DESIGN OF SEISMICALLY ISOLATED STRUCTURE UNDER RARE SEISMIC EVENT

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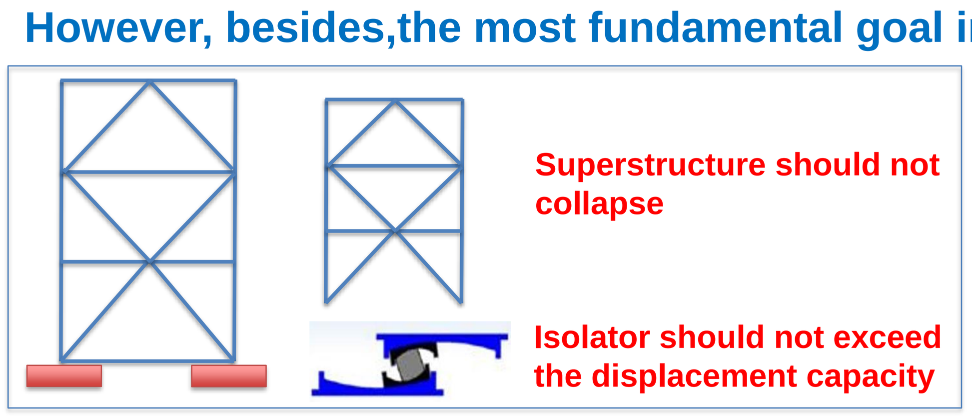
Motivation

❖ Seismic isolation is an effective way to minimum damage in seismic design due to uncoupling of ground motion and superstructure response with large period and deformation of isolator.

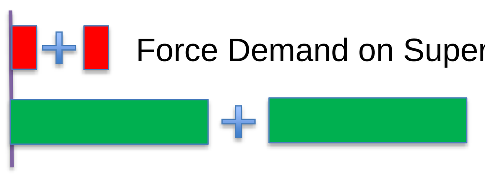
Well understood but ONLY when the performance goal is: Minimum damage
However, besides,the most fundamental goal in seismic design is: Safety!



❖ For safety consideration, for a isolation system both the bearing and superstructure should not fail under the seismic level specified for consideration for safety

❖ But what normally done nowadays to address safety issue is not conceptually right and results to much higher collapse probability level than normal requirement:

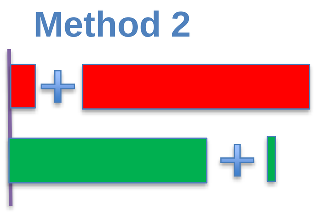
- **Method 1**



- Superstructure is still well protected but
- Huge bearing deformation will exceed the bearing deformation capacity

Bearing Failure and System Collapse

- **Method 2**

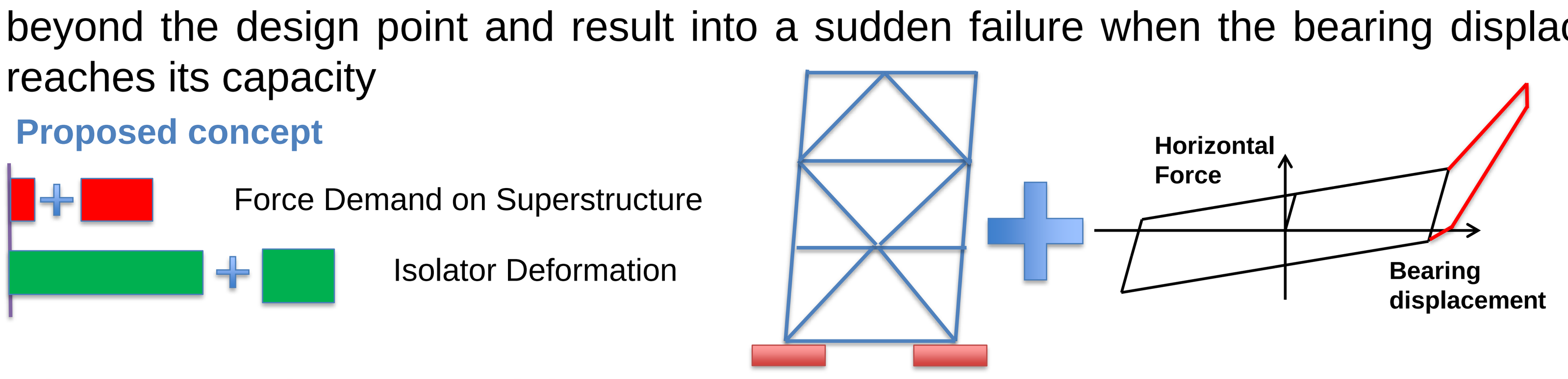


- Bearing is stopped with a rim or a moat wall
- Large impact load transferred into superstructure

Superstructure Failure and System Collapse

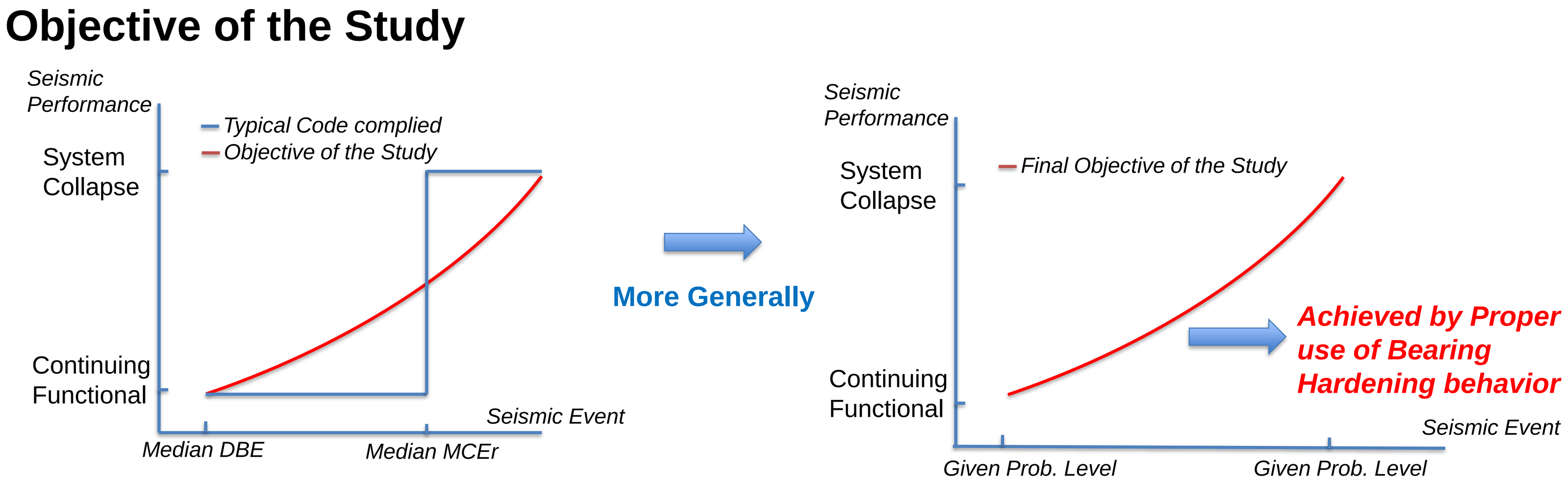
❖ Both two methods still use the concept of uncoupling of motion and structural response beyond the design point and result into a sudden failure when the bearing displacement reaches its capacity

- **Proposed concept**

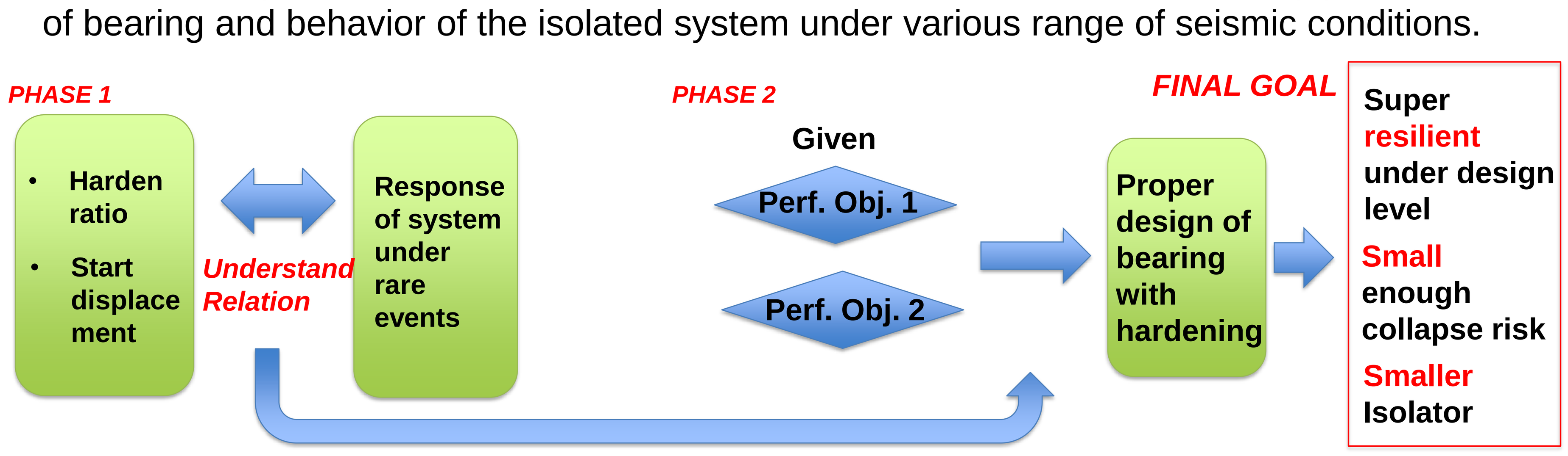


❖ **The proposed concept of the study under rare event: Yielding or Damage of superstructure + Controlled deformation of bearing**

Objective of the Study

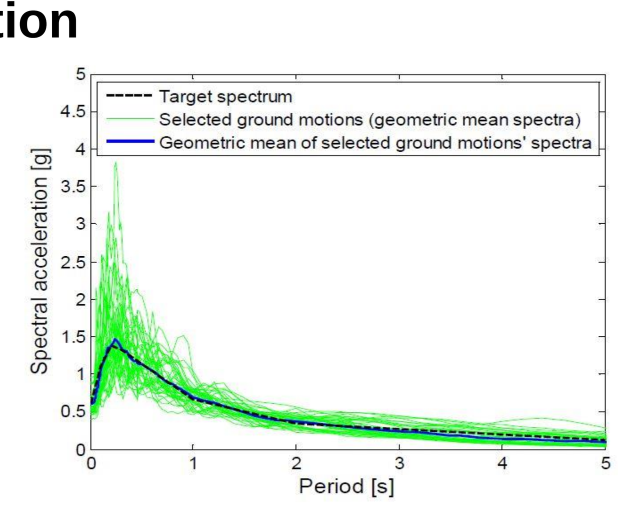


- As stated, a proper concept of yielding the superstructure using the hardening of bearing behavior, reduce bearing displacement demand, protecting the whole isolated system under rare seismic event is proposed in the study
- The proper design for hardening range of bearing to achieve performance objective under both level requires understanding of the relation between different hardening parameters of bearing and behavior of the isolated system under various range of seismic conditions.

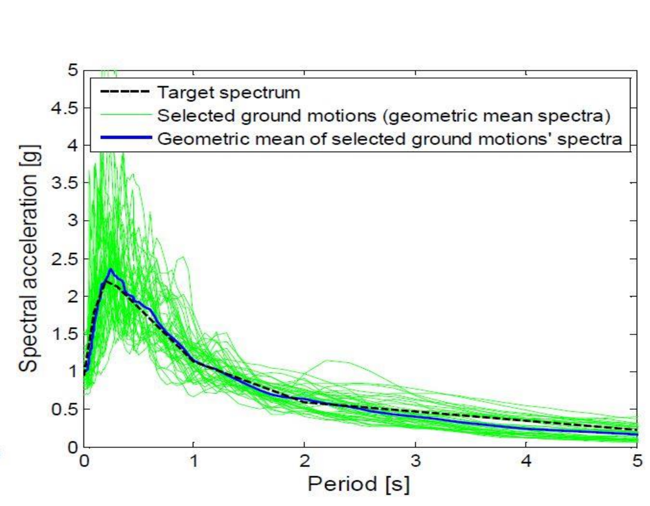


Ground Motion Selection

- **Location: Oakland, CA**
- **Database: NGAWest1**
- **Target Spectrum:**
  UHS 10% 50years
  UHS 2% 50years
- **Number: 40 time histories**
- **Analysis: Nonlinear Time History**



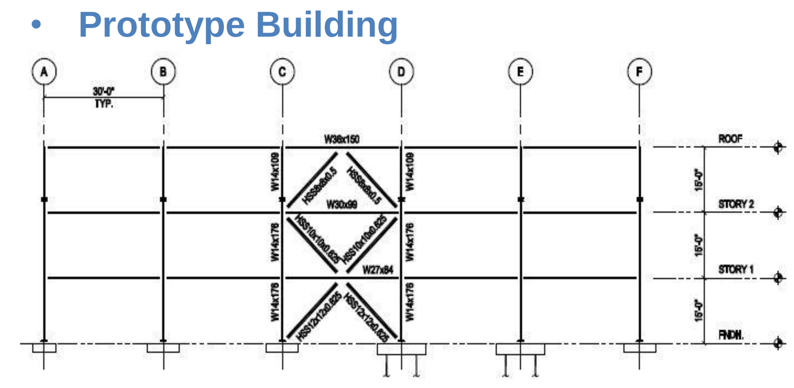
10% 50years



2% 50years

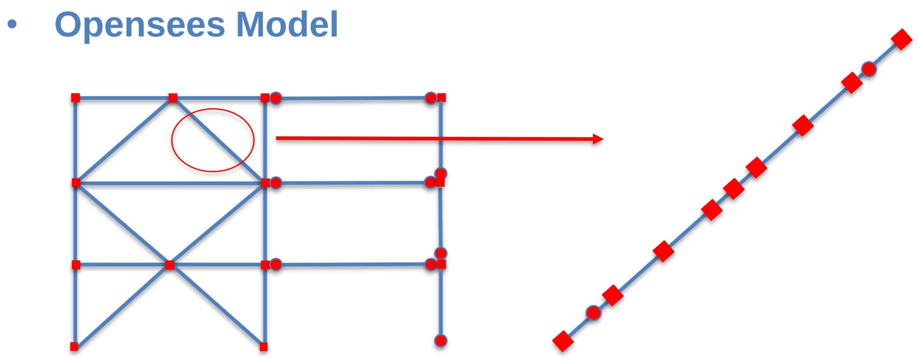
Analysis Model

- **Prototype Building**



- **Fictitious Location: Oakland, CA**
- **Code Spectrum: DBE Ss:1.04g**
- **Occupancy Category: II Office**

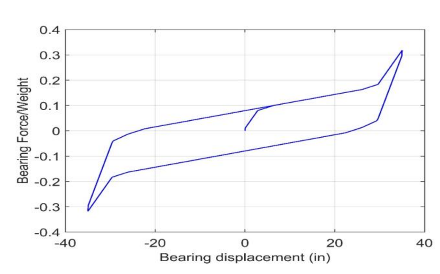
- **Opensees Model**



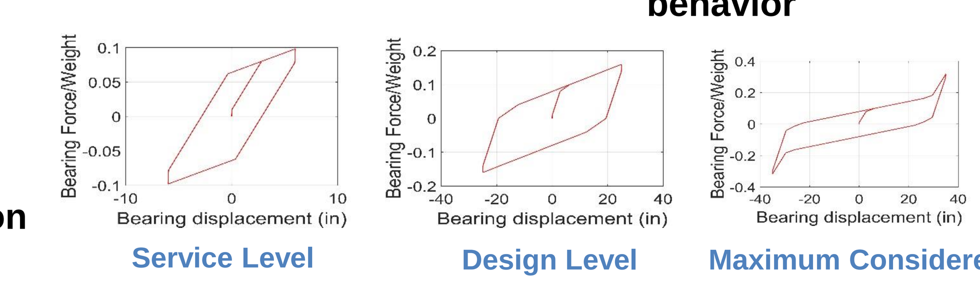
- **Nonlinear Force base element**
- **Nonlinear Geometry**
- **Rigidity of connection due to gusset plate**

- **Fatigue material record accumulated damage**
- **Capture post buckling and post fracture behavior**

- **Triple Friction Pendulum Bearing Model**

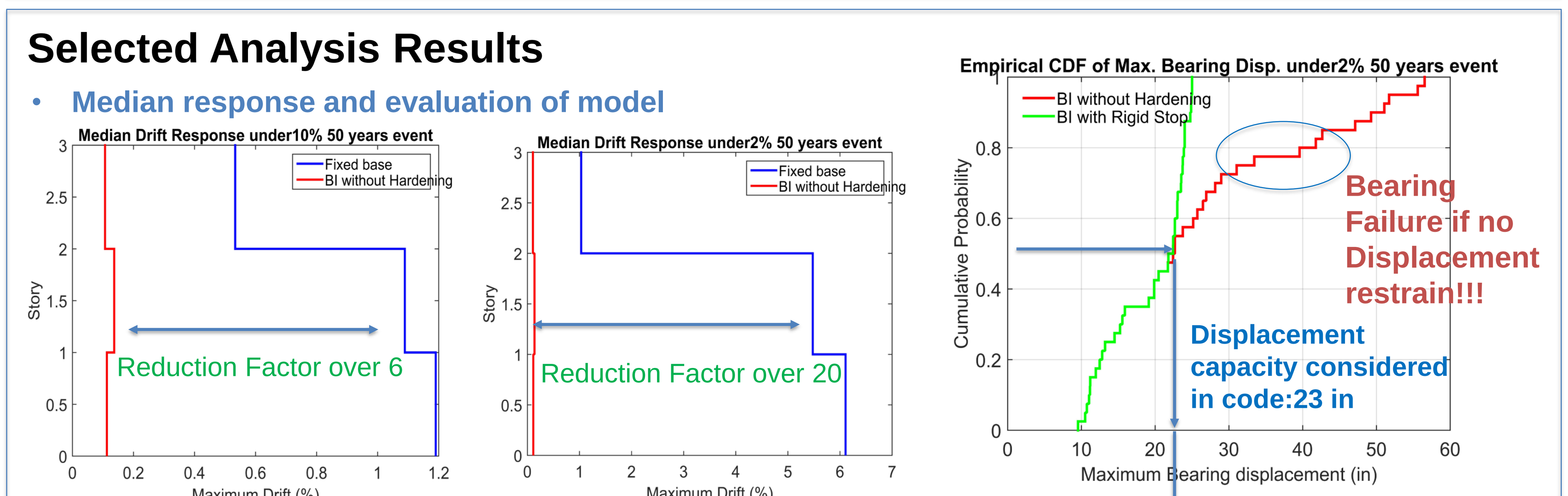


- **Parallel material Model**
- **No horizontal-vertical interaction**

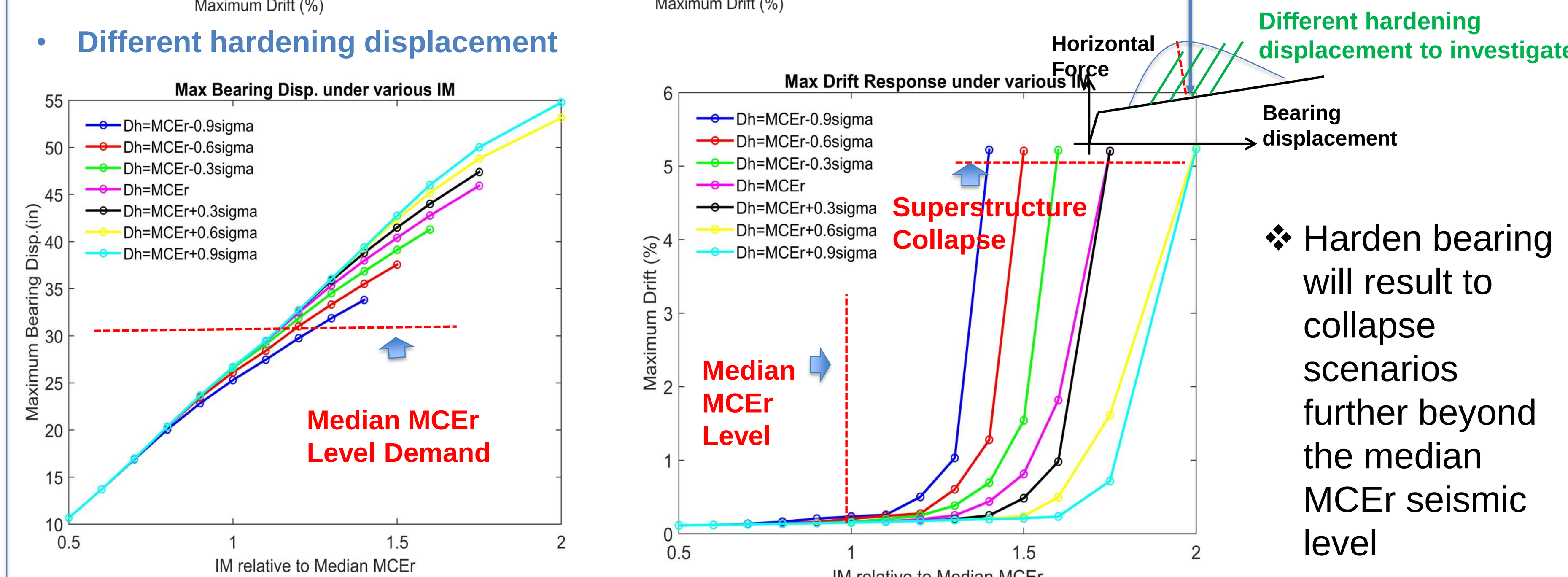


Selected Analysis Results

- **Median response and evaluation of model**



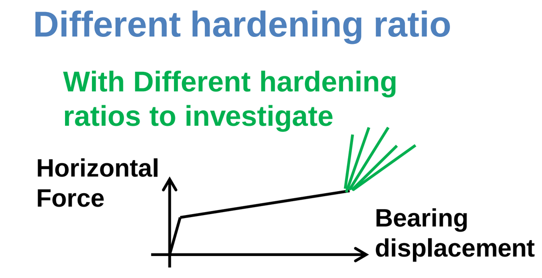
- **Different hardening displacement**



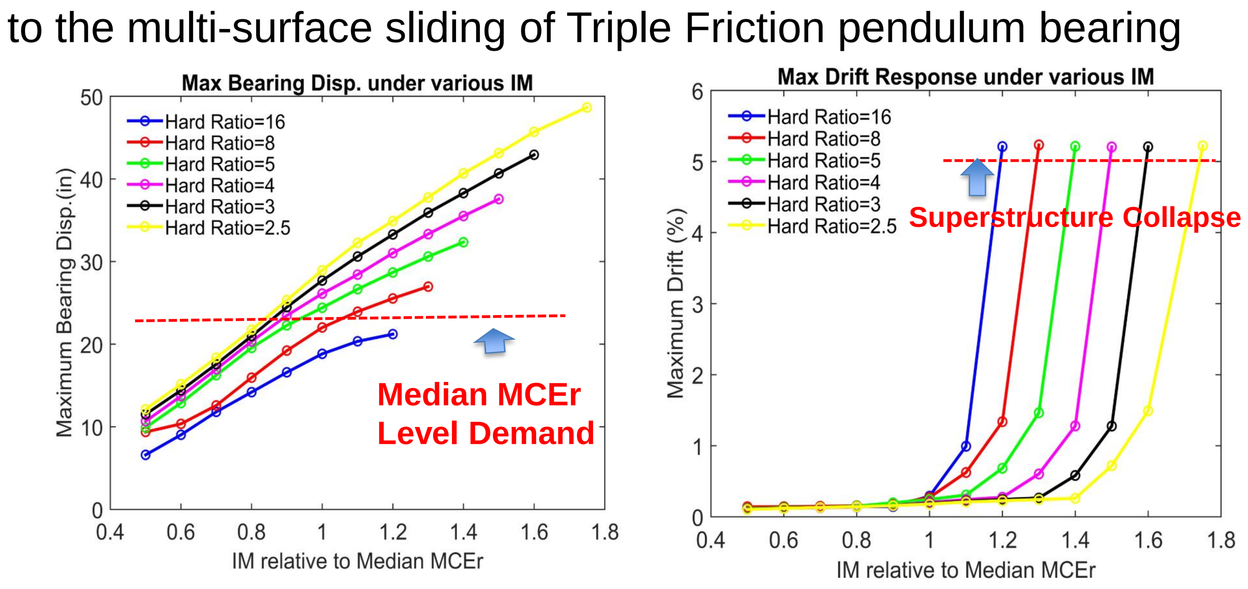
❖ Harden bearing will result to collapse scenarios further beyond the median MCEr seismic level

❖ Collapse probability under MCEr level event can be **reduced from around 50% to 25%** with a smaller isolator due to the multi-surface sliding of Triple Friction pendulum bearing

- **Different hardening ratio**



❖ Large hardening ratio behaves more like rigid stop. Reasonable smaller hardening ratio should be selected



Key Conclusions

- Great benefit in drift demand and floor acceleration demand will be expected using seismic isolation under design level Earthquake because of the decoupling of ground motion and the superstructure response.
- The collapse probability of isolated system under rare event can be reduced by properly choosing the hardening parameters of bearing.
- The displacement demand of bearing will not be reduced much using hardening of bearing
- Base isolated brace frame is sensitive to impact load at the base, the increase of the seismic intensity will increase the response of the superstructure rapidly

Selected References

[1] F. McKenna, M. Scott and G. Fenves, "Nonlinear finite-element analysis software architecture using object composition," *J. Comput. Civ. Eng.* , Vols. 10.1061/(ASCE)CP.1943-5487-0000002, pp. 96-107, 2010.

[2] P. Uriz and S. Mahin, "Toward earthquake-resistant design of concentrically braced steel-frame structures," Berkeley, CA, 2008.

[3] Zayas, V., Low, S., and Mahin, S., 1990. A Simple Pendulum Technique for Achieving Seismic Isolation, Earthquake Spectra 6, 317–333.

[4] Terzic, V., Mahin, S., and Comerio, M. (2015). Using PBEE in Seismic Design to Improve Performance of Moment Resisting Frames by Base-Isolation, Earthquake Spectra, EERI, Oakland (accepted for publication).

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