Review of the 2023 Kahramanmaraş Earthquake Sequence
May 2023
Turkey, Located in a Seismically Active Region, Has Seen Many Devastating Earthquakes in its History:

- 1939 Erzincan (Mw 7.8)
- 1983 Erzrum (Ms 6.9)
- 1992 Erzincan (Mw 6.7)
- 1995 Dinar (Ms 6.1)
- 1998 Ceyhan (Mw 6.3)
- 1999 Marmara (Mw 7.4 & Mw 7.2)
- 2003 Bingol (Mw 6.4)
- 2011 Van (Mw 7.2)
- 2020 Aegan Sea (Mw 6.9)
- 2023 Kahramanmaraş (Mw 7.8 & Mw 7.5)
Region Impacted by 2023 Earthquakes is at the "Triple Junction" of a Complex Tectonic Setting

Source: Acarel et al. 2019
A "Seismic Gap" in the Kahramanmaraş Segment of Eastern Anatolian Fault (EAF)

Significant Historical Ruptures
Mainshock M7.8 Pazarcik earthquake on southern EAF (6 Feb 2023)
- Depth of ~18km
- Rupture length of ~300km

Triggered M7.5 Elbistan earthquake on Sürgü fault (6 Feb 2023)
- Depth of ~10km
- Rupture length of ~100km

M6.3 aftershock on southern edge of EAF and northern extension of DSF (20 Feb 2023)

Source: USGS
Seismicity Models Should Correctly Reflect Higher Rupture Probability in the Kahramanmaraş Segment of EAF

- High stress accumulation capable of generating large earthquakes
- Region is capable of producing even higher magnitudes
Ground Motion Models Generally Performed Well

- Short period intensities impact low-rise buildings and infrastructure
- Recorded intensity compares well with modern GMMs within 100 km of rupture
- GMMs overestimate at farther distances where intensity is low, and damage is small

Source: METU-Earthquake Engineering Research Center (Gülerçe et al. 2023)
Short-Term Increase in Seismicity in Adjacent Faults and Long-Term Decrease in Large Magnitude Earthquakes in Ruptured Area

- Elevated seismicity of small to moderate earthquakes in Eastern Turkey
- Risk may have increased in NE EAF and Northern DSF
- Reduced risk from large scale (M>7.5) events in Central and southern EAF
Damage Observations and Lessons Learned
Seismic Design Codes in Turkey Have Evolved Significantly Since their Introduction in 1940

- 1939 Erzincan Earthquake
- 1975 Code updated with new hazard map
- 1998 Code updated with refined contours of design hazard
- 2007 Code updated - no significant change in design forces
- 2018 Code updated - no significant change in design forces
- 2023 Kahramanmaraş Earthquake sequence

Refinement in design force calculation and adding regional variation

First Turkey Seismic Code

Seismic code revised with ductility requirements

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The Earthquake Sequence Has Caused Widespread Damage and Destruction.

Yeni, Adıyaman

Mahmut Bozarslan Wikimedia Commons

Hilmi Hacaloğlu Wikimedia Commons

Hatay
The 2023 Kahramanmaraş, Turkey, Earthquake Sequence Clearinghouse
M7.8 | M7.5 FEBRUARY 6, 2023 AT 01:17 UTC

EEFIT Mission: February 2023 Turkey earthquake

MIDDLE EAST TECHNICAL UNIVERSITY
Preliminary Reconnaissance Report on
February 6, 2023, Pazarlık Mw=7.7 and Elbistan
Mw=7.6, Kahramanmaraş-Türkiye Earthquakes
Reconnaissance Reports and Damage Surveys Have Highlighted Recurring Vulnerability Issues in the Building Stock

RC & URM infill dominate building inventory. Mid-High Rise buildings were most severely damaged. Significant building defects were observed. Common problems of soft story and lack of ductility added to building vulnerability.

EEFIT survey found that >50% buildings in the affected region were built after 2001.
Extensive Damage in Turkey and Syria Highlight the Importance of Building Code Adoption and Enforcement

- Lack of code adoption by builders and contractors
- Lack of code enforcement
- Leniency towards construction permits
- Poor construction quality
Losses from the Kahramanmaraş Earthquake Sequence
Model correctly captures the extent and severity of damage at the local level.
Various Insured and Economic Loss Estimates Have Been Published
Main Conclusions

The main event and the wider sequence occurred on a well-known and well-studied part of EAF, with significant seismic gap. Recorded seismic motions broadly in line with well-established ground motion models in the area of main damage. Implications for short- and long-term regional seismicity established. Reliable damage surveys and reports have been published relatively quickly. Most point at lack of building code adoption and enforcement.