Feasibility Study for Seismic Base Isolation Design of a High-Rise Building

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Base Isolation

- What is Base Isolation?
- Spread of the Seismic Isolated Buildings
- Advantages
- Design Principle
- Applied Examples

Feasibility Study for Seismic Base Isolation Design of a High-Rise Building

- Scope of Work
- Building Information
- Performance Target and Analysis Method
- Structural Elements and Isolators
- Structural Behavior
- Cost
Base Isolation

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The Behavior of the High Rise Structures in Tokyo 2011 Tohoku (M 9.0) Earthquake
Many students did not understand what a great earthquake they were exposed to
Increase in base isolation usage

Spread of the Seismic Isolated Buildings in Japan

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The application of seismic isolation in high-rise buildings involves the following difficulties,

1. How to Provide vibration control against earthquake or wind?
2. How to Manage the story drift?
3. How to Ensure safety against overturning?
4. How to Replace isolators if necessary?
5. How to Ensure high material quality?
Why Seismic Isolated High Rise Buildings are not built?
"General opinion: Seismic isolation system is expensive"
It was also expensive in Japan 20 years ago.

1. Initially it was expensive
2. Implementation of seismic isolation in the public sector (e.g. hospitals) has become Mandatory
3. After proving performance, the system was Spread
4. Serial Production started
5. The initial costs have Decreased
6. Increased Cost Efficiency
7. System Spread even more
Cost Advantage

Seismic Isolated High Rise Building Cost Differences

- The amount of concrete decreases
- Reinforcement quantity decreases
Impact of Seismic Isolation System on High Rise Buildings

The natural period of high-rise buildings is also high without base isolation.

In conventional structures, each floor is displaced and the damage spreads to the building.

In seismic isolated structures, the displacement is damped at the isolation level, so the value of displacement is low at the superstructure.
Stability of High Rise Structures with Base Isolation

Compared to the conventional structure, seismic isolation systems are more resistant to tensile forces.
Examples of Seismic Isolated High Rise Structure from Japan

<table>
<thead>
<tr>
<th>Building</th>
<th>Number of Flats</th>
<th>Number of Floors</th>
<th>Completion Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEUX TOURS CANAL &amp; SPA</td>
<td>1,668</td>
<td>52</td>
<td>2015</td>
</tr>
<tr>
<td>CITY TOWER MUSASHIKOSUGI</td>
<td>800</td>
<td>53</td>
<td>2016</td>
</tr>
<tr>
<td>TOKYO NIHOMBASHI TOWER</td>
<td></td>
<td></td>
<td>133,335 m²</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>35</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2015</td>
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</table>
Feasibility Study for Seismic Base Isolation
Design of a High-Rise Building

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Real Estate Investment Company from Japan

Structural Feasibility Study

Miyamoto International Turkey

Conventional and Isolated Options Comparison

1- Structural Behavior
2- Comfort in use
3- Cost (Structural Elements)

Number of Floor: 30
Height: 102m
- 30 Floors (Per Floor 3.4m)
- Total Height: 102 m

Core Structure
13.5m x 13.5m (~182m²)
21% of Total Floor Area

Corridor
W: 1.75 m (~107 m²)
12% of Total Floor Area

Residential Area (~581 m²)
67% of Total Floor Area
Performance Target

Conventional Model

- DBE (Design Basis Earthquake)
  (Return Period: 475 Years)

- MCE (Maximum Considered Earthquake)
  (Return Period: 2475 Years)

Isolated Model

- Performance Target: Low

- Controlled Damage / Life safety

- Severe Damage / Collapse Prevention

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Conventional Model

Mode-Superposition Method (Earthquake : DBE) ➔ Design of Structural Elements

Earthquake Isolated Model (Ref: ASCE'07)

Determination of Axial Loads on Isolators ➔ Determination of Effective Stiffness of Isolators ➔ Superstructure Design ➔ Final Design of Isolators

- Design of Structural Elements
  - LRB, HRB
  - Determination of Axial Loads on Isolators (Static Analysis, DBE)
  - Determination of Effective Stiffness of Isolators (Pushover Analysis, DBE)
  - Superstructure Design (Mode-Superposition Method, DBE)
  - Final Design of Isolators (Time History Analysis, MCE, DBE)
Isolators – LRB Design

LRB: LH100G4
- Length: 100 cm
- 20 cm thickness
- 40 cm width
- 20 Pcs

LRB: LH130G4
- Length: 130 cm
- 26 cm thickness
- 38 cm width
- 16 Pcs
Isolators – HRB Design

HRB: HH095x6R
- 20 Pcs
- 40 cm
- 95 cm

HRB: HH120x6R
- 16 Pcs
- 39 cm
- 120 cm
The Impact of Isolators:

1. Total Residential Area Increase (1%)
2. Increase in Total Concrete Volume (1%) (Isolation Slab Thickness = 1m)
3. Total reinforcement Decreased Quantity (11%)
4. Increase in Excavation (3 times)
Structural Behavior - 2

Story Drift Ratio (DBE)

- **Level (m)**
- **Relative Displacement Ratio (%)**

- **Fixed Base X Dir**
- **Fixed Base Y Dir**
- **LRB X dir**
- **LRB Y Dir**
- **HRB X Dir**
- **HRB Y Dir**

**Eurocode 8 Limits**
- **1/400** (Having Non-Structural Elements of Brittle Materials)
- **1/200** (Having Ductile Non-Structural Elements)
- **1/133** (Having Non-Structural Element)

**FEMA445**
- **1/100** (External Damage Beginning)
**Floor Accelerations (DBE)**

- **Max: 0.35g** (HRB T: 4.8s)
- **Max: 0.45g** (LRB T: 4.2s)
- **Max: 1.00g** (Conventional T: 1.9s)

**Legend:**
- Fixed Base X Dir
- Fixed Base Y Dir
- LRB X dir
- LRB Y Dir
- HRB X Dir
- HRB Y Dir

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## Structural Cost

<table>
<thead>
<tr>
<th>Design Type</th>
<th>USD/m²</th>
<th>Total Cost (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>127</td>
<td>3,305.253</td>
</tr>
<tr>
<td>LRB</td>
<td>147</td>
<td>3,847.370</td>
</tr>
<tr>
<td>HRB</td>
<td>142</td>
<td>3,705.630</td>
</tr>
</tbody>
</table>

(Total Building Area : 26.108m²)

The costs are studied only for the skeleton construction.

%12 ~ 16 Increase

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