The Seismic Safety Program for Hospital Buildings in California

Part 2:
The Seismic Retrofit Program for Existing California Hospitals

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1. INTRODUCTION

The need for functioning hospitals after a major earthquake is obvious and rarely disputed. While emergency field hospitals, medical tents, and air-lifts to available facilities are often used to supplement for damaged hospitals, they will never provide a sufficient substitute. Only modern health care facilities, located within the damaged region and capable of functioning at full capacity can adequately provide the needed medical assistance.

The 1971 San Fernando earthquake brought government officials, design professionals and health care providers in California to this recognition. As a result, the Legislature passed the first Hospital Seismic Safety Act in 1972. Since March 7, 1973, the design, construction and maintenance of California's hospitals has been governed by special statutes, regulations and design standards aimed at assuring hospital functionality following a major earthquake. The standards are intended to ensure that vulnerable patients are safe in an earthquake, and the facilities remain functional after such a disaster in order to care for injured persons in the community. These standards are implemented by California's Office of Statewide Health Planning and Development (OSHPD) and include stringent seismic design requirements, extensive plan review, approval of all designs, continuous construction inspection, thorough materials testing, and strict monitoring of all remodel projects.

All hospitals either new or remodel or additions in California designed after 1973 have been built under these stringent requirements. To date, the performance of these facilities has been excellent though it must be recognized that none have experienced their maximum credible earthquake.

The 1972 Seismic Safety Act as originally proposed called for the immediate strengthening or replacement of all hospital buildings that did not meet the modern standards. However, it was quickly realized that this was an economic impossibility. The proposed law was changed to apply only to new hospital buildings and existing hospital buildings undergoing substantial structural remodel or expansion and, therefore, all hospitals licensed at the time were "grandfathered" in – that is, they were not required to meet the new statewide standards. The intent was to bring any building whose useful life was being extended by a modernization program up to the modern seismic standards. However, the rate of retrofitting or replacing pre-73 hospital buildings was much too slow. The unexpected result has been to maintain the existing facilities as they are and build new facilities as needed.

Fig. 1: St. John's Hospital damaged in the 1994 Northridge earthquake.

In the January of 1994 Northridge Earthquake, several of these older hospitals sustained significant damage. Hospitals built in accordance with the standards of the Seismic Safety Act resisted the Northridge earthquake with minimal structural damage, while several facilities built prior to the act experienced major structural damage and had to be evacuated. It must be noted that certain nonstructural components of the hospitals did incur damage, even in facilities built in accordance with the structural provisions of the Seismic Safety Act (Table 1).

Table 1: Performance of all hospital buildings in the Northridge Earthquake at 23 hospital sites with one or more yellow or red tagged buildings.

Type of Damage	**Number (%) of Buildings**	
	Pre Act	**Post Act**
Structural Damage		
Red tagged	12 (24%)	0 (0%)
Yellow tagged	17 (33%)	1 (3%)
Green tagged	22 (43%)	30 (97%)
Nonstructural Damage		
Major	31 (61%)	7(23%)
Minor	20 (39%)	24(77%)
Total Buildings	51	31

The lessons from the Northridge Earthquake clearly showed that the majority of California's hospitals located in regions of highest seismicity do not comply with the new "functionality" standards and their expected performance during a major earthquake varies from moderate damage to complete collapse. The California Legislature clearly understood that a program was needed to require hospitals to improve the seismic resistance of their existing buildings in a phased and prioritized manner with the ultimate goal of full strengthening or replacement. The legislative response was SB 1953, which required that all hospitals meet statewide seismic safety standards.

2. POLICIES TO IMPROVE THE SEISMIC PERFORMANCE OF EXISTING HOSPITAL BUILDINGS

Seismic hazards mitigation/reduction programs may be quantified in two distinct categories - those that are *required* (mandatory) and those that are *voluntary* (non-mandatory). A *"voluntary"* program is guided by the building owner's non-mandatory actions to reduce seismic hazards. The *"required"* program has a building owner meeting specific government standards (e.g. building code). Such requirements may be either active or passive within existing statutes, regulations or building standards.

Passive requirements are those which mandate seismic hazard reduction only when a "trigger" (predefined change in existing condition) is activated by the building owner. *Passive* requirements to improve existing buildings incorporate limits on remodeling or alterations beyond which seismic upgrade is required. These limits can be tied to structural alteration, nonstructural remodeling, or the cost of a given improvement project.

An *Active* requirement is one that requires either reduction of seismic hazards for specific buildings, categories of buildings or elements. *Active* requirements use government mandated deadlines to force seismic strengthening by given dates in order to improve the seismic performance of existing buildings.

Since early 1973 the California Building Code (CBC) has specified triggers tied to improvements that are related to structural conditions. The CBC also incorporated provisions for voluntary seismic upgrade of hospital buildings. The structural triggers specified in the CBC are extensive and detailed. They have been based on reductions in lateral force capacity or increases in story mass. They are divided into three categories:

1. Incidental structural alterations, repairs or additions;
2. Minor structural alterations, repairs or additions; and,
3. Major structural alterations, repairs or additions

The incidental category requires only consideration of the alteration and local elements, the minor requires overall structural conformance with force levels of 50% of new buildings, and the major requires full conformance with the code.

Passive triggers in the California Building Code have been ineffective because the triggers can be avoided, and a limit was not placed on nonstuctural alterations allowing hospitals to install costly medical upgrades in existing buildings without overall seismic performance considerations. The voluntary seismic upgrade provisions were taken advantage of only a few times.

In the aftermath of the Northridge earthquake it was recognized that the process in place was inadequate to improve or replace the aging hospital building stock. It was time for active requirements to be utilized in order to fulfill the mandates of the seismic safety act. On September 22, 1994 California passed SB 1953 which requires all hospital buildings provide life-safety to their occupants by the year 2008 and by 2030 to be able to provide continuous operations and acute care medical services after a major earthquake.

3. A RATIONAL AND REALISTIC SOLUTION TO THE SEISMIC HAZARD MITIGATION PROBLEM FOR HOSPITAL BUILDINGS: PRIORITIZED MITIGATION AND REPLACEMENT

A rational and realistic program to improve the seismic resistance of existing hospital buildings based on the success of partial mitigation efforts in previous earthquakes should be phased and implemented over an extended period of time (be cost effective). It should take into account modernization needs of existing hospitals and be prioritized in a manner that yields the maximum protection possible with each step. The principal steps are to develop:

1. An earthquake preparedness plan;
2. Determine the seismic deficiencies of each hospital building;
3. Mitigate those nonstructural items that are required for a safe and orderly evacuation of the building as well as those required for maintaining the *critical* functions of the hospital for patient care;
4. Determine a level of structural strengthening based on life-safety concerns and the economic benefits, schedule the structural strengthening at a time that other collateral deficiencies can be corrected; and
5. Correct the deficiencies in the architectural systems and finishes to be upgraded within the normal remodel process.

A complete earthquake preparedness program should include a variety of disaster plans, an emergency communications network, and training programs for administrative and medical staff. To be successful, the program needs to be developed in conjunction with the users and implemented regularly. The training component should include specific information related to the expected seismic performance of the facilities and include appropriate criteria for immediate evacuation.

A complete seismic assessment of all hospital buildings should be conducted to determine the deficiencies of the various components in terms of life-safety and functionality. Life-safety should be the minimum seismic performance standard that concentrates solely on the safety of the patients and staff during a major earthquake and their ability to exit afterwards. The assessment for life-safety should concentrate on the structural system and any non-structural elements that could be considered as falling hazards. Functionality needs to be judged based on the modern design standards with the expectation that all buildings, systems, and equipment will be operational after a major earthquake. Each of these assessments will result in a list of deficiencies related to life safety concerns, and additional items related to functional concerns. These lists will form the basis of the long-term mitigation program.

An independent retrofit program should be developed and implemented to anchor and brace all mechanical, electrical and medical equipment, major piping systems and all building contents. The program should include procedures for properly anchoring and bracing all new systems and equipment, and include annual inspections to verify that the program is being effectively maintained. This activity will substantially improve the ability of an existing non-conforming hospital building to remain functional after a moderate or greater earthquake.

The evaluation and strengthening of the structural systems should be addressed apart from the other mitigation activities. Buildings should be considered in order of their life-safety concerns with the most dangerous building evaluated and strengthened first. All buildings should be at least strengthened to the point that they are considered to be "life-safe" given the largest expected earthquake. It has been shown in every earthquake that loss of life from building failures is not acceptable. The decision to strengthen a building beyond life safety, in an effort to achieve operational performance (functionality), should be a cost-based decision. Consideration needs to be given to the present and future costs related to various strengthening options beyond life-safety. These include:

1. Strengthen to a life-safety level and plan to repair after each major earthquake.
2. Strengthen to a full functional level to avoid the cost of substantial repairs after a major earthquake.
3. Replace the entire facility.

There are a number of methodologies currently available that direct the evaluation of existing facilities for life-safety concerns. One of these is FEMA 178: NEHRP Handbook for the Seismic Evaluation of Existing Buildings (FEMA 1992). This methodology is based on the actual behavior of buildings in major earthquakes and results in a list of potential "weak-links" that could lead to life-safety concerns.

A life-safety concern is a condition in which the failure of a building or building component could lead to loss of life, injury to the point of immobilization, or entrapment.

Buildings judged to meet the FEMA 178 criteria are expected to provide adequate protection for their occupants and allow their egress after the earthquake. No consideration is given to the use or repair of the building after the earthquake. In most cases, buildings that barely meet this life-safety standard are expected to be unusable after a major earthquake.

All hospital buildings should be evaluated for life-safety concerns. Buildings failing to meet this standard should be given first priority for additional evaluation and strengthening. This group of buildings should be followed by those that meet the basic life-safety requirements but not the continuous operation requirements of the modern design standards.

At least two strengthening schemes should be developed conceptually for buildings with life-safety concerns. The first, a minimal strengthening scheme that corrects the deficiencies just to the point of meeting the life-safety standard. The second level should be a solution that brings the building into substantial conformance with the modern standards for continuous operation.

4. SB 1953 - THE SEISMIC RETROFIT PROGRAM FOR CALIFORNIA HOSPITALS

SB 1953 was introduced on February 25, 1994. It was signed into law on September 21, 1994 and became effective on September 22, 1994. The bill was an amendment of the Hospital Seismic Safety Act (HSSA) of 1983. There are approximately 470 general acute care hospital facilities in the State of California comprised of 2,673 hospital buildings that will be impacted by the provisions of SB 1953.
The specific provisions of the SB 1953 statutory language requires the OSHPD to develop definitions of earthquake performance categories in conjunction with seismic evaluation and retrofit procedures for general acute care hospital facilities within California. The regulations developed as a result of this legislation became effective on March 18, 1998.

The implementation of the bill is phased:

1. By January 1, 2001, all hospitals must complete and submit to OSHPD a seismic assessment of each building in which acute inpatient care is provided and if the buildings do not meet current standards a plan for achieving compliance must also be presented (e.g., taking the building out of inpatient service, seismic retrofitting, or demolition and reconstruction) (Figure 2).

2. By January 1, 2002 all acute inpatient hospitals must meet minimum equipment anchorage standards (affecting, for example, communications systems, emergency power, medical gas systems, and fire suppression systems) (Figure 2).

3. By January 1, 2008, all acute inpatient hospital buildings which, according to the assessment, pose a significant risk of collapse in an earthquake must be

taken out of service (Figure 2).

4. By January 1, 2030, all acute inpatient hospital buildings must meet standards designed to assure that they will remain operational after an earthquake (Figure 2).

As stated earlier, hospitals built in accordance with the standards of the HSSA resisted the January 1994 Northridge earthquake with minimal structural damage while several facilities built prior to the act experienced major structural damage and had to be evacuated. However, certain nonstructural components of the hospitals did incur damage, even in facilities built in accordance with the structural provisions of the HSSA. The provisions of SB 1953 and subsequent regulations were developed to address the issues of survivability of both nonstructural and structural components of hospital buildings after a seismic event.

SB 1953 required the OSHPD to consult with the Hospital Building Safety Board (HBSB) to identify the most critical non-structural systems and prioritize the timeframes for upgrading these systems. The HBSB is an advisory board, appointed by the Director of OSHPD, and made up of Architects, Structural Engineers, hospital representatives and public members. They are experts in the design, construction and operation of hospital buildings. The Board's collective expertise was vital to the completion of the regulations by the deadlines established in SB 1953.

The regulations were developed in two stages. The first step in the retrofit program is the seismic evaluation of individual buildings. The evaluation places each building in a Structural Performance Category (SPC), and a Nonstructural Performance Category (NPC). There are five levels of each. The combined SPC and NPC rating of a building formulates it's overall seismic performance category, SPC/NPC.

There are two methods which can be used to determine the SPC and NPC of a building.

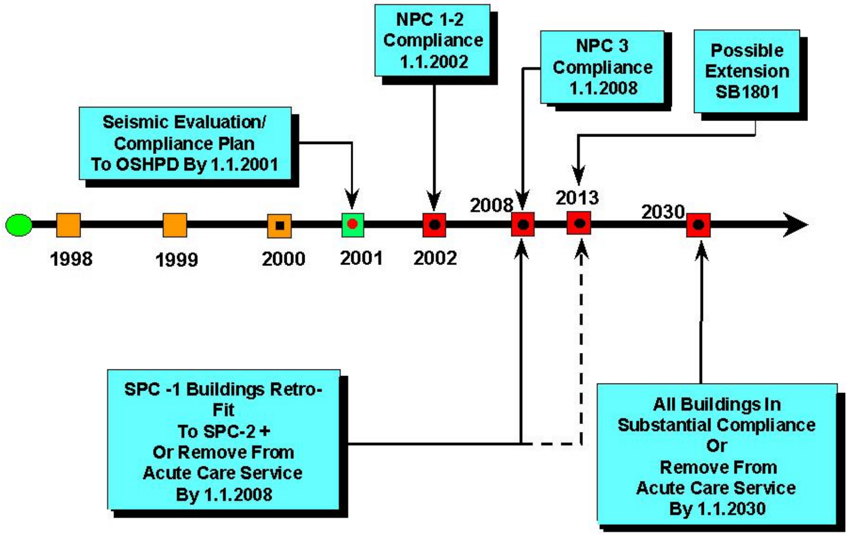

Fig. 2: SB 1953 Major Milestones

The first is a rapid evaluation process described in regulation. The second is an alternative analysis allowing the design professional to utilize all of the factors associated with the buildings lateral force resisting system to the hospital's advantage. Because hospital buildings are found in areas of different seismic risk, the alternative analysis provides for the use of site specific ground motion data. This will generally result in lower seismic forces and less need for retrofitting.

Once the appropriate category is established, the hospitals must develop a plan for compliance which is presented to the office in the form of a bar graph. The bar graph will depict the time allowed for each step necessary to comply with the dates set in both law and regulation.

The second stage of regulations development was to specify how to accomplish a retrofit. As with the evaluation, both a prescriptive method and an alternative method are established. The prescriptive method often referred to as method A defines each step to be followed as designing a retrofit solution. Under Method B, the alternative method, the design professional is allowed to be creative and use all of the state of the art tools of structural engineering to obtain compliance with the desired structural and non-structural performance category. This promises to be innovative, difficult and challenging.

The timelines are established in the law. OSHPD and the HBSB created the SPC and NPC based on a philosophy expressed in the law. Clearly, buildings which represent a "potential risk of collapse or pose a significant loss of life" are to be closed, retrofitted, or removed from acute care use by January 1, 2008. It is expected that during the years 2008 to 2030 a number of hospital buildings may be heavily damaged and non-functional as a result of earthquakes, but will not collapse. A category for non-structural compliance, (NPC-2) which preserves the systems deemed necessary for evacuation, was established with a January 1, 2002 deadline. In this case, the building may have partially collapsed and those systems need to be reasonably available to keep people alive and aid evacuation. The systems are communications, bulk medical gas, emergency power, and fire alarms.

In addition to preventing building collapse by January 1, 2008, there are additional non-structural system requirements which also must be met by 2008. These items are found in the California Building Code. No new items were created. In keeping with the philosophy of preventing loss of life, it was felt that persons undergoing invasive procedures should have some confidence in the reliability of the physical plant. Therefore, the systems serving defined Critical Care Areas within the hospital must be retrofitted by 2008. Preliminary estimates indicate that this requirement effects between 15% - 30% of the square footage of the hospital.

There is a provision in the law which allows delays in compliance with the 2008 deadline. The provision says, "A delay in this deadline may be granted by the office upon a demonstration by the owner that compliance will result in a loss of health care capacity that may not be provided by other general acute care hospitals within a reasonable proximity". This has been further defined in regulations to be a maximum of five years, in one-year increments.

The final steps occur between years 2008 and 2030. The law requires the buildings to be in substantial compliance with the Act by January 1, 2030. During this 22 year period, retrofitting and new construction will occur to reach substantial compliance while the buildings housing patients will at least not collapse and the systems serving critical care will function.

Since the inception of SB 1953, it has been understood that this is a huge financial as well as physical undertaking.

While working with the HBSB in developing the regulations for the seismic retrofit program considered the financial impact of each provision very carefully . As a group of experts keenly aware of the cost of retrofitting OSHPD attempted to require only the absolute minimum and give as much flexibility as possible for compliance.

5. THE SEISMIC EVALUATION PROCEDURE

OSHPD utilized as a source document *FEMA 178: NEHRP Handbook for the Seismic Evaluation of Existing Buildings* (FEMA 1992) to develop the seismic evaluation methodology for existing hospital buildings currently specified in the regulations of the

California Building Code.

The seismic evaluation procedure regulations consist of eleven articles. The primary purpose of these regulations is to evaluate the potential earthquake performance of a building or building components and to place the building into specified seismic performance categories. The evaluation procedures were developed from experience gained in evaluating and seismically retrofitting deficient buildings in areas of high seismicity. These evaluation statements should be used with engineering judgment and the current building codes as a guide. The methodology provided in the seismic evaluation identifies potential "weak links" as stated earlier that could lead to life safety concerns in the event of a major earthquake. This life safety performance level defined in FEMA 178 is stated as follows:

A building does not meet the life-safety objective of this handbook if in an earthquake the entire building collapses, portions of the building collapse, components of the building fail or fall, or exit and entry routes are blocked, preventing the evacuation and rescue of occupants.

The seismic evaluation in the California Building Code, as in FEMA 178, does not predict the level of damage that a building might experience nor is it satisfactory for determining if a building will remain operational. The evaluation methodology recognizes that successful structural performance is based on having a complete lateral force resisting system that has sufficient strength and ductility. The ductility is manifested in the manner in which the building has been detailed. Because it applies to existing buildings, the evaluation methodology provides a significant amount of instruction on how to deal with buildings that are not detailed in a manner consistent with the current code. Fundamentally, the evaluation methodology permits the code requirements for ductility to be superseded by extra strength.

The seismic evaluation procedure utilizes a series of true/ false statements to identify potential weak links in buildings. For each of the statements, procedures are suggested for doing detailed evaluations to determine if these potential-weak links are, in fact, sources of life-safety concern.

The building evaluation process begins with a site visit and the gathering of all information that is needed to do a seismic evaluation. This is followed by selecting the appropriate model building type and set of evaluation statements for the initial screening. Based on the available information, each evaluation statement is considered and answered either true of false. A true answer implies that the potential weak link is not a concern. A false statement implies that the potential weak link needs further evaluation. Following the first level evaluation, the engineer is encouraged to return to the site and gather additional information necessary to carry out the detailed evaluation of potential weak links. The seismic evaluation allows a number of different types of analysis for evaluating potential weak links. The engineer is given complete latitude to select an appropriate evaluation technique and advised to consider the result of the final evaluation in terms of the overall performance of the building.

5.1 Ground Motion Requirements

The ground motion criteria for the seismic evaluation of existing hospital buildings are defined by acceleration coefficients (as a measure of ground shaking level), the site coefficient (to account for the effects of local soil profile) and an elastic response spectrum to represent the change in acceleration with the predominant period of the ground motion.

As in FEMA 178, two parameters are used to characterize the intensity of the ground shaking. These parameters are known as the effective peak acceleration (EPA), A_a, and the effective peak velocity-related acceleration (EPV), A_v. The lower limit for both acceleration coefficients is set at 0.2g.

The methodology used for evaluation of existing buildings in FEMA 178 establishes seismic forces that are lower than those prescribed by the seismic design criteria for new buildings for the following reasons:

1. Buildings should be substantially below the current standards before triggering the requirement for a seismic upgrade; and,

2. A higher level of earthquake damage is acceptable in an existing building

The same concept has been maintained also in the evaluation criteria for existing hospital buildings. This is accomplished by modifying the spectral amplification factors for the ground acceleration and velocity to 85 percent and 67 percent respectively to represent mean values.

Where advanced analysis procedures are utilized for seismic evaluation of existing hospital buildings the ground motion representation shall be elastic response spectra or time histories developed for mean values for the specific site, in accordance with the procedures specified by Title 24.

5. CONCLUSION

Past earthquakes have clearly demonstrated the vulnerability of existing hospitals in major earthquakes and their unquestioned need thereafter. The repair and retrofit of hospital buildings requires determination of structural and non-structural deficiencies that exist, and effective methodologies for mitigating these deficiencies to preserve the usability of the hospital.

A hospital building that does not meet modern standards does not constitute an undependable structure. Even the most deficient buildings can be life-safe for lower intensity events. Partial mitigation and strengthening programs have been shown to be quite effective and can provide the basis for a realistic strengthening program.

OSHPD has developed a rational and realistic program to improve the seismic resistance of existing hospital buildings tailored after the success of mitigation efforts in past earthquakes. The principal steps are as follows:

1. Short term:
   a. Determine the seismic deficiencies of the each hospital building in terms of the structure, all systems, equipment and contents.
   b. Mitigate all non-structural deficiencies that can assure the safe and orderly evacuation of the hospital building as soon as possible.
   c. Determine a level of structural strengthening based on life-safety concerns and the economic benefits. Recognize that it may be economically beneficial to strengthen the structure to only the life-safety level and plan to use temporary facilities during the repair period after a major earthquake.

2. Intermediate term:
   a. Replace the hospital building or strengthen the structural system of the existing hospital building at least to the life safety performance level for an intermediate period in time. Schedule corrections to other collateral deficiencies to take place at the time of the structural strengthening in order to minimize construction impact.
   b. Anchor and brace the nonstructural components and systems (mechanical, electrical, medical, equipment, major piping and building contents) required for maintaining critical functions of the hospital for patient care (critical care areas).

3. Long term:
   a. Correct deficiencies in the architectural systems and finishes during the normal remodel process.
   b. Anchor and brace all mechanical, electrical, medical, equipment, major piping and all building contents to the requirements of modern building standards for the operational performance level.
   c. Replace the hospital building or Strengthen the structural system of the existing hospital building to meet substantial compliance with modern building standards (operational performance level).

In summary, it is postulated that SB1953 and the regulatory framework established to accomplish compliance is a reasonable and rational approach to necessary seismic retrofit. The seismic retrofit program as designed preserves as much flexibility to the process as can be possible.

6. REFERENCES

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