SLIDING BASE ISOLATION FOR LIGHT FRAME HOUSING

Materials Testing - PEER Internship Program – Summer 2013

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NEES@berkeley Lab~ UC Berkeley, Blume Center ~ Stanford University

Project Introduction and Motivation

Of the $44 billion in damages that resulted from the 1994 Northridge Earthquake, an estimated $20 billion was attributed to damage to light framed housing. Researchers at Stanford University and California State University at Sacramento seek to minimize these potential damages and provide reduced priced earthquake protection systems by a combination of two *affordable* methods:

1. Allow sturctural and non-structural components to work together to stiffen the frame, termed "*unibody method*"
2. Reduce base shear by *sliding base isolation* in housing foundations

This poster illustrates the research methods and studies of the second approach conducted by Stanford University. Sliding isolation was chosen over other forms of isolation for light frame housing because these systems (a) do not require a large mass like those of heavy civil projects, (b) have a peak base shear is equal to the coefficient of friction, and (c) they can be affordable and materially accessible for average homeowners.

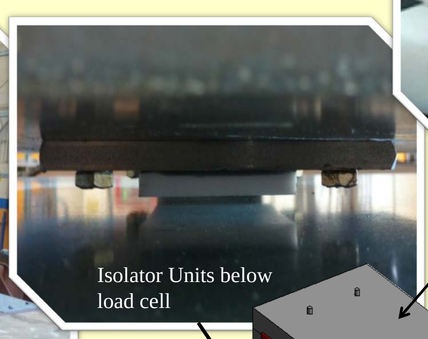
Methodology and Testing

Initial OpenSees Modeling predicts the relative displacement given ground acceleration and a friction model.

→ Particular interest in determining peak and residual displacements used to determine the size of the sliding surfaces.

Velocity Dependent Friction Model: $\mu = \mu_{max} - (\mu_{max} - \mu_{min})e^{-va}$

μ_{max} = maximum friction
μ_{min} = minimum friction
a = transition rate



Strut for Static Tests (Removed for Dynamic Tests)

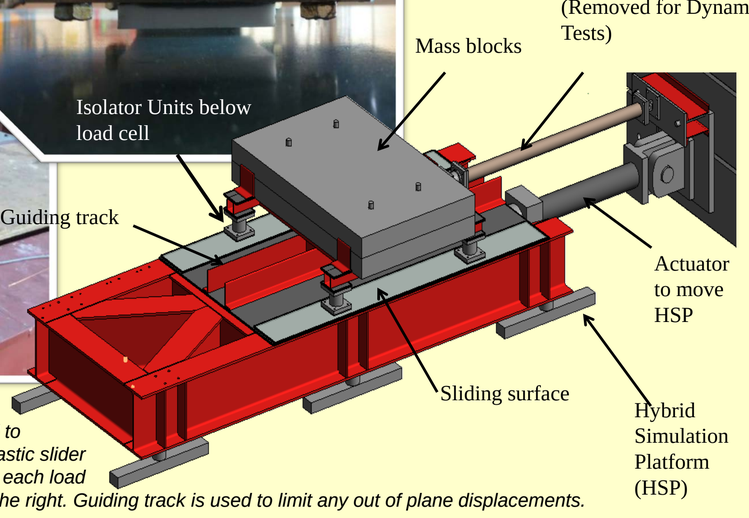


Figure 1: *Above is shown the total test set up on Hybrid Simulation Platform (red table). Concrete blocks are added to simulated the weight of a typical light frame house. Four plastic slider units (4.5 sq in) are placed on a steel sliding surface under each load cell (see above right). Revit model of test set up shown to the right. Guiding track is used to limit any out of plane displacements.*

Materials Testing was conducted on a shaking table. 6 material interfaces were chosen to be tested as potential sliders and sliding surfaces. Materials were chosen by cost and availability.

~Unfilled PTFE /galvanized steel	~Kevlar filled nylon /galvanized steel
~Glass filled PTFE (ConServ) /galvanized steel	~Glass filled PTFE (ConServ) /mirror finish SS
~HDPE /galvanized steel	~Unfilled PTFE /mirror finish SS

General Test Parameters: 10.3 kip mass ~ 570 psi (Low pressure s in a house can achieve higher friction levels).

Types of Testing:

A. Cyclical testing (at varying velocities from quasi-static to 16 in/s)
B. Five dynamic time histories (Each record was chosen to exhibit large sliding displacements up to 10 – 15" with 20% friction).

Dish Testing:

- 2 tests run on a galvanized steel dish base (80 in radius of curvature)
- Desire to minimize peak and residual displacements.
- Materials Tested: GF PTFE and HDPE on Galv Steel.
- The restoring force of this dish can be assessed using the formula:

$$K = \frac{\text{Weight of House}}{\text{Radius of curvature of Dish}} = 0.128 \text{ kip/in}$$

Figure 2: *Test set up for sliding unit on galvanized steel dish isolator*

References

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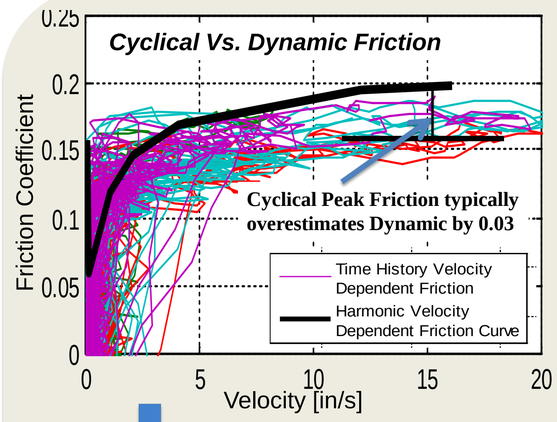
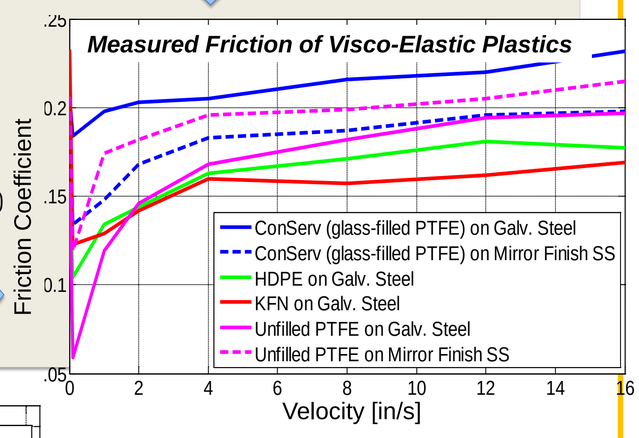
Results and Findings



1. ***Harmonic Velocity Dependent Friction Curves***



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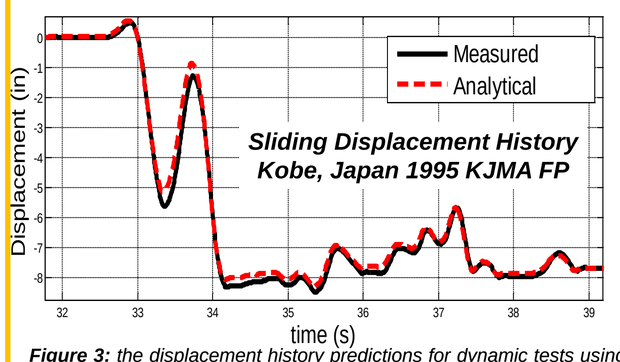


Figure 3: *the displacement history predictions for dynamic tests using OpenSees is compared to the measured history of ConServ on Galv Steel. Analysis predictions generally matched measured results very well, even during records with many sliding excursions (nonlinear response).*

Performance of Analytical Model:

1. < 10% error in peak displacement predictions
2. < 15% error in residual displacement predictions
3. Analysis usually slightly underestimates displacements

To simplify industry practice of design isolators, an optimization analysis provides a Coulomb friction model with values 0.01-0.02 less than the friction levels from obtained from cyclical materials testing above

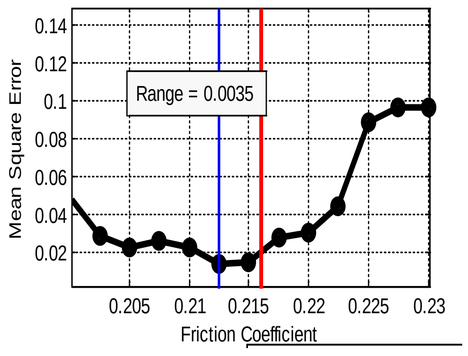
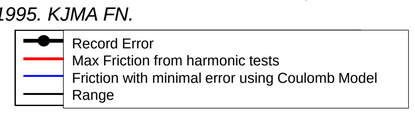


Figure 4. *The results of a Coulomb Friction optimization analysis for ConServ on Galvanized Steel, record Kobe, Japan 1995. KJMA FN.*



Dish System as a Restoring Force

Advantages:
→ Reduces peak displacements 30%
→ Eliminates residual displacements

Disadvantages:
- Expensive
- Larger base shear than a flat system.

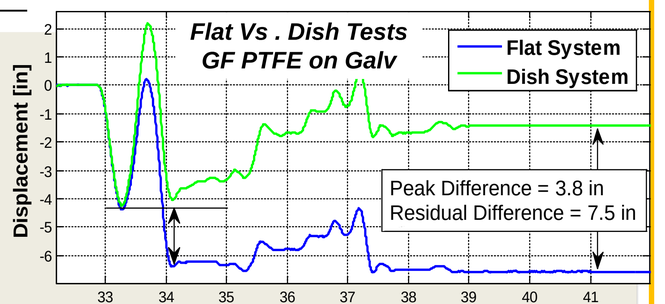


Figure 5: *A comparison of the flat and dish system displacement response to Kobe, Japan 1995*

Recommended Material Interface

Advantages of Galvanized Steel:
- High friction → lower displacements
- Inexpensive

Advantages of HDPE and GF PTFE:
- High friction → lower displacements
- Stiffer material → less pressure dependence
- No damage by significant sliding
- Inexpensive

Conclusions

This project has the potential to mitigate billions of dollars to the state in damages during the next large event by adhering to the shelter-in-place method to allow families to remain in homes that would otherwise been uninhabitable after a large event without protection.

→ Inexpensive and common materials can be used effectively in isolation systems.
→ Wear and tear is insignificant for the low pressures in light frame construction.
→ Uncertainty in interface friction and the use of a Coulomb friction model would suggest that a designer use a friction value 0.01 to 0.02 lower than those gathered from any material testing.
→ A dish system is only recommended in the case where no or little residual displacement is desired.
→ Recommendations for material interface in sliding base isolation systems:
~Glass filled PTFE by ConServ or HDPE on zinc galvanized steel

Acknowledgements

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