Enhanced Seismic Protection of Oil Rigs

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INTRODUCTION

CURRENT PETROLEUM MARKET

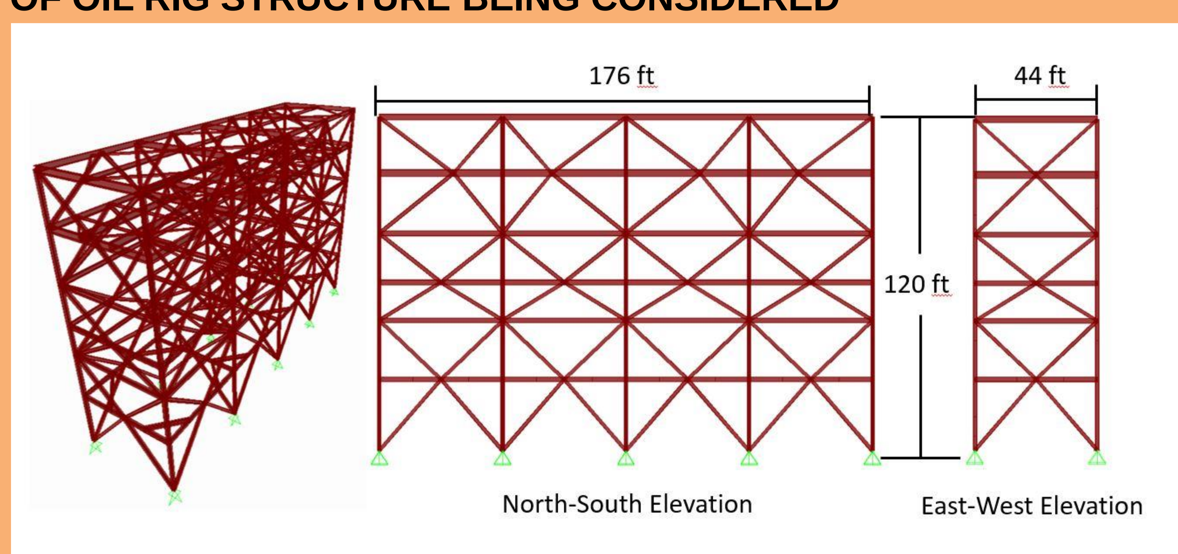
- An average Alaskan oil refinery can process more than 33,000 barrels of oil every day.
- A single refinery can produce more than $1.9 million per day.
- A large near-fault earthquake could result in millions of lost dollars per day of required delay, and could pose risk to the surrounding environment.

STRUCTURES USED IN PETROLEUM REFINERIES

- Structures used in Alaskan oil refineries are modular open steel-frame structures.
- These modules are constructed off-site and then transported to and installed in their permanent location.
- Modular structures are designed considering their transportation and accelerations based on Maximum Considered Events (MCE).
- These structures are not designed to withstand large near-fault earthquakes, which tend to induce accelerations exceeding those considered during design.

ISSUE VERIFICATION

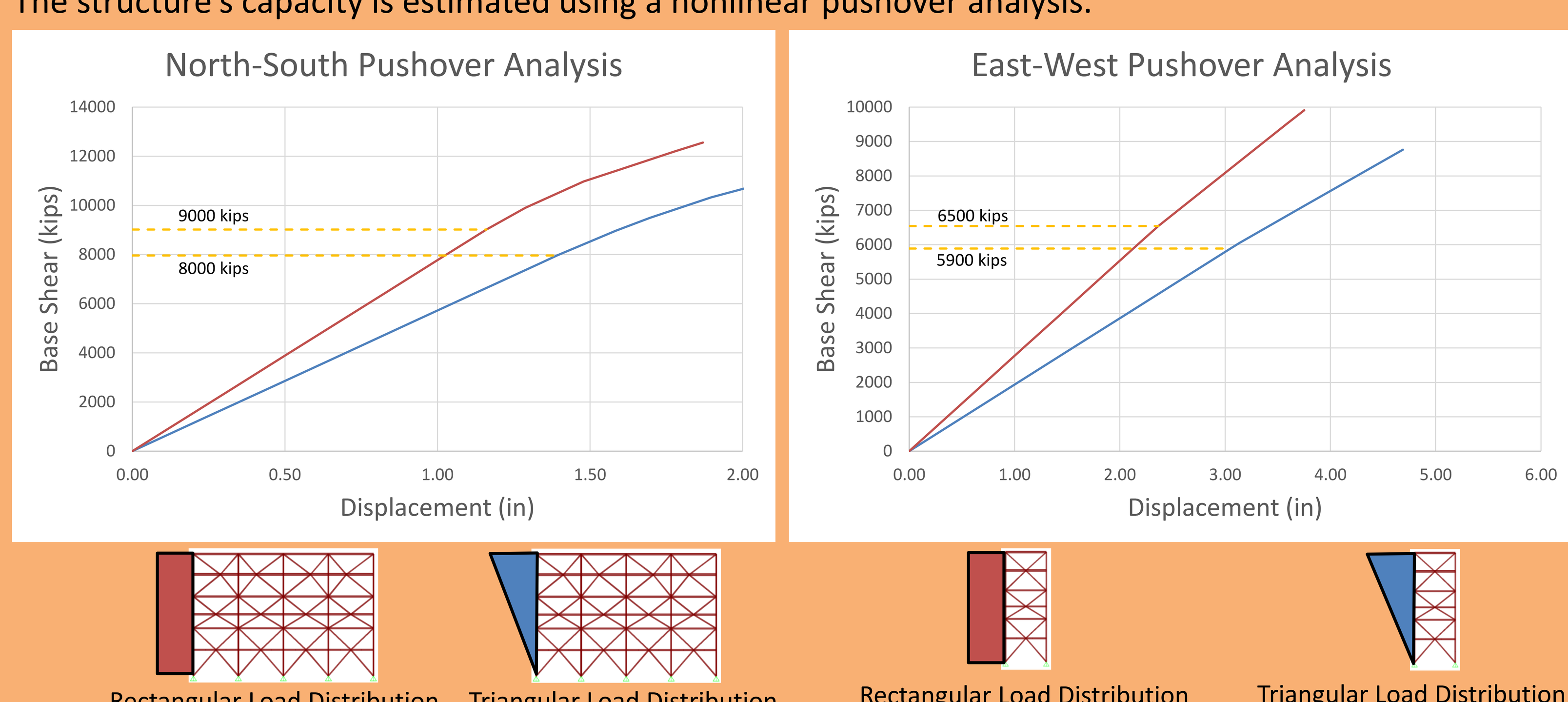
OVERVIEW OF OIL RIG STRUCTURE BEING CONSIDERED



- 2300 tons of weight
- Natural Period of 0.33 seconds

CAPACITY ANALYSIS

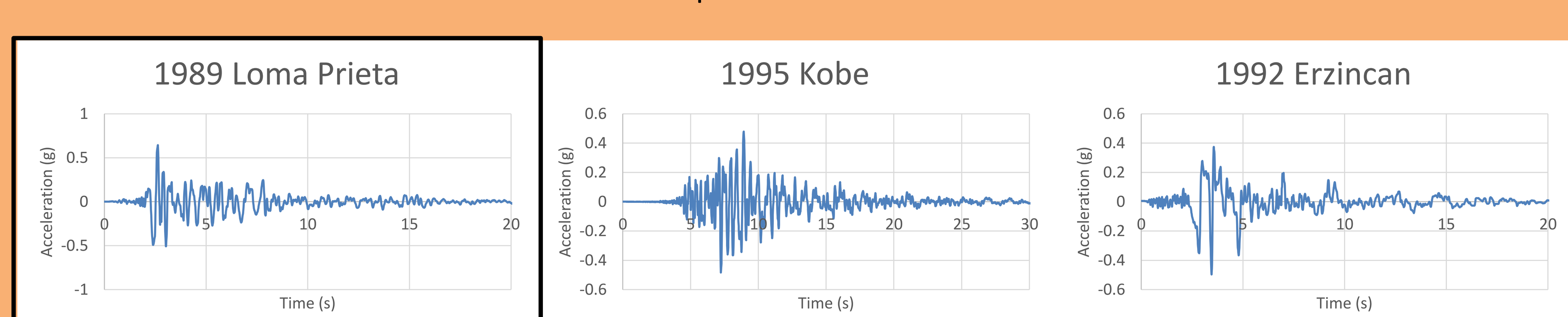
- The structure's capacity is estimated using a nonlinear pushover analysis.

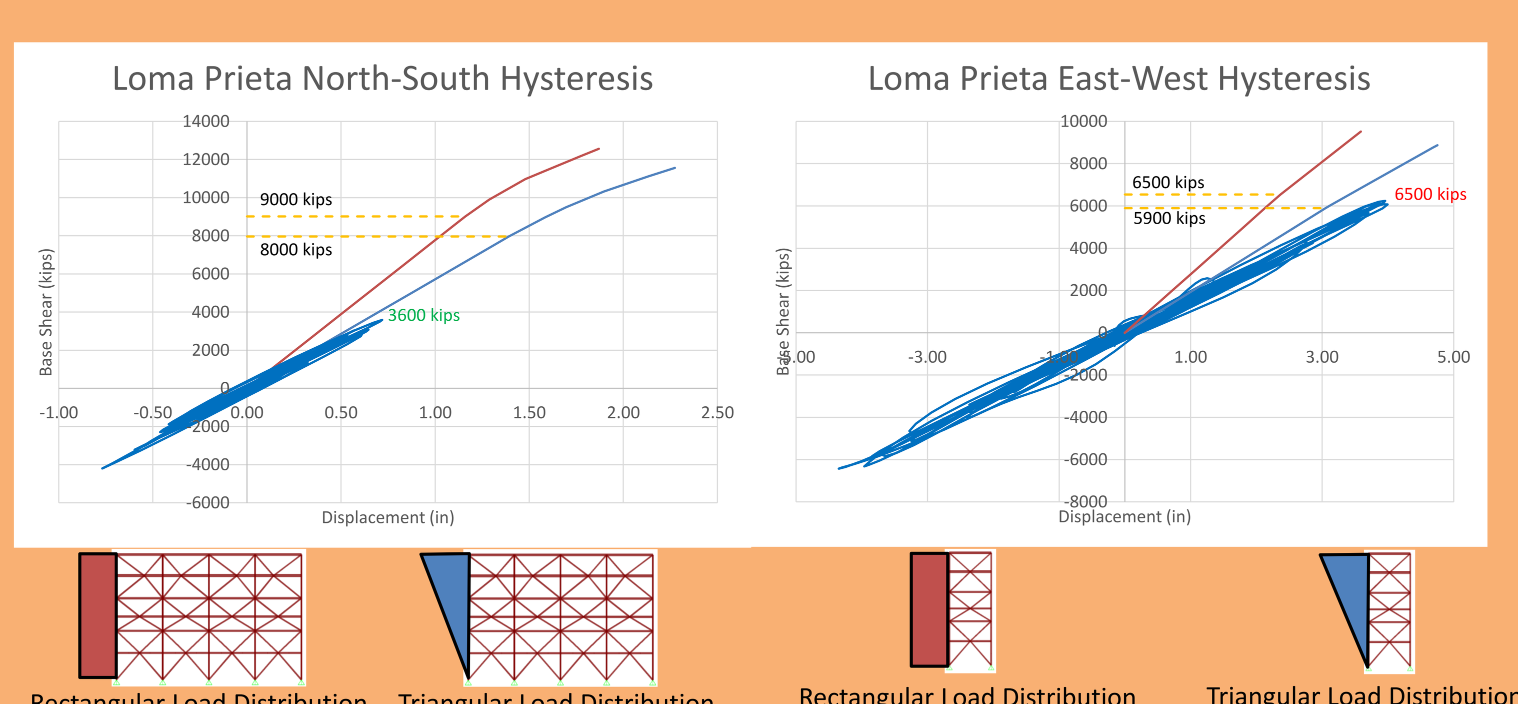


- At the indicated levels of base shear, the lateral bracing at the bottom level of the structure begins to buckle.

NONLINEAR TIME HISTORY ANALYSES

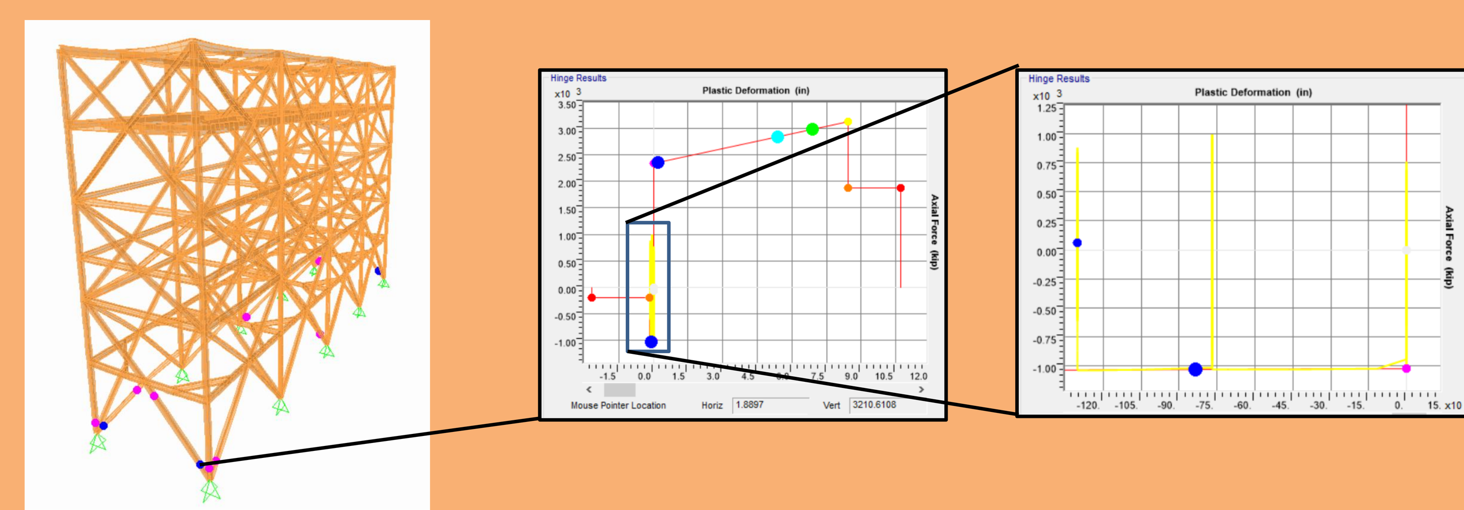
- The structure was tested against three earthquake records to verify whether or not a large near-fault earthquake would cause damage to the structure.
- The Loma Prieta results are the focus within this poster.





- In the north-south direction, induced base shear does not approach the structure's estimated strength.
- In the east-west direction, the earthquake induced a base shear equivalent to upper limit of the estimated capacity of the structure.

ISSUE VERIFICATION

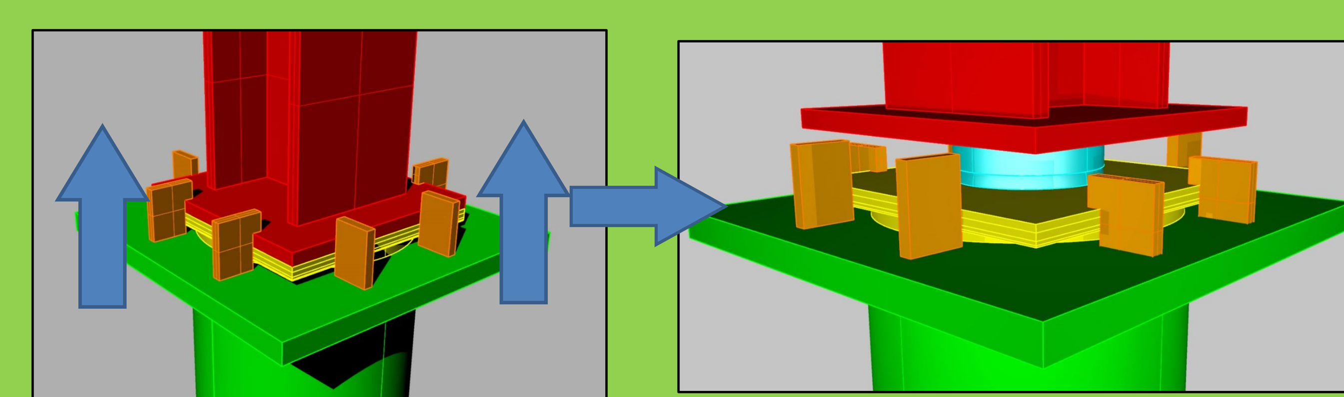


- Plastic hinge formations are displayed as colored orbs.
- The Loma Prieta earthquake induces 0.13 inches of permanent brace compression yielding in lateral bracing.
- Further yielding can cause buckling, which could result in sudden structural failure.

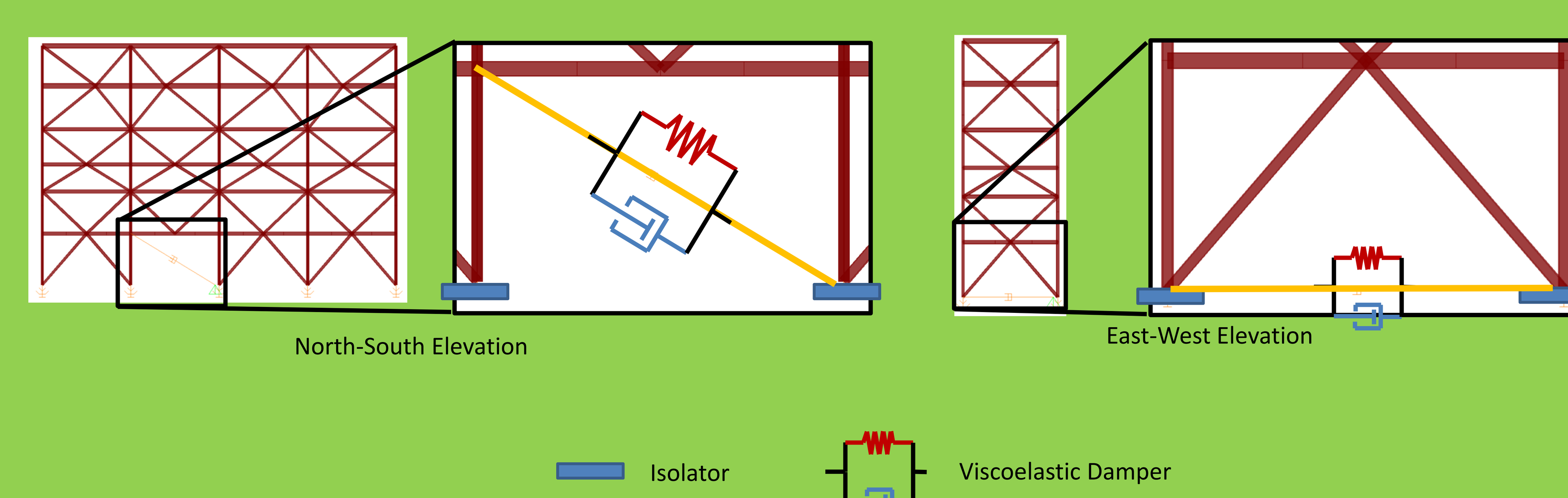
SOLUTION

POTENTIAL SOLUTIONS: FRICTION ISOLATORS AND VISCOELASTIC DAMPERS

- Friction pendulum systems (FPS) are effective at reducing vibration and decreasing base shear.
- Implementing FPS behavior transforms seismic energy to heat due to sliding friction, reducing vibrational energy transferred into a structure.
- Base shear is reduced to frictional forces.
- Implementing this solution in existing oil rigs is simple.

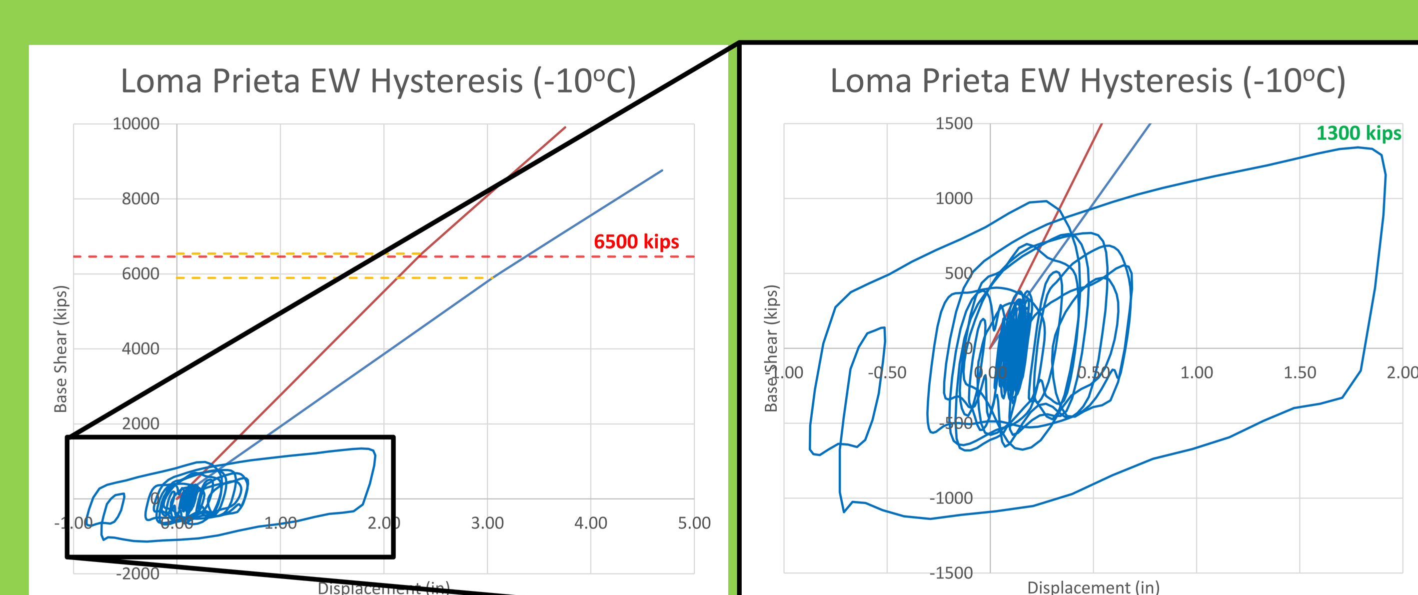


- A slider can be installed beneath the columns' base plates to implement FPS behavior.
- Flat shim plates provide no re-centering capability, which would likely result in excessive displacements.
- Viscoelastic dampers can provide re-centering force.
- Viscoelastic dampers would be installed from piles supporting the structure to the structure itself.



MODIFIED STRUCTURE PERFORMANCE

- The modified structure was tested against the same three earthquake records.
- Because of FPS and viscoelastic damper temperature-dependent behaviors, analyses were performed for a range of temperatures.



- Base shear is reduced by 80%.
- No plastic hinges form during any earthquake.
- The table below summarizes the results for every ground motion case.

	Loma Prieta		Erzincan		Kobe	
Temperature	-10°C	20°C	-10°C	20°C	-10°C	20°C
Max Base Shear (kips)	1300	700	1250	850	1250	570
Max Displacement (in)	2.0	2.9	1.4	8.8	1.0	1.7

CONCLUSION

- Proposed modifications effectively prevent structural damages.
- For higher temperatures, excess displacements may pose new problems.
- Further investigation is required for optimal base connection design.

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