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Utilizing Damping Devices to Improve Resiliency of Structures

Presented by:

Alan Klembczyk
Vice President, Sales & Engineering
TAYLOR DEVICES, INC.

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Introduction

After more than 20 years of using fluid dampers successfully to improve dynamic performance and resiliency of structures, we will return to some basic concepts.

We will then take a look at visual representations to help illustrate the benefits of added damping devices.

Why Fluid Dampers Work to Improve Performance of Structures

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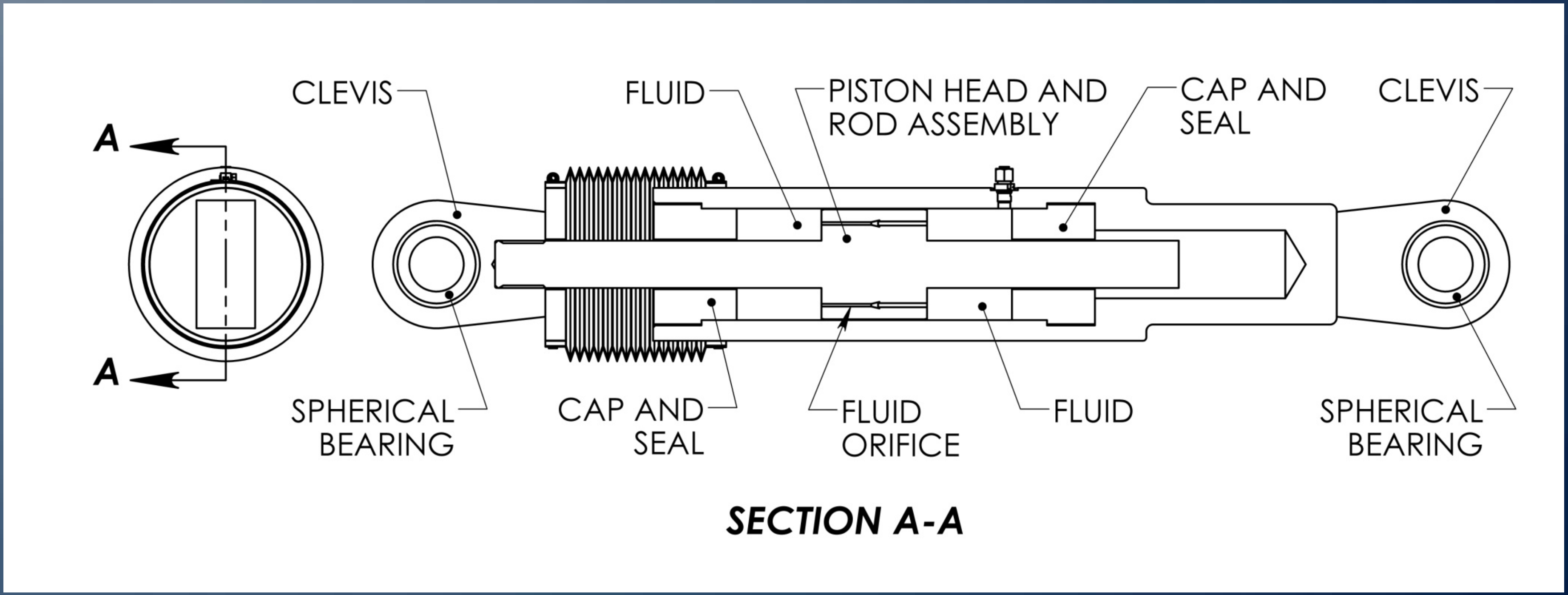
Viscous Damper Attributes:

- Generate very high and predictable internal fluid pressure to maximize damping force.
- Do not add stiffness.
- Generate force out of phase with the structural deflection stress. Maximum damper force is generated when the deflection stress is zero.
- Are readily analyzed in a building model to optimize performance for any structure.
- Energy is absorbed, not transferred elsewhere in the structure – does not excite higher mode frequencies.

Viscous Damper Cutaway



Viscous Damping Equation:

$F=CV^{\alpha}$

where

F = Force in Pounds

C = Damping coefficient, a constant that is specific for each damper

V = Velocity in inches per second

α = Damping exponent, a constant that is specific for each damper

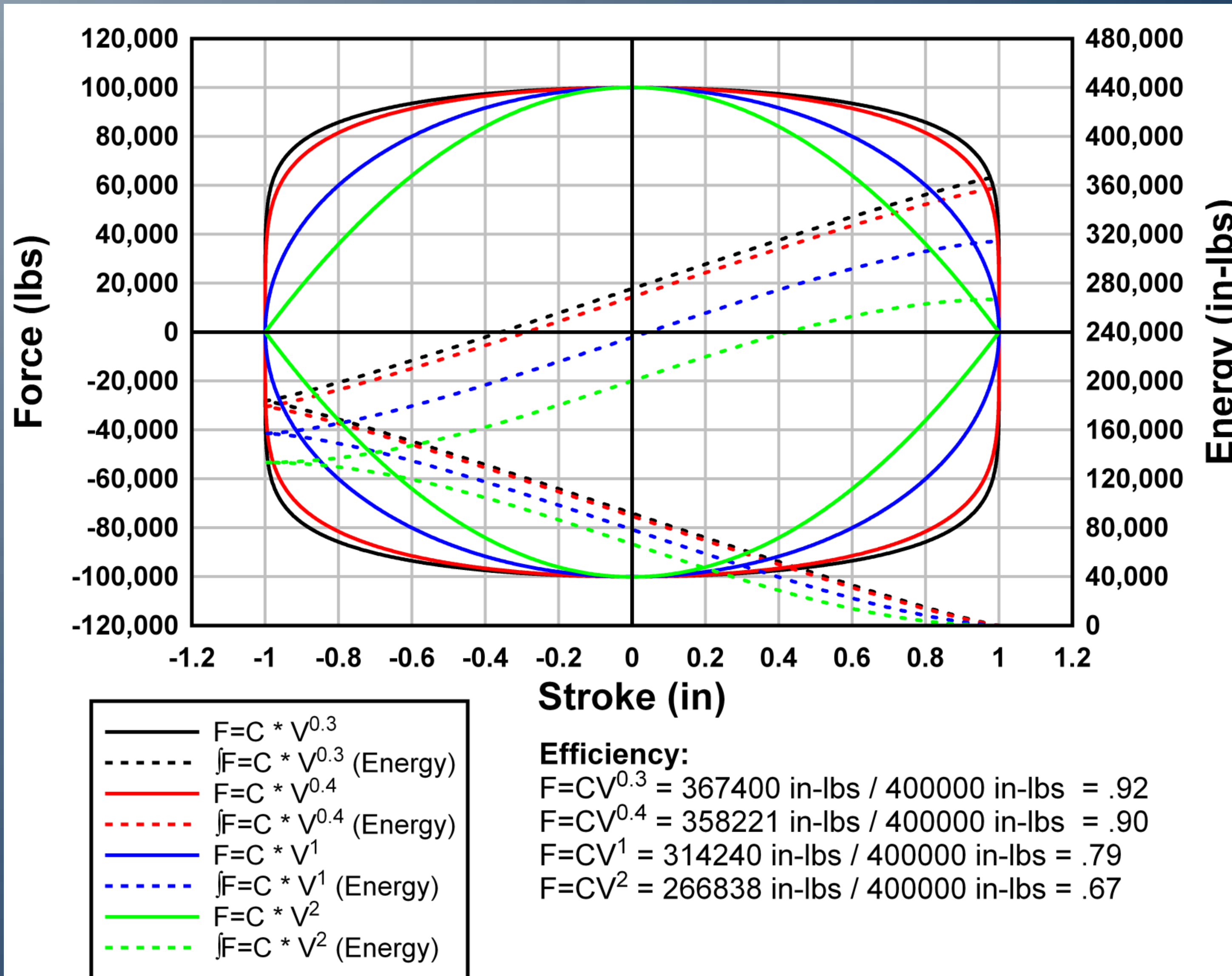
"α" can be set to any value from .3 < a < 2.0   In general, the lower this value, the greater the energy dissipation per cycle for a given maximum stress in the structure. α = 1 is easiest to analyze. Many optimized structures use α = .4

ENERGY ABSORBING COMPARISON FOR VARYING DAMPING EXPONENTS SUBJECTED TO SINUSOIDAL INPUT:

A linear damper (V^1) is approximately 78.5% efficient when integrating the energy under the force vs. displacement curve as it is subjected to a sinusoidal motion.

A special damper with a damping exponent of .4 is 89% efficient. That provides 13.4% more energy than a linear damper!

Therefore, performing a non-linear analysis using a non-linear damper can provide a substantial improvement in dynamic performance.



Hysteresis Loops for Varying Damping Exponents with Sinusoidal Input

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Benefits of Dampers:

- Reduced dynamic displacement……
  Over 50% reduction in many cases
- Decreased base shear and inter-story shear…..
  Up to 40%
- Much lower G forces in the structure…….
  Equipment keeps working and people are not injured
- Reduced displacement and forces usually means less steel and concrete……
  This offsets the damper cost and can sometimes reduce overall cost

Additional Points:

- Only fluid dampers reduce both stress and deflection in a structure during a seismic event, at damping levels to 40% of critical
- Successfully used since 1897, originated by the military
- Predictable at all times
- Relatively small size, self-contained
- Easily produced in forces of 10 mt to 800 mt, displacements to plus or minus 1.2 meters
- Easily installed in a structure as diagonal braces or as part of a base isolation system
- Stable, predictable performance at any temperature
- Long life, no maintenance

How to Analyze and Arrange Dampers in Structures

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Analyze – ETABS or SAP

1. Determine design spectral acceleration / ground motion time histories – ASCE7

2. Generate a structural model with column/beam elements, add damping elements

3. Set damper properties using known ranges for damping coefficient & exponent

4. Fine tune model – tributary masses, #modes, analysis options, etc.

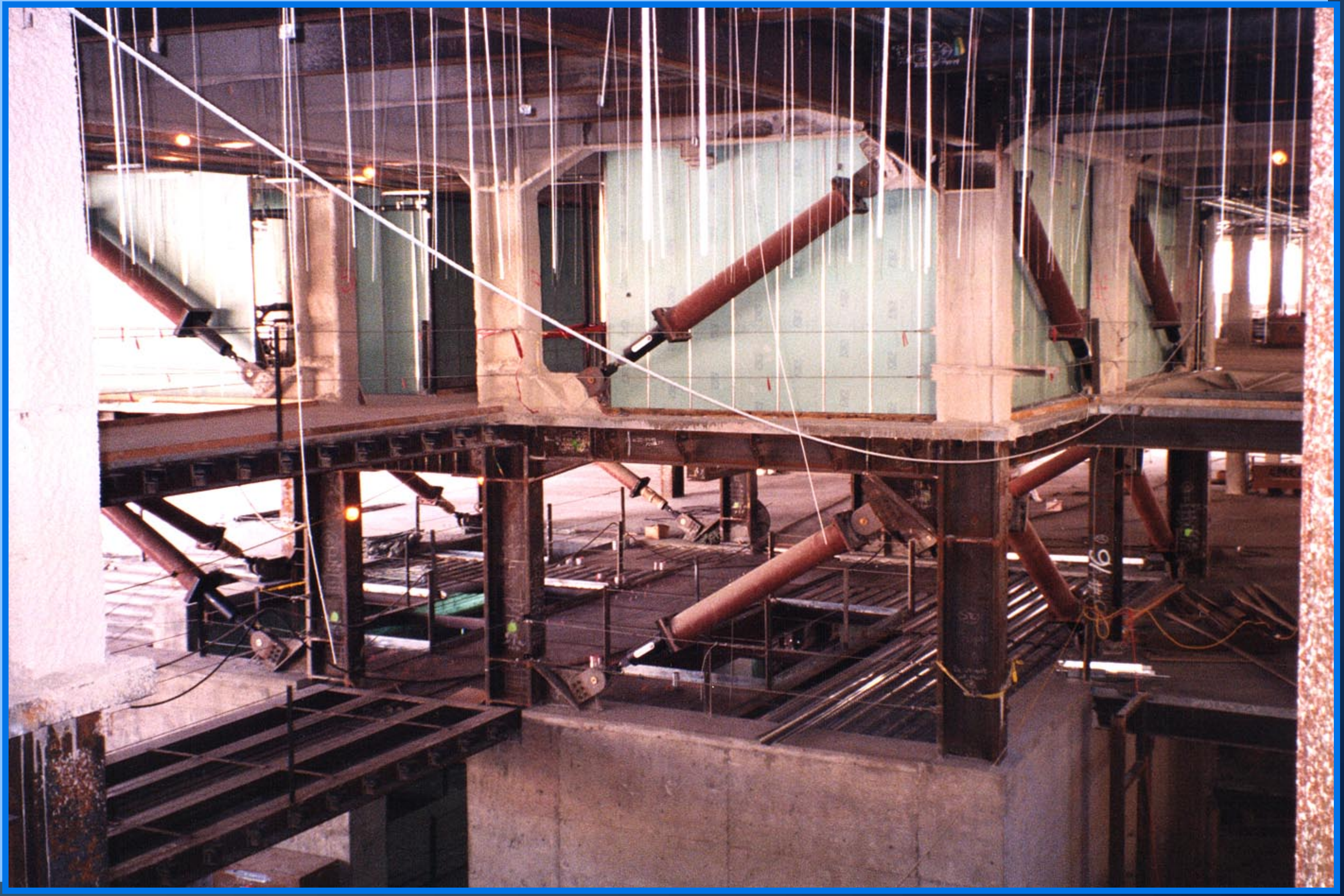
Analyze (continued)

5. Run analysis, check scaling of recorded ground motion, convert to Excel file, compare to Design Response Curve – ASCE7

6. Iterate with varying damping parameters

7. Finalize by adjusting damper force to available sizes as necessary

NOTE: Stay tuned… Taylor Devices to distribute a manual for analysis of structures



Seismic Damper installed at San Francisco Civic Center Office Building, San Francisco, California
Force = 230,000 lbs., Stroke = +/- 4 inches, Production = 292 pieces

Seismic Dampers installed at the Hotel Woodland, in Woodland, California
Force = 100,000 lbs., Stroke = +/- 2 inches
Production = 16 pieces

Seismic Dampers installed at Pacific Bell North Area Network Operations Center, Sacramento, California
Force = 30,000 lbs., Stroke = +/- 2 inches, Production = 62 Pieces

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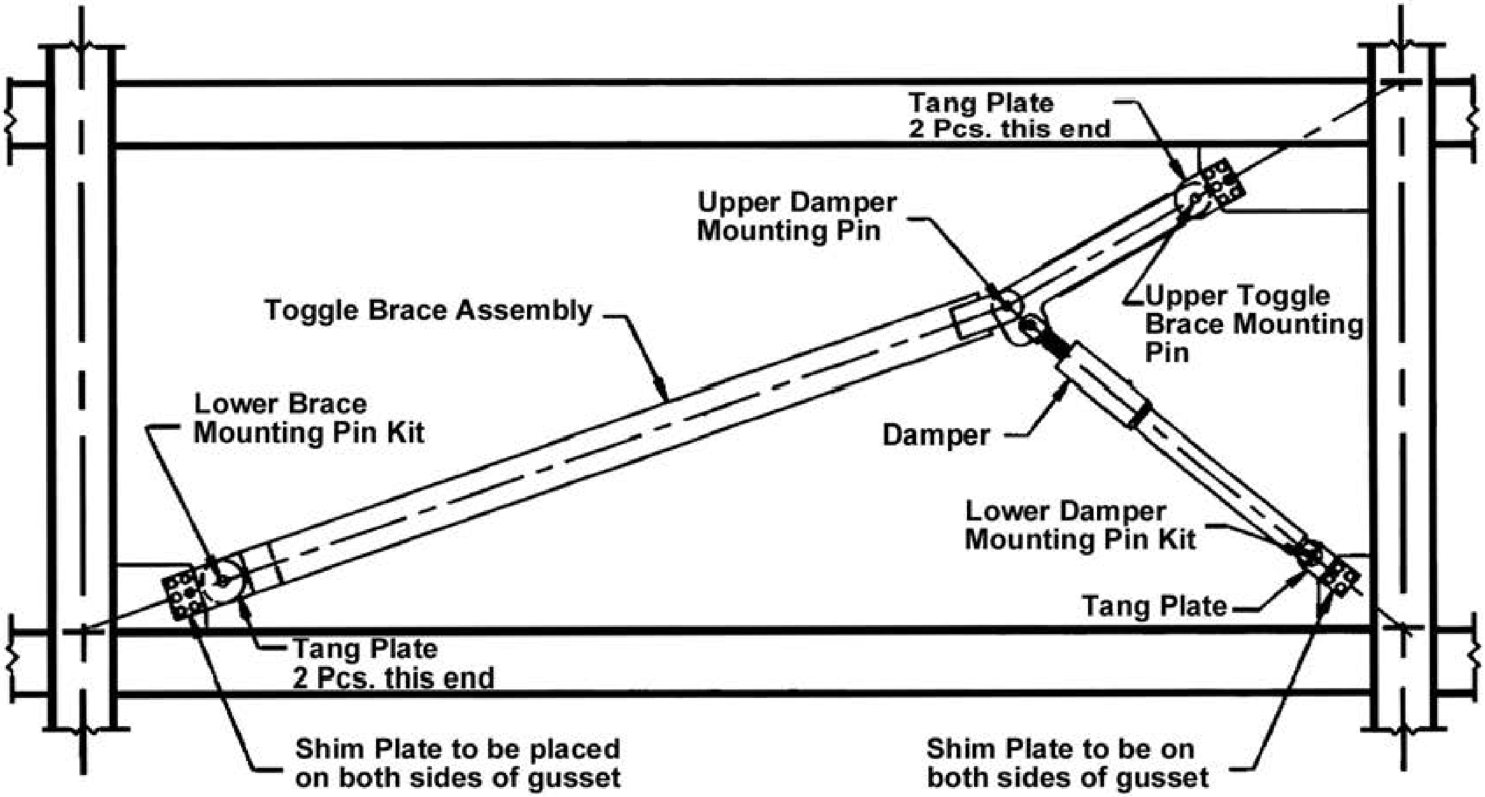
DAMPER TOGGLE BRACE ASSEMBLY



Tuned Mass Dampers

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Tuned Mass Damping ~

A suspended mass set near the natural frequency of the structure that oscillates out of phase with the structure to effectively damp the response of the structure to external influences

***Advantages*:**	**Relatively easy to incorporate and install into one location within a structure**
***Disadvantages*:**	**Works only at one frequency and provides only limited damping**

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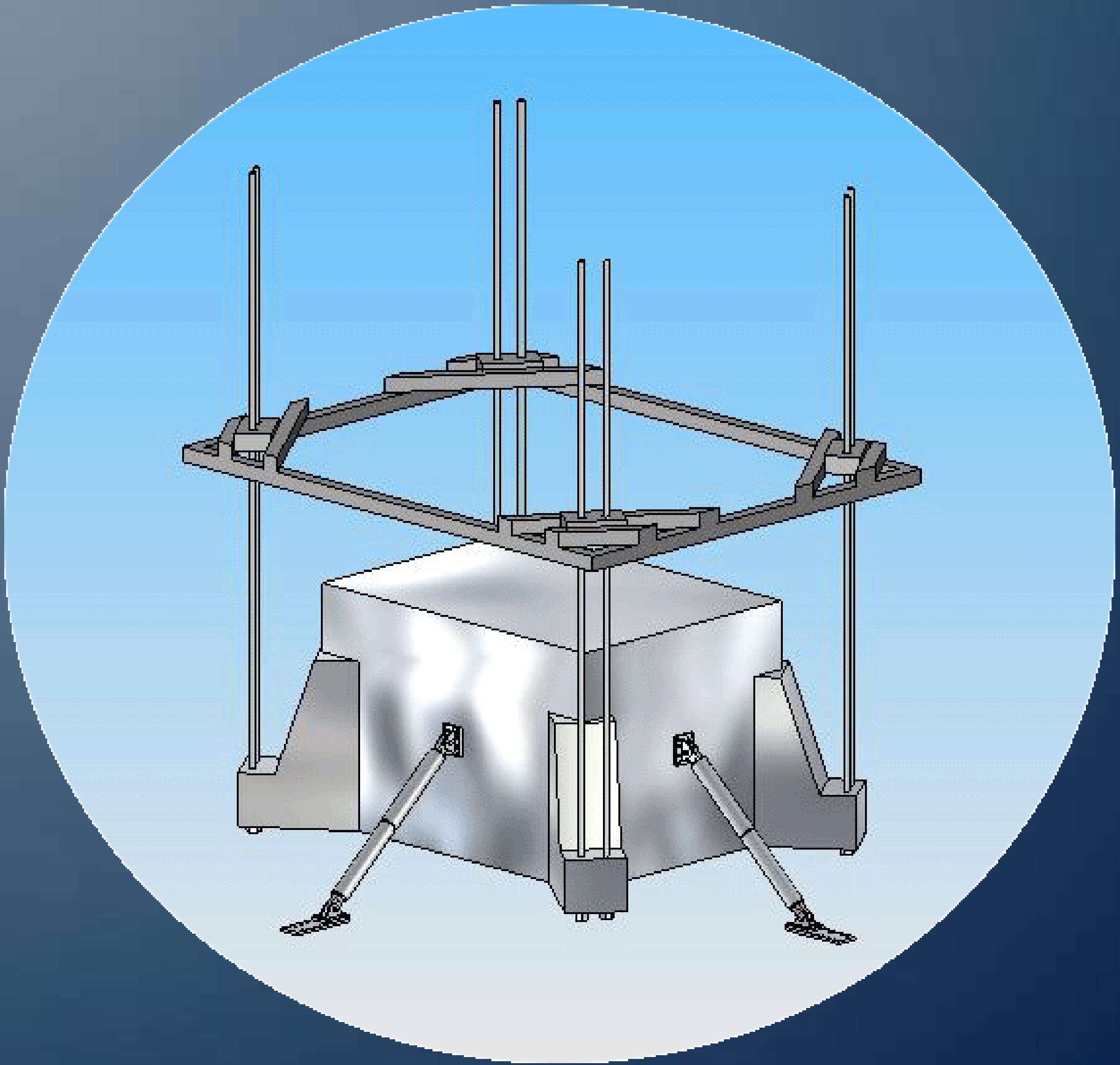
Tuned Mass Damper



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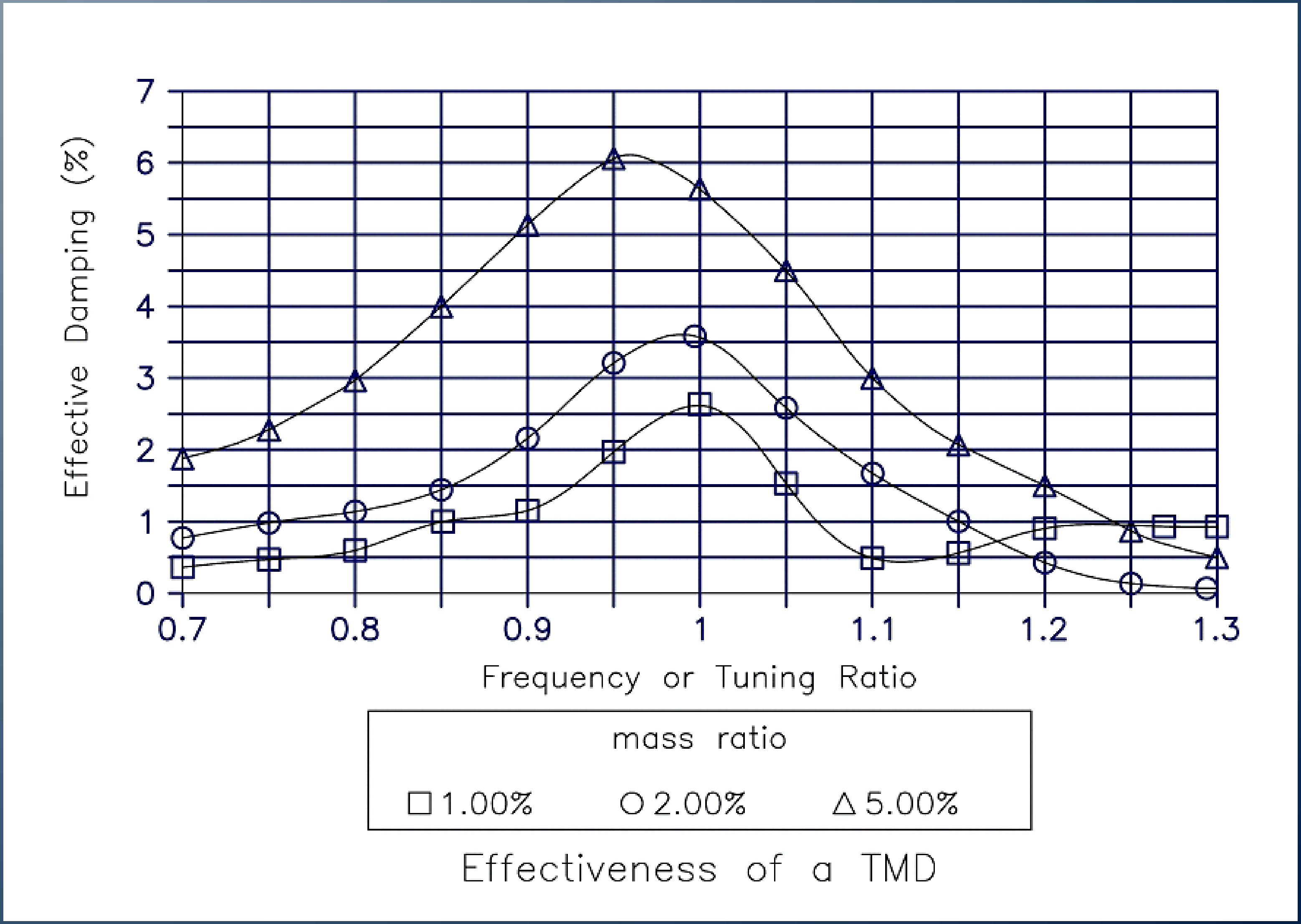
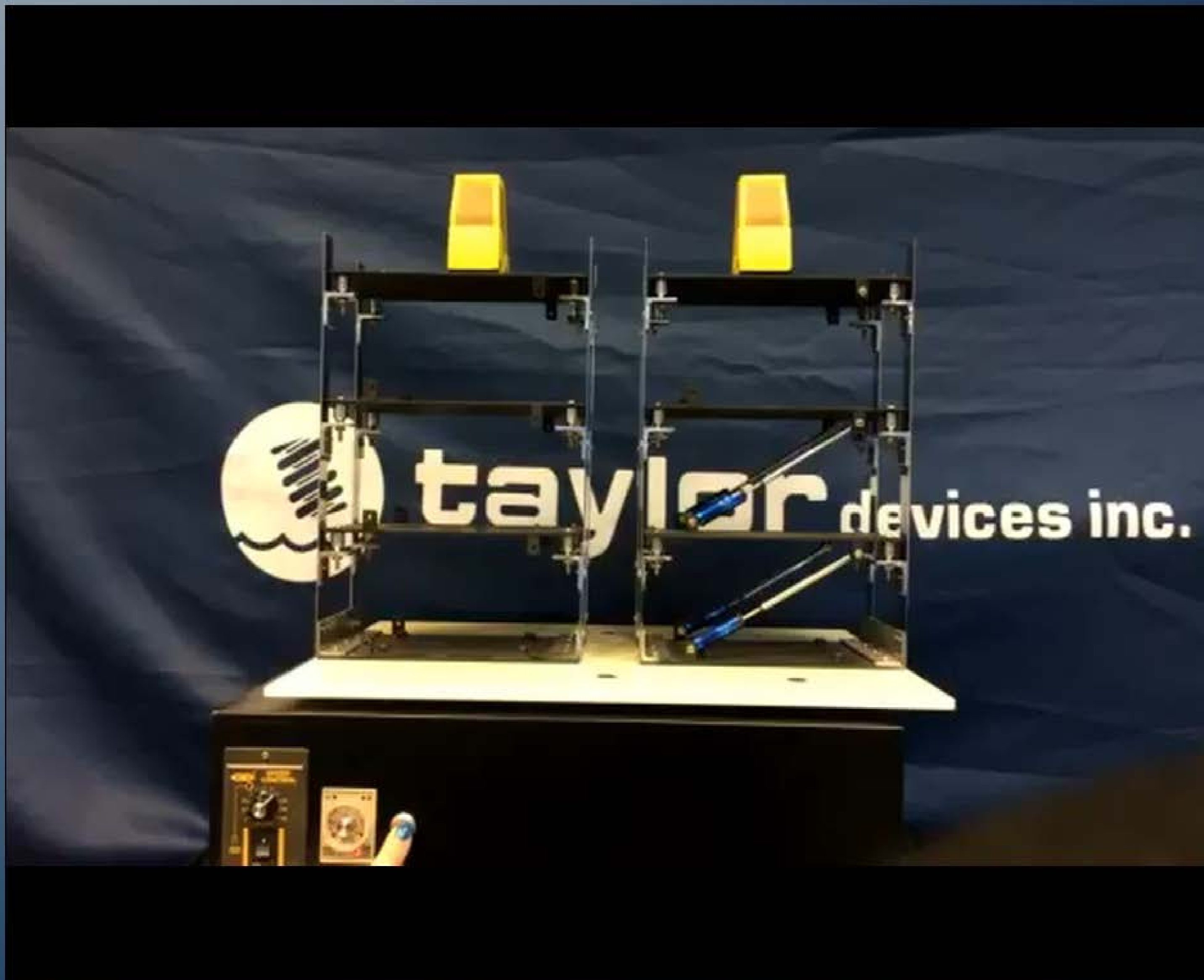
Effective Damping from TMD



Test Results in Visual Formats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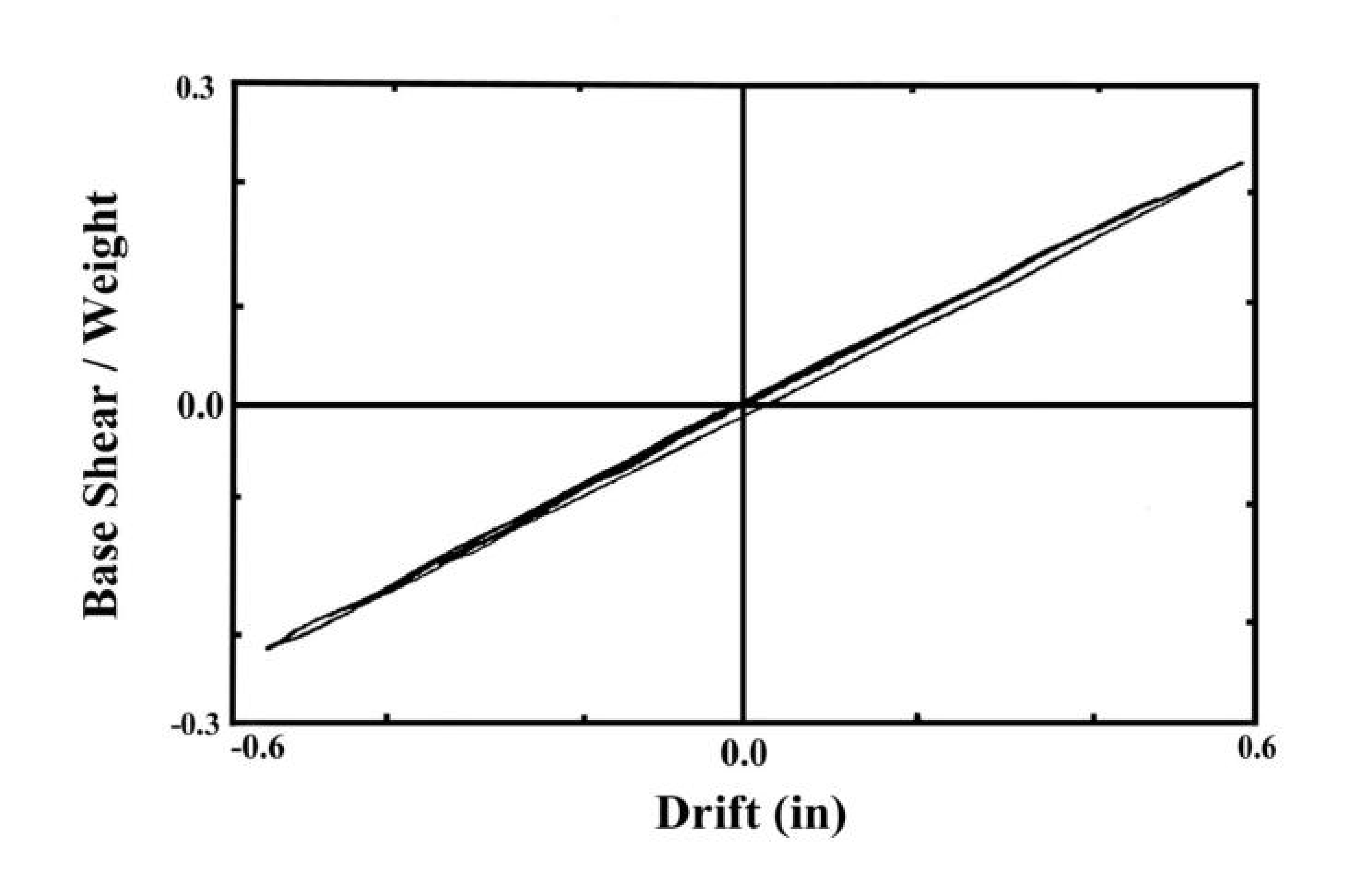
Test Results in a Building

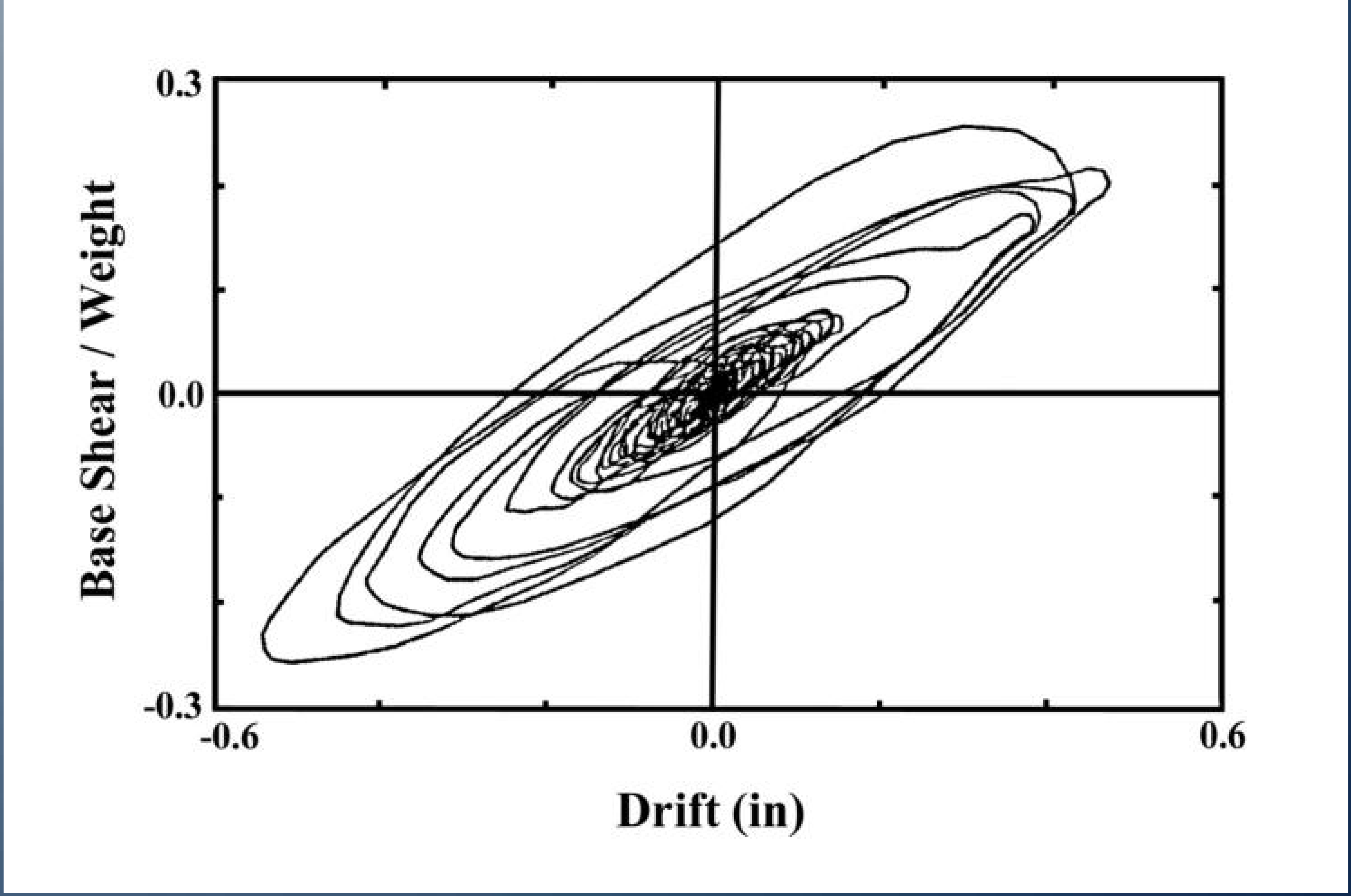
Let's consider some tests by MCEER with a complex seismic input into a structure, with added dampers.

In this case, the seismic pulse field indicated that a linear damper, F = CV, was a "best fit".



1-Story, No Dampers, El Centro 33.33%

Total Damping = 2%



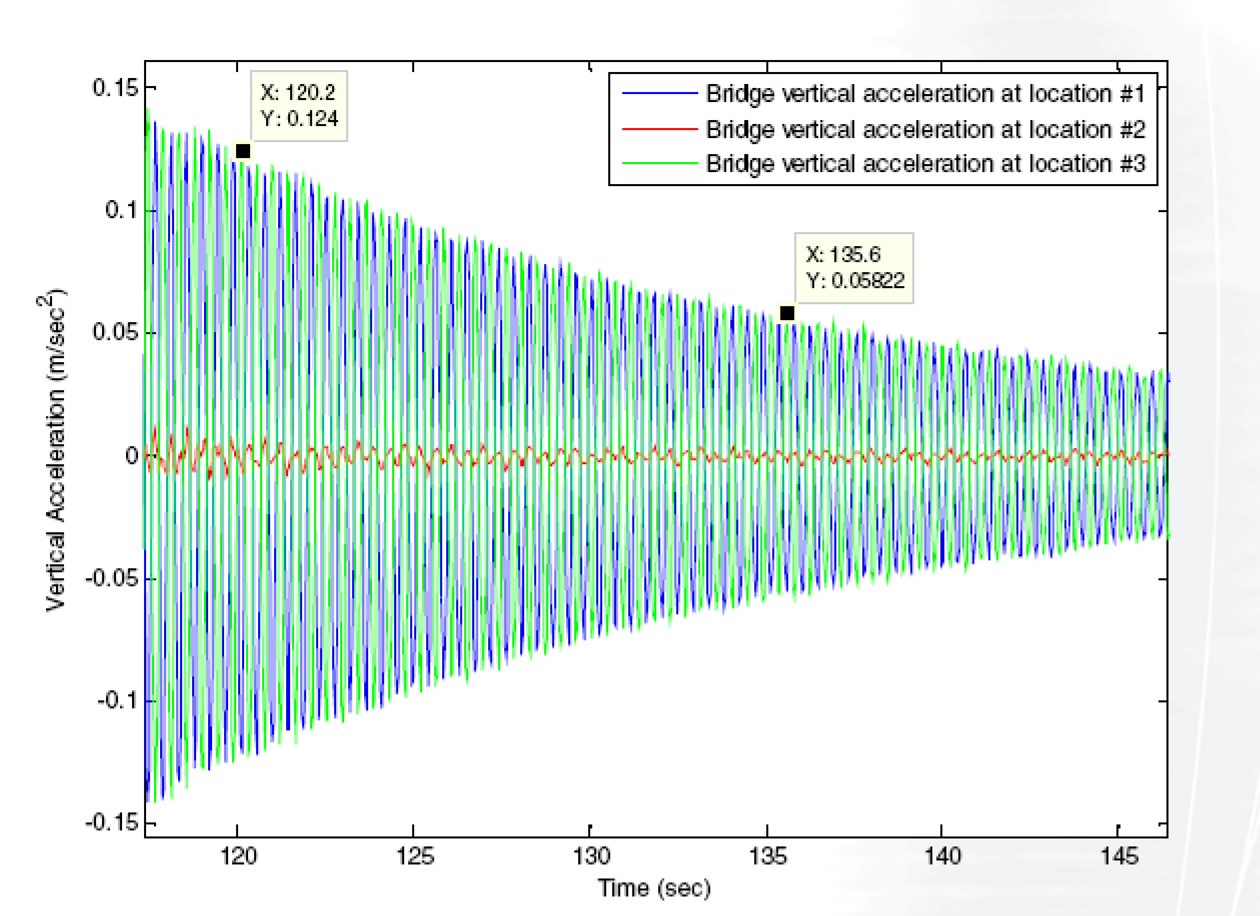
1-Story, 2 Dampers, El Centro 100%

Total Damping = 22%

Test Results on a Bridge

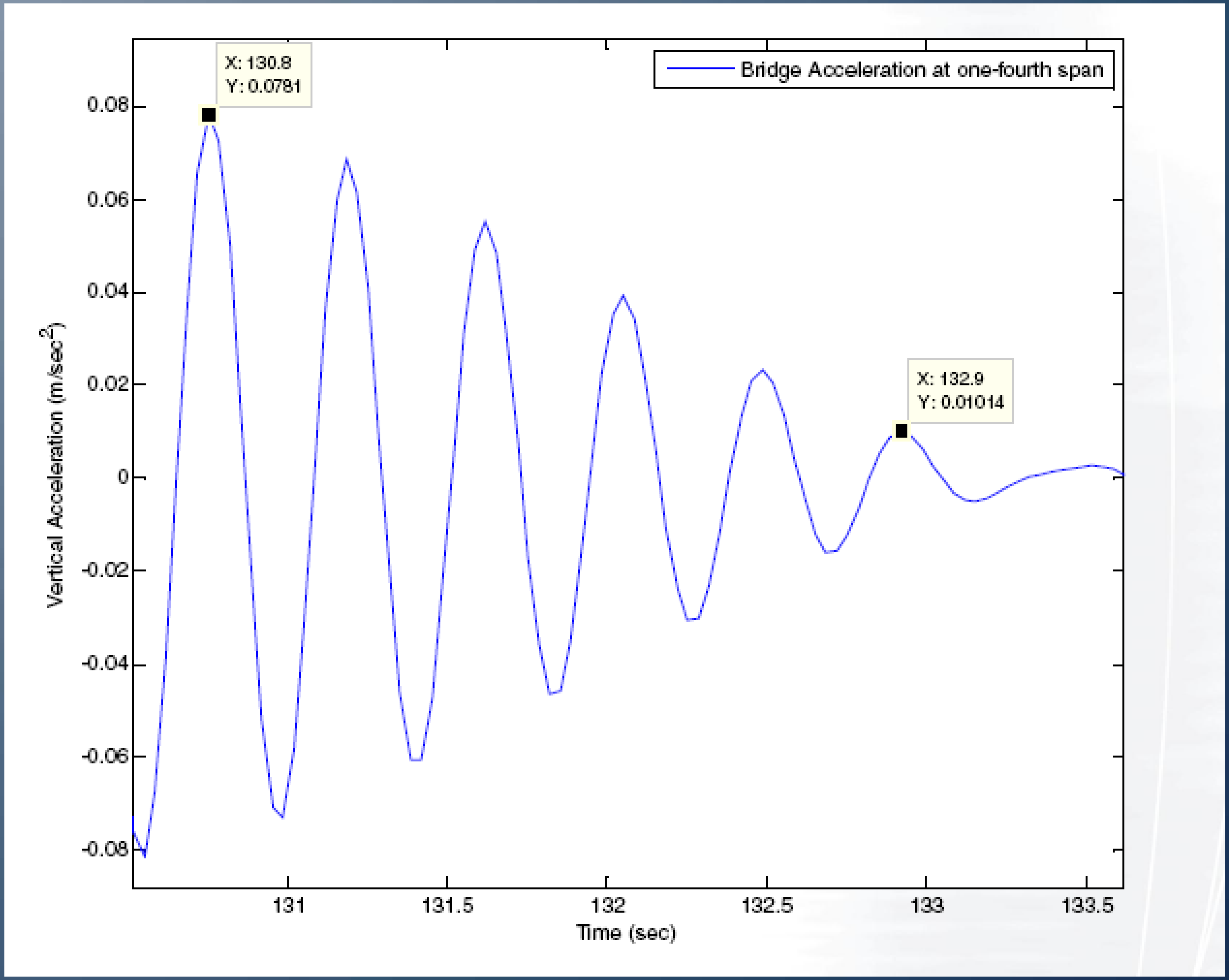
Let's take a look at actual test results measured on a bridge using accelerometers during an instantaneous excitation.

Watch the structural response both with and without dampers….



Response of Bridge with No Dampers:

After transient input, bridge oscillates for more than 30 seconds for dozens of cycles.



Response of Bridge with Dampers:

Bridge oscillates approximately 7 times and stops after 3-4 seconds.

Fluid Dampers ~ The Bottom Line

- **New Structures will be better, and will cost less**
- **Lifelines will be more survivable**
- **Historic structures can be preserved**
- **Existing structures can be simply upgraded**
- **Soft soil structural problems greatly reduced**

~ Conclusions ~

- U.S. Military Fluid Dampers from the Cold War are now widely used for seismic protection of commercial buildings and bridges
- Fluid Dampers offer greatly improved seismic performance for conventional and base isolated structures
- Only Fluid Dampers reduce stress and deflection from seismic or wind events, simultaneously
- Proven by long-term use from 1955 to date