ASCE-41 Evaluation of a Reinforced-Concrete Building Damaged in the 2016 Meinong Earthquake

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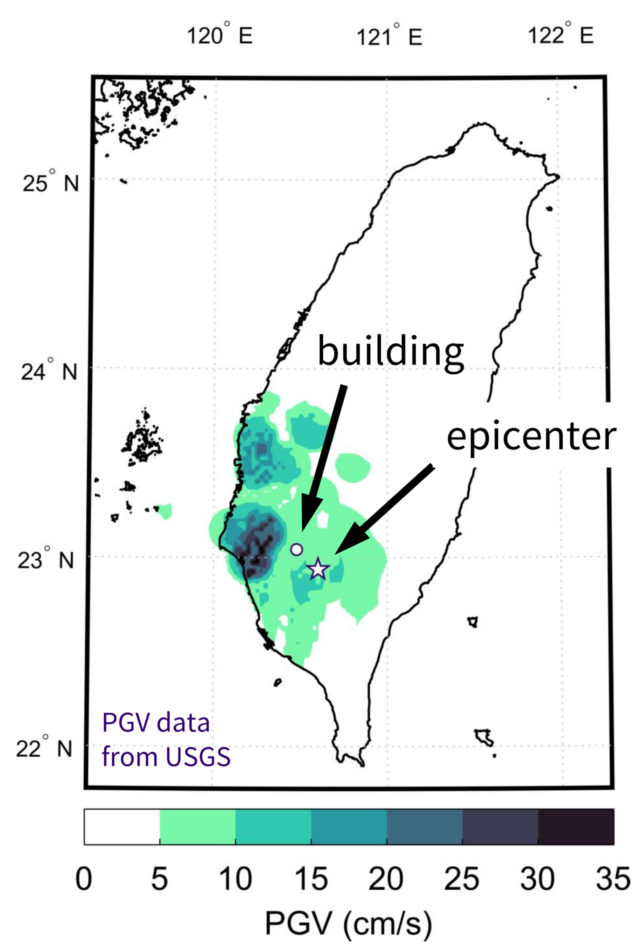
MOTIVATION AND OBJECTIVES

> Effectiveness of current seismic performance evaluation procedures to identify structural deficiencies and predict damage is largely unknown

> Primary objective: Benchmark *ASCE 41-17* seismic performance evaluation procedures using a case-study building

> Secondary objective: Develop new, robust approaches for implementing *ASCE 41-17* modeling recommendations

EARTHQUAKE BACKGROUND AND OBSERVED DAMAGE



> M6.4 earthquake occurred in southern Taiwan near the city of Tainan on February 6, 2016

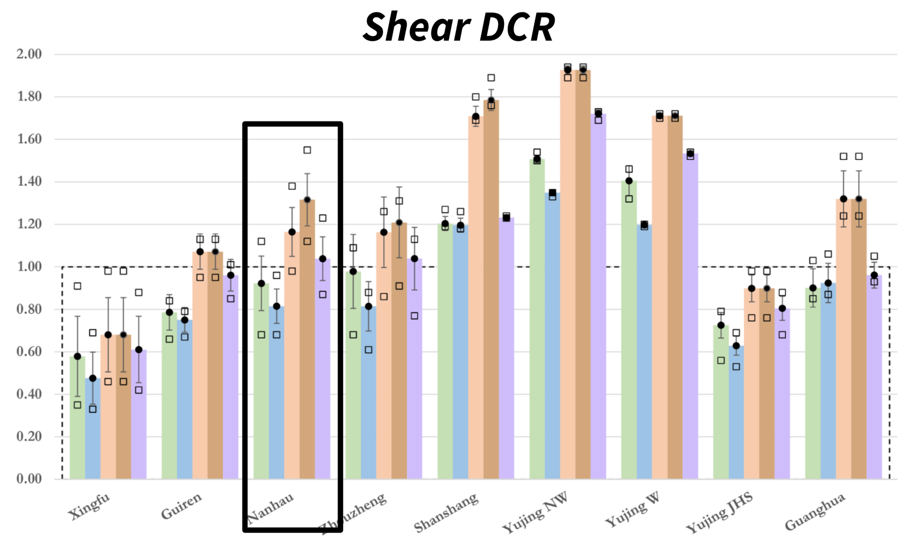
> Significant damage to reinforced-concrete buildings, particularly moment-resisting frames with masonry infill
> > Several major collapses
> > 3 district offices damaged, including Nanhua District Office (1967):

TIER 1 SCREENING

> Checklist-based approach to determine if further evaluation is required

> Typical deficiencies in damaged building stock:
> > Column shear stress demand
> > Strong column-weak beam condition
> > Column-tie spacing

Shear DCR

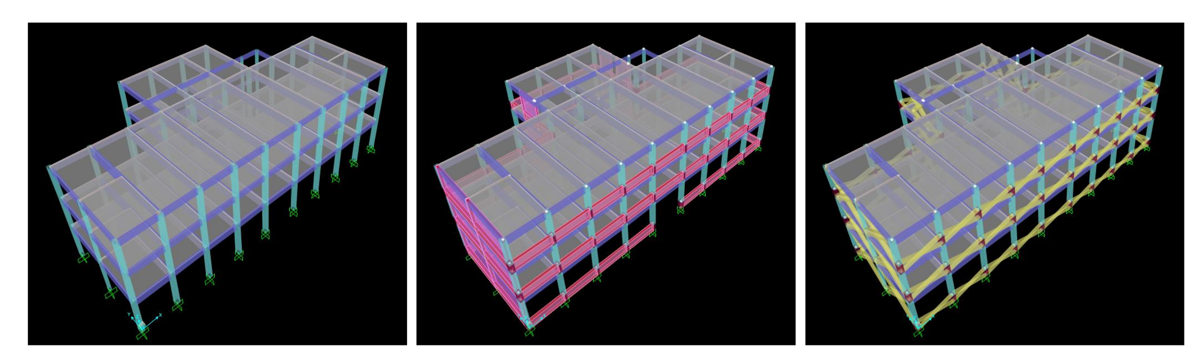


TIER 3 LINEAR-DYNAMIC EVALUATION

> Analyses performed in *SAP2000* using four model variations

> Ground motion is closest to building and captures forward-directivity effects

> Results:
> > Variation in response of models is not significant
> > Predicted damage modes inconsistent with observations

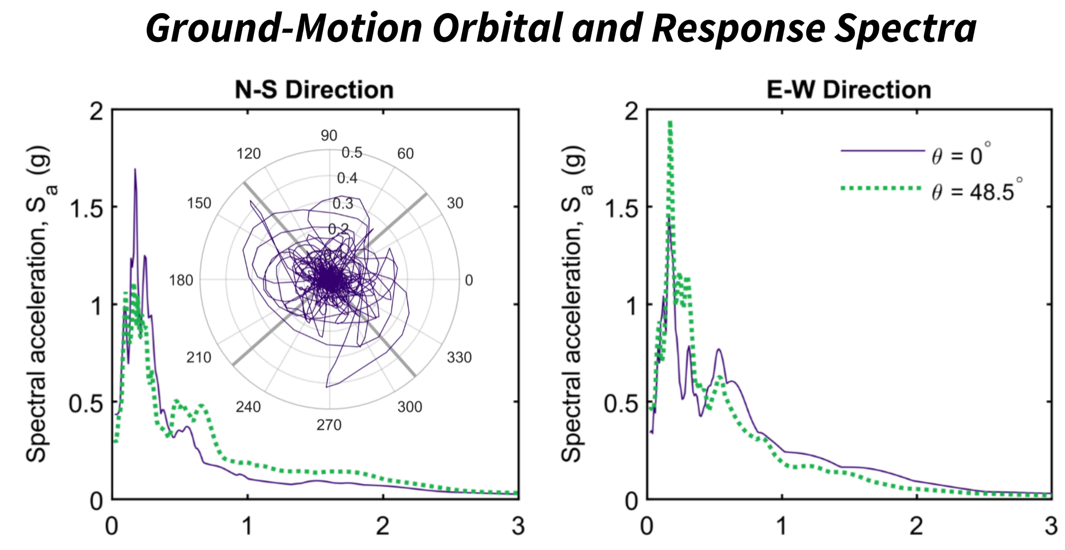


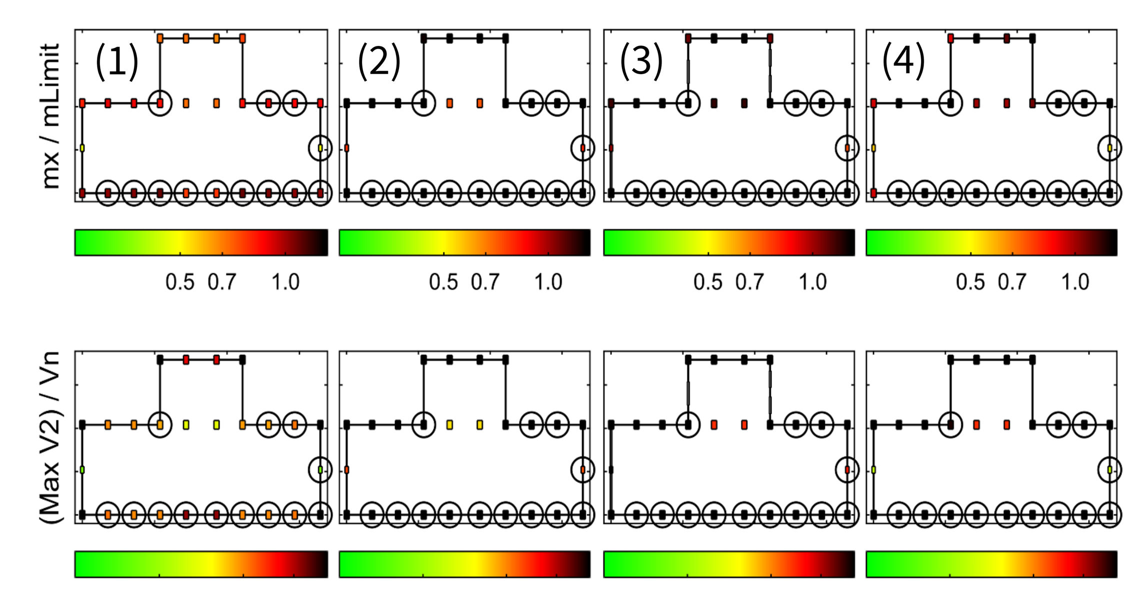
(1) Bare frame
(2) Infill offsets

(3) Infill Shell elements

(4) Infill diagonal struts

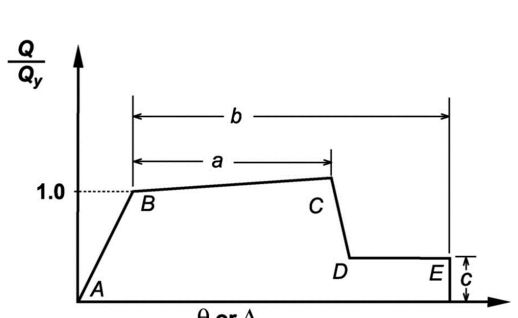
Ground-Motion Orbital and Response Spectra





TIER 3 NONLINEAR-DYNAMIC EVALUATION

> *ASCE-41* backbone curve represents column plastic-hinge moment-rotation behavior including degradation due to shear or flexure-shear failure modes

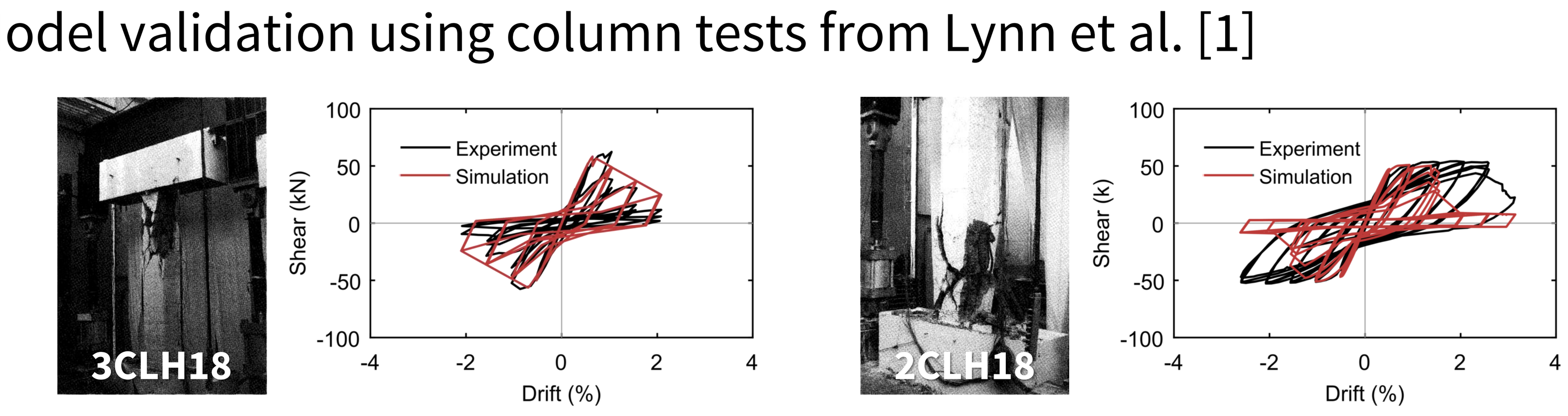


IO	$0.15a$
LS	$0.5b$
CP	$0.7b$

Parameter	Expression
a (rad)	$0.042 - 0.043\frac{N_{UD}}{A_g f'_{cE}} + 0.63\rho_t - 0.023\frac{V_{yE}}{V_{ColOE}} \geq 0.0$
b (rad)	$\frac{0.5}{5 + \frac{N_{UD}}{A_g f'_{cE}}\frac{1}{\rho_t}\frac{f'_{cE}}{f_{yt}}} - 0.01 \geq a$
c	$0.24 - 0.4\frac{N_{UD}}{A_g f'_{cE}} \geq 0.0$

Highlighting indicates time-dependent variables

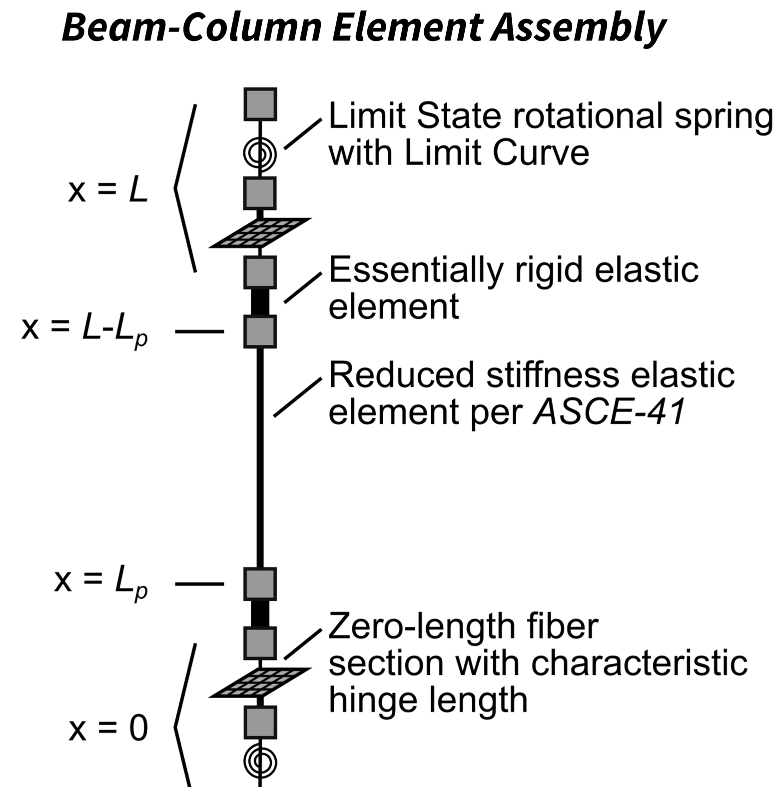
> Model validation using column tests from Lynn et al. [1]



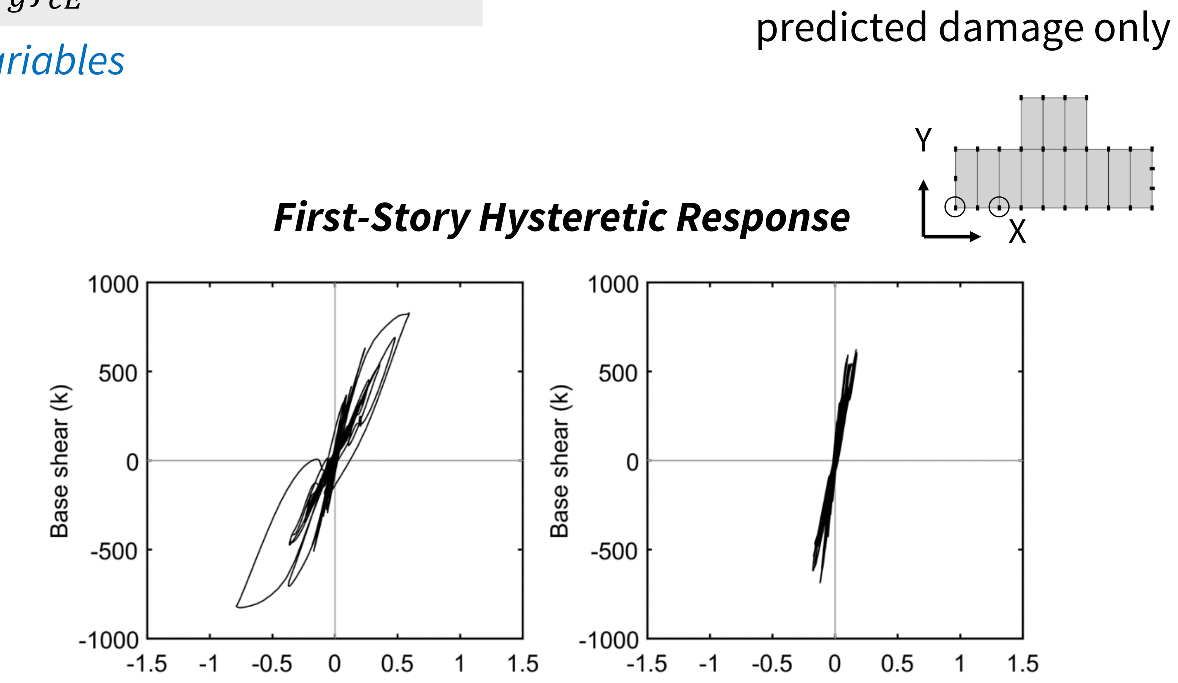
> Results:
> > Columns yield but do not sustain shear or flexure-shear degradation
> > Acceptance criteria for life safety exceeded in several cases
> > In contrast to linear analysis but in concert with post-earthquake reconnaissance, predicted damage only in longitudinal (X) direction of building

> New rotation limit curve developed in *OpenSees* after Elwood [1] to allow for use of fiber sections while complying with *ASCE 41-17*

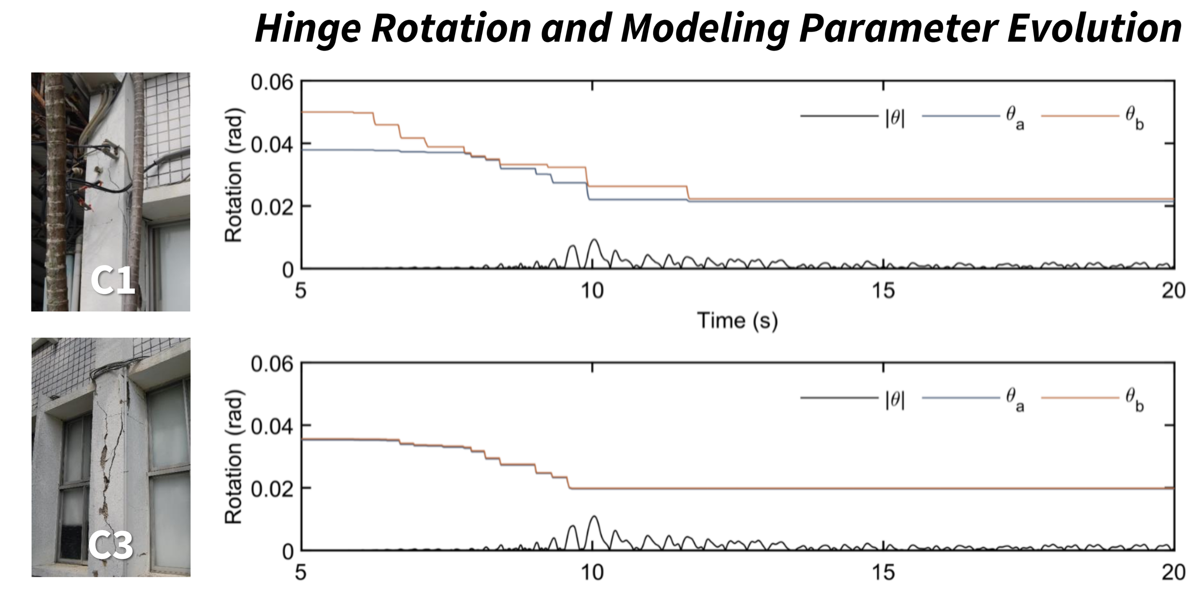
Beam-Column Element Assembly



First-Story Hysteretic Response



Hinge Rotation and Modeling Parameter Evolution



REFERENCES

[1] Elwood, K. J. (2004). "Modelling failures in existing reinforced concrete columns." *Canadian Journal of Civil Engineering*, 31, 846-859.
[2] Lynn, A. C., Moehle, J. P, Mahin, S. A., and Holmes, W. T. (1996). "Seismic evaluation of existing reinforced concrete building columns." *Earthquake Spectra*, 12(4), 715-739.

ACKNOWLEDGMENTS

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