Time History Analyses of Tall Buildings with Nonlinear Damped Outriggers

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Tuesday, June 26
The damped outrigger system (Fig 1) initially developed to minimize cross-wind accelerations for occupant comfort [1].

System behavior under seismic differs, and damper selection requires different approach.

**GOAL:** Study the performance of damped outrigger tall buildings utilizing nonlinear fluid viscous dampers under seismic excitation.

Direct Time Integration Method and SDOF Tests

For SDOF tests and MDOF analysis, used implicit numerical integration algorithm derived from Newmark’s method in MATLAB [2]

Damper force, \( F_D = c [\text{sgn}(\dot{u})] |\dot{u}|^\alpha \)

Fig 2 shows that a fractional FVD energetically equivalent to a linear FVD has a lower peak damper force.

Results of SDOF system with nonlinear dashpots, \( \zeta = 15\% \), \( \omega_n = 16.6 \text{ rads/s} \), \( k = 67.9 \text{ k/in} \) shown in Fig 3.

Resonant peak shifts left (lower \( \beta \)) when \( \alpha > 1 \).

MDOF Analytical Procedure

40, 60, 80 buildings condensed into 4 lumped masses and 8 DOFs.

Five earthquakes chosen for variety of frequency content/duration. Time histories normalized to 0.4 g’s.

Peak damper force ($F_D$) held at 1,500 kips. For each $\alpha$ and each building:

- Run all five unidirectional ground motions.
- Save peak $F_D$.
- If peak force exceeds 1,500 kips, reduce $c$. If less than 1,500 kips, increase $c$.
- Rerun analysis.
MDOF Response History Results

Fig 4. Peak roof drift vs. damping exponent for buildings with damped outriggers at roof. Peak $F_D = 1,500$ kips

Fig 5. Peak roof drift vs. damping exponent for buildings with damped outriggers at roof and mid-height. Peak $F_D = 1,500$ kips
FVD stroke and force from seismic is typically much greater than wind in high seismic areas, which may govern FVD and system design. Lower α values can be selected to limit FVD demands.

Damped outriggers are effective for a wide range of heights, from 40 to 80 stories. Lower bound of effectiveness is when shear deformation dominates. Upper bound is when required peak FVD force/stroke or number of FVDs is impractical.

<table>
<thead>
<tr>
<th>Number of Stories</th>
<th>α</th>
<th>Undamped Δ</th>
<th>Damped Δ</th>
<th>Roof Drift</th>
<th>Damper Stroke</th>
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<tbody>
<tr>
<td>80</td>
<td>2</td>
<td>4.97 ft</td>
<td>4.41 ft</td>
<td>H/245</td>
<td>0.71 ft</td>
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<td>4.03 ft</td>
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<td>H/327</td>
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<td>6.94 ft</td>
<td>H/117</td>
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<td>1.84 ft</td>
<td>H/294</td>
<td>0.35 ft</td>
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</tbody>
</table>

Table 1. Drift and damper stroke results for buildings with outriggers at roof only.
Let’s Chat!

Today: 5:15pm-7pm
Pasadena Room
Location 026

Thank you.