Seismic Behavior of Quasi-Isolated Bridge Systems and Components

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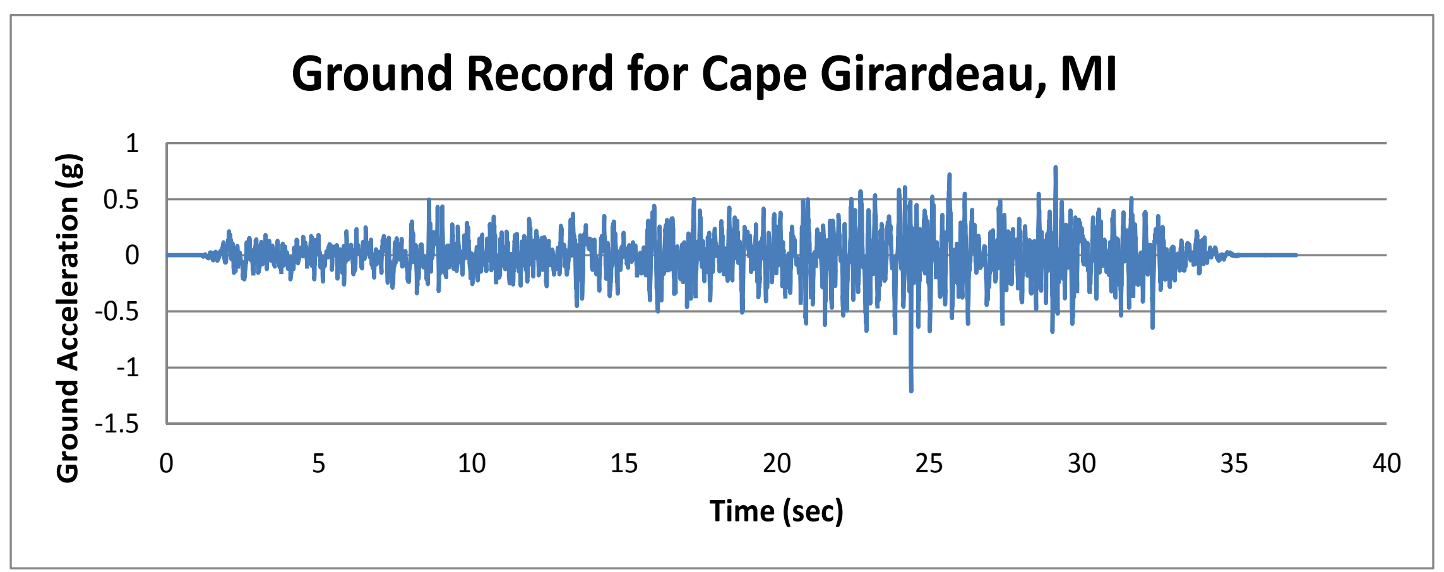
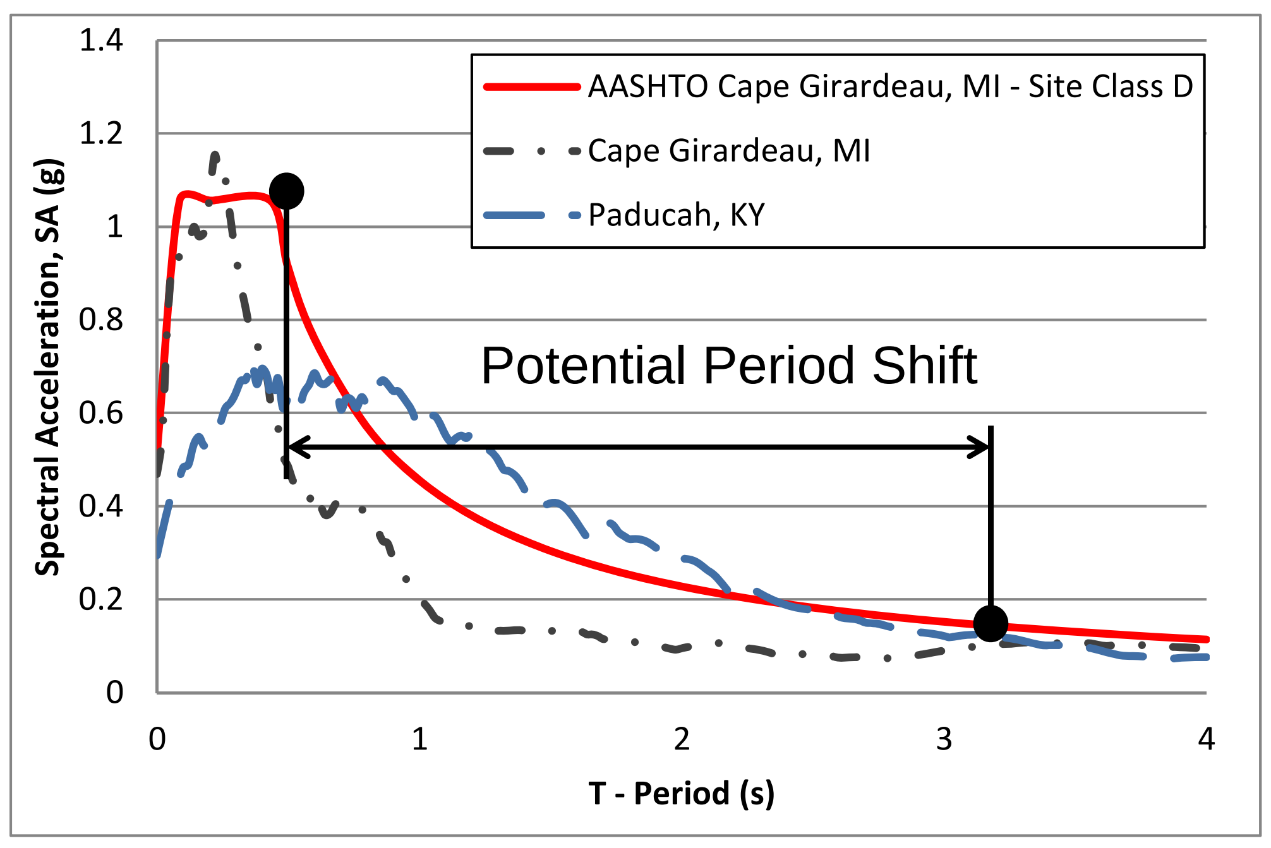
SEISMIC ISOLATION



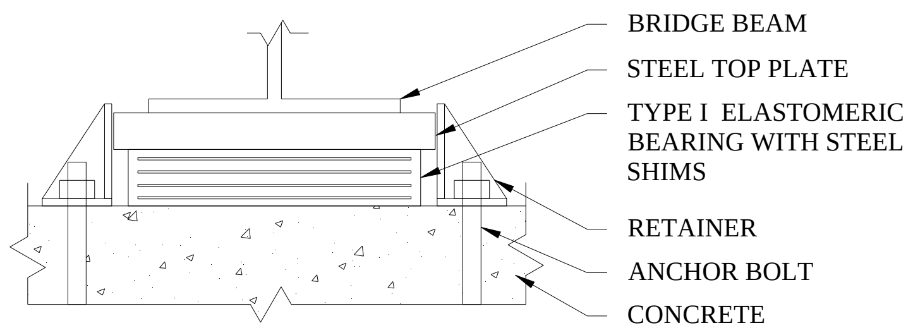
$$T = \frac{1}{f} = \frac{1}{2\pi * \omega} \qquad \omega = \sqrt{k/m}$$

- The ground record and an SDOF analysis is used to calculate an earthquake spectra (shown on right) that can be used to determine earthquake accelerations for a vibrating structure
- Seismic Isolation using elastomeric or sliding bearings reduces the effective stiffness of a structure and elongates the period of vibration
- Methodical design of a structural system can allow for a period shift that reduces the accelerations and thus the forces on a structure

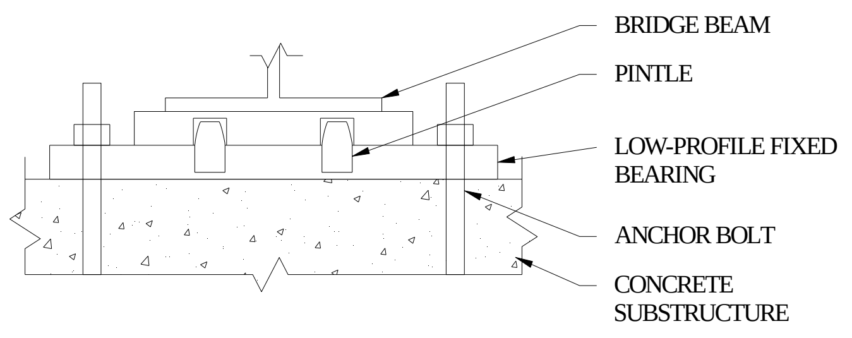


EXPERIMENTS AND MODEL VALIDATION

The research program at the University of Illinois combines experimental laboratory testing of bridge bearings with computational simulations of full bridge systems, in order to facilitate calibration and refinement of the earthquake resisting system bridge design methodology for the expected seismic hazard. Quasi-isolation of bridges implements alternative bearing components that respond elastically for service loading, but can permit sliding and can effectively limit the forces transferred between the superstructure and substructure in the event of an earthquake. Experimental testing has been carried out on different isolation bearings and retaining brackets to better understand the component nonlinear behavior and ultimate capacities. Phenomenological element models were formulated to capture the bi-directional stick-slip behaviors expected to occur in the bridge bearings, and elements were also created to model the bilinear behavior of the steel retainers.

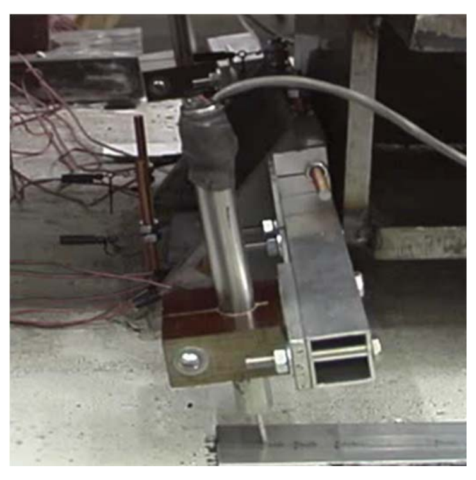


Type I elastomeric bearing on concrete

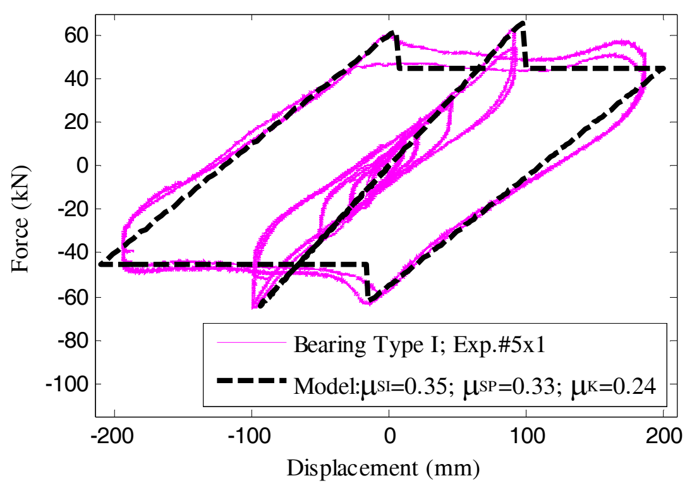


Low-profile fixed bearing

Type I bearing sliding on concrete under lateral load



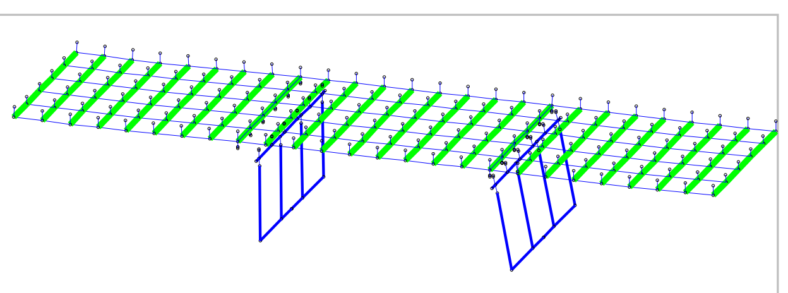
Individual retainer test



Cyclic Type I test with slip-stick model

SYSTEM ANALYSES

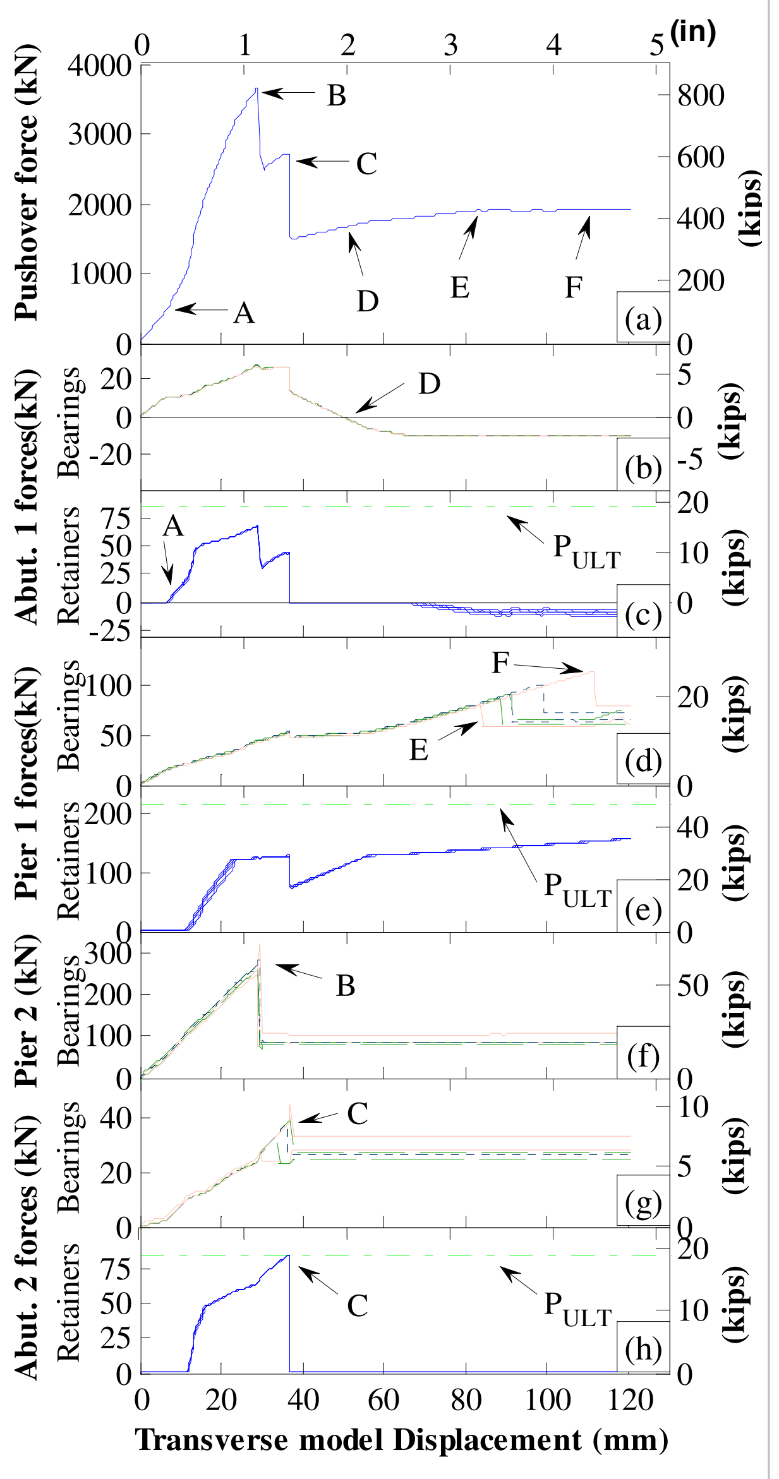
Incorporating phenomenological models based on the experiments, static and dynamic parametric nonlinear analyses are being performed to study the global system behavior.



OpenSees model mesh under longitudinal loading

Key events in transverse pushover analysis

A. Contact of bearing top plates with retainers at Abutment 1
B. Break-off of anchor bolts at low-profile fixed bearings and subsequent sliding
C. Failure of retainers and subsequent friction slip of bearings at Abutment 2
D. Rotation of deck about Pier 1, reverse movement of bearings at Abutment 1
E. Friction slip of bearings at Pier 1 and contact of retainers at Abutment 1 in reverse direction



Transverse Pushover Analysis

Preliminary results :

- Type I bearings tolerate approx. 100 – 200% equivalent shear strain without slip
- Friction coefficients approx. 0.25 – 0.5
- Experiments show that retainer fuse strength is currently underestimated
- Retainer elements and bearings need to be detailed to limit forces on substructures and to allow for a quasi-isolated response

ACKNOWLEDGEMENTS

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Topology optimization design of high-rise buildings subjected to dynamic loading

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Graduate Research Fellowship Program

- Proposed research will incorporate topology optimization techniques to improve real life structures to perform better when subjected to dynamic excitation such as those from wind or earthquake loading.
- Wind loading can cause structural vibrations of higher buildings, so optimizing the structural stiffness and dynamic properties can reduce displacements and improve occupant comfort.
- When buildings are subjected to low magnitude frequently occurring earthquakes, engineers prefer to minimize damage and repair costs. Improving the dynamic characteristics of a structure, it is possible to reduce inter-story drifts and system accelerations, in that way preventing damage to non-structural elements such as windows, wall partitions and building equipment.
- For large earthquakes, topology optimization can be used to elongate the structural period of vibration to provide the same benefits as seismic isolation (presented above).
- Initial developments will concentrate on elastic analyses of structures and will focus on optimum mass and stiffness distribution. Future work could lead into nonlinear analyses to better understand seismic performance of buildings.