Assessment of Base-isolated CAP1400 Nuclear Island Design

Yang Jie, Li Shaoping, Yuan Fang

Shanghai Nuclear Engineering Research & Design Institute
Outline

01 Introduction
02 SI Design of CAP1400
03 Shaking Table Test
04 Conclusions
1. Introduction

➢ Seismic Isolation

• Seismic isolation (SI) is a widely used strategy of earthquake-resistant design in civil engineering applications.

• To position a horizontal flexible layer of isolation units between the structure and the foundation.

• The dynamic response of the structure is modified.
1. Introduction

➢ Why SI in NPPs

• SI is one of the principal approaches used to mitigate the risks associated with earthquake ground shaking.

✓ Increasing safety margins

✓ Permitting current standard plant designs to be used in regions of higher seismic hazard

✓ Enabling a plant to adapt to changes in seismic hazard detected during the design/construction process or throughout life of the plant
2. SI Design of CAP1400

➢ Goal of Base-isolated CAP1400

• Making the seismic design benchmark of safe shut earthquake (SSE) to 0.6g in horizontal direction instead of the original 0.3g

• Floor response spectra with seismic isolation should be enveloped by FRS of CAP1400 NI standard design, in order to reduce modifications in CAP1400 NI original standard design
2. SI Design of CAP1400

- The isolated bearings are laid under the basemat, and the spacing is 3m~4m.
- The type of the isolated bearing is lead rubber bearing (LRB).
- The LRB is made of a low damping rubber and lead plugs insertions. The lead core is considered as a perfectly plastic material.
2. SI Design of CAP1400

- The analysis stick model of the nuclear island is composed of auxiliary and shield building, containment internal structure, steel containment vessel and reactor coolant loop.
- The isolation bearing is usually modeled with three uncoupled springs.

simplified model for FRS calculation
2. SI Design of CAP1400

- Seismic isolation for CAP1400 Nuclear Island

Horizontal FRS with and without SI

Vertical FRS with and without SI
3. Shaking Table Test

(1) Goal of the test

• To provide realistic data to validate the numerical method

• Focused on the response of superstructure and the isolation unit.

• The test results were compared with three-dimensional finite element simulation results.
3. Shaking Table Test

(2) Design of Model

- The geometric similarity coefficient for reduced-scale model is designated as 1/16.
- Four reduced-scale isolated bearings (LRB400) are used in the reduced-scale model.

<table>
<thead>
<tr>
<th>Structure</th>
<th>W (kN)</th>
<th>Isolated bearing</th>
<th>Isolation layer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$K_d$ (kN/mm)</td>
<td>$Q_d$ (kN)</td>
</tr>
<tr>
<td>Prototype</td>
<td>$21 \times 10^5$</td>
<td>2.51</td>
<td>362</td>
</tr>
<tr>
<td>Model</td>
<td>430</td>
<td>0.83</td>
<td>9.1</td>
</tr>
</tbody>
</table>
3. Shaking Table Test

( 3 ) Arrangement of measuring points

- Force sensors
- Displacement sensors
- Acceleration sensors

Force sensors

Displacement sensors

Acceleration sensors
3. Shaking Table Test

(4) Dynamic characteristics of prototype structure

**Base-isolated Model**

- The frequencies of the first two modes of the base-isolated model are slightly decreased.

**Non Base-isolated Model**

- The non-isolated model has a great change in the structural characteristics after the earthquake.
3. Shaking Table Test

(5) Acceleration response

Acceleration distribution plot in model

Acceleration time histories of analysis and test results
3. Shaking Table Test

(6) Hysteretic behaviour of isolation layer

Hysteretic curve under unidirectional loading condition

Hysteretic curve under biaxial loading condition
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4. Conclusions

- The peak acceleration response of the isolation layer is much smaller than the acceleration of the non-isolated structure.
- The hysteretic curve is full, which shows that it has good energy dissipation capacity.
- The calculation and analysis results of the isolated structure are in good agreement with the experimental results.
- Seismic isolation provides enhanced protection against the horizontal components of ground shaking. This will provide important reassurance to the public and regulatory officials about the safety of nuclear power.
谢谢！
THANK YOU！