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Base Isolation in Hospitals

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This paper is an annex to a slide presentation. Figures and tables are not copied in the paper.

Introduction

New requirements to preserve functionality and protect the user, equipment and components in hospitals prompted the used of base isolation.

The basic principle behind base isolation is to set the structural dynamic characteristics so earthquake inputs do not severely affect its response. In the ideal case the building is isolated from ground motions. This is attained setting a long predominant structural period, typically longer than 1.8 seconds in relative hard soils, and generating a nearly constant mode shape for the first mode in each horizontal direction. These dynamic properties reduce the spectral demand for all the modes in the system. Because longer structural periods are associated with large displacements, energy dissipation is also included in the base isolation system.

There are several ways to base-isolate a structure: high-damping rubber base isolators, friction pendulum devices and low-damping rubber with additional damping devices, among others. The selection of the appropriate system depends on the general acceptance of the system, cost and especial functional requirements.

In the last years, an important number of hospital buildings in United States, Japan, Italy, New Zealand, Chile and India have been designed including base isolation, Table 1.

For example, the main characteristics of the base-isolated Military Hospital in Chile are presented below.

Chilean Military Hospital

The HOSMIL consortium designed the hospital. This hospital is now in the final process of bidding. The total final cost of the structure was 112.8 million dollars, the number of beds 330 and the total constructed area is approximately 88.000 m^2. This mean that the average bed cost is 342 thousand dollars, and the average construction was 267 square meters per bed. The site cost is not included. Several buildings form up the complex. The clinical and emergency services are located in a base-isolated structure, (Figure 1) in order to protect the investment and the functionality of their services. The structural system of this building consists on a moment-resistant frame with an approximate built area of 50.000 m^2. It has 5 levels, including a basement level for parking. The highest level of the structure corresponds to a mechanical floor. The plan view dimensions are 126 m by 115 m. The column spacing is 9 meters in both directions. The floor height is 5.75 m at the basement level and 4.5 m at the remaining levels (Figure 2).

The building's columns have a typical section of 80x80 cm, except in the basement level, where the typical section is 110x110 cm. The beams of the building have a typical section of 60x90 cm, except in the ceiling of the basement level, where the beams have a 60x110 cm section (Figure 3). The stronger system at the basement level is required to comply with a below isolation system elastic structure for the design base isolation displacement and to reduce the drift at this level.

The structure is mounted on 164 seismic isolators located in the top part of the basement level. 114 of these isolators are manufactured with high-damping rubber (Figure 4). These devices have diameters of 70 and 90 cm and are made of 20 rubber layers of 8 mm of thickness and 4 mm thick steel plates. The remaining isolators have a 15 cm diameter central lead plug to increase its energy-dissipation capacity. These isolators are 90 cm in diameter and are located in the perimeter of the structure, in order to reduce torsional effects. The design displacement varied from 24 to 34 cm, depending on the position of the isolators.

The damping provided by the isolation system is nearly 12%. The period of the isolated structure is nearly 2.5 seconds, which, together with the additional damping, help reducing the deformation and forces in the superstructure.

The isolator design was made considering a local spectrum of displacements and in accordance to the requirements of the Uniform Building Code of 1997 and the 2000 International Building Code.

An interesting conclusion can be drawn from this experience. It was estimated that the total base isolation system cost 1 million US dollars. This is 0.9% of the total cost, nevertheless the other two bidding offers for the construction of this hospital complex were 133.2 and 135.1 million dollars. It means that the different between the winning offer and the following one, nearly 20 million dollars, was 20 times more than the cost of the additional safety of the structure.

Table 1. Some based isolated hospitals and their characteristics.

Hospital	Location	Description / Other antecedents
Hsien Dien/Tzu Chi Hospital	Taiwan/Taipei	Year: 2002 New construction, dampers (Taylor Fluid Dampers) used to add energy dissipation to a base isolation system. Total: 48 dampers
Tokyo Rinkai Hospital	Japan/Tokyo	Year: 2001 New construction, dampers (Taylor Fluid Dampers) used to add energy dissipation to a base isolation system. Total: 45 dampers
Tillamook Hospital	USA/Tillamook	Year: 1998 Retrofit of an existing hospital to meet current seismic protection code levels. Dampers (Taylor) Fluid Dampers used in chevron braces to dissipate earthquake energy. Total: 30 dampers
Long Beach V.A. Hospital	California/Long Beach	Year: 1995 12-story 350,000 sq.ft. Retrofit of nonductile- concrete-shear-wall building 110 lead-rubber bearing 18 natural rubber bearing (DIS/Furon)
Arrowhead Regional Medical Center	California/Colton	six-story 341234 sq. Ft 414 beds The isolators are 20 inches high and 35 inches in diameter High Damping Rubber Isolators used in conjunction with viscous damping devices
USC University of Southern California University Hospital	California/Los Angeles	1991 350,000 sq.ft Eight-story concentrically braced steel frame supported on 68 lead rubber Isolators and 81 elastomeric isolators 68 lead-rubber bearing 81 natural rubber bearing (DIS/Furon)
Martin Luther King Drew Medical Center	Los Angeles, CA	1995 Five story 13,000 m^2 (140,000 ft^2) 70 high-damping natural rubber bearings (1.0 m in diameter) and 12 sliding bearings with lead bronze plates that slide on stainless steel surface fabricated in United States
Los Angeles County Hospital	Los Angeles, CA	1993 Base-isolated hospital
LAC + USC	Los Angeles, CA	2000 550,000 sq.ft

Medical Center		Base-isolated hospital. 150 high damping rubber (BTR/Andre) (Under design)
St. John's Health Center	Los Angeles, CA	1996 Base-isolated hospital

Hospital	Location	Description / Other antecedents
Hoag Memorial Hospital	California/Newport Beach	1995 100,000 sf 150 beds Base isolation retrofit project
San Bernardino County Medical Center		1997 373-bed facility six-story 367,722 square-foot patient tower 480,878 square-foot diagnostic and treatment center 102,203 square-foot mental health center 21,845 square-foot central plan New construction Base-isolated hospital (400 high damping rubber (DIS)). Dampers used to add energy dissipation to rubber bearing isolation system in five independently isolated buildings (186 Viscous Dampers (Taylor))
Hays Hospital		1987 Base isolation retrofit project
Washington Hospital	Fremont, California	This two-story, 100,000 sf The building consists of a structural steel moment frame supported on a base isolation system
Kyorin University School of Medicine	Shinkawa, Mitaka City, Tokyo	Project name: Extension Work of Kyorin University School of Medicine University Building use: University, hospital Design: Takenaka Corporation (building) & Sanki Engineering Co., Ltd. (facilities) Construction: Takenaka Corporation (building) & Sanki Engineering Co., Ltd. (facilities) Site area: 58,389.84 m² Building area: 5,877.20 m² Total floor space: 34,601.98 m² Number of floors: Outpatient building: 2 Fl. below ground, 10 Fl. above ground, 1 Fl. Penthouse New hospital ward building: 1 Fl. below ground, 5 Fl. above ground, 1 Fl. Penthouse Maximum height: 40.30 m Construction type: Outpatient building: Steel-framed reinforced concrete New hospital ward building: Reinforced concrete Number of beds: 320 Work period: December 1996 to December 2000 Design: Takenaka Corporation Construction: Takenaka Corporation Location of devices: Foundation base isolation (foundation beam) Devices: 4 LRB- 650(200 mm in rubber thickness) 10 LRB- 700(200 mm in rubber thickness) 21 LRB-750(200 mm in rubber thickness) 9 LRB- 800(200 mm in rubber thickness) 21 LRB-850(198 mm in rubber thickness) 7 LRB- 900(198 mm in rubber thickness)

		7 LRB- 950(198 mm in rubber thickness) 4 LRB-1000(198 mm in rubber thickness) 8 RB – 650(200 mm in rubber thickness) 2 RB – 700(200 mm in rubber thickness)

Hospital	Location	Description / Other antecedents
Maiya Matsumoto	Kyoto City	Project Name: Maiya Matsumoto Client: Toshi Matsumoto Use: Hospital Design: YX Corporation, Konoike Construction Co., Ltd. Construction: Takenaka Corporation Year of completion: March 1997 Location of devices: Foundation base isolation (foundation beam) Devices: 15 RB-500(98 mm in rubber thickness) 9 RB-600(117 mm in rubber thickness) 8 Lead dampers 14 Steel bar dampers
Newly added building of Kitazato University Hospital	Sagamihara City	Client: Kitazato Gakuin Use: Hospital Design: Nissei Design and Architects Construction: Takenaka Corporation Year of completion: February 1998 Location of devices: Foundation base isolation (foundation beam) Devices: 48 LRB-850(198 mm in rubber thickness) 19 LRB-1000(203 mm in rubber thickness) 4 LRB-1100(203 mm in rubber thickness)
Bhuj District Hospital	India	300-bed Bearings have been contract manufactured and tested by cluster member Robinson Seismic Ltd
Hutt Valley Health Ltd. Hospital	New Zealand	First seismic base-isolated hospital building constructed in New Zealand. 36 lead rubber bearings
Capital Coast Health	Wellington, NZ	Under design
Hospital Siena	Siena/Tuscany	1988 Friction dissipators
Navy Medical Centre	Augusta (Siracusa, Sicily)	1992-93 High Damping Rubber Bearings 16 Isolators 400 mm in diameter (H=354 mm) 8 Isolators 500 mm in diameter (H=328 mm)
New Hospital	Perugia (Umbria)	Under Design
New Hospital	Frosinone (Lazio)	Under Design
Kanto Teishin Hospital	Tokyo	1996 73,654 m^2 208 Viscous Damping Wall
Centro Clínico San Carlos de Apoquindo Universidad Católica	Santiago/Chile	6 story First isolated hospital to the south of Mexico 52 isolators
Nuevo Hospital Militar La Reina	Santiago/Chile	See text

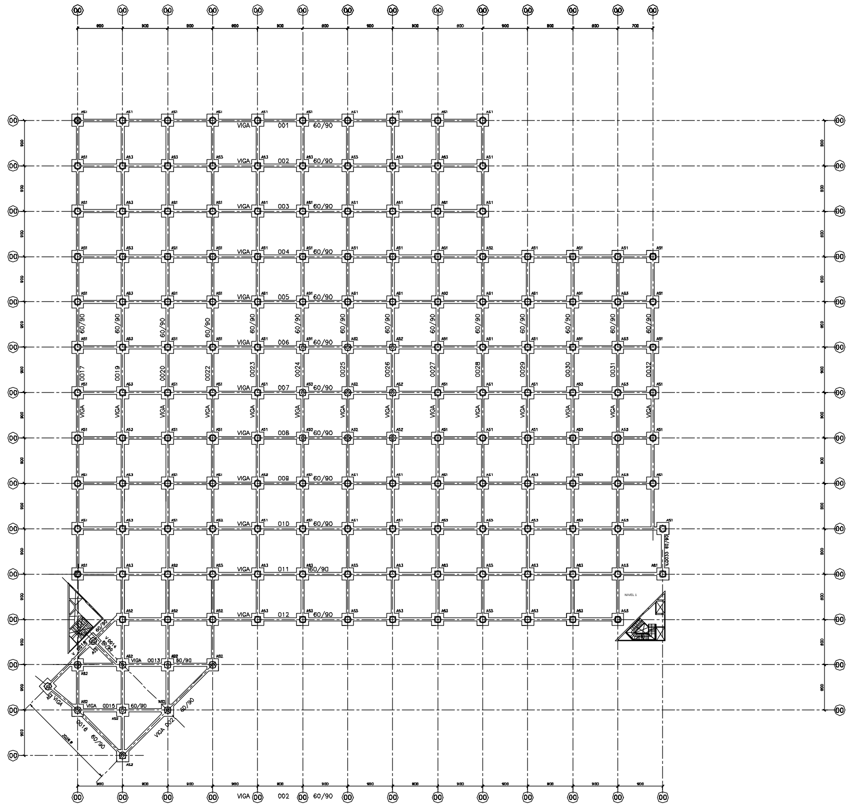

Figure 1. Basement Ceiling Plan. (Courtesy of Hoehmman, Stagno & Associates).

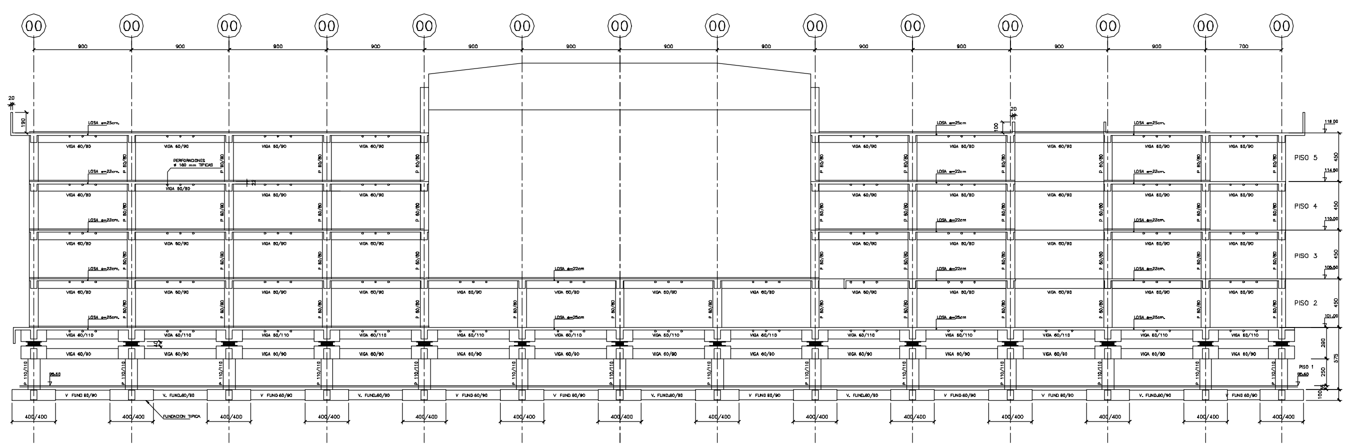

Figure 2. Elevation. (Courtesy of Hoehmman, Stagno & Associates).

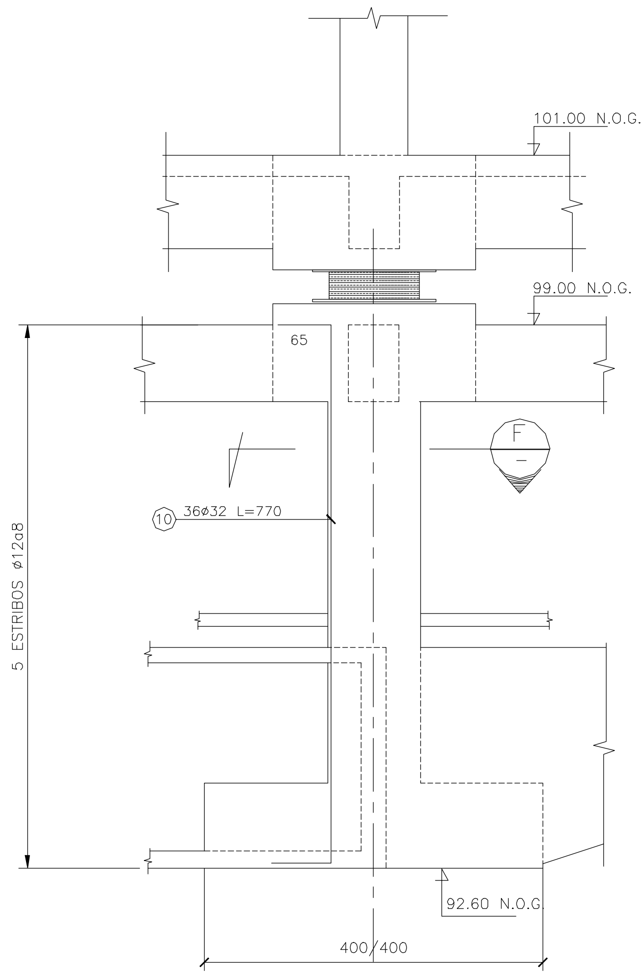

Figure 3. Typical basement and first level columns and typical basement ceiling beams. (Courtesy of Hoehmman, Stagno & Associates).

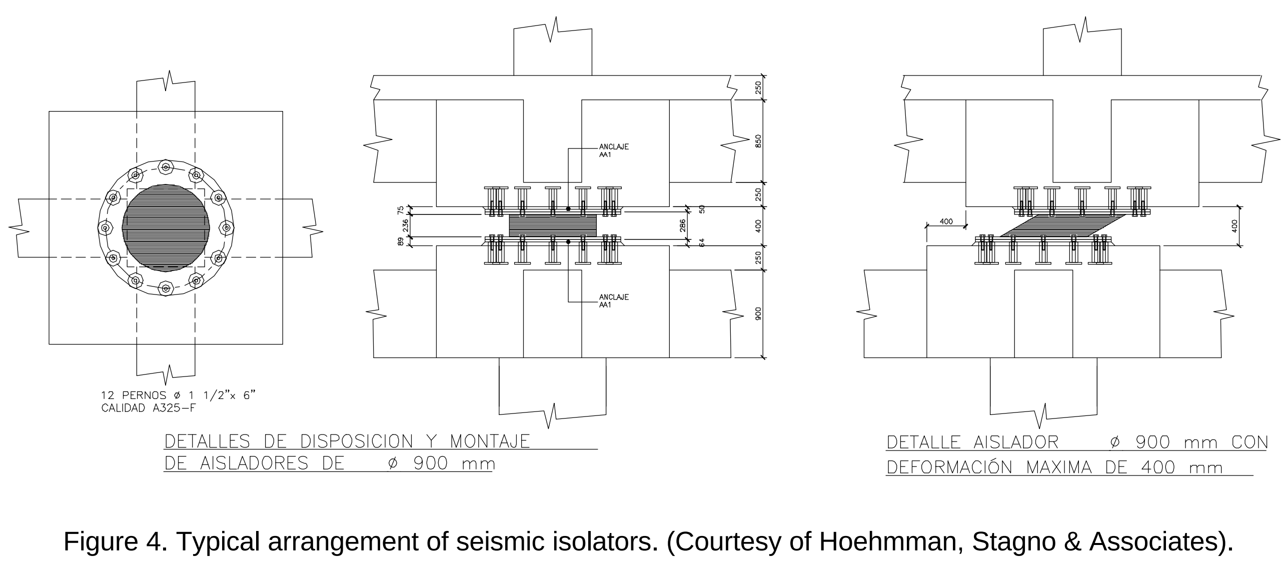

Figure 4. Typical arrangement of seismic isolators. (Courtesy of Hoehmman, Stagno & Associates).