BACKGROUND AND HISTORY OF THE SEISMIC HOSPITAL PROGRAM IN CALIFORNIA

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INTRODUCTION

The program that controls seismic protection of hospitals in California is the result of gradual evolution of seismic awareness in the state, punctuated by recurring earthquakes. Although the state suffered several earthquakes prior to the 1925 Santa Barbara event, organized societal or political action did not take place until then. Shortly after, in 1927, the first U. S. seismic code was published, formalizing seismic design practice at the time. Shortly after, in 1933, the devastating Long Beach earthquake occurred, seriously damaging several unreinforced masonry school buildings. Fortunately, school was not in session and no students were harmed, but the specter of many casualties among school children jarred the state legislature to action and a state law was passed to require seismic design for schools.

The Field Act, passed in 1933, was intended to assure that all public schools in the state were safe in earthquakes. This would be accomplished by:

- use of design rules in excess of normal buildings,
- limiting the design of schools to structural engineers knowledgeable in earthquake engineering,
- strict plan-checking of designs by the state,
- systematic inspection of construction

All new schools were subject to these new controls, but there were no retroactive provisions to force consideration of the existing school inventory. In 1939 the Garrison Act was passed that required local school districts to have seismic evaluations on all pre-Field Act buildings by 1970 and all substandard buildings to be retrofit or abandoned by 1975. But, due to the limited resources and other priorities of local school districts, and the absence of an effective enforcement mechanism, little was done. Beginning in 1967, shortly before the deadline for completion of evaluations, additional laws were passed (the Greene Acts) forcing school districts to comply, and most school buildings were retrofit or abandoned by 1975 (SSC, 1979).

Efforts to obtain effective legislation to accomplish the original goals of the Field Act in the late 1960's, had created a renewed awareness of the earthquake problem in California, and a small group of technical experts and social scientists turned their attention to other possible improvements in seismic safety for the state. This led to the formulation of California's Joint Legislative Committee on Seismic Safety in 1969. Actions recommended by the Joint Committee included creation of a state commission to oversee all seismic issues in the state, development of special planning controls in areas threatened by fault rupture, and methods to improve the seismic

performance of hospitals in the state (Joint Committee, 1974). Thus, when the San Fernando earthquake struck in 1971, recommended political actions were available, and several landmark state laws were passed, including one that created the California Seismic Safety Commission, the Alquist-Priolo Act that controlled construction in near-fault areas, and the Hospital Safety Act covering seismic safety in hospitals.

THE HOSPITAL SAFETY ACT OF 1972—SENATE BILL 519

The San Fernando earthquake had been particularly damaging to hospital buildings, most notably the Olive View Medical Center, a brand new facility that was damaged so badly that it was eventually demolished. However, it was understood that hospital buildings were far larger, more complicated, and more expensive to retrofit than schools, and the new law covered only new hospital construction. It was also expected that the high level of medical/technological advances would require new facilities and that natural hospital replacement would reduce the inventory of older buildings rapidly. The intent of the law was both to protect acute care patients and to provide post-earthquake medical care, as stated in the law itself:

> It is the intent of the Legislature that hospitals, which house patients who have less than the capacity of normal healthy persons to protect themselves, and which must be reasonably capable of providing services to the public after a disaster, shall be designed and constructed to resist, insofar as practical forces generated by earthquakes, gravity, and wind.

Features of the Act included:

- The law was patterned after the Field Act covering schools in California, specifying the same state review agency, and stipulating design by specially experienced and approved "Structural Engineers."
- The law covered new buildings only
- The law provided for a "Building Safety Board" of industry design professionals and facility experts, appointed by the Director of Health Services, to advise the state on implementation of requirements.
- The law and regulations included four main considerations:
  - geologic hazard studies for sites
  - structural design forces in excess of those used for "normal" buildings (initially a "K-factor" of 3.0; later, an importance factor, I, of 1.5)
  - specific design requirements for nonstructural elements
  - strict review of design and inspection of construction

The California law did not require provisions to assure self-dependence by each hospital facility in the few days following an earthquake. On the other hand, the Veteran's Administration, under the jurisdiction of the federal government, also reacting to severe damage at their Sylmar facility, quickly developed requirements to provide for four days of water, power, sanitary service, steam, and oxygen at all of their facilities in zones of high seismicity (VA, 1974)).

CONCERN ABOUT PRE-ACT BUILDINGS

In the first years of the law, the Building Safety Board concerned itself with development of its own administrative and appeals procedures, but also advised the Department of Health concerning appropriate design requirements for hospital structures as well as nonstructural elements,

application of design requirements for additions and alterations, and identification of essential services in hospital facilities. In 1978, the entire Hospital Act program, including staffing for the Building Safety Board, was transferred to the relatively new Office of Statewide Health Planning and Development (OSHPD), Division of Facilities Development, because of its growing needs and importance.

In the early 1980's the Building Safety Board, through its design professional members, began to realize that hospital buildings were not being rapidly replaced and that the existing pre-Hospital Act inventory represented a large risk. Further, because the Hospital Act did not control the extent of nonstructural remodeling in older buildings, it was possible to update and modernize medical functions without replacement. Therefore, the expected seismic performance of various buildings was not even considered in development of master plans for large facilities. Based on the previous California experience with schools and also considering the unique characteristics of hospitals, the Board established desirable characteristics of a program that could reduce and eventually eliminate this risk from older hospital buildings, as follows:

- Long period for total compliance (30-40 years)
- Established rules to force seismic considerations in master planning
- Flexible requirements that allow trade-offs of risk reduction and response to changing conditions, but that eventually lead to complete compliance with the Hospital Act.
- Flexibility would be provided with rules that would allow gradual compliance based on risk presented based on:
  - Seismic hazard
  - Expected structural performance
  - Extent of critical functions present
- Financial incentives or support from the State

A specific numerical system was derived to serve as an example and to test usability. The risk presented by each building was measured considering both the structural (and nonstructural) vulnerability and the critical functions (e.g. surgery, critical care beds, etc.) contained in the building. A numerical scoring system was devised that was used to set a compliance deadline. In general, buildings susceptible to collapse or significant life threatening damage were to comply in 10 years, buildings with marginal structural systems in 20 years, and "life-safe" (but not complying with operational requirements) buildings would have the entire 30 year period to reach compliance. A high concentration of essential functions in a building would reduce its compliance period and a low level of such functions would increase the period.

The compliance deadline was to be recalculated if a major change was made to the building. For example a nominal 10-year life could be changed to 30 years with a "life safety" structural retrofit. A short 8-year life, caused by the housing of extensive critical functions, could be extended to 13 or 14 years by removing many of the functions. The compliance deadline might even be shortened if a critical function was to be added to a non-complying building; this would be acceptable, but the economic benefits to the owner would have to be weighed against the shortened building life.

The numerical values (termed e_i in the proposal) used to measure the importance of certain occupancies was based on previous work done by the Board which identified critical functions. The e_i values for all functions within the building were added up to determine its *essential function exposure*. The importance of seismic protection of nonstructural elements was emphasized by the use of multipliers on the e_i of critical equipment.

Table 1: Relative Importance of Various Occupancies

e_i	**Function or Occupancy**
0.20	Emergency Room Surgery Labor and Delivery Critical Care Beds: Each 12 beds or fraction thereof Emergency Generator
0.15	Laboratory Radiology
0.10	Beds other than Critical Care: Each 50 beds or fraction thereof
0.05	Pharmacy Dietary Required General Storage Boilers[1] Medical Gases[1] Transformers, Main Switchgear[1]

1. e_i value to be tripled for items with non-complying seismic protection.

To complete the numerical system to set compliance deadlines, a formula was created for a *Compliance Priority Rating, P,* for each building:

$$P = D \times E \quad \text{, where}$$

D = Structure Deficiency Index
- D = 9.00 for clearly hazardous structures
- D = 2.25 for intermediate structures
- D = 1.00 for non-complying structures judged "life safe"

E = Essential Function Exposure
- $E = 0.5 + \Sigma e_i$ (e_i from table above)

The number of years to compliance, Y, from any base year would be,

$$Y = \sqrt{\frac{440}{P}}$$

This numerical formula was developed using three structural categories, as described above, and basic compliance deadlines for each, respectively of 10, 20, and 30 years. This relationship is graphed as shown in Figure 1:

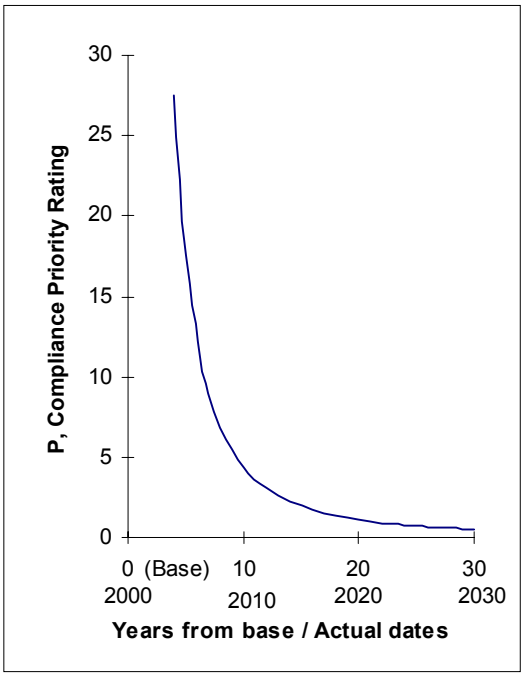

Figure 1: Relationship of compliance deadline with risk

The political will to put such a system in place by law did not exist at that time and the work of the Building Safety Board went largely unnoticed.

SENATE BILL 961—ADJUSTMENTS TO THE HOSPITAL ACT

New hospitals building and remodels were ongoing and the requirements of the Hospital Act were causing confusing among state enforcement agencies and local jurisdictions who had final decision power concerning construction in their area. To create a single point of authority and enforcement, in 1983, the State Legislature passed another law, SB 961, that pre-empted local authority and placed all permitting authority for hospitals within OSHPD. The law also eliminated the requirement that was contained in the 1972 Act that the state agency responsible for the structural aspects of schools would also control hospitals. Thus, all aspects of hospital construction were under the control of OSHPD. Another important feature of this act was to authorize OSHPD to undertake research that would facilitate the goals of the program. The name of the overall Act became the Alfred E. Alquist Hospital Seismic Safety Act (HSSA) after the State Senator who had championed the program since its inception.

COLLECTION OF HOSPITAL INVENTORY (ATC 23)

In 1990, the California Seismic Safety Commission, also concerned about the hospital inventory of older buildings, recommend a survey to evaluate the anticipated seismic performance of hospitals in six counties of Southern California in response to a geologic anomaly known as “The Palmdale Bulge.” The evaluations were based on a “walk-through” and a review of available drawings. Although the Palmdale Bulge never generated seismic activity, an excellent inventory collection and

rapid evaluation method was developed and complete data was collected for the six counties. It was concluded that many of these buildings would not survive a significant earthquake.

The Commission used this data as a resource in the preparation of a major policy report, *California at Risk, Reducing Earthquake Hazards 1987 to 1992* (SSC, 1986). This report covered all aspects of seismic risk in California, and had a section outlining recommendations for OSHPD regarding the HSSA. One of these recommendations was for OSHPD to use its newly acquired research authority to complete the hospital inventory for the entire state. Another, known as *Milestone 4*, directed OSHPD to develop a program to bring older existing hospitals into compliance with the intent of the HSSA. The *Milestone 4 Report* (Building Safety Board, 1990), as described in a later section, later became an important resource for the legislature following the Northridge earthquake.

In 1989, an expanded version of the survey was completed that included all hospital facilities in California. The survey results indicated that two-thirds of the State's hospital buildings were constructed prior to the Act and that normal replacement of the older facilities was occurring at a very slow pace. The survey also indicated that many facilities were potentially hazardous to their occupants in a major earthquake. A description of the classifications used in the survey is given in Table 2. A cross-section of the state inventory using this classification system is given in Table 3. The survey also contained extensive data on the seismic condition of nonstructural systems, as well as the ability of hospital facilities to be self-sustaining the first days following a major event. (ATC, 1990)

Table 2: Earthquake Survivability Classifications from ATC 23

Earthquake Survivability Index Classification	**Design and Construction Standard**	**Expected Building Performance in Strong Ground Motion**
A & B	Substantially in compliance with Hospital Act	Good
C	Designed to seismic standards for "normal" buildings in force at the time of construction	Moderate Damage
D	Same as "C," but with known weakness due to evolution of codes	Highly variable with potentially high risk
E & F	Constructed prior to any requirements for lateral forces	Potentially high risk

Table 3: Summary of Results from ATC 23 Inventory collection

Survivability Index Classification	**Number Of Buildings (%)**	**Building Area (%) ft^2/1000 m^2/10,763**	**Number Of Beds (%)**
A	854 (32%)	21,644 (24%)	14,875 (16%)
B	7 (<1%)	102 (<1%)	11 (<1%)
C	1,244 (47%)	50,306 (54%)	52,459 (58%)
D	297 (11%)	12,687 (14%)	15,459 (58%)
E	125 (5%)	4,997 (5%)	5,809 (2%)
F	146 (5%)	2,662 (3%)	2,115 (2%)
Total	**2,673 (100%)**	**92,398 (100%)**	**91,050 (100%)**

THE LOMA PRIETA EARTHQUAKE—1989

The Loma Prieta earthquake struck the San Francisco Bay Area in 1989. Despite well-publicized losses, very few hospitals were structurally damaged. However, nonstructural damage was wide spread. The Building Safety Board collected damage reports from hospital owners and design professions and found that certain hospital components exhibited a high incidence of damage. These included:

- emergency generators
- elevators
- communications systems
- bulk oxygen tanks
- furniture, fixtures, and supplies

It was noted that damage to generators, communications systems, and oxygen tanks was completed related to seismic anchorage, was relatively easy to prevent, and that the components were important to the function of the hospital. The other issues were more complex, but warranted evaluation on a facility by facility basis. As a result, the Building Safety Board developed a seismic checklist of nonstructural elements judged "exceptionally vulnerable" to seismic damage that eventually was sent by OSHPD to all hospitals in the state. Although there is little evidence that this warning was effective, these vulnerable systems were placed as a high priority for retrofit when retroactive seismic regulations were finally passed following the Northridge earthquake in 1994.

THE MILESTONE 4 REPORT

As previously mentioned, the Seismic Safety Commission's report, *California at Risk, Reducing Earthquake Hazards 1987 to 1992,* included initiatives to both collect hospital inventory as well as Milestone 4, "to recommend a program by July, 1991 to bring existing hospitals into substantial compliance with the Hospital Seismic Safety Act by 2020." In December 1990, OSHPD issued its response to Milestone 4, *A Recommended Program to Seismically Strengthen Pre-Hospital Act Hospital Facilities* (Building Safety Board, 1990). The Milestone 4 Report, put together by the Building Safety Board based on its previous work, proposed the following program elements:

- The Program recommended a five-year evaluation and planning phase, followed by a thirty-year implementation phase. Within the period of the implementation phase, it was intended that the overall hospital building inventory be gradually brought into compliance, addressing first those buildings presenting the highest risks. A building's upgrading priority would reflect site seismicity, seismic performance characteristics of the structure, the extent of hospital essential functions and the number of beds in the building. The upgrading priority (and thus the compliance deadline) for any individual building could be changed within the overall 30-year program period by changing the structural performance and/or the building's occupancy.
- The Program addressed both seismic strengthening of structures and retrofitting of nonstructural systems and equipment.
- Finally, the Program anticipated that financial incentives or support would be available in some situations.

THE NORTHRIDGE EARTHQUAKE—1994

Surprisingly, only 23 years after the San Fernando earthquake, another damaging event occurred in almost the same spot. In January of 1994, the Northridge earthquake produced very large ground motions in the San Fernando Valley just north of Los Angeles. Just as the San Fernando event had a profound effect on hospital design in California, so would Northridge. Although Northridge did not cause any failures in hospitals comparable to the Olive View or Sylmar disasters, several hospitals required evacuation, due both to failure of structural and nonstructural systems. These high-profile evacuations once again put the hospital building inventory in the spotlight. Analysis and comparison of the performance of buildings built before and after the HSSA clearly indicated the effectiveness of the Act, as shown in Table 4. This analysis also indicated that further improvements were needed in the performance of nonstructural systems.

Given the well documented data on the extensive inventory of pre-Act buildings from the ATC-23 survey, the proven improvement in performance from the Northridge event, and the availability of the Milestone 4 Report, shortly after the Northridge event the Seismic Safety Commission successfully lobbied the State legislature to pass Senate Bill 1953, creating rules and timelines for retroactive implementation of the HSSA.

Table 4 Performance of Hospitals in Northridge Earthquake (SSC, 1994)

Performance of all Buildings 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

FULL RETROACTIVITY—SENATE BILL 1953

Senate Bill 1953, legislating a plan to bring all pre-Act hospital buildings into compliance with the HSSA by the year 2030, was signed into law by the governor of California in September, 1994. Most of the recommendations of the Milestone 4 Report were reflected in this legislation, but a feature requiring public disclosure and emergency planning was added. Unfortunately, no funding was provided by the State for the individual hospitals to comply with the new requirements. The content of the legislation is summarized below.

- Standards and Regulations needed to implement the law shall be adopted by June 30, 1996 including:
  - Definition of structural vulnerabilities and evaluation standards
  - Definition of nonstructural vulnerabilities and evaluation standards
  - Standards for retrofit

- Building evaluations and facility compliance plans shall be submitted to OSHPD by January 1, 2001
- Facility owners, 60 days after approval by OSHPD, shall:
  - Submit building performance categories to local emergency service agencies
  - Use the performance information to improve emergency training, response and recovery plans.
- Hospital buildings with a high risk of collapse cannot be used for acute care purposes after January 1, 2008. These buildings must be retrofit (to a "life safe" performance), demolished, or abandoned for acute care use by that date.
- High risk nonstructural systems (Pre and Post Act) shall be mitigated in accordance with priorities and timelines to be set in regulation by OSHPD, in consultation with the Hospital Building Safety Board.
- All facilities shall be in substantial compliance the intent of the HSSA by January 1, 2030

A keystone of the implementation regulations is definition of seismic performance categories. Performance categories are defined for both structural performance and nonstructural performance and will be determined by formal evaluations performed by the owner's professional consultants. The performance categories assigned to each building will become public knowledge when submitted to OSHPD and will be used by local emergency responders for the purposes of regional planning. The performance categories also are used in the regulations to define the interim seismic improvements and timelines required by the legislation.

A summary of structural and nonstructural performance categories is shown in Tables 5 and 6. A complete building seismic performance expectation is composed of assignment of a structural and nonstructural category.

Table 5 SB 1953 Structural Performance Categories

SPC	**Description of minimum acceptable characteristics**	**Date SPC must be reached by Pre-Act Structures**
SPC 1	Pre-Act buildings posing a risk of collapse	not applicable
SPC 2	Pre-Act buildings not significantly jeopardizing life	2008
SPC 3	Post-Act buildings utilizing steel moment resisting frames, designed prior to 1994, and located near a fault. These buildings may experience sufficient damage to inhibit ability to provide services to public after a major event. Damage to frame connections may require evacuation for repairs.	no requirement to reach SPC 5 unless seismically damaged
SPC 4	Post-Act buildings with no steel moment frames designed prior to the 1988 California Code. These buildings may experience sufficient damage to inhibit ability to provide services to public after a major event.	no requirement to reach SPC 5
SPC 5	Post-Act buildings designed after 1988 and reasonably capable of providing services to the public	2030

Table 6 SB 1953 Nonstructural Performance Categories

NPC	Description of minimum acceptable characteristics	Date NPC must be reached
NPC 1	No compliance, most specifically with NPC 2/3	not applicable
NPC 2	Communication, emergency power, bulk medical gas, fire alarm equipment and emergency lights anchored per Part 2, Title 24	2002
NPC 3	NPC 2 plus most Title 24 anchorage in critical care, clinical labs, pharmaceutical service, radiological spaces, and central and sterile supply areas. (Post 1982 construction[1] will comply except for bracing of fire sprinkler lines).	2008
NPC 4	All nonstructural anchorage requirements of Part 2, Title 24 throughout the facility. (Post 1982 construction will comply except for bracing of fire sprinkler lines).	see NPC 5
NPC 5	NPC 4 plus provisions for 72 hour emergency operations	2030

1. SB 961 was passed in 1982. Anchorage of nonstructural elements was enforced by OSHPD after that date and is considered more reliable.

Estimates set the cost of the overall program at $14 billion in 1990. Early results from ongoing evaluations indicate a higher SPC 2 failure rate for pre-Act buildings than anticipated, and the costs will undoubtedly increase. Some facilities have merged and some closed, partially due to the requirements of SB 1953. Regulations defining evaluation standards and procedures have been extremely difficult to write and interpret. Despite the requirements of the law being well known since 1996, many owners will probably not be able to meeting the specified timelines. The practicality and success of SB 1953 probably will not be known until after 2008.

CONCLUSIONS

The current California Hospital Seismic Safety Program evolved over thirty years due to careful planning by advocates of seismic safety in California and the occurrence of several damaging earthquakes. Adjustments to the law itself as well as the implementation regulations have been needed from time to time. The success of the concepts of SB 1953 in eliminating the risks from older hospital buildings cannot yet be measured and additional adjustments may be required.

However, there is no question that the program has significantly improved the seismic performance of the overall acute care medical system in California. In addition, codes and regulations have been written specifically for hospital facilities and each significant earthquake in California yields valuable lessons on how these codes can be improved. Any jurisdiction in the world seeking to improve hospital preparedness for earthquakes should review this California experience.

REFERENCES

ATC, 1990, General Acute Care Hospital Earthquake Survivability Inventory for California, ATC-23, Funded by the Office of Statewide Health Planning and Development, Applied Technology Council, Redwood City.

Building Safety Board, 1990, *A Recommended Program to Seismically Strengthen Pre-Hospital Act Hospital Buildings, A Response to Milestone 4, Initiative 1.2, California at Risk*, Office of Statewide Health Planning and Development, Sacramento.

Joint Committee, 1974, *Meeting the Earthquake Challenge*, Final Report to the Legislature State of California by the Joint Committee on Seismic Safety, Reprinted June 1974, California Division of Mines and Geology SP 45, Sacramento.

Meehan, J.G., 1986, "California's Hospital Seismic Safety Act", *Proceedings of the 8th World Conference on Earthquake Engineering*, Vol. 1, pp. 731-739, San Francisco.

SSC, 1979, *The Field Act and California Schools*, Seismic Safety Commission, SSC 79-02, Sacramento.

SSC, 1986, *California at Risk: Reducing Earthquake Hazards 1987 to 1992,* Seismic Safety Commission, Sacramento.

SSC, 1994, *A Compendium of Background Reports on the Northridge Earthquake,* Seismic Safety Commission, SSC No. 94-08, Sacramento.

VA, 1972, *Post Earthquake Emergency Utility Services and Access Facilities*, CD-54, Veteran's Administration, Washington DC.