Overview of the NIST-ATC Project on Benchmarking of Evaluation Methodologies for Existing Buildings

Siamak Sattar

Research Structural Engineer

National Institute of Standards and Technology

Motivation/Objective

- There are multiple evaluation and assessment methodologies for RC buildings including ASCE 41, ATC-78, Eurocode 8, New Zealand guidelines.
- No systematic study have been conducted to compare the estimated response with respect to the observed damage
  - How well do evaluation procedure predict the observed damage?
- Objective: to benchmark the evaluation procedures from various guidelines and standards against field or lab observations, and develop recommendations to improve future editions of ASCE 41

Project Members

- **Technical Committee**

  Russ Berkowitz – *Forell/Elsesser*

  Abbie Liel – *Univ. Colorado*

  Laura Lowes – *Univ. Washington*

  Dawn Lehman - *Univ. Washington*

  Wassim Ghannoum - *UTSA*

  Insung Kim - *Degenkolb*

  Farzad Naeim – *Farzad Naeim*

  Rob Smith - *ARUP*

  Ken Elwood – *Univ. Auckland*

  John Egan - Consultant

- **NIST**

  Siamak Sattar

  Steven McCabe

- **ATC**

  Ayse Hortacsu

- **Review Committee**

  John Wallace - *UCLA*

  Santiago Pujol – *Purdue University*

  Peter Somers - *MKA*

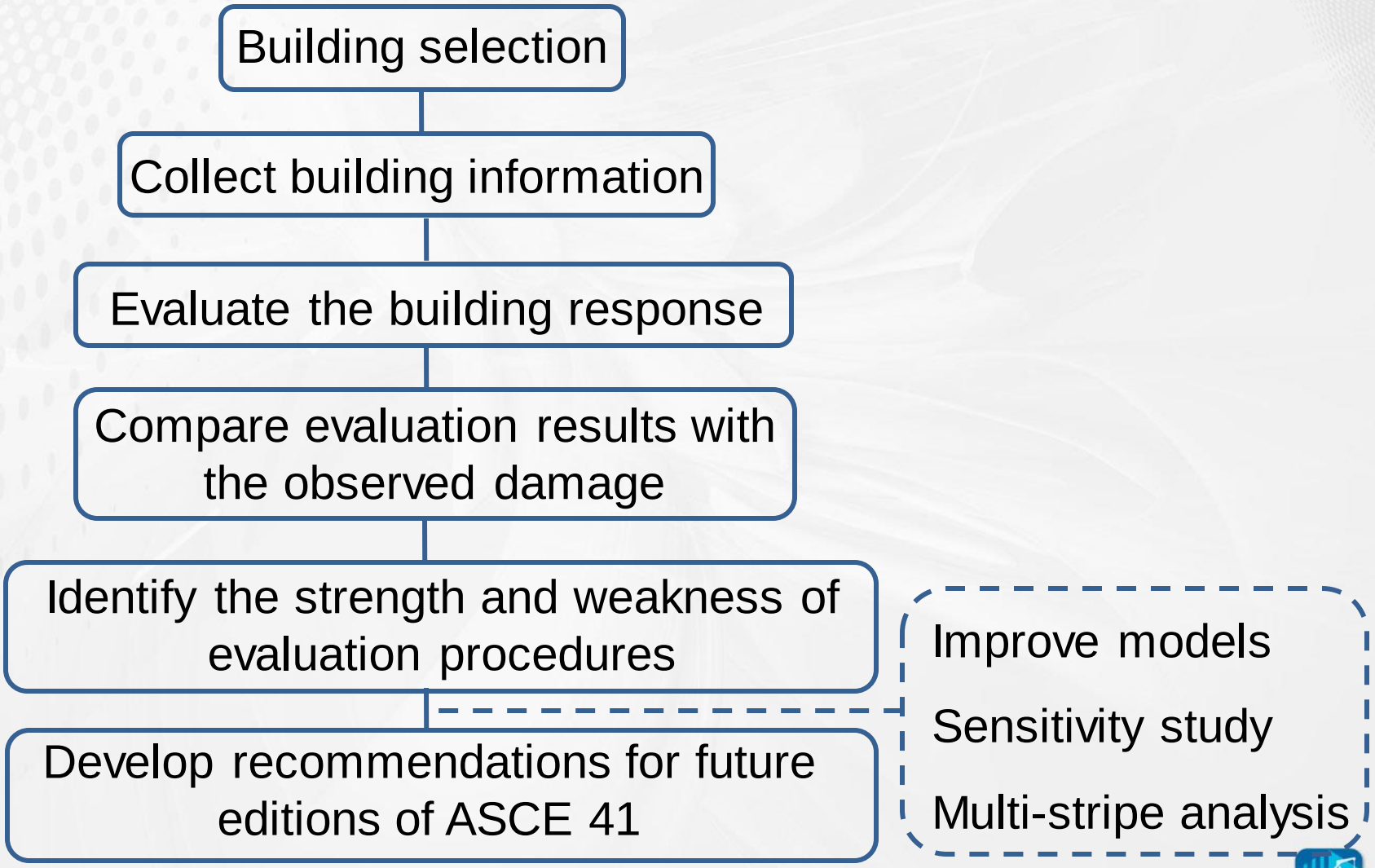
  Brian Kehoe – *WJE*

  Daniel Zepeda - *Degenkolb*

  Michael Fardis - *University of Patras*

  Don Dusenberry – *SGH*

Research Method



Building Selection Criteria

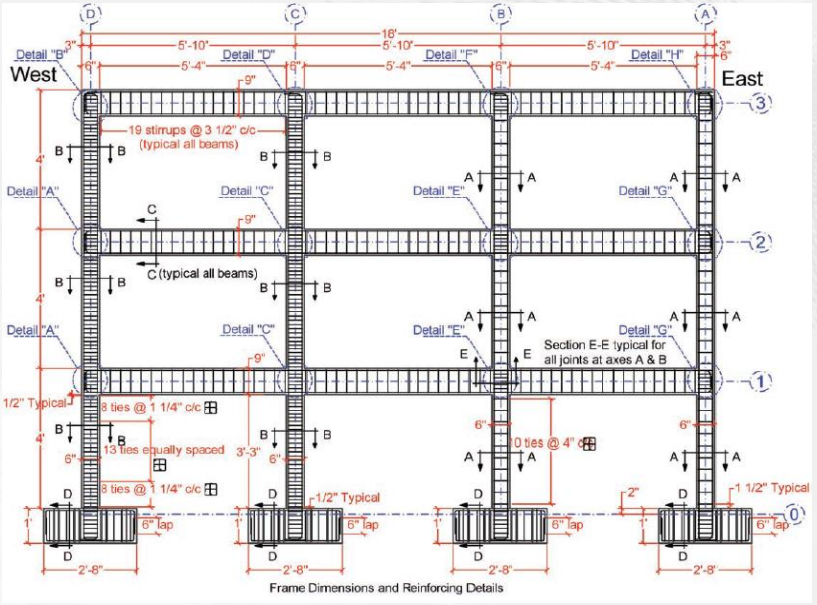
- At least six reinforced concrete structures
- A mix of frame and shear wall buildings
- At least two pre-1980 buildings
- At least two buildings from the US
- Similarity to buildings common in the US
- Detailed building information including drawings
- Detailed post-event reconnaissance survey data
- Availability / proximity of recorded ground motion data

Building Selection

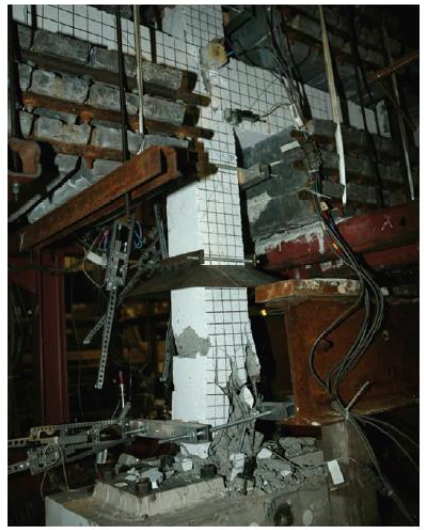
- **2-D Test Frame** - Berkeley
- **E-Defense Shake Table Test** - Japan
- **Imperial County Services Building** – U.S.
- **Van Nuys Holiday Inn** – U.S.
- **Pyne Gould** – New Zealand
- **Nanhua District Office Building**- Taiwan
- **Xingfu District Office Building**- Taiwan

2-D Test Frame

- 3-story moment frame
- Ductile/nonductile
- Uni-directional shaking
- Damage:
  - Column and beam hinging
  - Shear and axial failure of columns

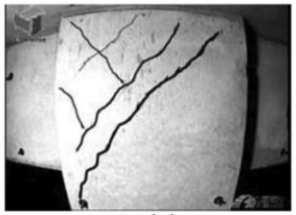


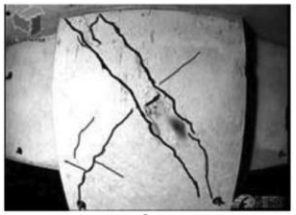
Frame Dimensions and Reinforcing Details

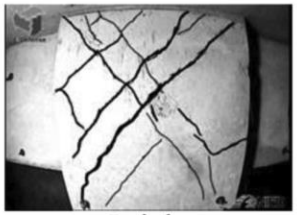


E-Defense Shake Table Test

- 4-story full scale reinforced concrete frame and shear wall buildings
- Tested under multi-directional seismic loading
- Damage:
  - Column and beam hinging
  - Sever joint shear failure
  - Sever damage in the boundary element of shear walls and sliding





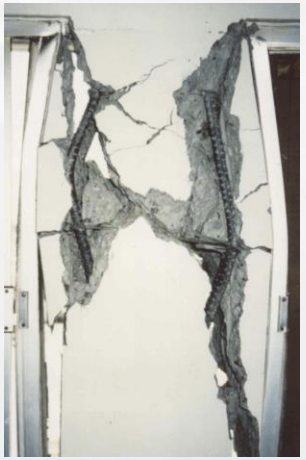


Imperial County Services Building

- 6-story building
- Frame in one direction and wall-frame in another direction
- Damaged in 1979 Imperial Valley EQ
- Include irregularities: weak/soft story, wall discontinuity, torsional sensitivity
- Damage:
  - Biaxially driven column failure on the east end

Holiday Inn Van Nuys

- 7-story building
- Built in1966
- Perimeter spandrel beam-column frame and interior slab-column frame
- Damage:
  - 1994 Northridge earthquake caused shear failure in several columns in the 4th and 5th stories



Pyne Gould

- 5-story building
- Built in 1966 in Christ Church
- Reinforced concrete walls with gravity RC frame
- Damage:
  - The building was collapsed

Nanhua District Office Taiwan (2016 Meinong EQ)

- 3-story building
- Built in 1967
- One-way slab-beam-column moment frame
- Full-height and partial-height infill walls
- Damage:
  - Diagonal cracking of columns and infill walls in the first story

Xingfu District Office Taiwan

- 7-story building
- Built in 2000
- Slab-beam-column moment frame
- Full-height RC walls and partial-height infill walls
- Damage:
  - Partial collapse of the building

Analysis / Evaluation Procedures

- Linear and nonlinear models are developed for each building per ASCE 41-17 modeling recommendations
  - Models are adjusted based on judgement where ASCE 41 is not explicit
- Nonlinear models are developed using either the lumped–plasticity or fiber modeling approach
- **The analyses are underway**
- Link the analysis results to the observed damage to benchmark the evaluation methods
  - Challenge: the analysis results are in terms of component/story deformation, but the observed damage is usually reported with pictures or in a written format

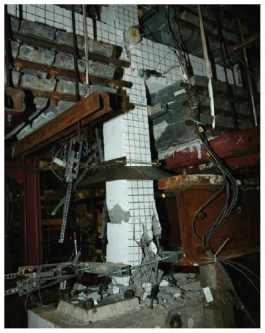
Link Analysis Results to the Observed Damage: Approach 1

Extract the component rotation from analysis results

Create a database of pictures that shows the type and extent of damage for different components at different deformation demands

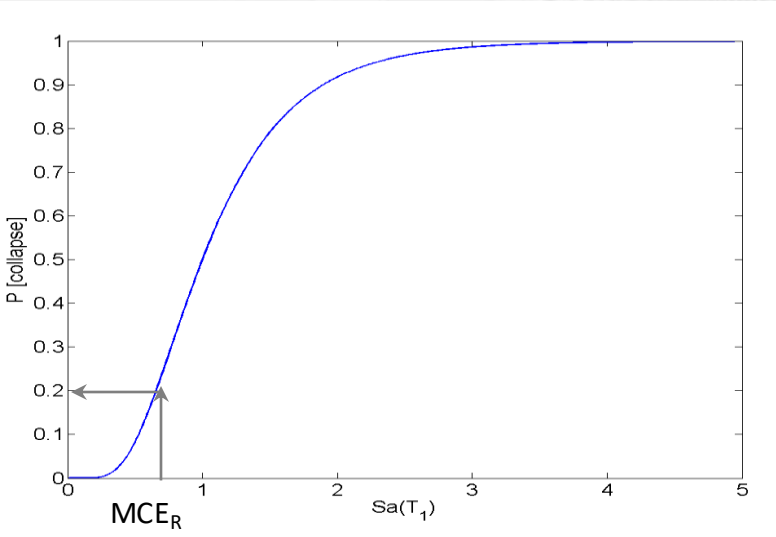
Estimate the damage for each component

Compare the predicted damage with the actual damage

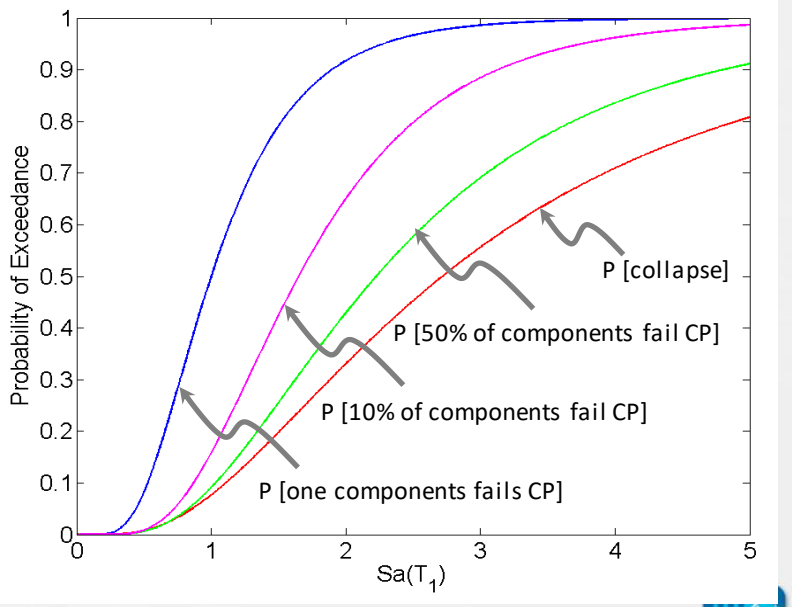


Assess the Global Performance

- Knowing P [collapse] |MCE_R would identify the expected performance of the buildings with respect to the target performance in ASCE 7.



- Linking the component level performance to the system level performance, i.e. global collapse to ASCE 41 definition of collapse.



Potential Outcomes / Timeline

- Improve understanding of the expected accuracy of the current evaluation methods.
- Develop recommendations to improve ASCE 41 evaluation procedures.
- The project is expected to be completed by the end of 2019.
- We are planning to extend the scope of the project and investigate two buildings damaged during the 2017 Central Mexico earthquake.
- You will hear more about Nanhua building from Prof. Lowes.

Thanks!