Pounding Effect between Adjacent Buildings during Seismic Shaking

Introduction

The occurrence of structural pounding in major cities is caused by insufficient gap between adjacent buildings. As a result, buildings will have larger deformation due to high amplitude of impact force. The easiest way to mitigate pounding problem is by providing a safe separation gap, therefore it is important to determine the minimum gap between adjacent buildings and subsequently can reduce the impact during collision.

Objectives

- Identify the structural response of adjacent buildings with different layouts.
- Calibrate the finite element modeling (FEM) with experimental work.
- Investigate the correlation of using experimental work and analytical analysis (Ref: Moustafa et al., 2014).

Methodology

1) Lab modeling

- 2 layouts were being considered in the experiment.
- Scale of lab model – 1:30.
- Material – PVC.
- Gap between buildings were adjusted between 3mm – 6mm.

2) Finite element modeling

- Building A & B were modeled using SeismoStruct.
- Pounding force was captured using ‘link beam’ element.
- 2 analyses were conducted:
  1. Eigenvalue analysis – to obtain natural frequency of each building.
  2. Time history analysis – to measure building response under ground excitation.

- Friuli, Kobe (000) and Loma Prieta (909) earthquake record were used as ground excitation in this study.

3) Analytical modeling

- Hertz Law was adopted to simulate the pounding effect.
- Pounding force was calculated using following formulas:

\[
F_{pd}(t) = \frac{1}{\pi} \times \frac{\delta(t)}{d(t)} \times \frac{\beta c^2}{\delta + \beta c} 
\]

where:

- \( \delta \) = relative displacement
- \( \beta \) = impact stiffness parameter
- \( c \) = impact element damping

Results & Discussions

1) Natural frequency determination

<table>
<thead>
<tr>
<th>Mode</th>
<th>Building A</th>
<th>Building B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15 – 16 Hz</td>
<td>5 – 5.5 Hz</td>
</tr>
<tr>
<td>2</td>
<td>17 – 18 Hz</td>
<td>8 Hz</td>
</tr>
</tbody>
</table>

- Building A has higher natural frequency compared to Building B due to less mass than the latter one.

2) Pounding results – under Friuli excitation

<table>
<thead>
<tr>
<th>Gap (mm)</th>
<th>Pounding force (N) Lab results</th>
<th>Pounding force (N) SeismoStruct results</th>
<th>Comparison on pounding force between experimental work vs. finite element modeling</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>31.83</td>
<td>25.13</td>
<td>41.81 34.77</td>
</tr>
<tr>
<td>4</td>
<td>27.95</td>
<td>14.10</td>
<td>37.37 34.06</td>
</tr>
<tr>
<td>6</td>
<td>15.12</td>
<td>12.31</td>
<td>27.65 31.18</td>
</tr>
</tbody>
</table>

Comparison on pounding force between experimental work vs. finite element model.

- Layout 1 is more vulnerable during ground shaking motion compared to layout 2.
- Greater displacement was observed in layout 1 during ground shaking motion.

3) Comparison between Experimental, SeismoStruct and Analytical modeling

- 4 ground excitations were used to compare pounding force obtained from experimental, SeismoStruct and analytical modeling:

<table>
<thead>
<tr>
<th>Excitation</th>
<th>Maximum pounding force (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab model</td>
<td>SeismoStruct model</td>
</tr>
<tr>
<td>6Hz frequency</td>
<td>5.85</td>
</tr>
<tr>
<td>Friuli earthquake</td>
<td>27.95</td>
</tr>
<tr>
<td>Kobe (000)</td>
<td>33.34</td>
</tr>
<tr>
<td>Loma Prieta (909)</td>
<td>31.37</td>
</tr>
</tbody>
</table>

Comparison on pounding force in Layout 1 at 4mm separation gap using various modeling.

Conclusion

- Pounding force between adjacent buildings is affected by the different of building layout.
- Finite element modeling is observed to have a good correlation with experimental work by providing similar mass distribution and beam-column connection.
- Analytical modeling using Hertz law is capable to measure pounding force and shows a good correlation with experimental work.

References