SEISMIC RENOVATION OF THE HISTORIC GALLERIA BUILDING USING FLUID VISCOUS DAMPERS by Mark Tobin, PE, SE

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OVERVIEW

• The Galleria Building is an historic mixed use building in downtown Portland

• Target moved into the building, taking about half the floor area

• The increase in occupancy triggered a code mandated full seismic upgrade.
OVERVIEW

• Upgrade was designed in accordance with ASCE 41-06 “Seismic Rehabilitation of Existing Buildings”

• Added Fluid Viscous Dampers at the 1st, 2nd, 3rd, and 4th floors (not at 5th). Ranged from 175 kip to 425 kip dampers.

• Locally strengthened diaphragms

• Added grade beams
EXISTING BUILDING

• Built in 1910
• 200’ x 200’ footprint
• 5 stories over a basement
• Column grid is about 22’ x 22’
EXISTING BUILDING

- Designed to be 11 stories, but only built 5.
- Steel semi-rigid moment frames in one direction.
- Concrete joists in the other direction.
- Direction of steel frames alternates floors.
Like a Buffet:
The existing frames are not great,
But there are a lot of them.
Indicates existing semi-rigid moment frame
WHY DAMPERS?

• Flexible steel frame makes it a good candidate – allows movement.
• Flexible layout, they don’t need to stack vertically – necessary because all floors have different tenants.
• Historic Terra Cotta Skin – had to control drifts and accelerations.
• Cost effective.
Fluid Viscous Dampers - General

Effect of Damping on Spectral Acceleration

Reference ASCE-41
Section 1.6.1.5 for relationship between damping and $S_a$
Fluid Viscous Dampers - General

General relationship for damper is:

\[ F = C \ V^\alpha \]

- \( F \) = Force developed in damper
- \( C \) = Damping coefficient – property of damper
- \( V \) = Velocity imposed on damper
- \( \alpha \) = damping exponent – property of damper

- No movement \( \Rightarrow \) No velocity \( \Rightarrow \) No damping.
Fluid Viscous Dampers - General

• C is a coefficient that we determine based on our analysis / design.
  • Determines how much force the damper attracts – similar to a stiffness.

• $\alpha$ determines if damper is linear ($\alpha = 1$) or non-linear ($\alpha < 1$) based on our design.
  • Practical range is from 0.4 to 1.0
Linear vs. Non-Linear Damper

Non-linear dissipates more energy:

\[ F = C V^\alpha \]

- For \( C = 170 \), \( \alpha = 0.5 \)
- For \( C = 60 \), \( \alpha = 1.0 \)
DAMPER SYSTEM

- Need a mechanism to impose movement (and velocity) between floors into dampers.
- System must have adequate strength and stiffness.
GALLERIA DESIGN CRITERIA

• ASCE 41-06 Enhanced Rehabilitation Objective - Occupancy Category III

• Analysis Type = Non-Linear Dynamic (Time History)
GROUND MOTIONS

- GeoDesign Provided Scaled Ground Acceleration Records for:
  - Imperial Valley, 1979 - 64 sec. (local fault)
  - N. Palm Springs, 1986 - 26 sec. (local fault)
  - Valparaiso, Chile, 1985 - 55 sec. (subduction)
  - N/S and E/W Components at BSE-2 and BSE-1.
Modeling and Analysis

- ETABS was used to do a 3D, non-linear time history analysis.

- Non-Linear elements were limited to dampers and grade beam springs.

- “Gravity” Time History was run first to “pre-load” the columns so that DL and LL could be included in analysis.
Modeling and Analysis

- Diaphragms modeled as shell elements – Semi-Rigid.

- Load path from diaphragm (N+1) to diaphragm N (collectors, dead-man plates, HSS braces, etc.) designed to elastically develop 130% of $V_{\text{max}}$.

- Beams and Columns were modeled as elastic frame elements.
Modeling and Analysis

- Damper Assembly Modeled as HSS Diagonal Braces + NL Link Elements.
- NL Link was a Damper Type, Non-Linear.
- No Linear Stiffness
- Non-Linear Stiffness provided by Taylor Devices.
- $\alpha = 0.5$
Modeling and Analysis

- Existing Semi-Rigid Connections Modeled as Linear Rotational Springs
  - Only Developed about 10% of the Capacity of the Beams – Clearly the “Fuse”
  - Non-Linear Behavior Difficult to Predict and Justify – Therefore Kept Them Elastic.
  - Enveloped with Lower-Bound and Upper-Bound Stiffness.
Modeling and Analysis

- Columns Difficult to Check – Maximum P, M₂, and M₃ do not occur at the same time.
Modeling and Analysis

- Foundations Typically Modeled as Fixed Base.
- Some Columns Have Large Uplift Forces.
  - Modeled Grade Beam as a Gap / Spring Element.
  - Fully resisted compression
  - In tension, the spring was tuned to the strength and stiffness of the grade beam.
SUMMARY

• Cost Effective for this Application
  • $13 / sq. ft. Versus $25 / sq. ft. for “conventional” scheme

• Very Good Seismic Performance – Essentially Elastic Response

• Significant Decrease in Drifts & Accelerations – Saved Terra Cotta Skin

• Flexible Layout – Don’t Have to Stack
  • Minimized impact on tenants
QUESTIONS?