National Applied Research Laboratories

Introduction to Taiwan Earthquake Assessment for Structures by Pushover Analysis (TEASPA)

國家地震工程研究中心 蕭輔沛博士

NCREE Dr. Fu-Pei Hsiao

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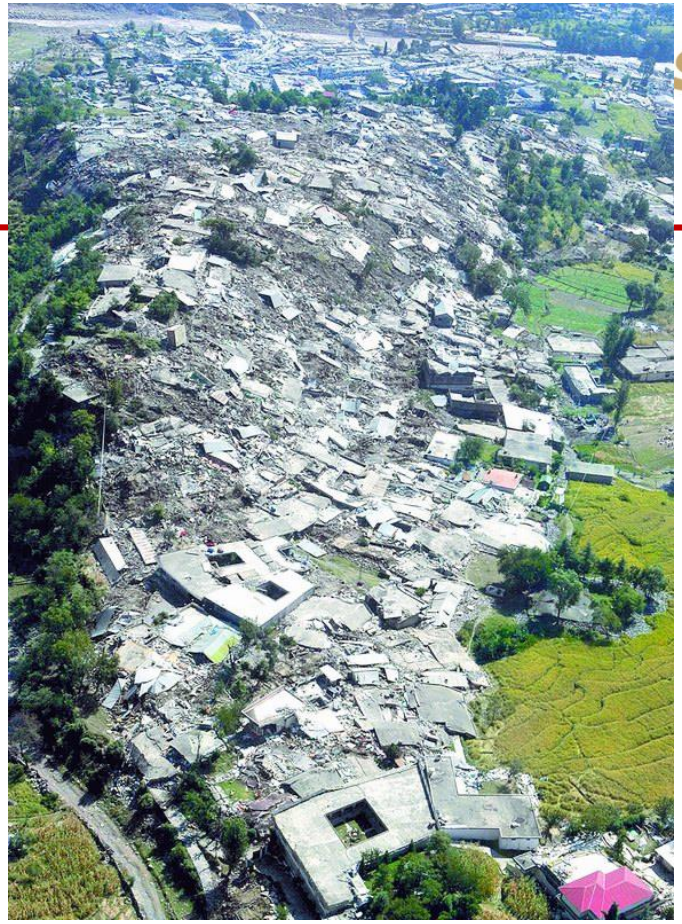
History review

Wenchuan Earthquake (Mw=8.0)
May 12, 2008
2:28 pm
Death : more than 69,255



Earthquake in Pakistan (Mw=7.6)
Oct. 8th, 2005
8:50 am
Death: about 87,000
19,000 children died in collapsed school buildings

NARLabs

921 Chi-Chi Earthquake

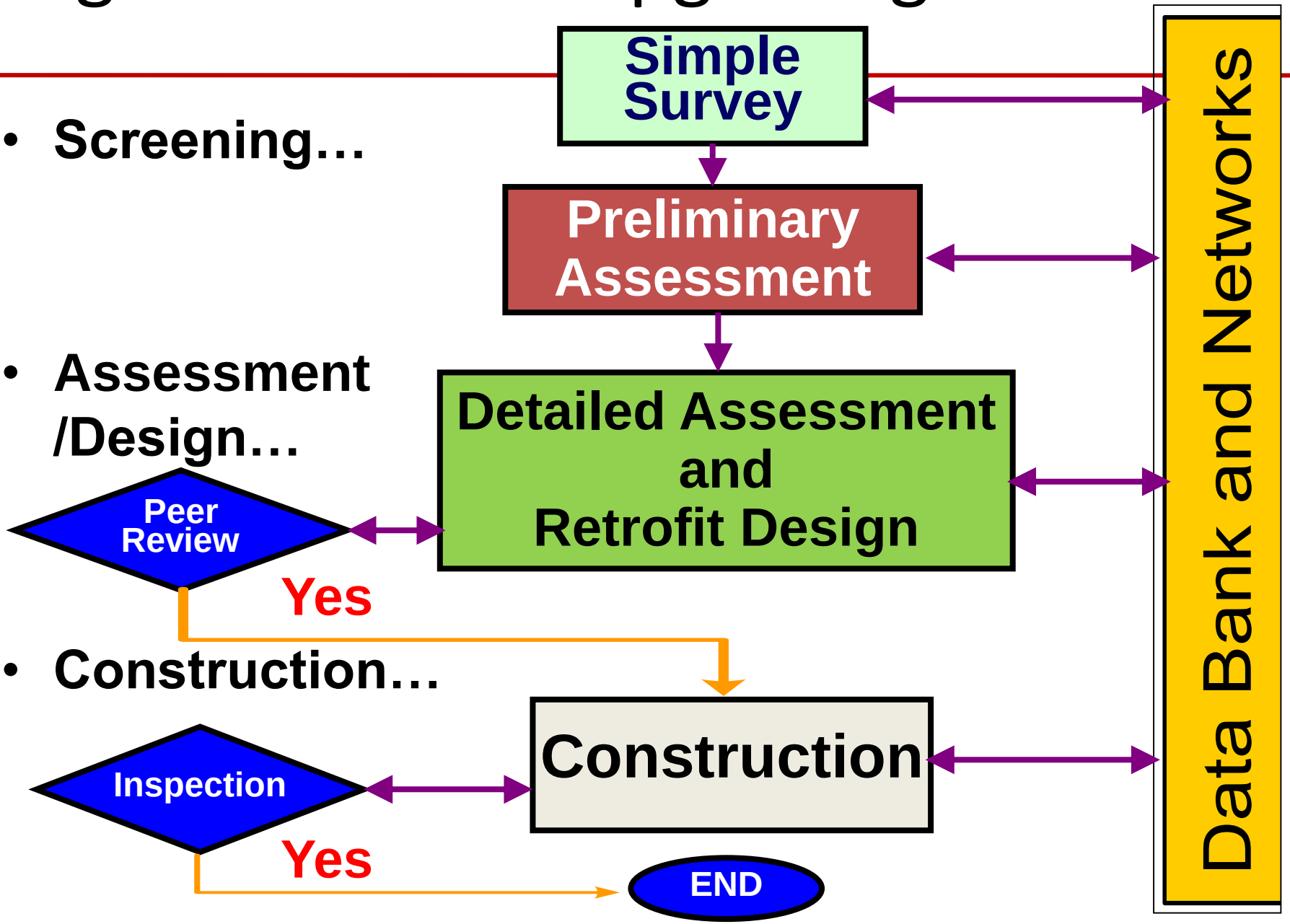
Sep. 21, 1999
01:47 am
Mw=7.3
Death: about 2,413

656 primary and secondary school buildings were damaged in Chi-Chi earthquake

Stages for School Upgrading

NARLabs

- **Screening…**
- **Assessment /Design…**
- **Construction…**



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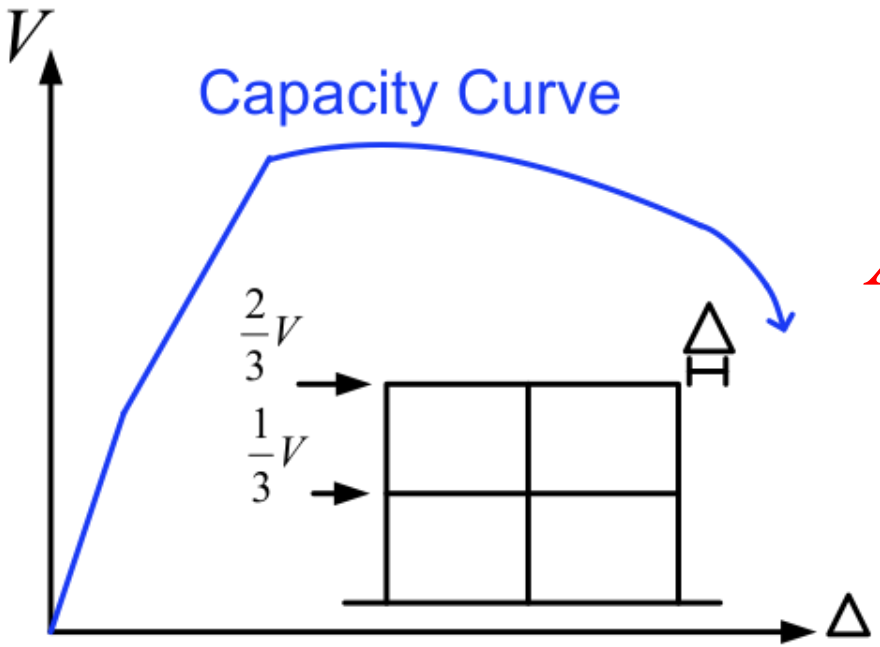
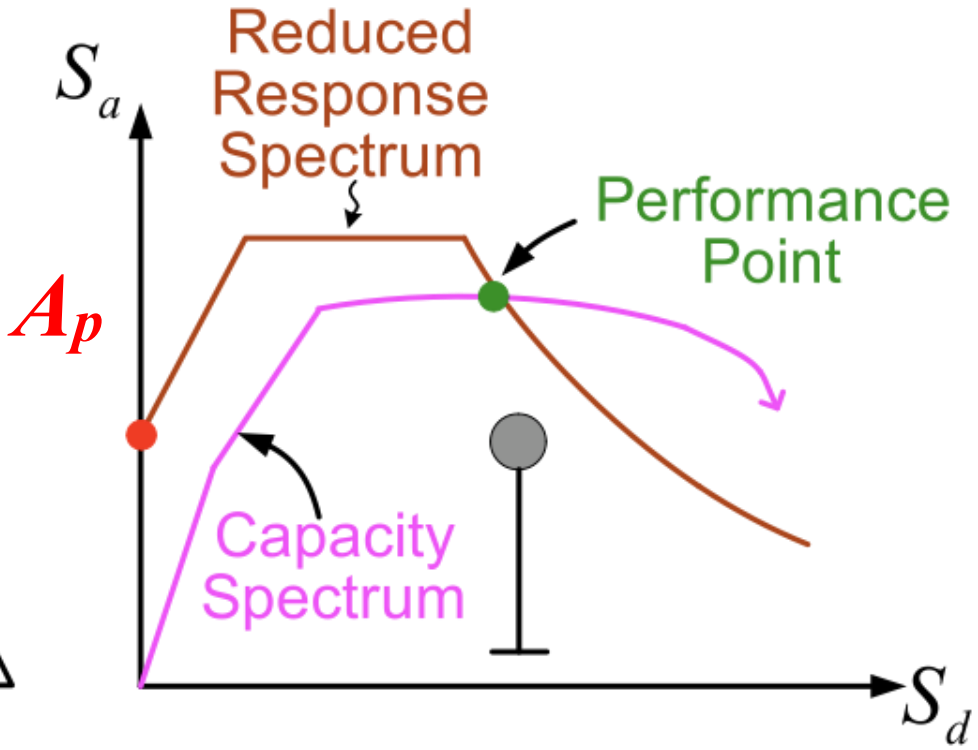
Detailed Assessment and Retrofit Design

- Performed by the same P. E.
- Pushover analysis
  for lateral load-deflection curves
- Response spectrum analysis
  for effective PGA leading to collapse

Detailed Assessment with Pushover Analysis

Pushover Analysis ⇨ **Response Spectrum Method**





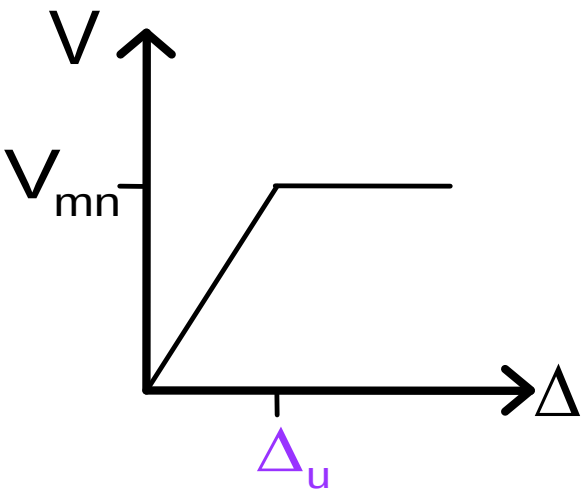
⇨ Find A_p

NARLabs

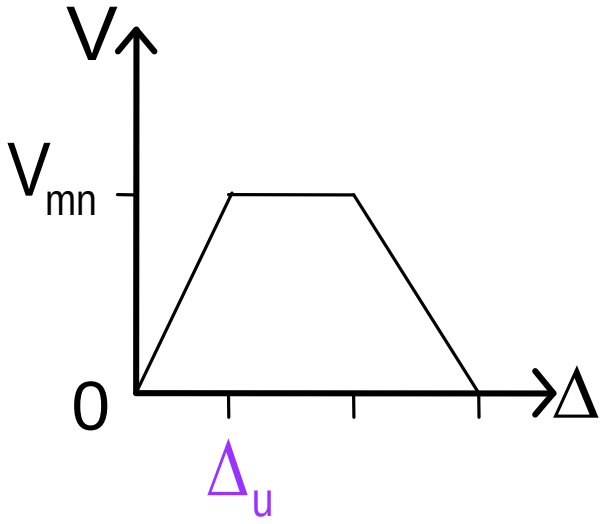
Failure Modes of Column

Flexure, Flexural Shear and Shear Failures

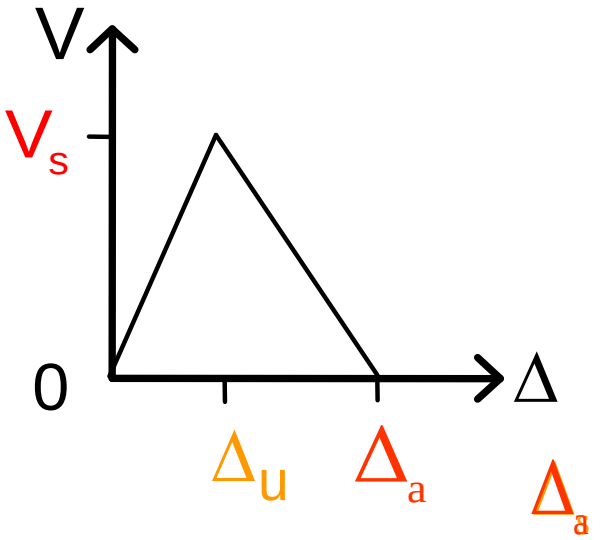
Load-Deflection Curves of Column



Flexure

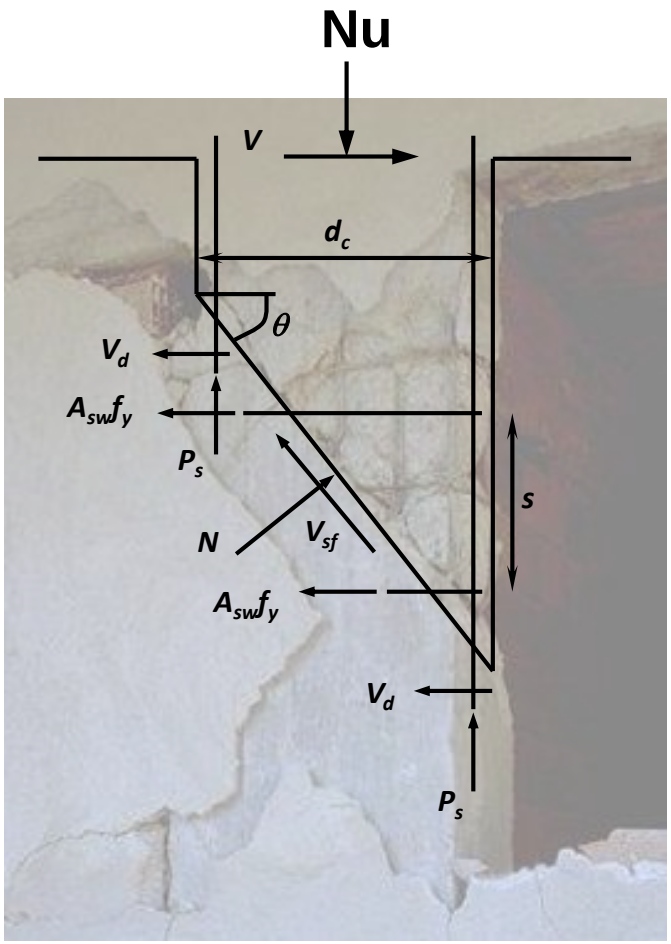


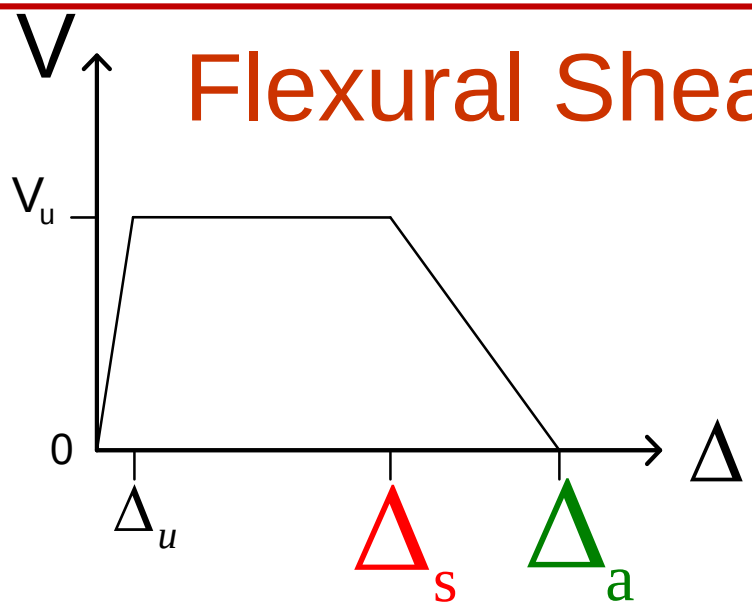
Flexural Shear



Shear

Idealized Shear-Drift Backbone





Flexural Shear

Elwood & Moehle (Spectra 2005; ACI 2005)

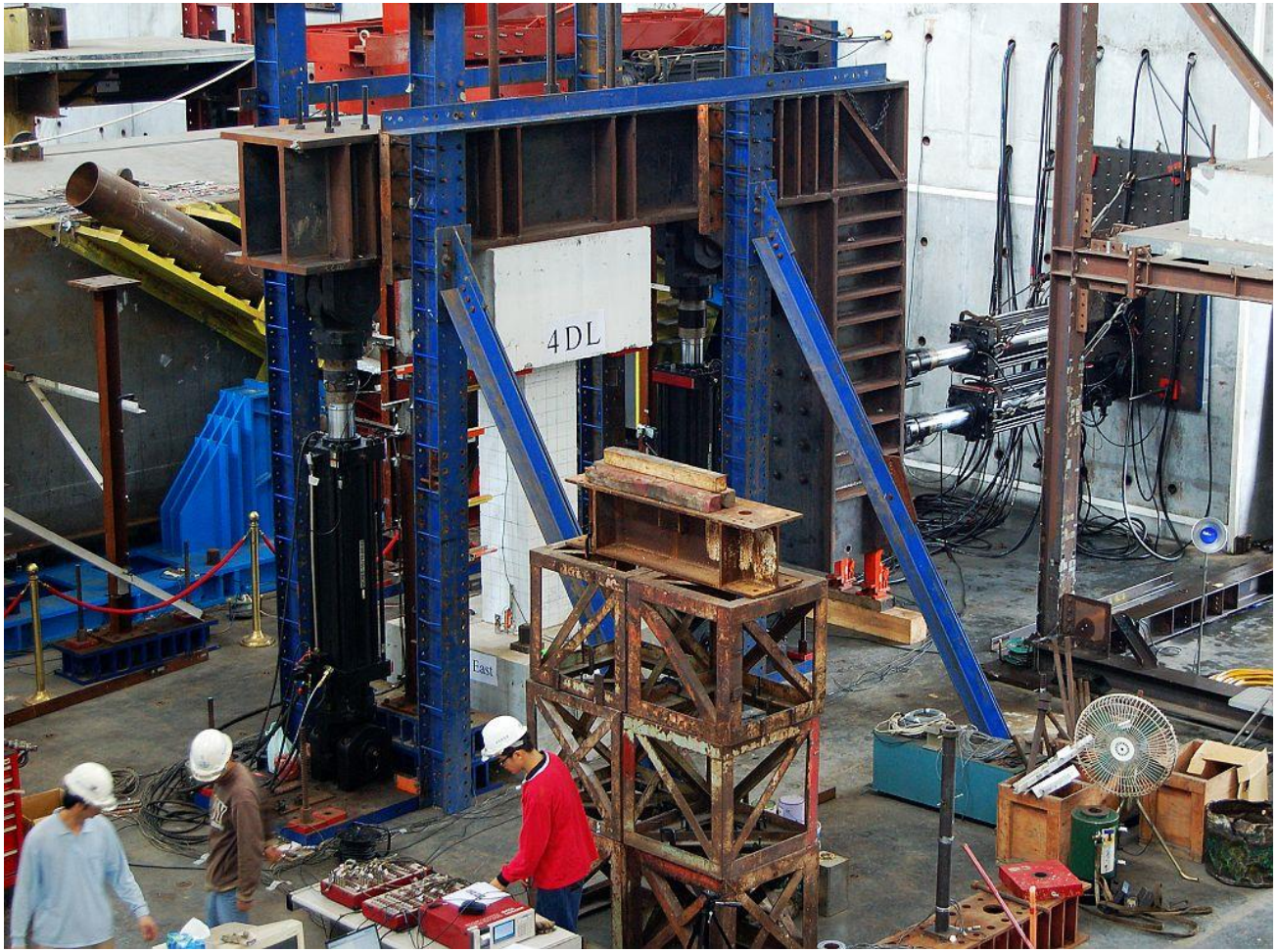
$$\frac{\Delta_s}{H_n} = \frac{3}{100} + 4\rho'' - \frac{1}{40}\frac{\upsilon}{\sqrt{f'_c}} - \frac{1}{40}\frac{N_u}{A_g f'_c} \geq \frac{1}{100}$$

(MPa)

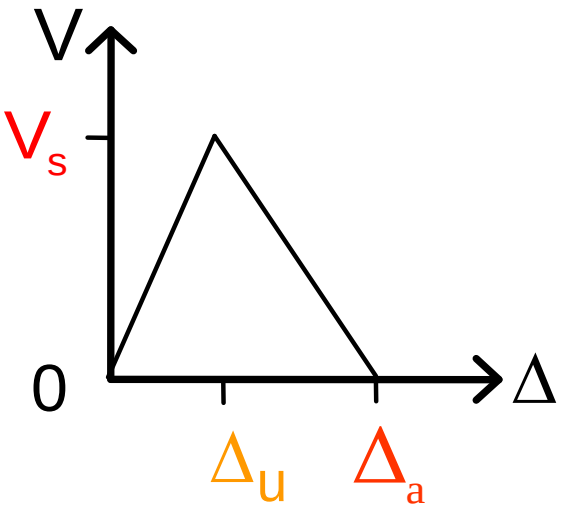
$$\frac{\Delta_a}{H_n} = \frac{4}{100}\frac{1+(\tan\theta)^2}{\tan\theta + N_u\left(\frac{s}{A_{st}f_{yt}d_c\tan\theta}\right)}$$

NARLabs

Test of Column Failed in Shear

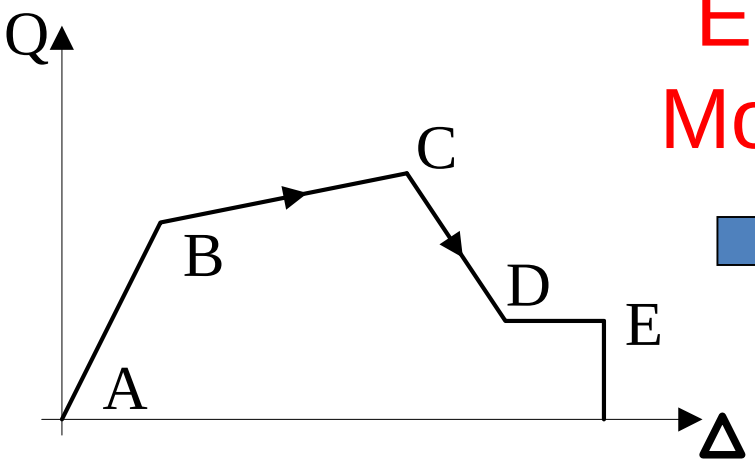


Shear Failure

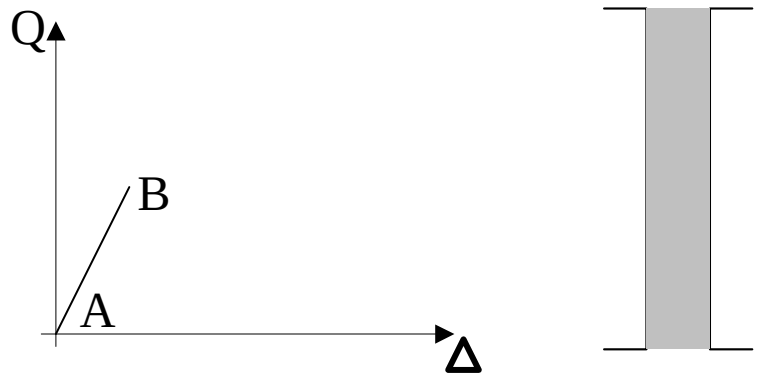


Implementation of ETABS Modeling

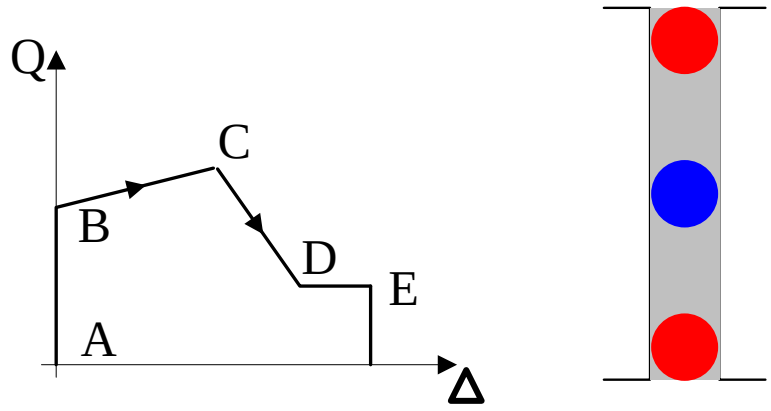
Load-Deformation Curve of Member



ETABS Modeling

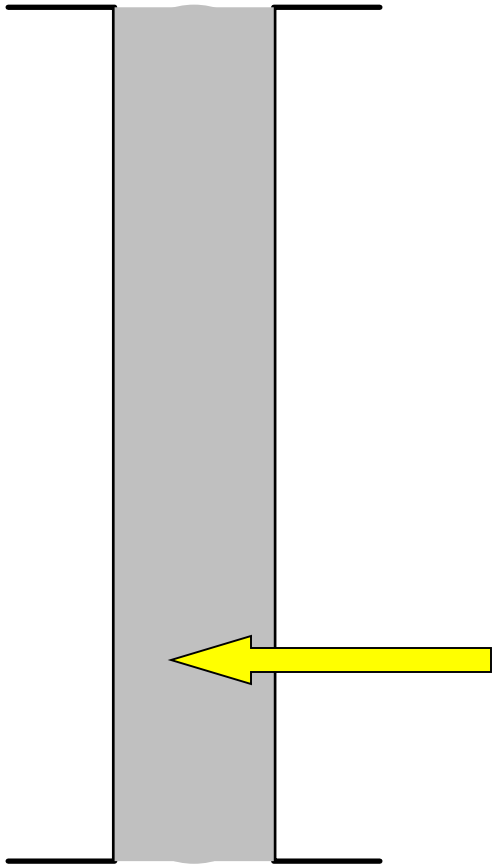


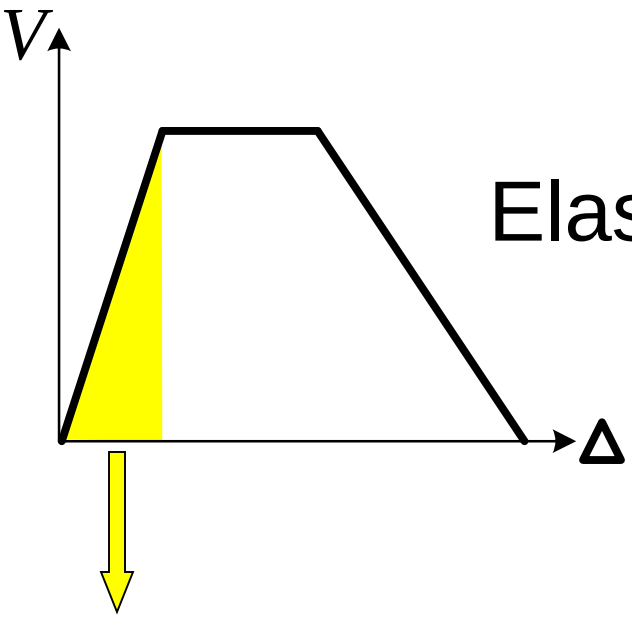
Member Parameters



Plastic Hinges

Column Modeling in ETABS(1/2)

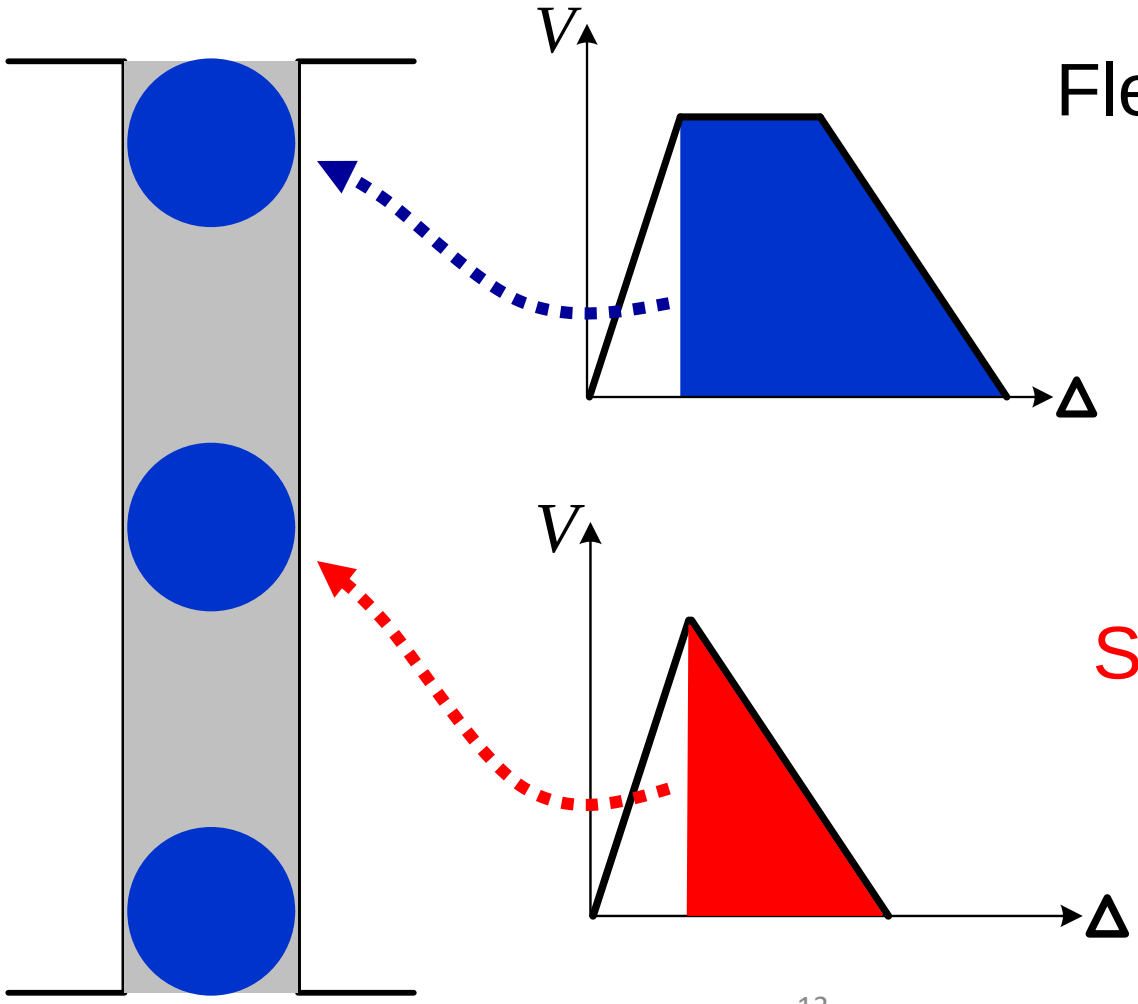




Elastic Behavior

Member parameters
E, A, I, υ

Column Modeling in ETABS(2/2)



Flexure and Flexural Shear Plasticity

↓

Moment Hinge

Shear Deterioration

↓

Shear Hinge

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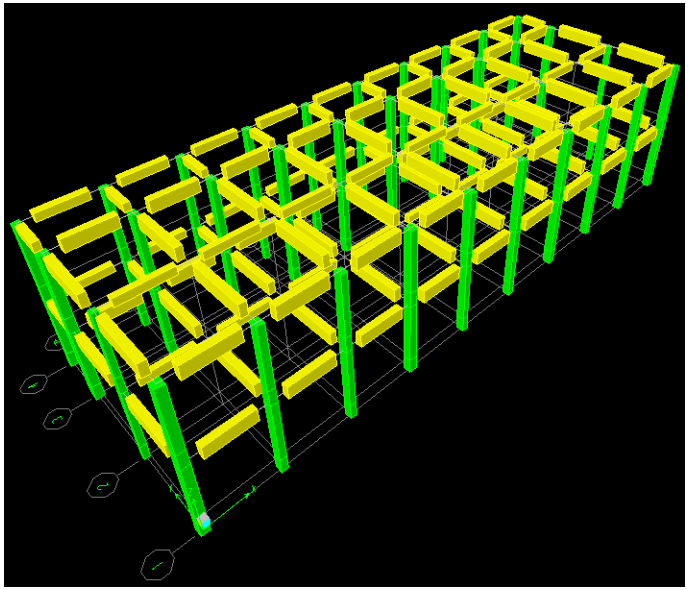
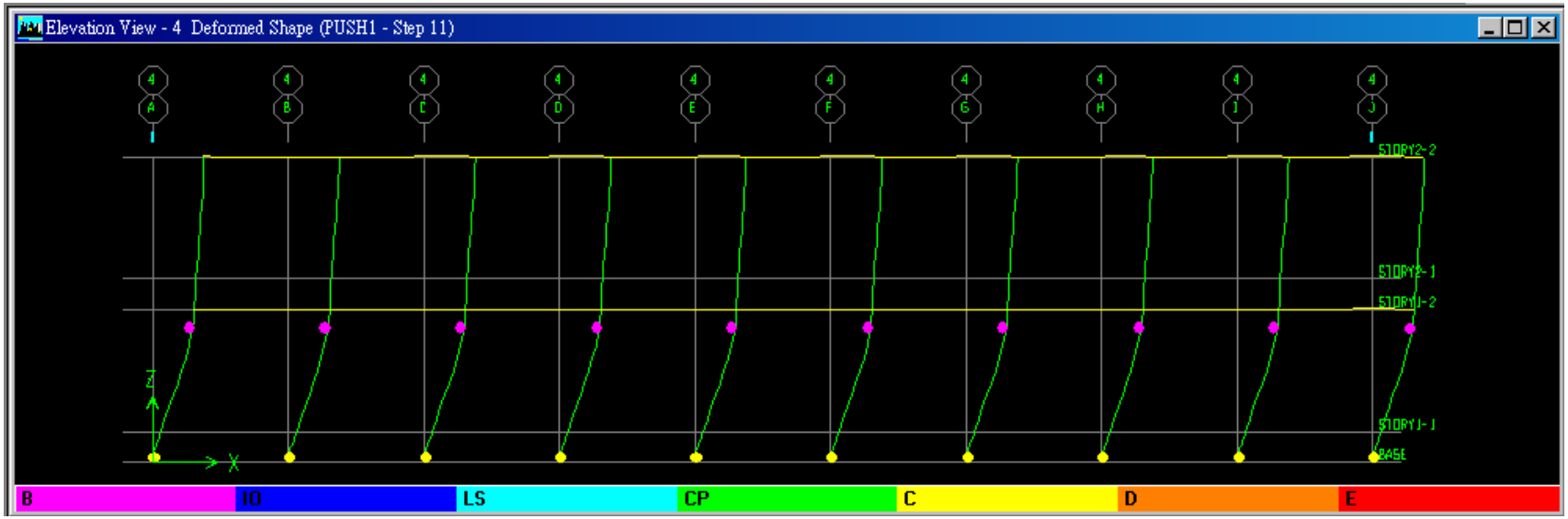
Pushover Analysis Using ETABS



- **Modeling for School Building**
- **Properties of** Plastic Hinges



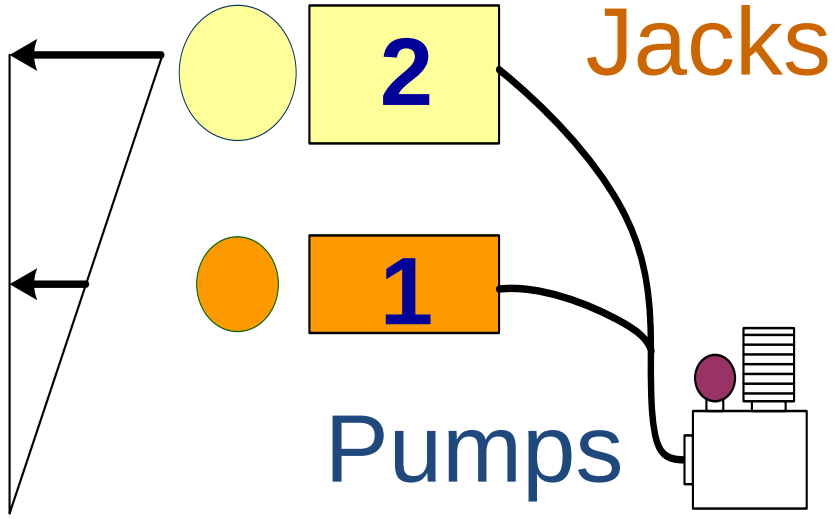
NARLabs

In-situ Pushover Tests

- **Understanding the seismic capacity of existing school buildings**
- **Calibrating the detailed assessment**
- **Verifying the seismic retrofitting methods**

NARLabs

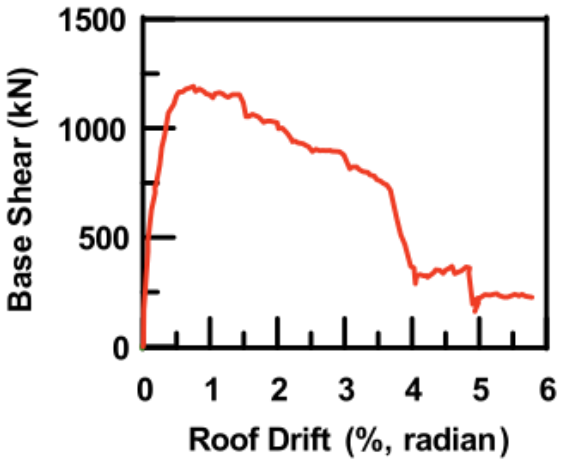
In-situ Pushover Tests

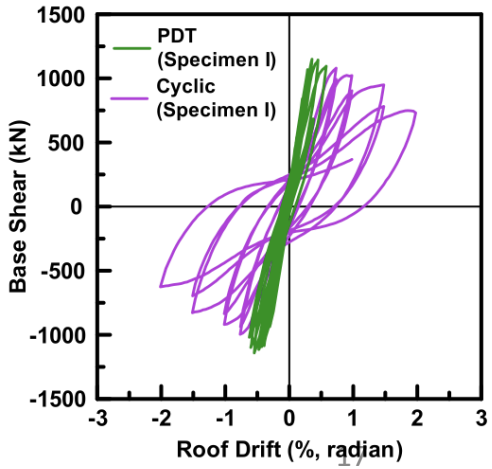


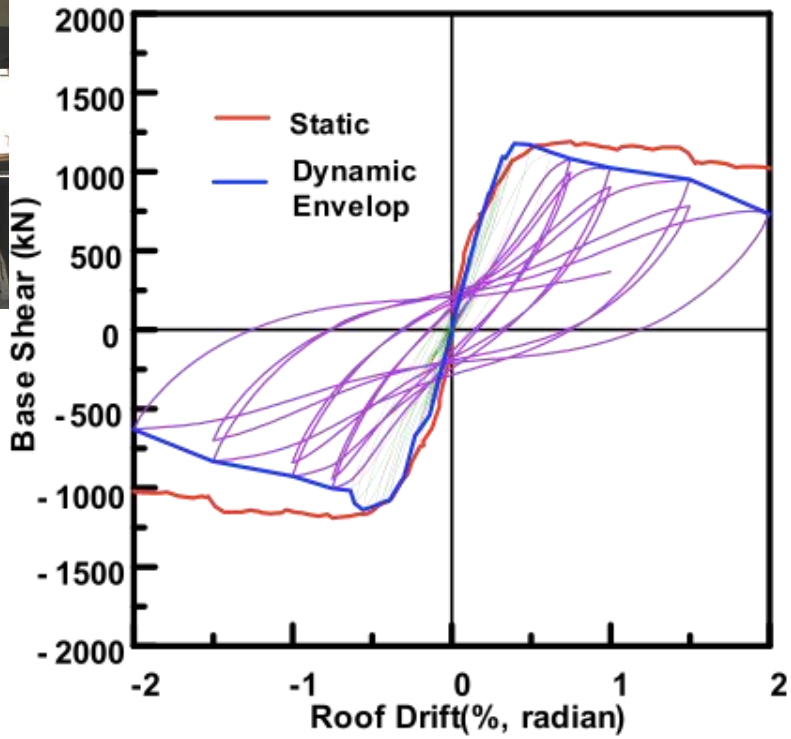
Correction the pushover curve with dynamic effect

Monotonic pushover test

Pseudo/cyclic dynamic test

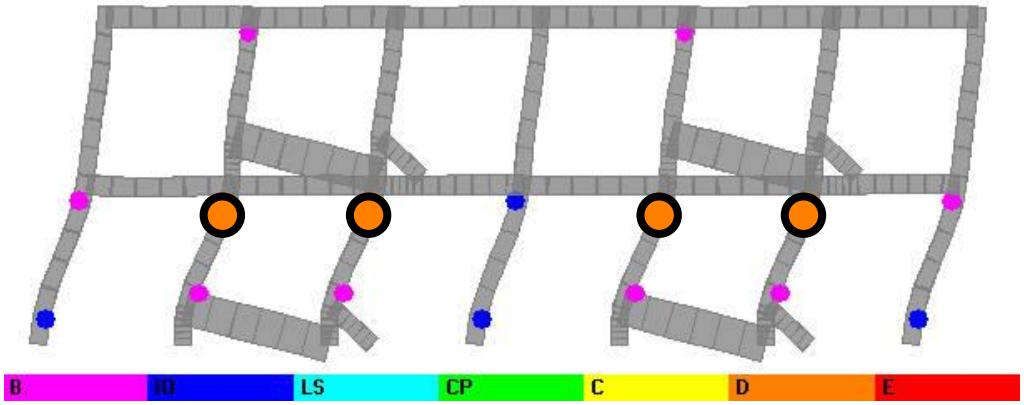


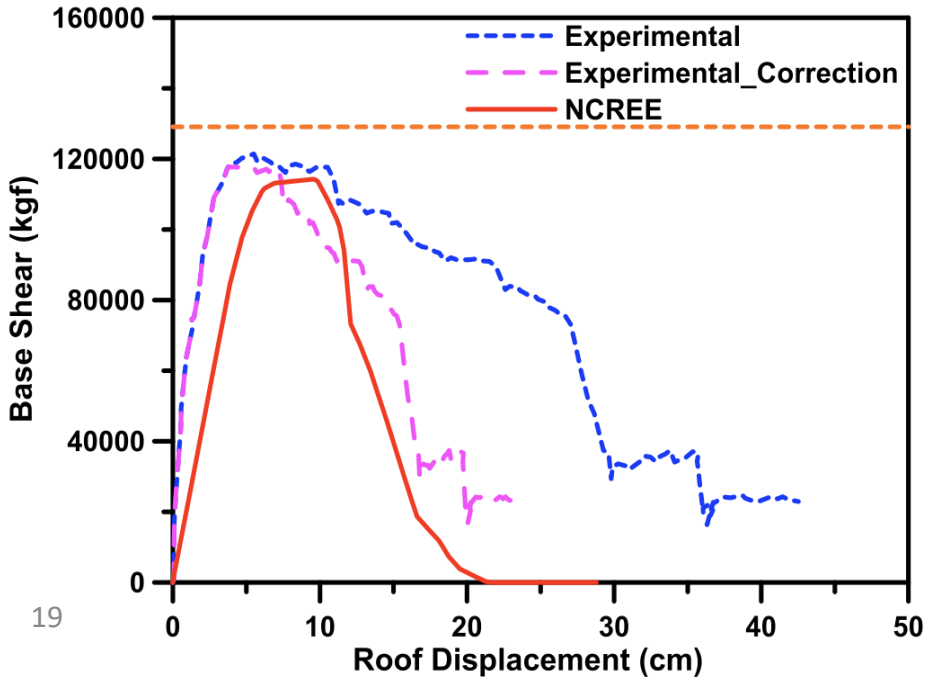




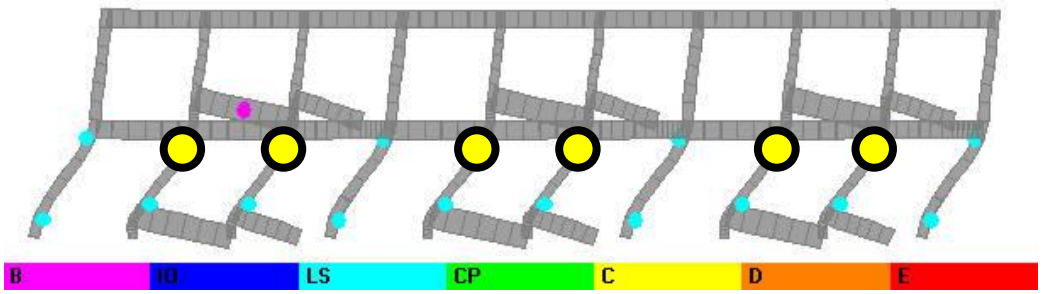
Pushover analysis and test result

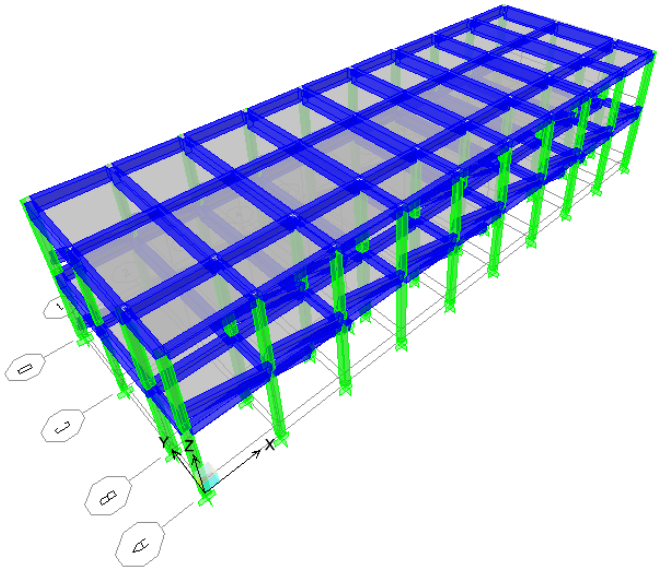
Verifications of pushover curves with Reui-Pu elementary school

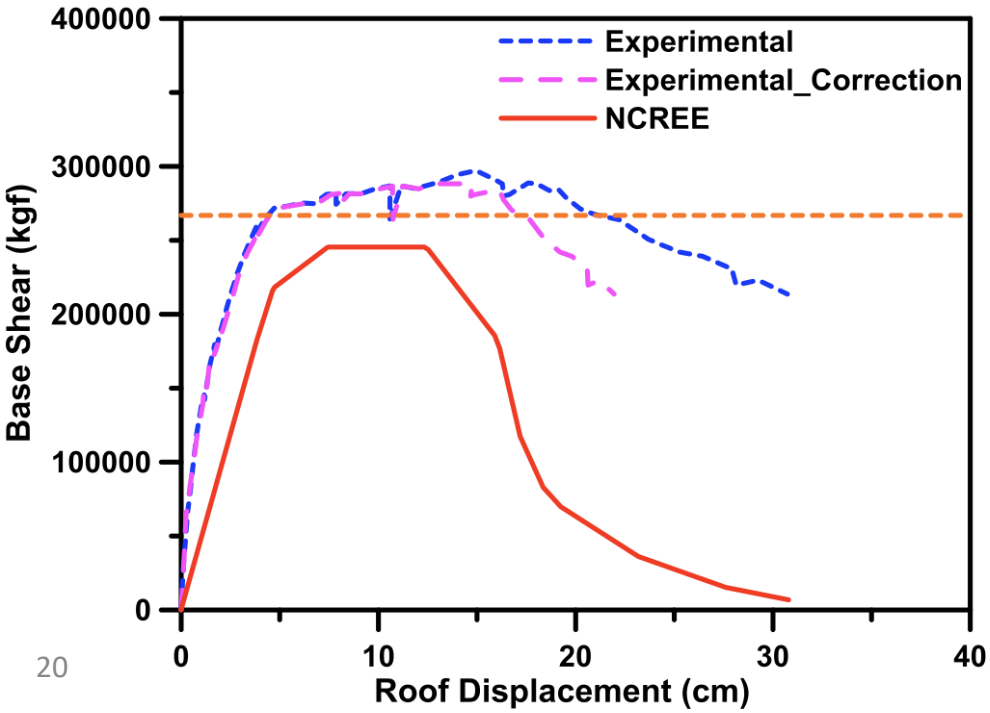




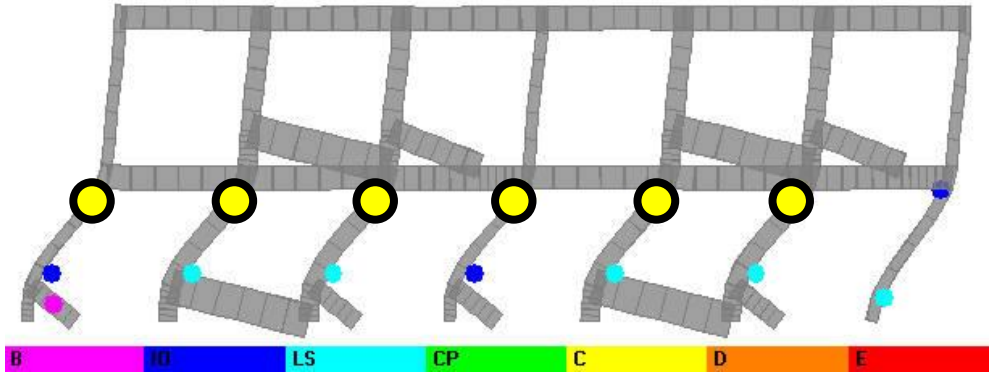
Verifications of pushover curves with Sin-Chen junior high school

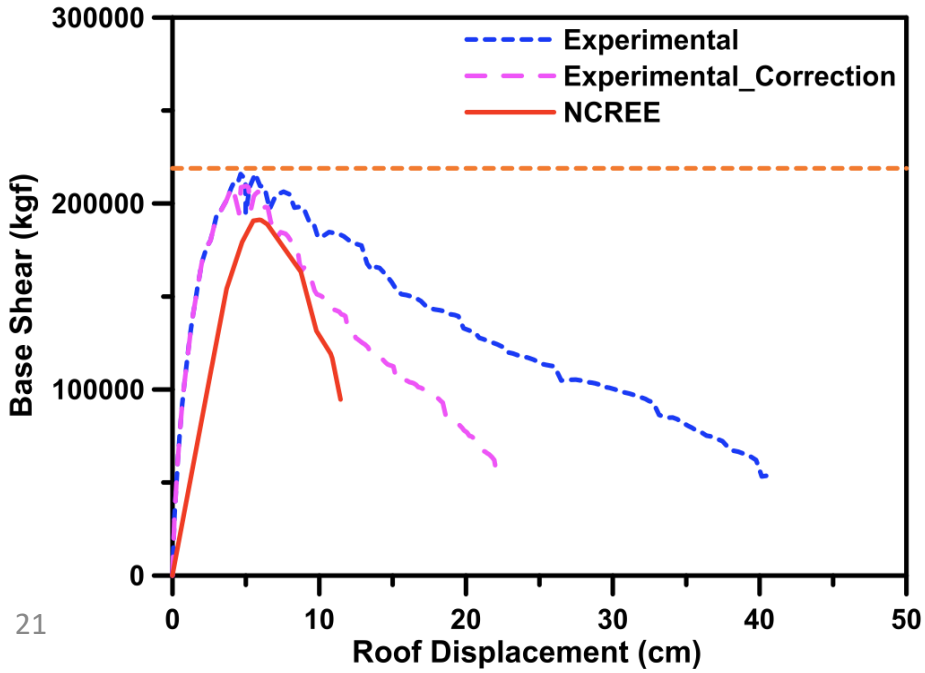






Verifications of pushover curves with Kao-Hu elementary school





Verifications of pushover curves with Guan-Miao elementary school

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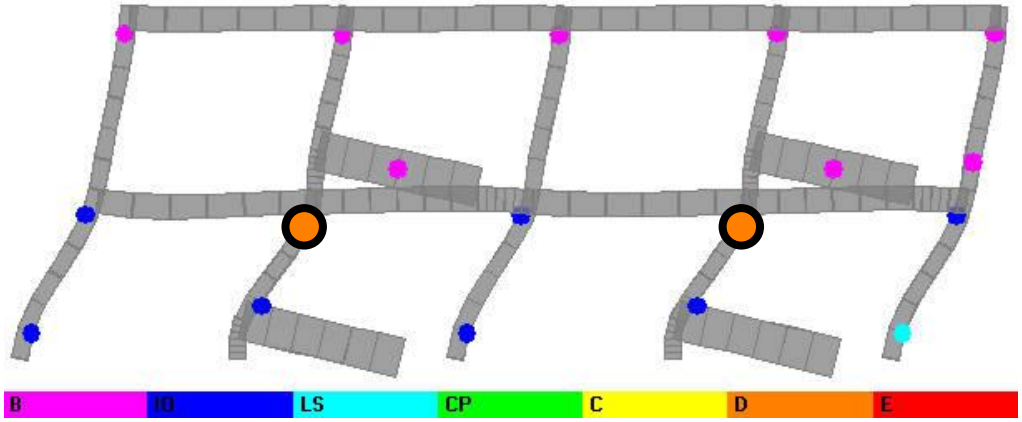
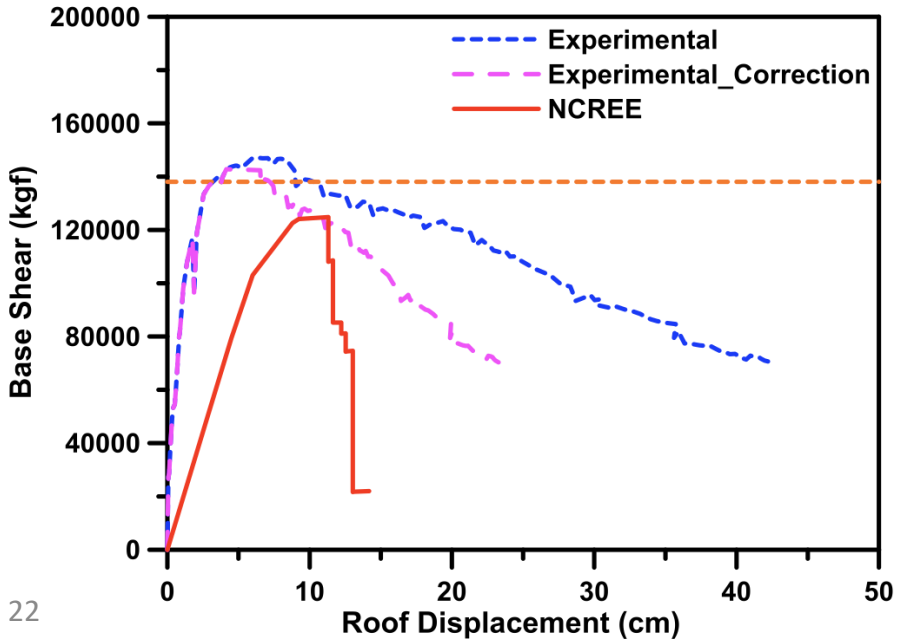
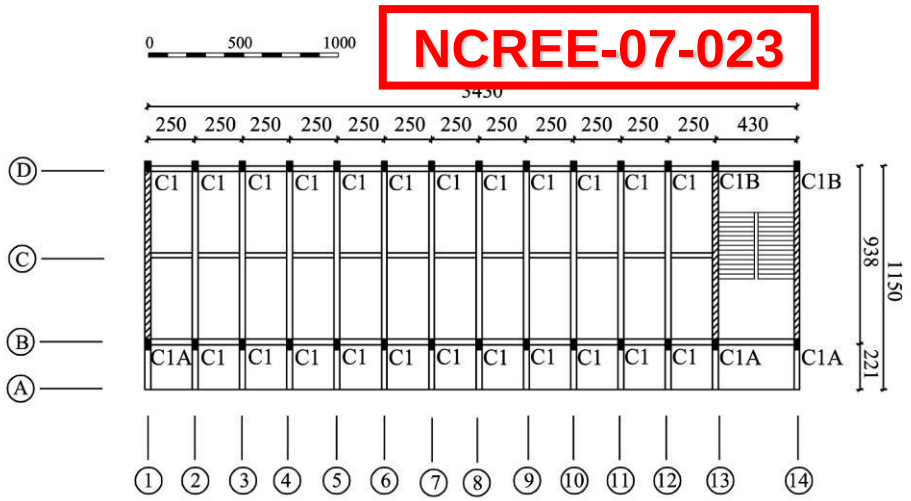


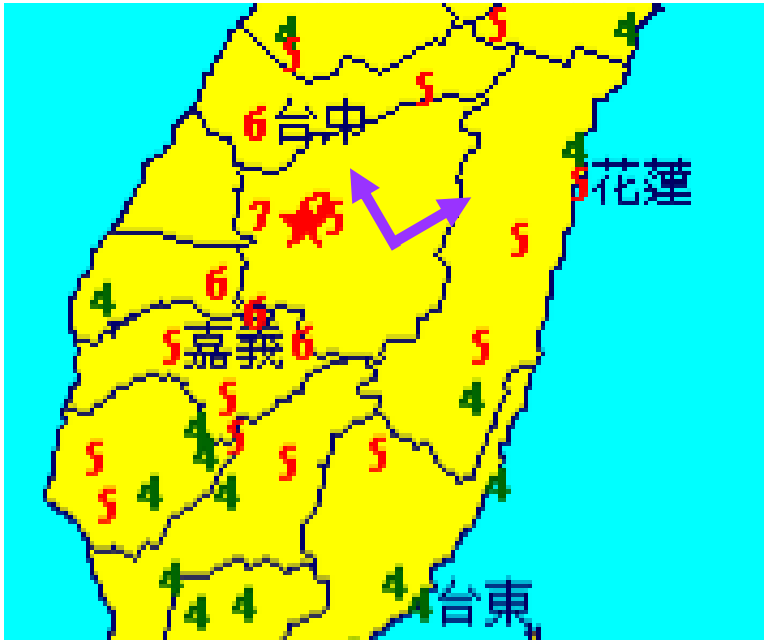


Chi-Chi earthquake damage database of school buildings in the midland of Taiwan

NARLabs

- **35 typical school buildings**
- **Sketches and blueprints**
- **Damaged pictures and field interviews**
- **Actual and demand PGA of sites**





NARLabs

Damage level of 35 typical school buildings

Collapse

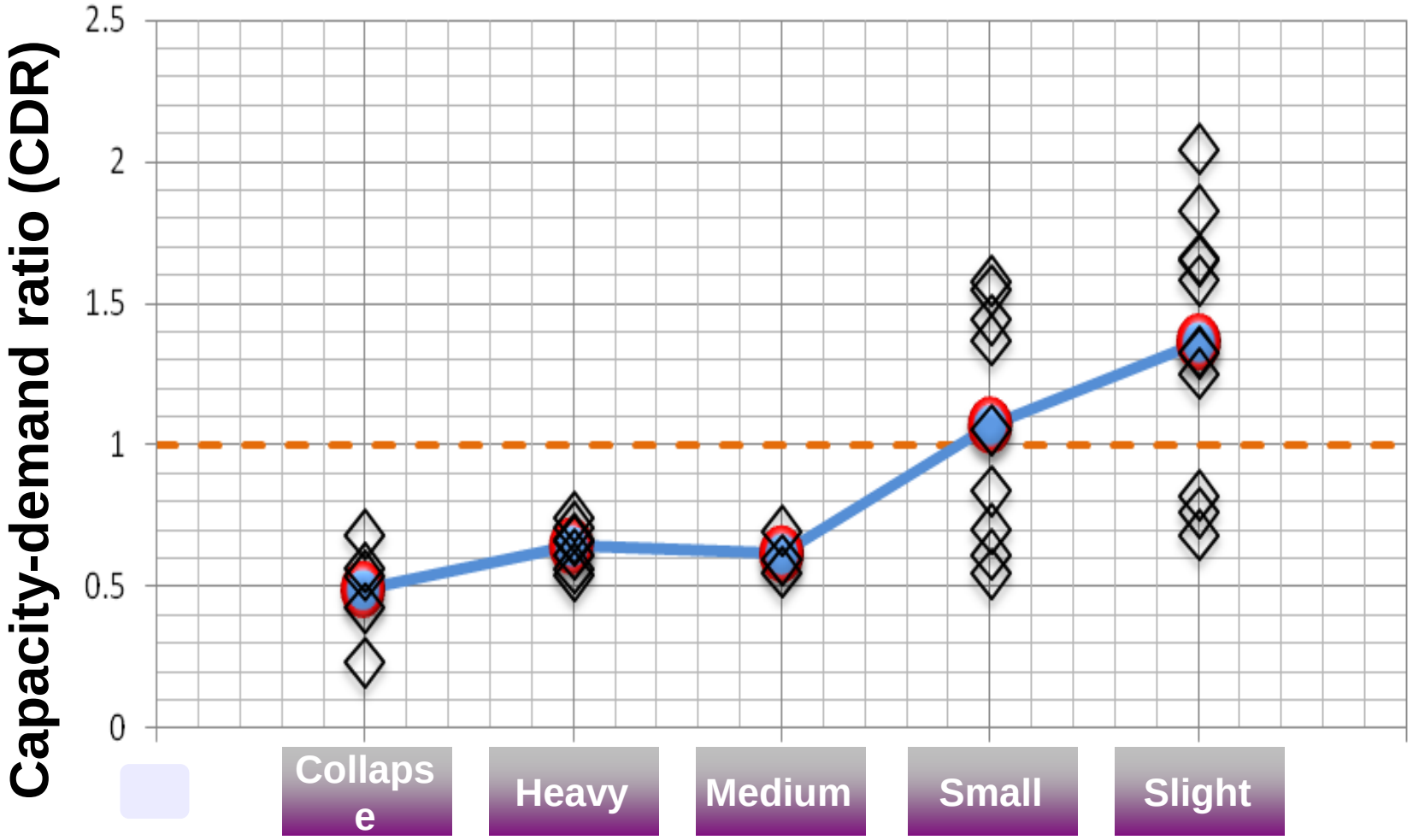
Heavy damaged

Medium damaged

Small damaged

Slight damaged

$$CDR = \frac{Capacity}{Demand} \geq 1 \qquad OK$$



NARLabs

Conclusions

For our next generation, do something to upgrade school buildings before next disastrous earthquake.