Field Observations Following the 2023 Turkiye-Syria Earthquakes

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AFAD

The Earthquakes

The Earthquakes

- February 6, 2023
  - Pazarcik: $M_w = 7.8$
  - Elbistan: $M_w = 7.5$
- Impacts:
  - Nearly 60,000 deaths
  - 3 million displaced
  - Economic losses > 1/10 of GDP

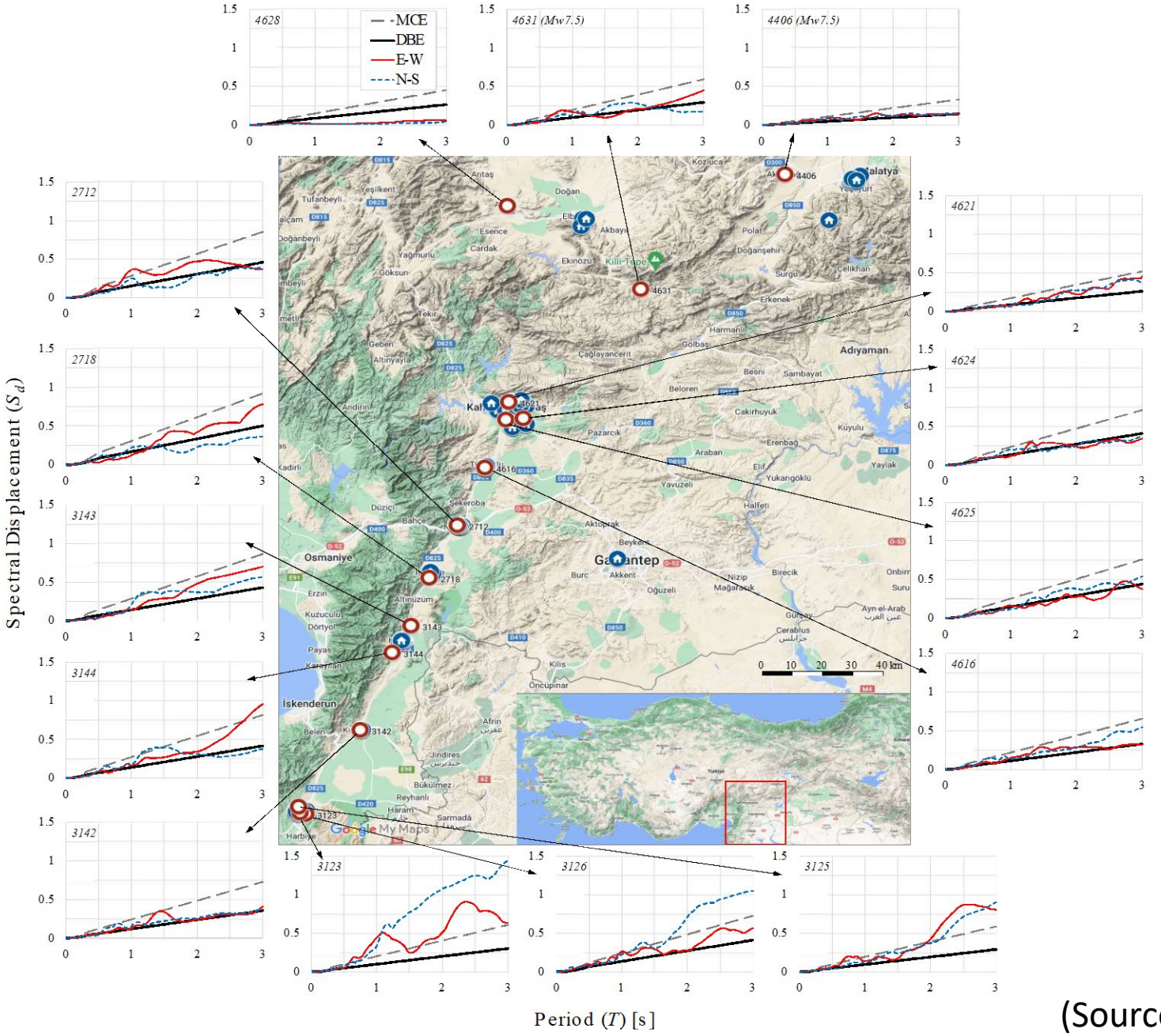
Sources:

https://earthquake.usgs.gov/storymap/index-turkey2023.html

https://www.redcross.org.uk/stories/disasters-and-emergencies/world/turkey-syria-earthquake

https://www.npr.org/2023/08/30/1191264192/turkey-earthquake-rebuild-displaced-people-adiyaman

https://www.barrons.com/news/donor-conference-seeks-to-rally-quake-aid-for-turkey-syria-bce11409



(Source: Egemen Sonmez, AFAD)

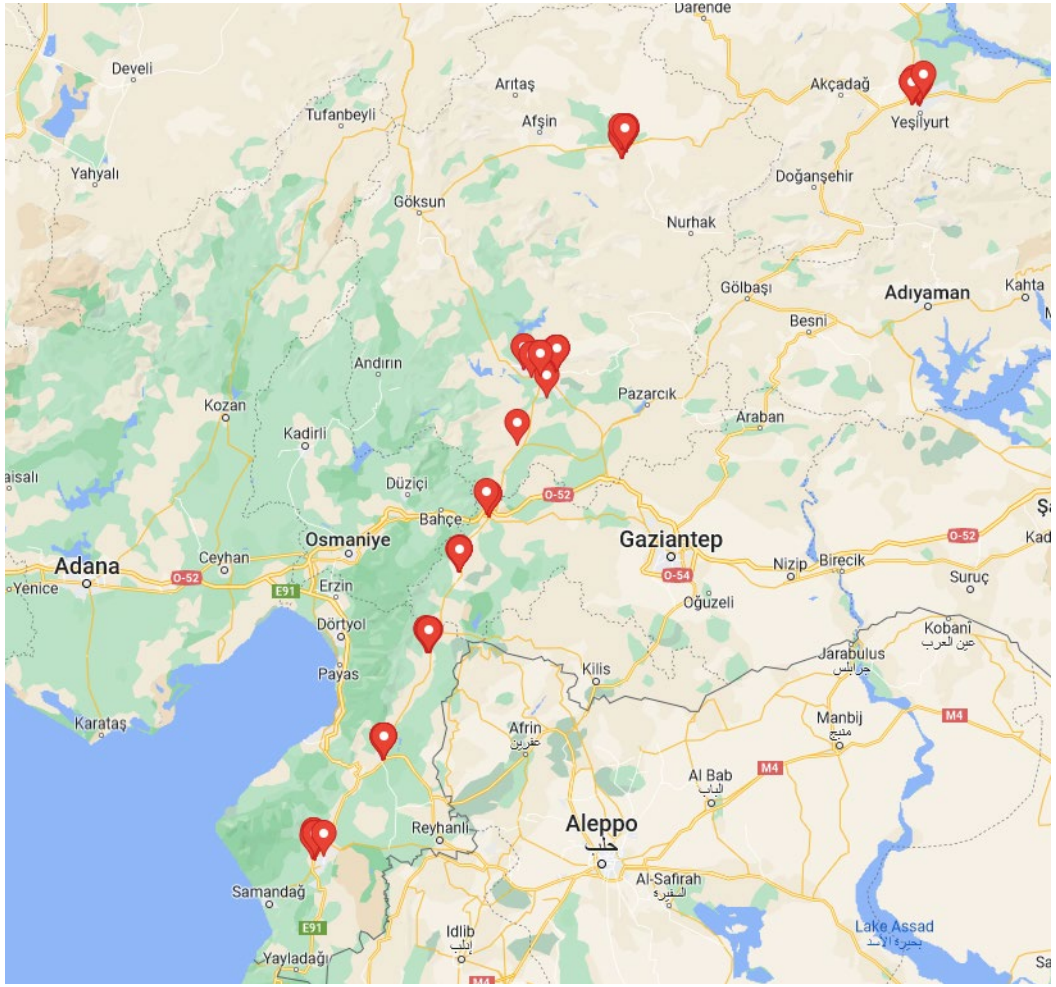
The ACI 133 Survey

The Survey

American Concrete Institute (ACI)

Dicle University
Eskisehir Osmangazi University
Hacettepe University
Harran University
Izmir Institute of Technology
Izmir University of Economics
National Institute of Standards and Technology (NIST)
Purdue University
University of Canterbury
University of Kansas
University of Nebraska
Wiss, Janney, Elstner Associates (WJE)

The ACI 133 Survey



March 25 to April 6, 2023

10 Cities

Surveyed 322 buildings; complete records obtained for 242 buildings

The ACI 133 Survey

For each building, groups of three to four engineers:

1) Documented damage

2) Measured span lengths and column/wall dimensions

Observed Damage:
Problematic Reinforcement Details

Problematic Details

Concrete cover or longitudinal bar spacing smaller than required

Lack of crossties

Problematic Details

Lack of 135-degree hooks

Widely spaced transverse reinforcement around small-diameter longitudinal bars

Problematic Details

Widely spaced transverse reinforcement at cold joints

Problematic Details

Offset-bent longitudinal bars (so-called “dog-Leg” detail) at the base of columns/walls

Problematic Details

Lap splices at column and wall bases

Problematic Details

Bar terminations in beams

Problematic Details

Detailing of short “non-participating” beams

Code Compliant (?) Problematic Details

Lack of confinement for column and wall longitudinal bars inside foundation

ACI 318 prohibits in SDC D, E, F; Consider extending to IMF?

Code Compliant (?) Problematic Details

Unconfined beam bars in beam-column joints

ACI 318 prohibits in SMF; Consider extending to “non-participating”, IMF, and OMF

Nonstructural Damage

Nonstructural Damage

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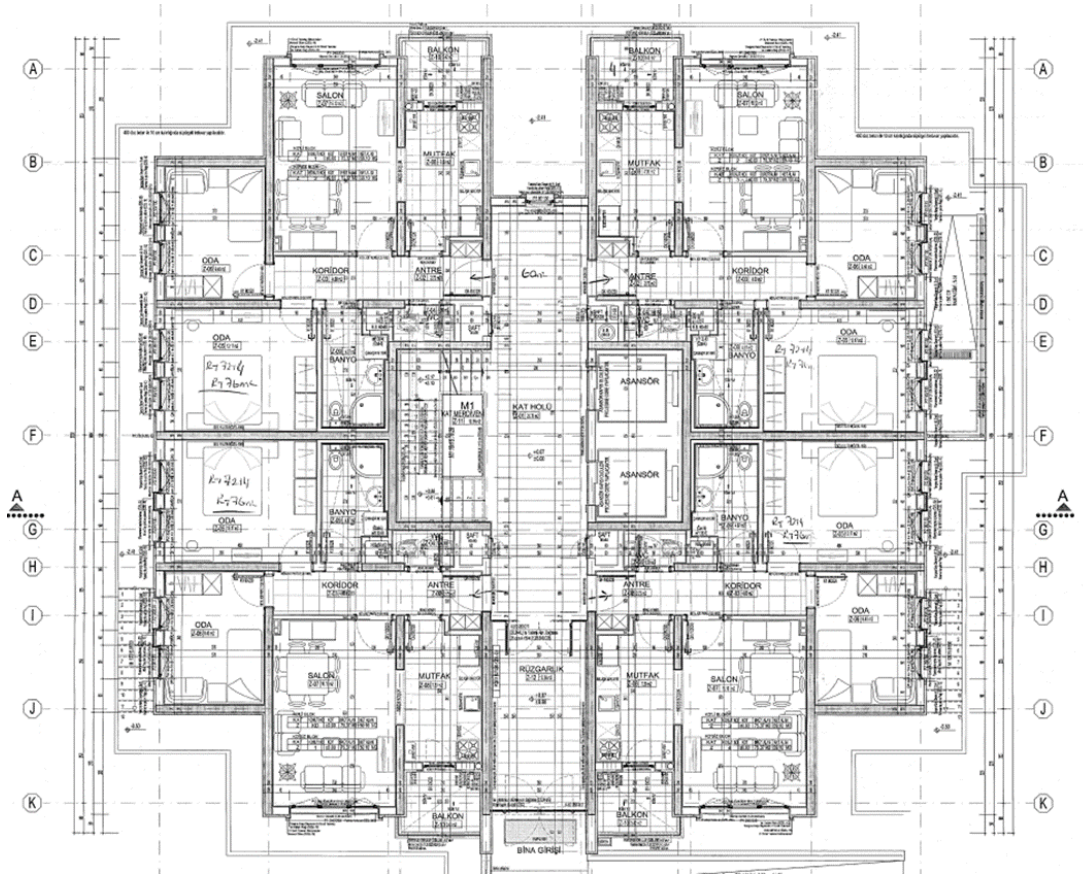
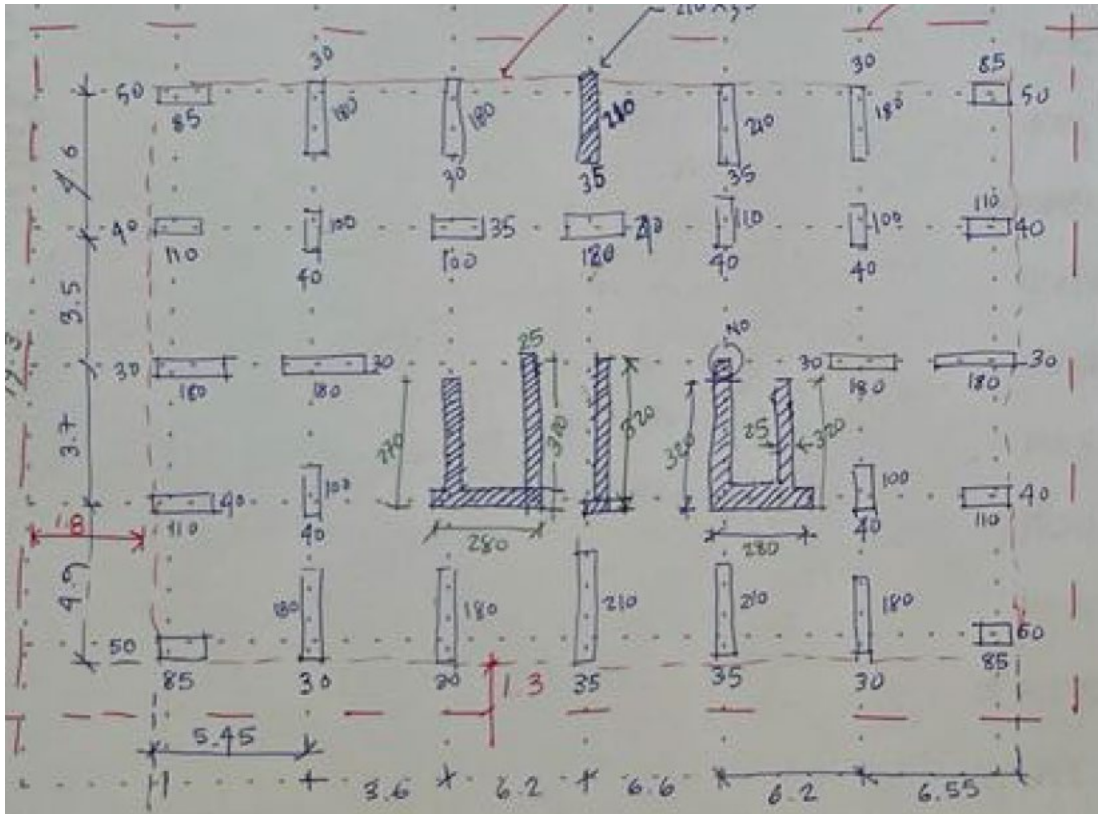
Damage and Robustness

Damage and Robustness





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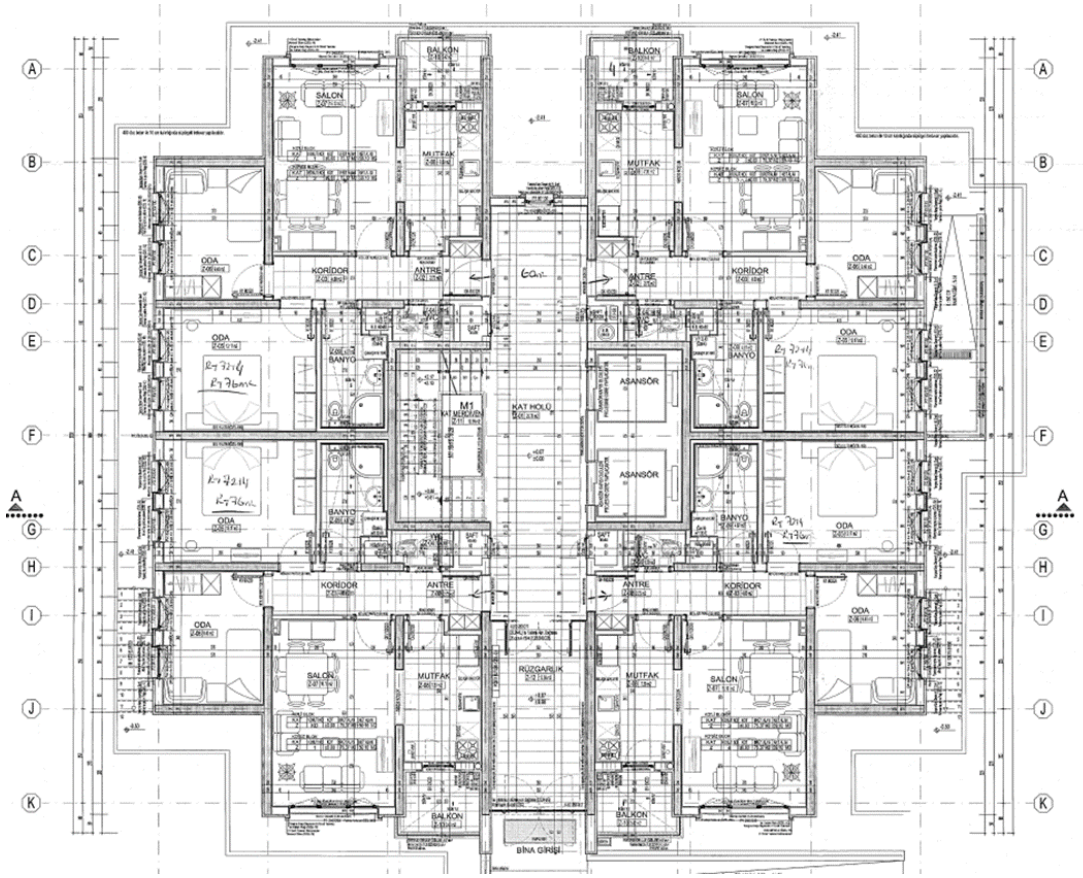

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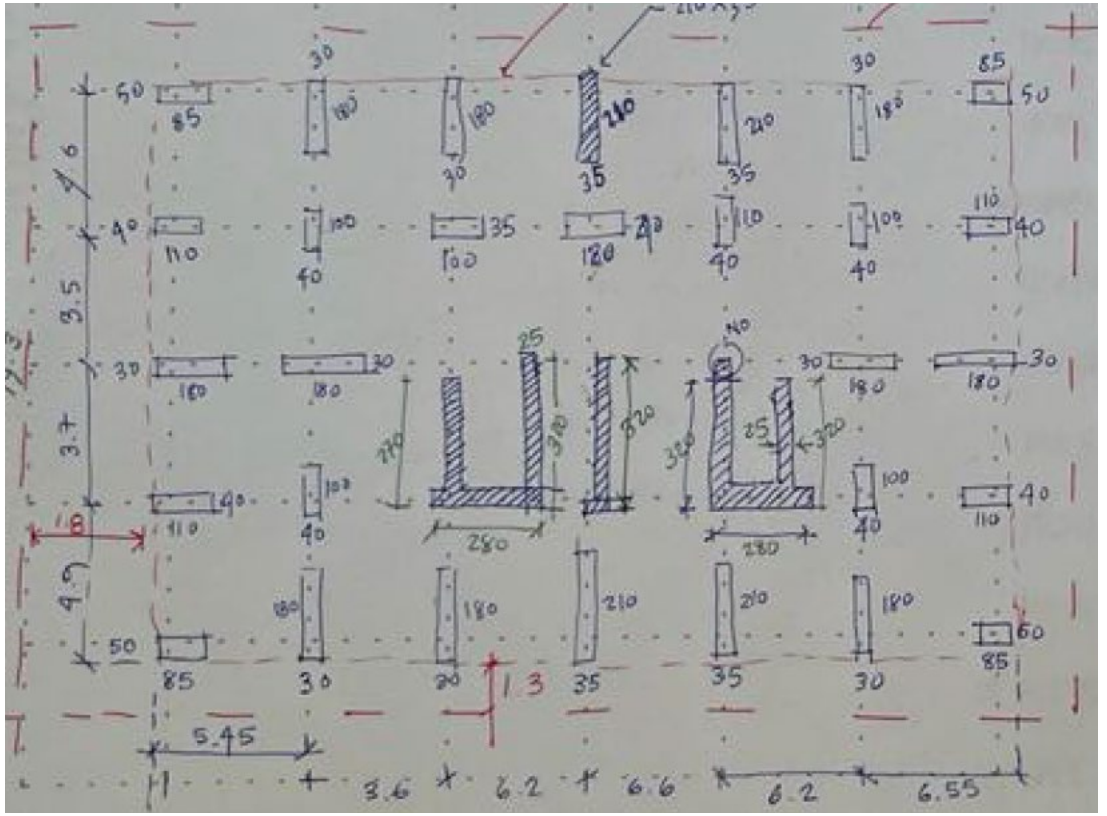

Damage and Robustness

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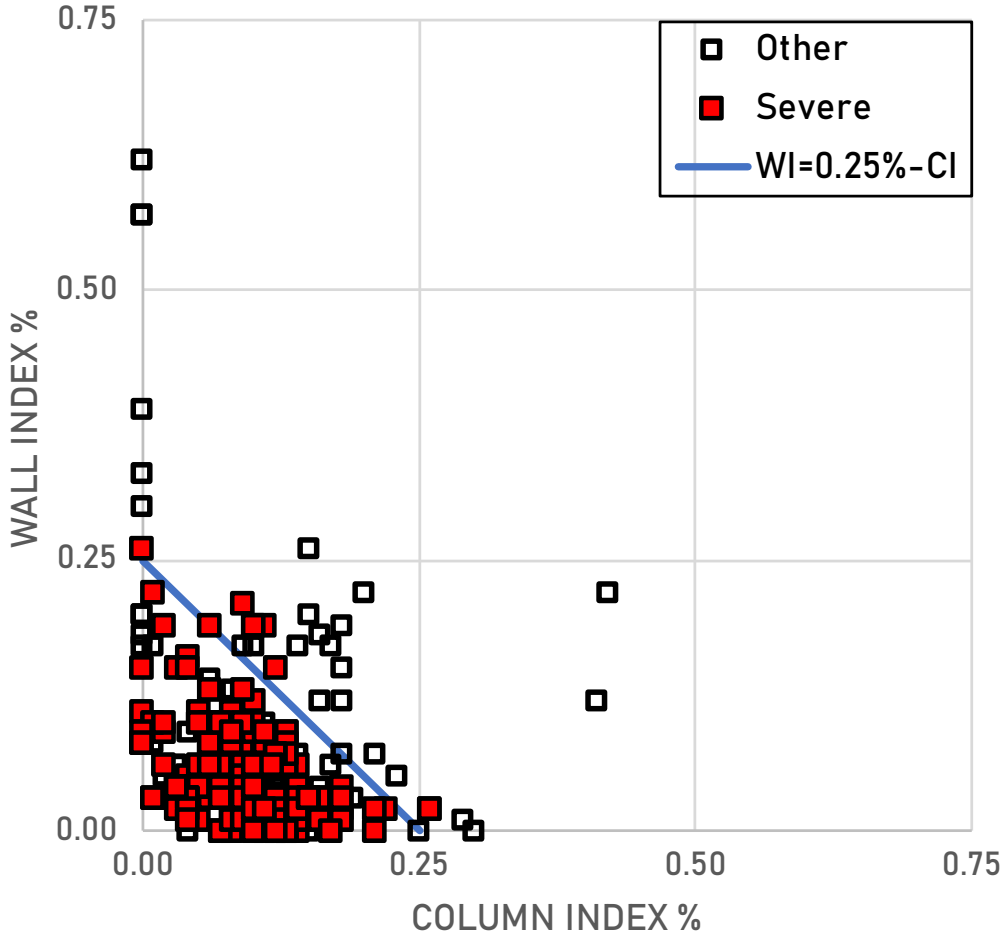
- Hassan and Sozen (1997):

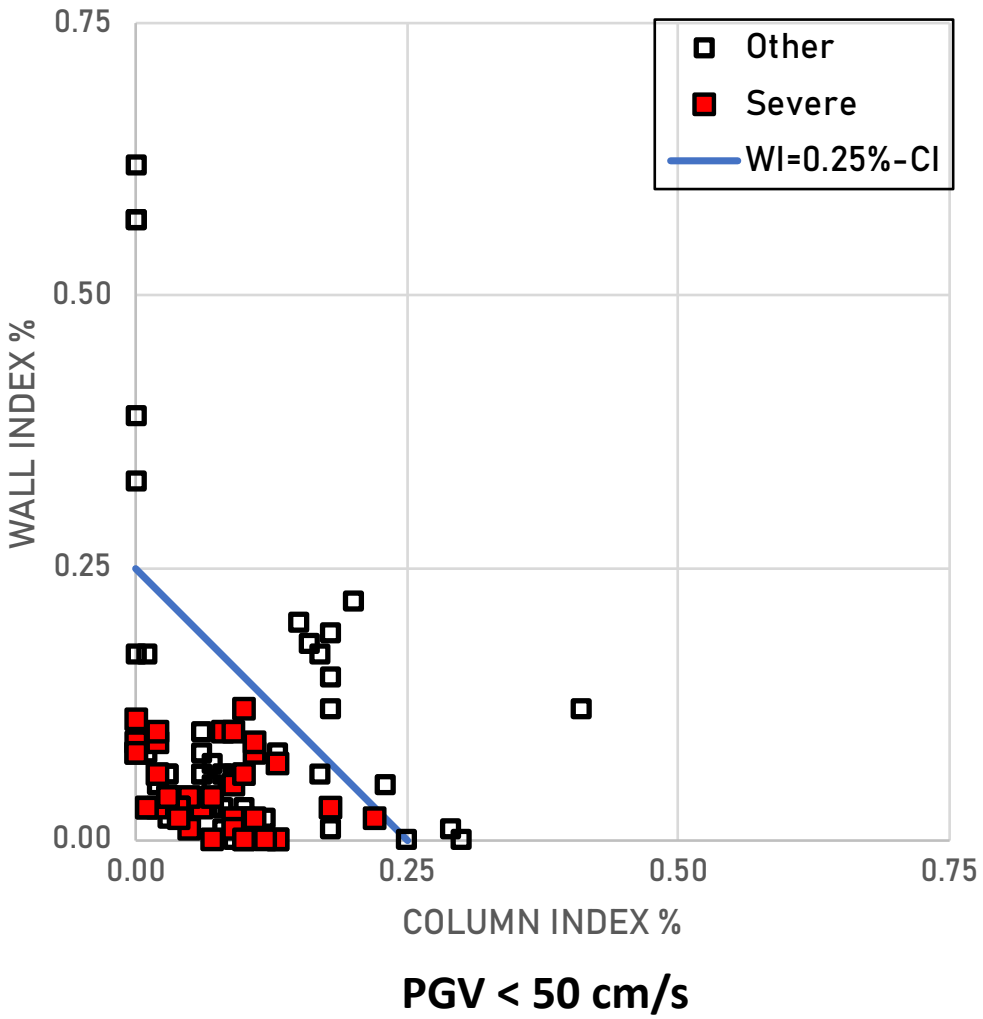
$$\text{Wall Index: } WI = \frac{Area(RC\ Walls) + Area(Masonry\ Walls)/10}{Total\ Floor\ Area\ Above\ Critical}$$

$$\text{Column Index: } CI = \frac{Area(Columns)/2}{Total\ Floor\ Area\ Above\ Critical}$$

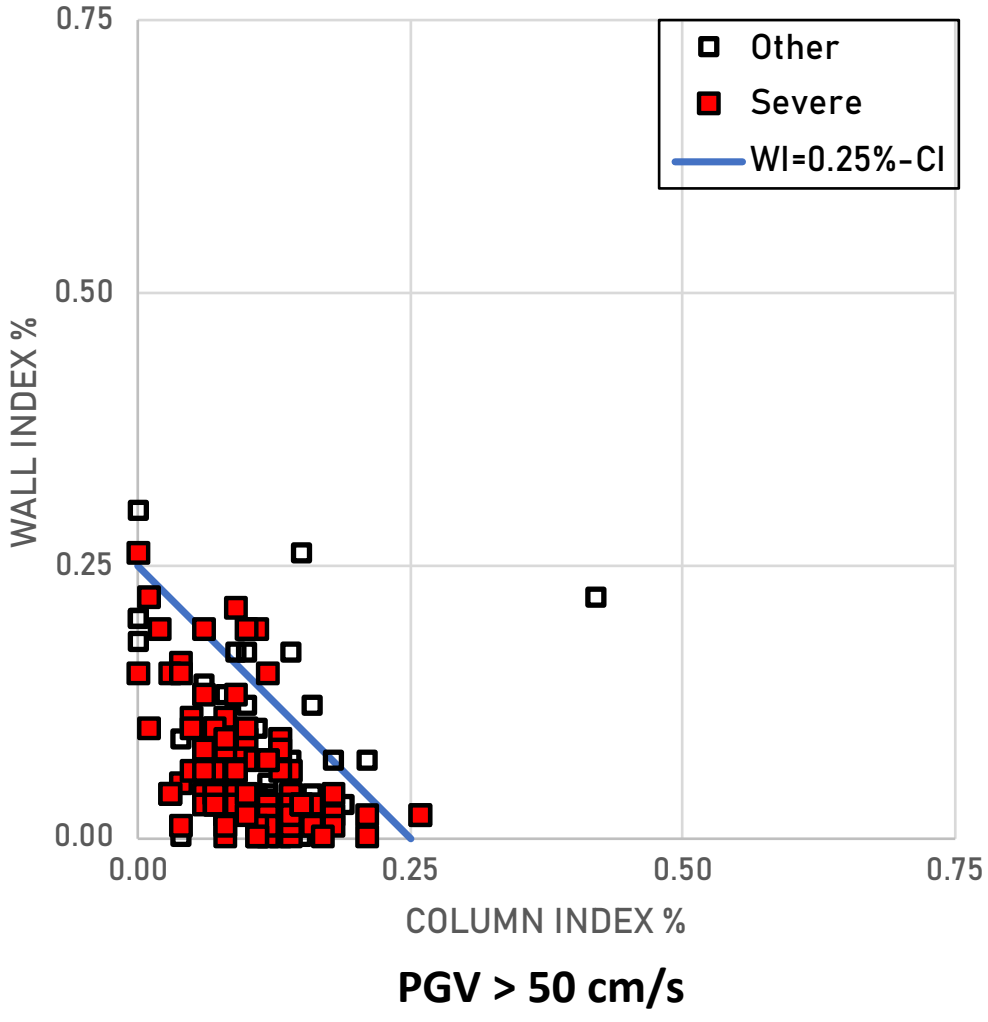
Damage and Robustness



Damage and Robustness

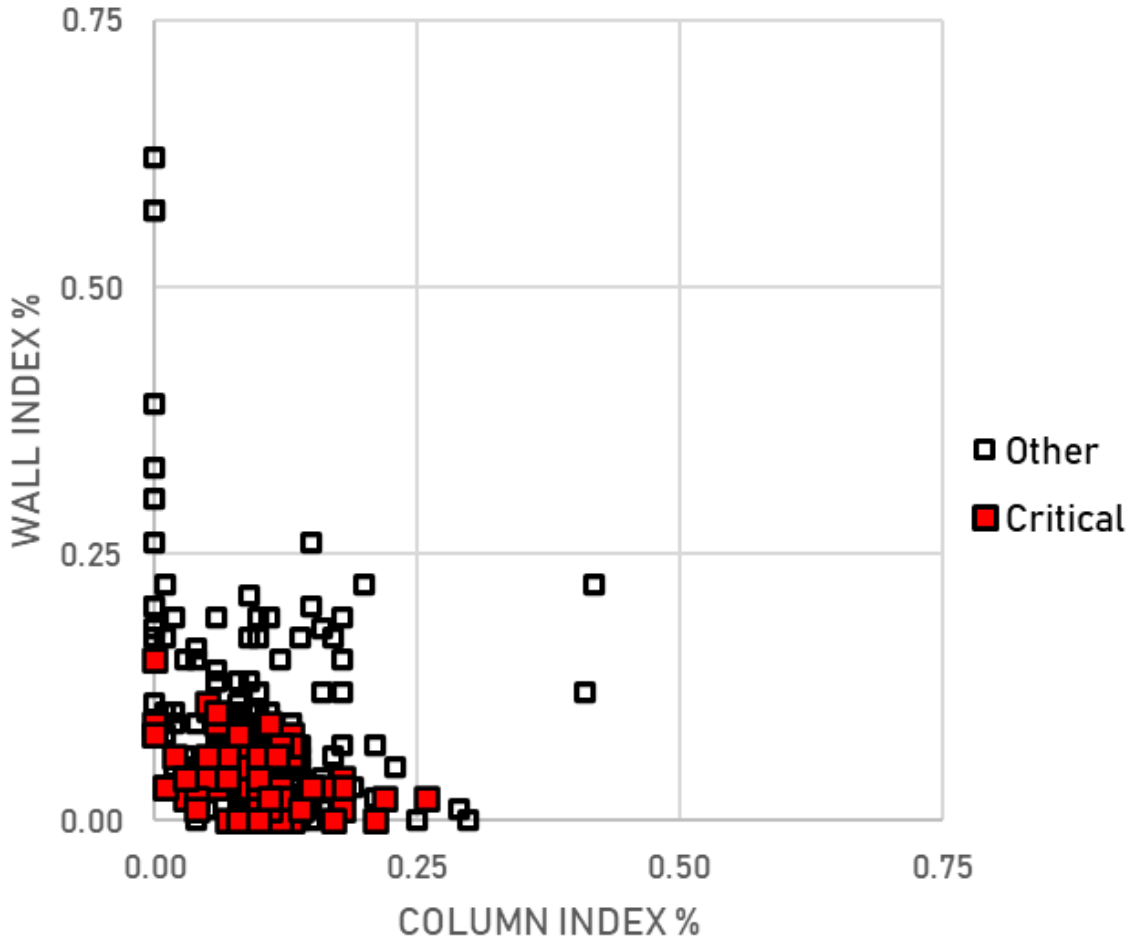


PGV < 50 cm/s



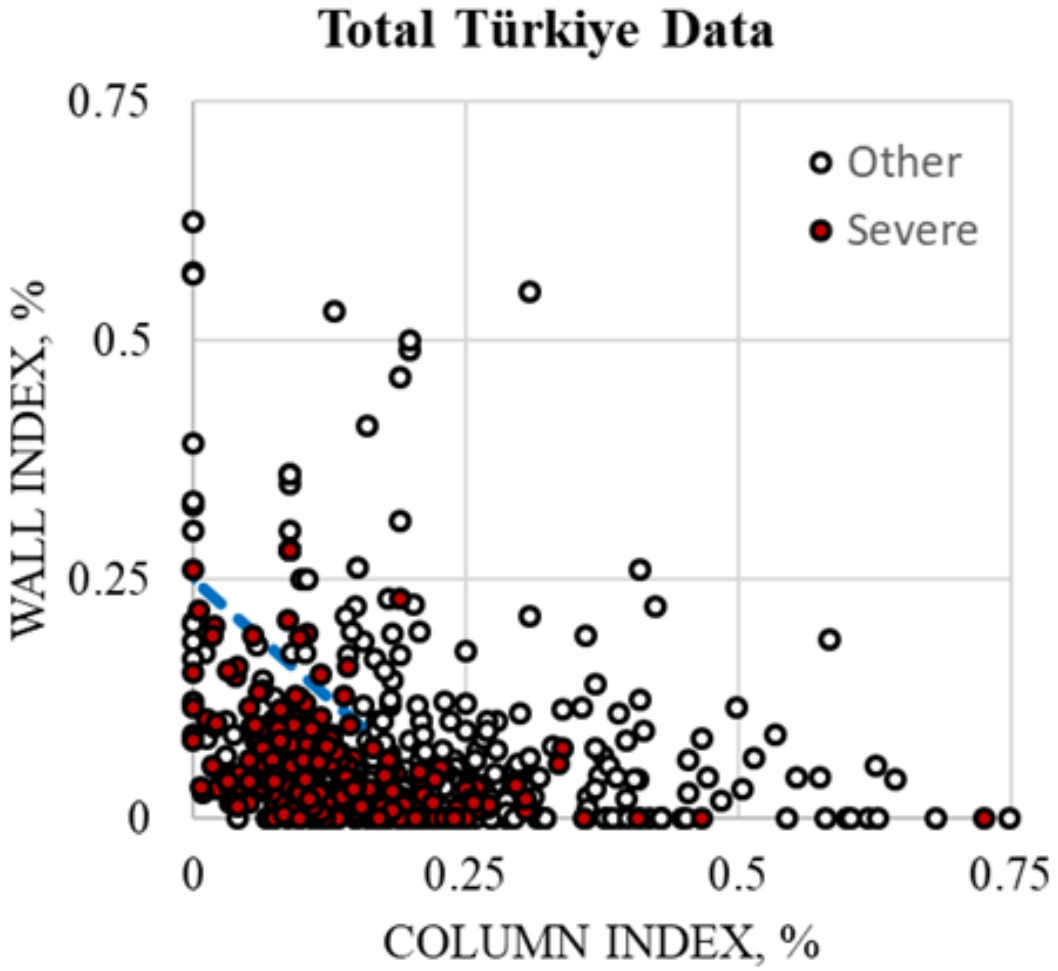
PGV > 50 cm/s

Damage and Robustness



Damage and Robustness

- 1992 Erzincan
- 1999 Bolüzce
- 2023 Pazarcik



Source: Donmez et al., (2023) “Lessons from the 2023 Southeast Türkiye Earthquakes: A Study on Damaged RC Buildings Considering the Hassan Index,” *18th World Conference on Earthquake Engineering.*

Summary of Contributing Factors

- Ground motion intensity was substantially greater than expected
- Large drifts revealed problematic reinforcement details, many of which were not code compliant
- Damage to non-structural elements made well-designed buildings dangerous and unusable
- Buildings with more walls did better

Recommendations

- Drift control should be prioritized; recommend WI > 0.25%
- Reducing damage to nonstructural elements is essential for reducing population dislocation
- Proper reinforcement detailing is essential for limiting damage
- Engineers should bear in mind that design ground motions may be substantially exceeded

Containers in Besni in 2024, Source: Aljazeera

Tents in Antakya in 2024, Source: Washington Post


Thank you