EFFECT OF VERTICAL COMPONENT OF GROUND MOTIONS ON TALL BUILDINGS: AN RC DUAL SYSTEM CASE STUDY

S. Ebrahimi1, Z. T. Deger2, and F. Zareian3

1 Engineer, Saiful Bouquet Structural Engineers
2Assistant Professor, Earthquake Engineering and Disaster Management Institute, Istanbul Technical University
3Associate Professor, Department of Civil & Environmental Engineering, University of California

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Introduction

Introduction & Motivation

- 0.2 SDS is commonly used in lieu of vertical component of ground motions for all buildings per code (ASCE 7-10, CBC 2016).
- The vertical component of ground motion can have an adverse effect on structures, especially given individual site conditions.
- This study quantifies the effect of the vertical component of ground motions on a 42-story reinforced concrete dual system tall building

Building Description

- Building 2B of PEER’s Case Studies of the Seismic Performance of Tall Buildings (TBI-Task 12)
- 42 Story Reinforced Concrete dual system
- Located at highly seismic site
- The building is modeled in Opensees

(a) 3D view and (b) plan view of the building (Moehle, et al. 2011)
Analyses and Procedure

Ground Motion Records

- Earthquake M6 and above with soil class C and D
- Reverse and Strike-Slip faults were used
- Both Far-Field and Near Field faults were considered
- 30 records for each group

<table>
<thead>
<tr>
<th>Group</th>
<th>Distance (km)</th>
<th>Fault</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0-10</td>
<td>Strike-Slip</td>
</tr>
<tr>
<td>2</td>
<td>10-25</td>
<td>Strike-Slip</td>
</tr>
<tr>
<td>3</td>
<td>0-10</td>
<td>Reverse</td>
</tr>
<tr>
<td>4</td>
<td>10-25</td>
<td>Reverse</td>
</tr>
</tbody>
</table>

Defining Intensity Measure

- IM is called \( \varepsilon \) (“epsilon”) is defined to be able to correlate well with building response and can appreciate the peculiarity of the vertical and horizontal components of a ground motion alike.
- IM (“epsilon”) considered consists of along with a third set of parameters: the Magnitude (M), Distance (R), and 30-m shear-wave velocity (Vs30) associated with the ground motion.

\[
\varepsilon = \ln\left(\frac{PGA_v}{PGA_h}\right) - \ln\left(\frac{\mu_{V/H}}{\sigma_{V/H}}\right)
\]

Response to Earthquake Ground Motions

- Maximum Axial Force in Column and Shear Wall
- Maximum Inter-Story Drift Ratio
- Maximum Story Shear
- Peak Floor Vertical Acceleration and Vertical Displacement

\[
\alpha = \frac{EDP_{H+V}}{EDP_H}
\]
Results

Axial Force

- 20% to 100% increase in axial load
- Near-Fault records have more effect in axial load increase than Far-Field records
- Earthquakes with reverse faulting have stronger effect than Strick slip fault

Axial Force on Exterior, Interior Columns and Shear Walls for Near Field Reverse Fault
Results

Axial Force (Cont)

Equations for magnification factor of Interior column maximum axial load due to vertical component of ground motions.

<table>
<thead>
<tr>
<th></th>
<th>Strike-Slip</th>
<th>Reverse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Near Field</td>
<td>$\hat{\alpha}<em>{\text{axial load}} = 1.23 + 0.09\varepsilon</em>{VH}$</td>
<td>$\hat{\alpha}<em>{\text{axial load}} = 1.35 + 0.03\varepsilon</em>{VH}$</td>
</tr>
<tr>
<td></td>
<td>$\sigma_{\text{axial load}} = 0.20$</td>
<td>$\sigma_{\text{axial load}} = 0.20$</td>
</tr>
<tr>
<td>Far Field</td>
<td>$\hat{\alpha}<em>{\text{axial load}} = 1.15 + 0.02\varepsilon</em>{VH}$</td>
<td>$\hat{\alpha}<em>{\text{axial load}} = 1.16 + 0.03\varepsilon</em>{VH}$</td>
</tr>
<tr>
<td></td>
<td>$\sigma_{\text{axial load}} = 0.11$</td>
<td>$\sigma_{\text{axial load}} = 0.11$</td>
</tr>
</tbody>
</table>

35% increase for common EQ

InterStory Drifts and Story Shear

- No Considerable change for most strong earthquakes
- Small increase in magnification factor for rare records with high $\frac{PGA_v}{PGA_h}$
Results

Peak Floor Vertical Acceleration

- Significant effect on slab vertical acceleration and displacement.
- Vertical component of ground motions should be considered for slab design purposes.
- The peak floor vertical acceleration and displacement drops along the height of the building.

Maximum vertical acceleration at Mid-Span of the corner slab for near field Reverse fault
Thank You !