sides of the border.

Other objectives of the workshop were:

- To establish a closer professional relationship between SMIS and EERI
- To identify professionals and institutions in both countries that may be interested in participating in the SMIS-EERI research agenda for Safe Hospitals
- To identify professionals and institutions that may provide information that may further the SMIS-EERI agenda
- To identify the interest of government agencies on both sides of the border vis-a-vis the SMIS-EERI agenda

The participants that attended the first SMIS-EERI Workshop on Safe Hospital under Natural Hazards are listed in Table 1.

Program

The SMIS-EERI Workshop on Safe Hospital under Natural Hazards had six sessions. The objective of the first session, entitled *Current Situation and Challenges*, was to identify the issues involved in the design of essential structures subjected to natural phenomena, and to provide, from the perspective of the Pan-American Health Organization (*PAHO*), an initial diagnosis on its Safe Hospital Program.

The second section, entitled *Vulnerability and Seismic Risk*, addressed the performance of Mexican and Californian hospitals during past seismic events. The adequacy of current design laws for healthcare infrastructure to protect hospitals and their contents from excessive structural and non-structural damage was discussed. Also, the considerations that must be taken into account to establish the vulnerability of hospitals, including socio-economic issues, were discussed.

During the third section, entitled *Implications of the Concept of Safe Hospital*, several participants discussed, from a profession-based perspective, the concept of safe hospital. Among other things, the minimum operation requirements for healthcare facilities after suffering an intense seismic event were discussed, as well as everyday operation requirements in hospitals, and their implications regarding structural rehabilitation.

The fourth session, entitled *the Role of Structural Engineers*, addressed the issue of how structural engineers can make possible the concept of safe hospital. Issues that arise during the rehabilitation of existing healthcare facilities were discussed, as well as the role of innovation in terms of design methodologies, structural systems and education.

The fifth session, entitled *The Commitment of Authorities*, discussed the actions that

authorities should promote to realize the concept of safe hospital. The California regulatory process was discussed, and possible improvements identified. Socio-economic issues were also addressed.

Finally, the sixth session, entitled *Conclusions*, integrated the views of the participants, and provided general themes for a common research/work agenda.

Table 1. First SMIS-EERI Workshop on Safe Hospital under Natural Hazards, participants.

Participant	Position	Institution
James Jirsa	Professor	University of Texas at Austin
Mary Comerio	Chair/Professor	Department of Architecture, UC Berkeley
Ricardo Guzmán	Supervising Structural Engineer	WILLDAN
Gilberto Mosqueda	Professor	University at Buffalo
Eduardo Miranda	Professor	Stanford University
Jay Love	Senior Principal S. E.	Degenkolb
Carlos Villalva	Executive Architect	San Francisco General Hospital
Sergio Alcocer	Professor	Universidad Nacional Autónoma de México
Roberto Meli	Professor	Universidad Nacional Autónoma de México
Mario Ordaz	Professor	Universidad Nacional Autónoma de México
Eduardo Reinoso	Professor/President	Universidad Nacional Autónoma de México/ Sociedad Mexicana de Ingeniería Sísmica
Sonia Ruiz	Professor	Universidad Nacional Autónoma de México
Luis Esteva	Professor	Universidad Nacional Autónoma de México
Arturo Tena	Professor	Universidad Autónoma Metropolitana
Amador Terán	Professor	Universidad Autónoma Metropolitana
Sergio Puente	Professor	El Colegio de México
Salvador Duarte	Professor/President	Universidad Autónoma Metropolitana/Sociedad Mexicana de Arquitectos Especializados en Salud
Felipe Cruz	Director of the Division of Support during Disasters	Instituto Mexicano del Seguro Social
Guillherme Franco Netto	Health Consultant	Organización Panamericana de la Salud
Ferdinand Recio	President/Director	Asociación Mexicana de Hospitales/Coordinación General de Protección Civil
Horst Agata	Director	GenRE Corporation

Summary

Current situation and challenges

According to *PAHO* Safe Hospital can be defined as a “*healthcare facility whose services remain accessible and operating at full installed capacity within its own infrastructure, immediately after the occurrence of destructive phenomena of natural origin.*”

The objectives of a national Safe Hospital Program should be:

- 1) Develop national policies and regulations for safe hospitals.

- 2) Protect the life of occupants, the investment and function of all new health facilities and those identified as having priority within the health service network.
- 3) Systemize and permanently track the implementation of national and international policies and regulations.

PAHO considers that a country can reduce the vulnerability of hospitals and achieve the concept of Safe Hospital if political will exists (in spite of technical or economical constraints), and that mitigation costs are reduced almost to zero for new structures.

Vulnerability and Seismic Risk

Because of their geographical location, the health infrastructure of Mexico and California is vulnerable to the action of multiple natural hazards, including earthquakes and hurricanes.

A hospital facility is a highly complex system that requires a sound structural system, undamaged non-structural systems and operational contents to remain fully operational. Because the highly complex and refined operation of a hospital demands safety and order, the design of healthcare facilities demands careful consideration of the seismic performance of all their subsystems.

Large social and economic losses are associated with damage to and operational interruption of healthcare facilities. A large percentage of losses are not direct costs. Care should be exercised when assessing the nature and magnitude of losses. Among the costs that cannot be ignored are: a) socio-economic impact of operational losses; and B) closure.

Heavy structural damage to healthcare infrastructure occurred as a consequence of the 1971 San Fernando Earthquake. Collapses were observed in modern healthcare facilities. As a consequence, the regulatory process for design and construction of hospitals in California was changed to require an independent revision for the design and construction of healthcare facilities. From a structural point of view, an importance factor larger than one was introduced in the design process to increase the structural safety of healthcare facilities through an increment in the design lateral forces. Twenty three years later during the 1994 Northridge Earthquake, large epicentral acceleration pulses resulted in total loss of operations in several healthcare facilities. Although changes in the regulatory process after San Fernando resulted in enhanced structural performance, heavy damage was observed in non-structural elements and contents. Emphasis after Northridge has been placed on the design and detailing of anchorages and close supervision during construction.

During the various seismic events that have occurred in recent decades, extensive structural, non-structural and content damage has been observed in the Mexican healthcare infrastructure. Although damage tends to concentrate in sub-urban clinics, spectacular collapses of large hospitals occurred during the 1985 Michoacán Earthquake. In fact, a large percentage of the total loss associated with that earthquake has been attributed to the extensive damage observed in its educational and healthcare infrastructure. Although the Mexican Building Codes have incorporated the use of an importance factor to improve structural safety, no specific

measures have been directed towards the improvement of nonstructural and content performance.

From the experiences of both, California and Mexico, it can be said that progress has been achieved, particularly on terms of structural performance. Nevertheless, several measures still need to be carried out to achieve the concept of safe hospital in both locations. Among them:

- 1) Diagnosis/Identification of the most vulnerable facilities (structural, non-structural and contents performance should be accounted for).
- 2) Initiation/Continuation of mitigation efforts.
- 3) Certification of healthcare infrastructure.
- 4) Elaboration of specific performance-based design guidelines for hospitals.

A real understanding of the issues that need to be addressed to achieve the concept of safe hospital requires a multidisciplinary approach. Any framework formulated to address such issues requires a full understanding of the potential losses, the cost/benefit balance of the different risk mitigation options, and strategic planning that accounts for socio-economic needs and possibilities.

Concept of Safe Hospital

There have been several initiatives worldwide that promote the achievement of the concept of Safe Hospital, particularly in developing nations. Important initiatives in this direction were the 2004 *PAHO Safe Hospital Initiative* and the 2005 *World Conference on Disaster Reduction*, promoted by the General Assembly of the United Nations. Mexico has committed itself to have its healthcare infrastructure comply with the concept of Safe Hospital by the year 2015. Of forty high complexity healthcare facilities of the Mexican Institute of Social Security, seventy percent can be found in high risk zones. Fifty percent of its two hundred and twenty medium complexity health care facilities are similarly located.

A Mexican multidisciplinary group involving different institutions was organized since 1999 to formulate goals and certification procedures. In spite of political support, the Mexican plan seems unrealistic and lacking focus when contrasted to the Californian experience. Particularly, three and a half decades after initiating a similar initiative, Californians have realized the complexity of the task. Costs and times to achieve goals have been considerably greater than initially expected. Several Mexican and American experts in the panel pointed out that the Mexican Safe Hospital initiative reflect a lack of understanding of the dimension of the problem, and thus its goals seem unrealistic. While the Mexican authorities need to understand some key issues offered by the California experience, feedback of Mexican and Californian structural engineers and architects to the current Safe Hospital initiative is needed.

The concept of safe hospital has different connotations to different professions. Specialists from diverse background can contribute key elements to such concept. There is consensus that there are two criteria that a safe hospital should meet after intense loading: 1) Immediate Operation and 2) Overall Safety. Nevertheless, several issues arise when an attempt is

made to define the minimum and ideal conditions to achieve the criteria. For example, it was suggested by several specialists that a healthcare facility needs to be fully operational after a major seismic event. In contrast, some studies carried out in California suggest that only 20% of the equipment in a facility is essential to deal with an emergency situation. Mitigation costs could be reduced considerably if attention is concentrated on critical hospitals and critical areas within healthcare facilities. Regarding overall safety, focus should be extended to include the need to actively isolate some physical spaces from strangers, and provide passive protection to installations (e.g., control of infectious materials). It was concluded that there are problems of definition and purpose around the concept of safe hospital. Particularly, there is need to establish:

- 1) Minimum structural, non-structural and content performance requirements.
- 2) Performance-based evaluation and design procedures
- 3) Cost/Benefit guidelines
- 4) Diagnosis and certification procedures

These needs are particularly critical for the seismic rehabilitation of existing hospitals. The extra cost and effort that needs to be invested in case of a new facility is relatively low.

The Role of Structural Engineers

There are several tools developed recently by the structural engineering profession that aid in the execution of the concept of Safe Hospital. The design approach for an existing and new facility is fairly different. In the case of structural rehabilitation, there are many limitations to the structural project, especially with respect to interruption of the optimum functions in the building.

In the structural design, there is a need to acknowledge that a health facility is a complex system that involves several subsystems (structural, non-structural and contents). Damage control in the different subsystems requires specific performance criteria. While displacement control is required in terms of adequate structural and nonstructural performance, velocity and acceleration control is required to ensure adequate content performance. Rational damage control associated with different design objectives or limit states requires the formulation of performance-based design methodologies, the harmonization of design actions in structural and mechanical systems, and response control through the implementation of innovative structural systems (e.g., base isolation).

The use of innovative design methodologies and structural systems must be based on:

- 1) Understanding the socio-economic consequences derived from selection of such systems for rehabilitation of an existing facility. Innovation may be reflected in longer duration of the structural project and delay the completion of the project.
- 2) Clear definition of the design objectives in general terms for healthcare facilities, and in specific terms for a particular hospital.

- 3) Harmonization of the design objectives of the different subsystems (structural, nonstructural and contents).

Relatively simple methodologies can be used to evaluate the expected dynamic response of a building subjected to postulated seismic events. The use of such methods should be contemplated to complement the methodologies currently used during the diagnosis of an existing healthcare facility. Estimates of expected displacement, velocity and acceleration demands at the story level need to be used to characterize the expected performance of the different subsystems within the facility.

Care should be exercised when using anchoring devices to promote damage control in nonstructural systems and contents. Although held in place by the anchors, some contents (e.g. highly refined and delicate medical equipment) are susceptible to incorrect operation and damage due to high acceleration pulses. There is a need for experimental studies on the dynamic response of contents and for the elaboration of design guidelines for them. In the case of Mexico, there is a need to develop and implement low cost base isolation and energy dissipating systems.

The Commitment of Authorities

There have been positive and negative experiences around the regulation process that California established for its hospitals in 1973. On one hand, structural performance of healthcare facilities has improved dramatically. On the other, not all the actual results of the application of the regulation were expected; particularly costs and execution times have been larger than first thought. Experience has resulted in new laws complementing the original ones and in extension of some deadlines. A key issue when formulating regulations is the understanding of changes that healthcare may undergo during the time horizon initially contemplated. Therefore, the law should be formulated in flexible terms without renouncing its original purpose.

Because of the complexity inherent to healthcare infrastructure, Mexico needs to formulate specific design and construction code for hospitals, and to develop tools to accomplish full compliance. While the design code should be developed around a performance-based format, the California model can be used as a basis in terms of compliance.

Authorities need to engage the safe hospital initiative at different levels. Besides the technical issues, the socio-demographic vulnerability should be assessed and reduced. There are under-used national and international funds that may be available for risk mitigation. New financing schemes should be developed. It is important to understand that the specialists of different disciplines (engineers, physicians, architects, sociologists, insurers, etc.) are tied together by a common goal: loss minimization. The integrated work of specialists requires the elaboration of procedures to allow:

- 1) Identification of the specialist's capacity
- 2) Definition of the quality of the project
- 3) Definition of the amount of work involved in the project

- 4) Integration and presentation of the project information

An opportunity for international cooperation

In the short term, Mexico and the U.S. need to make a joint, concerted effort to establish proper channels of communication with regulatory authorities, health planners, and electrical/mechanical engineers.

In the medium and long term, joint research should be carried out around specific topics:

- 1) Experimental studies and development of guidelines for contents.
- 2) Implication of the use of Importance factors.
- 3) Development of performance-based design formats.

Conclusion

There are many challenges that need to be met before the concept of Safe Hospital is achievable. Although some of these challenges have a technical nature, many of them have social and economical connotations. A multi-disciplinary effort will be essential for addressing the challenges. International cooperation provides an ideal setting to achieve progress in this direction.