Base Isolation in Hospitals

Rubén Boroschek K, Ph. D.
Rodrigo Retamales
WHO Collaborating Center
Disaster Mitigation in Health Facilities
rborosch@ing.uchile.cl
www.hospitalseguro.cl

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 m². 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 m². 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>
<thead>
<tr>
<th>Hospital</th>
<th>Location</th>
<th>Description / Other antecedents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hsien Dien/Tzu Chi Hospital</td>
<td>Taiwan/Taipei</td>
<td>Year: 2002  New construction, dampers (Taylor Fluid Dampers) used to add energy dissipation to a base isolation system. Total: 48 dampers</td>
</tr>
<tr>
<td>Tokyo Rinkai Hospital</td>
<td>Japan/Tokyo</td>
<td>Year: 2001  New construction, dampers (Taylor Fluid Dampers) used to add energy dissipation to a base isolation system. Total: 45 dampers</td>
</tr>
<tr>
<td>Tillamook Hospital</td>
<td>USA/Tillamook</td>
<td>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</td>
</tr>
<tr>
<td>Long Beach V.A. Hospital</td>
<td>California/Long Beach</td>
<td>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)</td>
</tr>
<tr>
<td>Arrowhead Regional Medical Center</td>
<td>California/Colton</td>
<td>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</td>
</tr>
<tr>
<td>USC University of Southern California University Hospital</td>
<td>California/Los Angeles</td>
<td>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)</td>
</tr>
<tr>
<td>Martin Luther King Drew Medical Center</td>
<td>Los Angeles, CA</td>
<td>1995  Five story 13,000 m² (140,000 ft²) 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</td>
</tr>
<tr>
<td>Los Angeles County Hospital</td>
<td>Los Angeles, CA</td>
<td>1993  Base-isolated hospital</td>
</tr>
<tr>
<td>LAC + USC</td>
<td>Los Angeles, CA</td>
<td>2000 550,000 sq.ft</td>
</tr>
<tr>
<td>Hospital</td>
<td>Location</td>
<td>Description / Other antecedents</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>---------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| 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             | 1996  
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) |
<table>
<thead>
<tr>
<th>Hospital</th>
<th>Location</th>
<th>Description / Other antecedents</th>
</tr>
</thead>
</table>
| 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  
Bears 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 Hospital | Wellington, NZ | Under design                                                                                                                                               |
| Capital Coast Health Hospital | Siena/Tuscany | Under Design                                                                                                                                               |
| 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 m²  
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).