Canadian Association for Earthquake Engineering and Seismology (CAEES)
L'Association Canadienne du Génie Parasismique et de la Sismologie (ACGPS)

NEWSLETTER

April 2024
Volume 8, Issue 2

http://caee.ca/

From the Editor's Desk

by Tuna Onur

The devastating earthquake sequence in Turkey last year in early February was a stark reminder of how earthquakes can severely impact communities. Two earthquakes of magnitude larger than 7.5 happened within nine hours of each other, followed by numerous aftershocks.

CAEES sent a reconnaissance team of structural and geotechnical earthquake engineers and earth scientists to Turkey, three months after the earthquakes. Our team captured observations over a large geographical area and summarized their findings in a report that will be available to CAEES membership soon. This issue highlights the earthquake sequence and some preliminary seismological and structural engineering observations ahead of the publication of the CAEES reconnaissance team's report.

Our Newsletter is a great way to share short articles, news or other items related to earthquake engineering with your colleagues. Please send your contributions to secretary@caee-acgp.ca

Inside This Issue

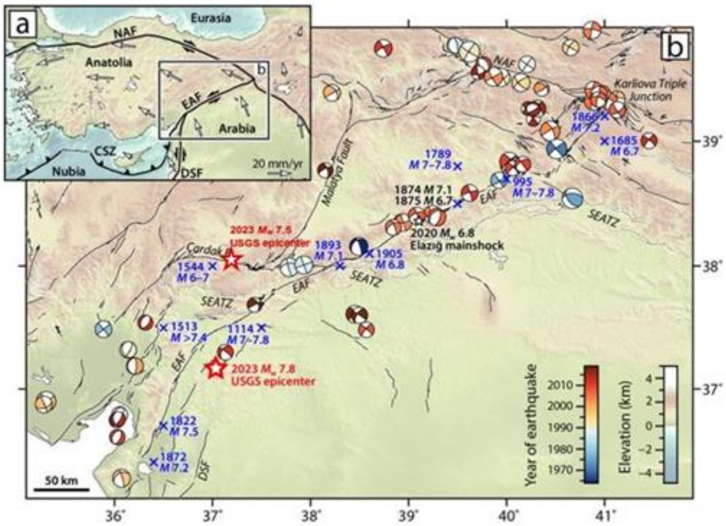
The February 2023 Earthquake Sequence in Turkey: Seismological Aspects

by Edwin Nissen, University of Victoria

The February 6, 2023 moment magnitude (Mw) 7.8 and 7.5 earthquakes shocked the world in their size and destructive power, but did not come as a complete surprise to many seismologists, both occurring on well-studied faults that were known to have been steadily accumulating tectonic strain for centuries. The initial Mw 7.8 earthquake ruptured the left-lateral strike-slip East Anatolian Fault (EAF), while the subsequent Mw 7.5 earthquake ruptured a major splay known as the Çardak fault, which is also left-lateral strike-slip.

The EAF forms the active plate boundary between the Arabian plate, which is moving northwards in a Eurasia reference frame, and the Anatolian plate, which is moving westwards (see Figure). The EAF is therefore a counterpart of the more famous, right-lateral North Anatolian fault (NAF), the two faults working together to allow westward escape of Anatolia from the Arabia-Eurasia collision zone. However, whereas the NAF hosted the classic sequence of a dozen Mw 7-8 earthquakes during the past century—culminating in the damaging Izmit and Düzce earthquakes of 1999 east of Istanbul—the EAF had a considerably quieter instrumental record until the 2023 earthquakes. The eastern part of the EAF had seen the most action, with Mw 6.8 earthquakes in 2020 (Elazig) and 1971 (Bingöl). The western part of the fault, responsible for the 2023 Mw 7.8 earthquake, had not ruptured for far longer.

The February 2023 Earthquake Sequence: Seismological… *Continued from Page 1*



Inset: Tectonic summary of eastern Turkey. Main: 2023 Mw 7.8 and Mw 7.5 epicenters (red stars), instrumental EQs since 1960s (beach balls), historical EQs (blue Xs), and mapped active faults. Updated from: Pousse-Beltran et al. "The 2020 Mw 6.8 Elazığ (Turkey) earthquake reveals rupture behavior of the East Anatolian Fault." Geophysical Research Letters 47.13 (2020): e2020GL088136

Within a few days of the earthquakes, analyses of satellite imagery, regional and global seismograms had already revealed the essential characteristics of the two events and were being shared on social media. The Mw 7.8 earthquake initiated on a secondary fault, quickly jumped onto the EAF proper, and from there ruptured bilaterally to the northeast and southwest for a total rupture length of around 300 km. Satellite pixel offsets reveal left-lateral offsets of 4-5 m for much of this distance. The Mw 7.5 earthquake ruptured a much shorter, around 100 km-long fault length, but involved greater average slip of up to 7-8 m, indicating a much higher stress drop than in the Mw 7.8 event.

The EAF is often subdivided structurally into distinct segments separated by bends and stepovers. These segment boundaries normally act to halt any earthquake rupture propagating along the fault, limiting the length (and thus the magnitude) of most "characteristic" earthquakes. The principal reason for the unexpected size of the first 2023 earthquake is that it ruptured across several of these boundaries, generating a much longer rupture length (and larger magnitude) in the process. This was considered unexpected behaviour by some seismologists, but many such "multi-fault" earthquakes have been observed in other parts of the world. The 2016 Kaikoura earthquake, which also reached Mw 7.8, ruptured across so many structural boundaries that an incredible twenty discrete faults or fault segments were likely involved.

The EAF is associated with a roughly 2,000 year written history of destructive earthquakes, though the locations and approximate rupture extents get sketchier the earlier one looks. The central section of the 2023 earthquake may not have ruptured since 1513 AD, and before that, 1114 AD. Both of these historical events caused extreme damage over wide areas, and seismologically speaking might have looked somewhat similar to the 2023 mainshock. Since the EAF slips at a long-term rate of ~10 mm/yr, the roughly 500-year gap between earthquakes on this central section fits the 5 m of slip that occurred there in the 2023 earthquake. However, other parts of the 2023 sequence are more puzzling. In the northeast, the Mw 7.8 earthquake propagated through the rupture area of a magnitude 7 earthquake in 1893. Assuming that event released all of its accumulated strain, it should have only accumulated around 1.5 m of slip since; yet the 2023 earthquake generated 3-5 m of slip here. The Mw 7.5 earthquake on the Çardak fault is more puzzling still. This fault slips at just 2-3 mm/yr, and is believed to have last ruptured in 1544. Since then, strain that is only enough for 1-1.5 m slip should have accumulated. The 2023 Mw 7.5 earthquake generated up to five times this amount of slip.

The 2023 earthquakes therefore illustrate just what a challenge it still is to forecast the locations, lengths, magnitudes and timings of future ruptures, even on the best studied faults.

The February 2023 Earthquake Sequence in Turkey: Performance of Structures

by Murat Saatçioğlu, University of Ottawa

Two major earthquakes occurred, nine hours apart, in Turkey on February 6th, 2023 near the city of Kahramanmaraş affecting much of southeastern Turkey. The first event occurred at 4:17am local time with a magnitude (Mw) of 7.8, 33 km southeast of the city, and the second with Mw 7.5 occurred at 1:24pm local time about 62 km northeast of the city. Both were shallow depth earthquakes within the upper 10km of the crust. More than 50,000 casualties were reported with over 110,000 injuries. More than 100,000 buildings either collapsed or were heavily damaged. According to a World Bank rapid damage assessment report, the estimated value of the direct physical damage was around US$34.3billion. The earthquake affected 11 provinces in Turkey and about 14 million residents in the region.

Turkey has had a Seismic Building Code since 1940, updated regularly following the advances in earthquake engineering worldwide. Prior to the 1997 version of the Seismic Building Code, ductile design requirements were specified but not made mandatory. The 1997 code adopted a new seismic zonation map based on peak ground acceleration (PGA) on very stiff soil with an earthquake return period of 475 years. A design response spectrum was introduced in 1997 with linear and nonlinear dynamic analysis procedures specified. Seismic force modification factors were given for high and normal ductility of seismic force resisting systems. The subsequent 2007 code implemented capacity design principles with force reduction factors for ductile design, as well as detailed design requirements for structural irregularities. A new seismic hazard map was published in 2018 with seismic hazard expressed in terms of spectral accelerations for stiff soil sites, and for return periods of 2475, 475, 72 and 43 years. The 2019 seismic code follows the new seismic hazard values, while incorporating performance-based design principles. Four different levels of ground motion are considered, consisting of maximum expected earthquake ground motion with 2% probability of exceedance in 50 years (2475-year return period), standard design earthquake with 10% in 50 years (475-year return period), frequently expected earthquake with 50% in 50 years (72-year return period) and service level earthquake with 50% in 30 years (43-year return period). Four levels of building performance are specified for continued operation, limited damage, controlled damage, and collapse prevention. Design target levels are specified as either ordinary performance or advanced performance targets based on building use, seismic level, and building height categories. Structural design is based on either the conventional force-based design approach or performance-based assessment and re-design when necessary.

The building inventory in the disaster area primarily consists of reinforced concrete frame systems with masonry infill walls or load bearing unreinforced masonry buildings. A limited number of reinforced concrete shear wall buildings were built after the 1999 Izmit Earthquake.

The extensive damage observed in the area can be attributed to a combination of factors. The strong shaking associated with the two large-magnitude shallow earthquakes hitting the region nine hours within each other and being followed by many aftershocks with magnitudes larger than 6 placed very high force and deformation demands on structures in the region. The preliminary analysis of the strong motion data collected through the Turkish National Strong Motion Network indicated that the response spectra of the recorded motions in some places exceeded the standard design earthquake (475-year earthquake), and in a few locations also exceeded the maximum expected earthquake (2475-year earthquake).

The February 2023 Earthquake Sequence: Structural… *Continued from Page 3*

Strong motion records at Antakya (Hatay), Kahramanmaraş and Gaziantep city centres indicate higher spectral values than the maximum expected design earthquake between 0.5 sec and 4.0 sec, damaging multistorey buildings. Furthermore, a large area of the disaster region has soft soil conditions with some areas vulnerable to liquefaction, resulting in various site effects. Many buildings suffered from poor foundation performance associated with soft soil conditions in Antakya (Hatay), Iskenderun and Adıyaman, some buildings with shallow foundations toppling over due to soil liquefaction. Unsuitable soil conditions, landslides and surface cracks affected lifelines, damaged the highway between Gaziantep and Kahramanmaraş, as well as the runway for Hatay airport, which was built on a reclaimed land on former Amik Lake, interfering with relief and response efforts.

The performance of buildings indicates brittle behavior with little or no energy dissipation capacity. Despite the ductile design and detailing requirements of the Turkish Design Code for Reinforced Concrete Structures and the ductile design requirements of the Turkish Seismic Code, the frame elements performed poorly. This is true for not only older buildings but also many of the recently designed and constructed reinforced concrete buildings. Lack of sufficient column seismic ties was observed to be a widespread problem, resulting in the collapse of many residential buildings. Lack of concrete confinement and shear reinforcement against diagonal tension, including joint shear reinforcement, can be blamed for many collapses in multistorey buildings. This became especially critical for buildings with commercially attractive soft stories and the resulting increase in deformation demands in the critical lower stories. Soft storey collapses were very common throughout the region. The column deformation demands further increased during the earthquakes because of the use of strong beams/floor-weak columns, which appears to be a common construction practice despite the capacity design requirements clearly specified in the building code, often resulting in the pancake type collapses as shown in Fig. 3. The difference between the code requirements and what was observed in the field clearly indicates lack of code enforcement as a major problem, some of which is attributed to periodic construction amnesties issued for buildings without building permits by the government. The few reinforced concrete shear wall buildings built in recent years performed well. The "tunnel form" buildings that has become popular after the 1999 Izmit Earthquake in Turkey performed extremely well.

The second most common construction type in the region is unreinforced masonry (URM), mainly seen in rural areas. URM units in Turkey often consist of clay bricks, stones, autoclaved aerated concrete, or pumice stone. URM walls are commonly used for building façade or internal separation walls in concrete frames as infill walls. Though they are non-structural elements, they were observed to provide lateral strength and stiffness until their elastic limits were exceeded under strong seismic loads. However, because of the large URM wall to floor area ratios used in residential construction they helped non-ductile reinforced concrete frames until their elastic capacities were exceeded. Some of the old historic URM churches and mosques in the area suffered extensive damage.

Retrofitted buildings, though very few in numbers, performed well and none collapsed. One 8-storey non-ductile reinforced concrete frame building, retrofitted by replacing a few of the existing URM walls with reinforced concrete walls and strengthening some of the existing URM walls with surface-bonded carbon fibre polymer (CFRP) sheets survived the earthquake without any damage whereas similar buildings nearby that were not retrofitted collapsed. This indicates the effectiveness of seismic retrofitting at the system level as an effective risk mitigation strategy.

CAEES
Dept. of Civil Engineering
Univ. of British Columbia
2324 Main Mall
Vancouver, BC,
Canada V6T 1Z4
Fax:
604-822-6901
E-mail:
secretary@caee-acgp.ca

We're on the Web!

Visit us at:

http://caee.ca

News

University of Victoria Wins 3rd Place in EERI's Seismic Design Competition! Congratulations!

The 2024 EERI Seismic Design Competition ran this month in Seattle, WA, and brought together more than 400 students in 40 university teams from 10 countries.

The University of Victoria team won 3rd place overall. Canadian universities especially stood out in the Analysis Predicted Score category, with the University of Victoria in 1st place, the University of Toronto in 2nd place, and the University of British Columbia in 6th place.

Congratulations to our young seismic engineers!

News and Upcoming Events

Below, we provide some information on upcoming events related to earthquake engineering and seismology. Please send us any events you would like highlighted here.

Upcoming events

Seismological Society of America (SSA) Annual Meeting
29 April – 3 May 2024
Anchorage, AK
meetings.seismosoc.org/

8th International Conference on Earthquake Geotechnical Engineering (ICEGE)
7 – 10 May 2024
Osaka, Japan
sites.google.com/site/geodpriku/home/8icege?pli=1

Kinemetrics Webinar: OasisPlus Earthquake Response Platform
8 May 2024
Online. Free. Registration required (link below).
kinemetrics.zoom.us/webinar/register/8417122083199/WN_wQpopqY_TRi-vvTfr1RGRg#/registration

18th World Conference on Earthquake Engineering
30 June – 5 July 2024
Milan, Italy
www.wcee2024.it/

4th International Bridge Seismic Workshop
11 – 14 August 2024
Ottawa, ON
carleton.ca/4ibsw/

GeoMontréal 2024
15 – 18 September 2024
Montréal, QC
www.geomontreal2024.ca/