REFERENCES

1. Cardona O.D., "Evaluación de la Amenaza, la Vulnerabilidad y el Riesgo", Taller Regional de Capacitación para la Administración de Desastres, ONAD/PNUD/OPS/OEA, Bogotá, May 1991; *II Simposio Latinoamericano de Riesgo Geológico Urbano*, Vol.1, EAFIT, Pereira, Julio 1992.

2. Cardona O.D., "Términos de Uso Común en Manejo de Riesgos", AGID Report No. 13, EAFIT, *I Seminario Andino de Geología Ambiental*, Medellín, Abril 1990.

3. Bolt, B.A., "Terremotos," *Serie Reverté Ciencia y Sociedad*, Barcelona, 1981.

4. Organización Panamerican de la Salud, *Guías para la Mitigación de Riesgos Naturales en las Instalaciones de la Salud de los Países de América Latina*, Washington, D.C., 1992.

5. Pan American Health Organization, *Disaster Mitigation Guidelines for Hospitals and Other Health Care Facilities in the Caribbean*, Washington, D.C., 1992.

6. Arnold C., Durkin M., *Hospitals and the San Fernando Earthquake*, Building Systems Development Inc., 1983.

7. Wheeler, E.T., *Diseño Funcional y Organización de Hospitales*. Madrid: Instituto de Estudios de Administración Local, 1976.

8. Savage, P.E.A., *Planeamiento Hospitalario para Desastres*, México: Harla/OPS, 1989.

9. Organización Panamericana de la Salud, *Programa de Reconstrucción y Reordenamiento de los Servicios de Salud*, México: Secretaría de Salud, 1986.

10. Sanz Septien, M., "La Seguridad Contra Incendios en Hospitales", Mapfre Seguridad, Vol 7, No. 27 (Jul-sep) 1987.

11. Rodríguez Tellez, C., *Manual de Vigilancia y Protección de Instalaciones*, Consejo Colombiano de Seguridad, Bogotá, 1988.

12. Earthquake Engineering Research Institue (EERI), *Reducing Earthquake Hazards: Lessons Learned from Earthquakes* (Publication No. 86-02), Oakland, California: EERI, November 1986.

13. Arnold, C., Reitherman, R., *Building Configuration and Seismic Design*, New York: John Wiley & Sons, 1982.

14. Organización Panamericana de la Sauld, *Análisis de Riesgo en el Diseño de Hospitales en Zonas Sísmicas*, Washington, D.C., 1989.

15. Dowrick, D.J., *Diseño de Estructuras Resistentes a Sismos para Ingenieros y Arquitectos*. México: Limusa, 1984.

16. Arnold, C., et al., *Seismic Considerations for Health Care Facilities* (FEMA report no. 150, EHRS 35), Washington, D.C., 1987.

17. Federal Emergency Management Agency (FEMA), *Instructor Guide for Nonstructural Earthquake Mitigation for Hospitals and other Health Care Facilities*, Emmitsburg, Maryland, 1988.

18. EERI, *Nonstructural Issues of Seismic Design and Construction* (Publication no. 84-04), 1984.

19. FEMA, *Non Structural Earthquake Hazard Mitigation for Hospitals and Other Care Facilities* (FEMA report no. IG 370), 1989.

20. Reitherman, R., *Reducing the Risks of Nonstructural Earthquake Damage: A Practical Guide*, San Francisco: Bay Area Earthquake Preparedness Project, 1986, (FEMA report no. 74, 1985.)

21. FEMA, *Seismic Protection Provisions for Furniture, Equipment, and Supplies for Veterans Administration Hospitals*, Washington, D.C., 1987.

ANNEX 1

CASE STUDY OF SEISMIC DESIGN*

VETERANS ADMINISTRATION HOSPITAL

Case Study of Seismic Design in Hospital Architecture

An internationally known example of hospital architectural design, which stands out because it unites various aspects of seismic risk mitigation, is the Veterans Administration Hospital in Loma Linda, California.

The site for this hospital complex was chosen after a detailed analysis of the potential sites available in a region that has 11 known active faults within a 65-mile radius, including the San Jacinto fault and two segments of the San Andreas fault. Intensive seismic studies indicated that, although the Loma Linda fault was in close proximity to the chosen location, it was 200 to 400 feet southwest of the site and surface rupture at the site was not likely.

The building structure was designed for a peak acceleration of 0.5 g and its nonstructural components for an acceleration of 2.0 g.

The primary considerations for building configuration were as follows:

*1. **Site geometry:*** The 40-acre site allowed the designers to consider a free-standing building unrestricted by site geometry. The site area was large enough to accommodate a low building, laid out horizontally.

*2. **Programmatic considerations:*** Research studies on hospital organization and planning carried out by architects before the Loma Linda project pointed to some of the advantages of horizontal planning, defined as plans in which clinical and diagnostic areas are placed on the same floor as patient care areas, instead of being concentrated in a base structure with a vertical connection to bed-related functions.

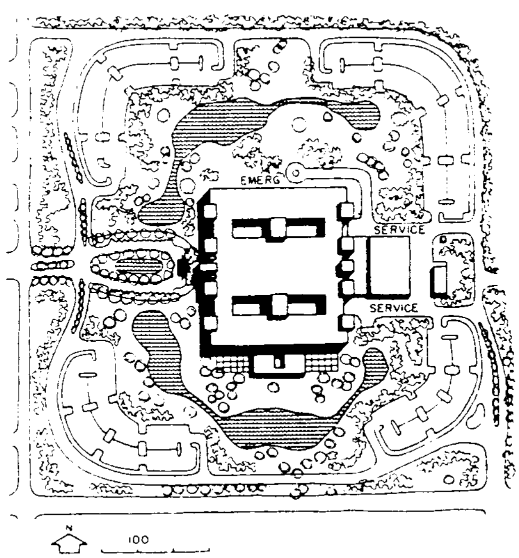
The advantages related generally to internal transportation questions, which were studied separately by the architects during the schematic design phase of the Loma Linda Hospital under a separate contract from the Veterans Administration. Experience in vertically planned VA hospitals had

*Adapted from: Arnold, Christopher and Reitherman, Robert. *Building Configuration and Seismic Design* (John Wiley & Sons, New York: 1982, pp.216-222). Reprinted with permission of John Wiley & Sons.

indicated some problems with providing for adequate circulation, since the concentration of vertical circulation in a single tower tended to result in over- or under-capacity, depending on the time of day. Hospital staff also showed a general preference for horizontal as opposed to vertical movement, and there were indications that it would be desirable to reduce vertical circulation for severely ill patients, for example, during the pre- and postoperative period.

3. Aesthetics: Hospital design tends to be dominated by the need to solve very complex planning, service, and equipment problems, making appearance a secondary consideration. The city of Loma Linda wanted the hospital site to be "parklike." In response to this desire, and given the relatively small scale of the site's immediate surroundings, it seemed appropriate to envision a low building, blending into its surroundings, placed toward the middle of the site (Figure A.1). The building, because of its nearly 700,000 square feet, would be large, but its relatively low height and large site would help to reduce its impact on the community.

FIGURE A.1. THE LARGE, PARKLIKE SITE PLAN OF LOMA LINDA VETERANS ADMINISTRATION HOSPITAL



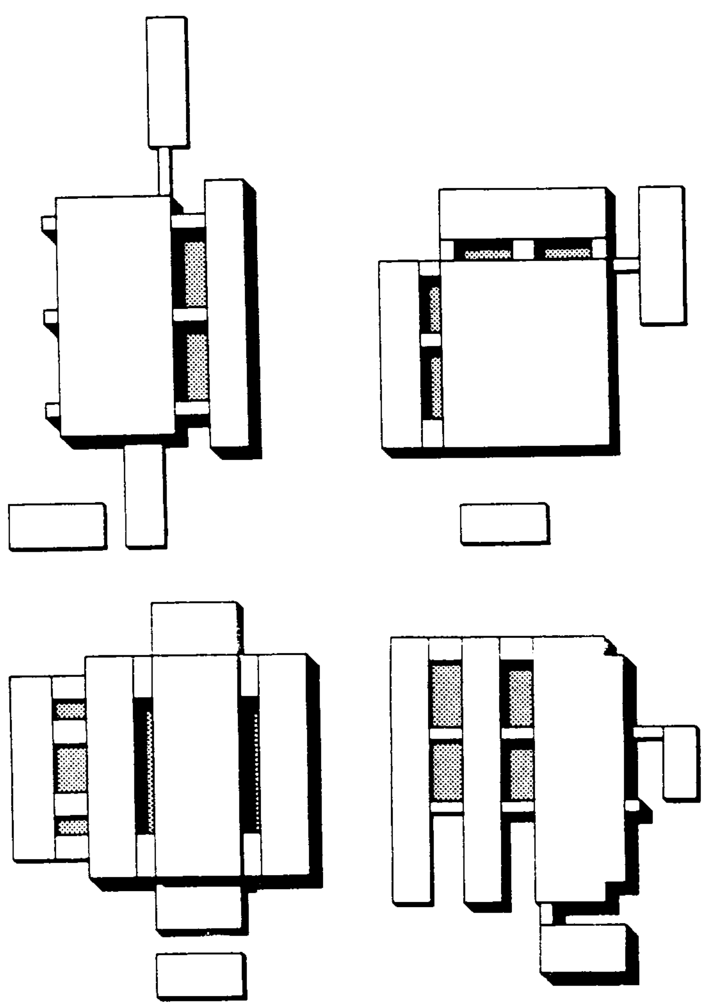
4. Building system: The building was proposed as a demonstration of the Veterans Administration Building System, which was developed over several years by the same advisory team responsible for the design of this hospital. The building system consisted of a set of carefully crafted design concepts aimed at rationalizing and organizing the preliminary hospital design.

The structural features of the system consisted of a moderate-span simple post and beam shallow floor framing system, large floor-to-floor heights, and lateral force resistance elements concentrated in the service tower and at the end of each of the service modules that together made up each floor of the building. The possibility that the system could be used under the extreme seismic conditions found in Loma Linda had not been anticipated, but the structural approach allowed the stringent seismic requirements to be met successfully.

Planning and aesthetic requirements, then, made a low, wide building desirable, which coincided very well with a stiff seismic design that would minimize story drift, and the consequent architectural, mechanical, electrical, and contents damage, and loss of operating capacity. In addition, a low, stiff building would have a shorter vibration period and a potentially lower response than the projected response spectra peaks from the nearby geographical faults.

The preceding requirements were specifically expressed by the structural engineers as a preferred design of no more than four floors, symmetrical in two plan axes and in section. Any complex configuration would be subdivided so as to allow each component, as far as possible, to accommodate these requirements. Accordingly, the architects carefully studied various schemes using single and multiple buildings of three, four, and five stories, with full basement, half basement or no basement. To assess seismic resistance, consideration was given to symmetry, shear wall availability, separation joint requirements, and continuity of vertical stiffnesses (Figure A.2).

FIGURE A.2. PRELIMINARY ALTERNATIVE SCHEMATIC DESIGNS STUDIED BY THE ARCHITECTS



All solutions that included basements produced vertical stiffness discontinuity at the first floor level. Multiple building solutions required a number of connecting bridges to maintain reasonable circulation and these in turn required a number of seismic joints.

The chosen configuration was the simplest of all those studied: a simple block, almost square in plan, with no basement and with four symmetrically placed courtyards within the block. The courtyards were relatively small. The plan had evenly distributed shear walls throughout, running uninterrupted from roof to foundation and having direct continuity in plan with the structural framing members (Figures A.3-A.5).

FIGURE A.3. SECTION THROUGH COURTYARDS, SHOWING SHEAR WALLS AT END

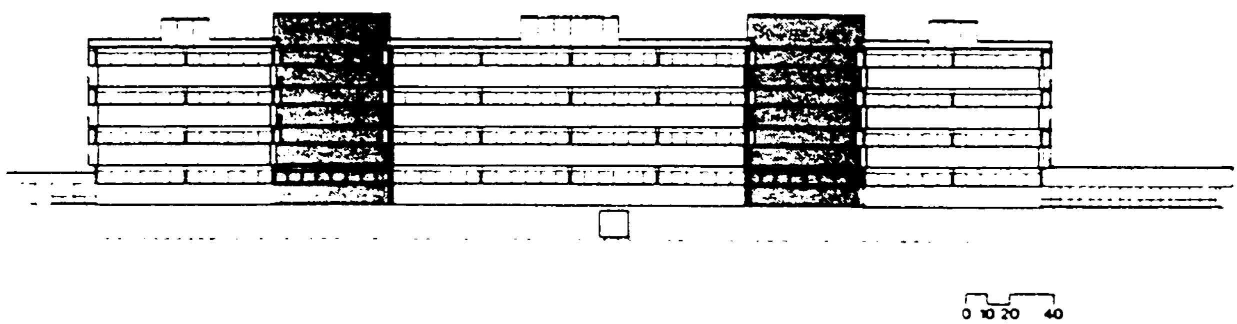


FIGURE A.4. TYPICAL STRUCTURAL FRAMING PLAN

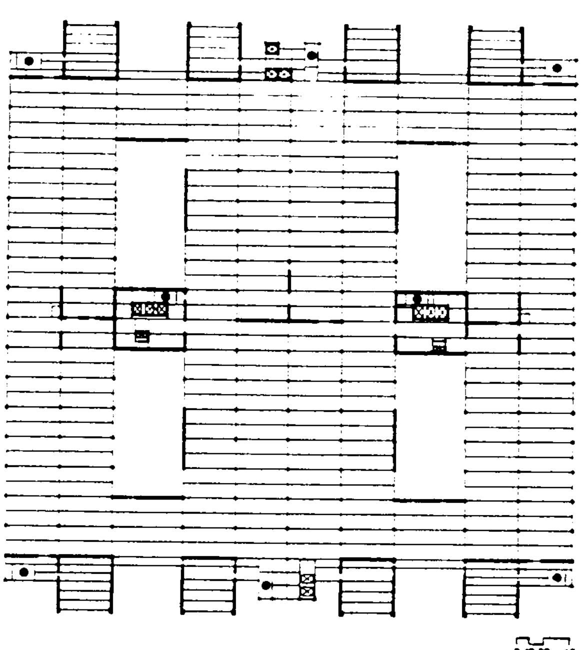
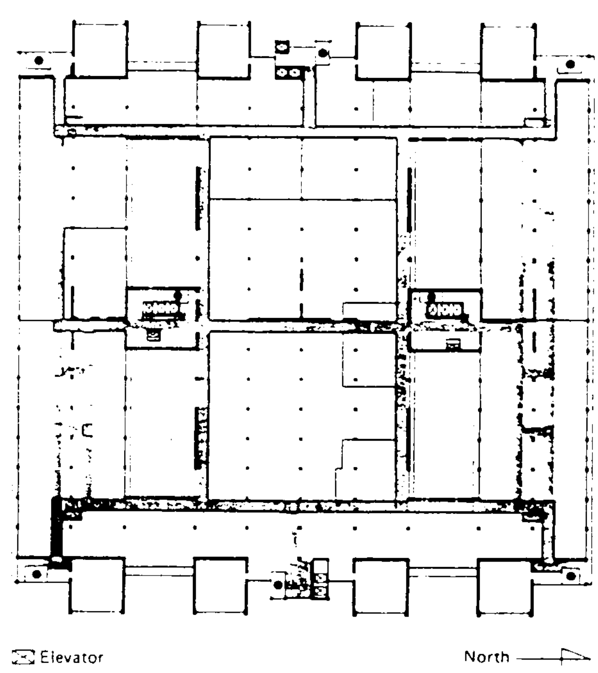
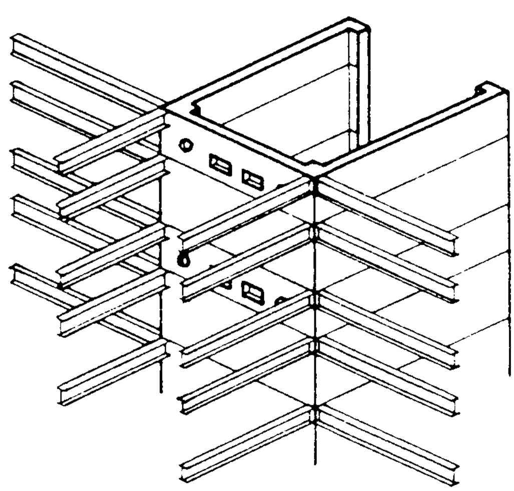


FIGURE A.5. THIRD-FLOOR PLAN, SHOWING CIRCULATION PATTERN



The planning and circulation of the building were carefully related to shear wall layout so that there was minimum shear wall penetration, and the departmental and public planning were clearly defined and highly accessible. The final result was notably uncompromised in both categories. The eight service towers (four at each end) provide a location for the major shear walls. Each tower provides two east-west shear walls and one in the north-south direction. The latter is an interior wall penetrated by large ducts and other horizontal services. However, these openings are repetitive and carefully controlled, and the use of an interior wall allowed these shear walls to be continuous with the perimeter framing of the building. This would not have been the case if the end walls of the tower had been used (Figure A.6).

FIGURE A.6. CAREFUL PENETRATION OF SHEAR WALLS WITH OPENINGS FOR CORRIDORS AND SERVICE DUCTS



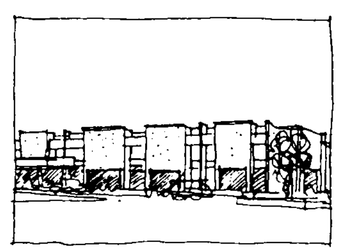
The general lateral resisting system used concrete shear walls and a ductile moment-resistant "back-up" frame. The stiff primary shear wall system was designed for a high force level, so that the structure would tend to have low lateral deflections for the design earthquakes mentioned earlier. The maximum story-to-story drift calculated was 0.004H, well within presently accepted desirable ranges for hospitals.

This hospital design was thus satisfactorily and harmoniously completed, and met all the requirements of an ideal design, since the engineers and architects worked together from the beginning of the project and were able to integrate all the aspects needed to ensure that the hospital would continue to function even in the event of a severe earthquake.

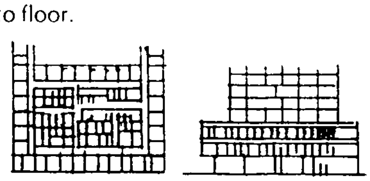
ANNEX 2

FORM AND VOLUME OF BUILDINGS*

Medical Facility, Low-Rise

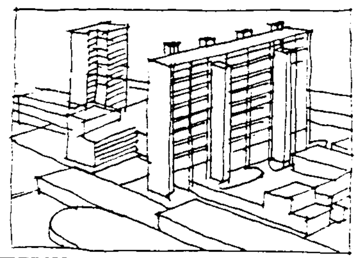


hospital
health clinic

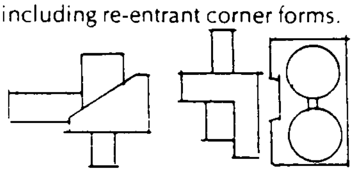
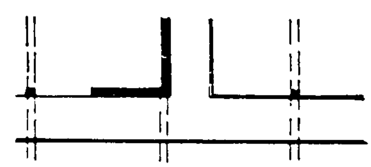
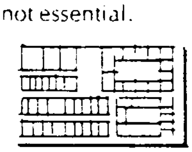
Typical Architectural Characteristics	Seismic Design Implications	Seismic Design Solutions
Great variety of configurations.	Variety of appropriate seismic design approaches.	Shear walls, frames, combinations.
Predominantly small rooms. Often complex planning requirements. May be nonrepetitive plan from floor to floor. 	Possible difficulty in maintaining uniform framing, shear wall location within each floor and floor to floor. However, forces in low-rise structure are fairly small because of low mass, so extent of bracing and shear walls not great.	Moment-resistant frame structure ideal to provide maximum adaptability of planning, but check drift limits. **Shear walls must be continuous.** Manipulate plan to achieve this.
Facility function dependent on equipment and utilities.	Structural design to reduce seismic effect on nonstructural components. Design seismic protection for equipment and utilities.	Design building for stiffness and low drift limits. Careful detailing of equipment and utility relationship to building structure. Check for overturning.
Extreme seismic code standards (California) if provides overnight care.	Rigorous plan checking and site inspection by state increases cost and design time.	Serious consideration of seismic issues from design inception essential.

*Arnold, Christopher and Reitherman, Robert, *Building Configuration and Seismic Design* (John Wiley & Sons, New York: 1982, pp. 169-170). Reprinted with permission of John Wiley & Sons.

Medical Facility, Medium- to High-Rise



hospital

Typical Architectural Characteristics	Seismic Design Implications	Seismic Design Solutions
Large variety of configuration types, including re-entrant corner forms. 	Possibility of stress concentration, torsion.	Subdivide by seismic joints.
Complex planning requirements: much horizontal and vertical movement of people, materials and equipment.	Limitations on placement of shear wall and bracing; must be related to circulation.	Careful planning relationships between shear walls, bracing and circulation. 
Large elevators result in large vertical circulation cores.	See High-rise offices, but larger cores increase shear wall possibilities.	See High-rise offices.
Large clinical and diagnostic areas need many small rooms, perimeter location not essential. 	Generally large floor area may result in need for interior shear walls, braces.	Care in locating shear walls, braces to permit planning function.
Hospital function very dependent on equipment and utilities.	Structural design to reduce seismic effect on nonstructural components. Design seismic protection for equipment and utilities.	Design stiff structure to limit drift, best done by shear walls or frames. Interstitial framing may be beneficial in limiting story drift. Careful detailing of equipment and utility relationship to building structure. Check for overturning.
Extreme seismic code standards (California).	Rigorous plan checking and site inspection by state increases cost and design time.	Serious consideration of seismic issues from design inception essential.

PAN AMERICAN HEALTH ORGANIZATION
REGIONAL OFFICE OF THE
WORLD HEALTH ORGANIZATION
525 TWENTY-THIRD STREET, N.W.
WASHINGTON, D.C. 20037 U.S.A.