StEER STRUCTURAL EXTREME EVENTS RECONNAISSANCE	**EVENT BRIEFING**		
	Event:	2 July 2022, Iran, Mw 6.0 Earthquake Sequence	
	Region:	Asia	
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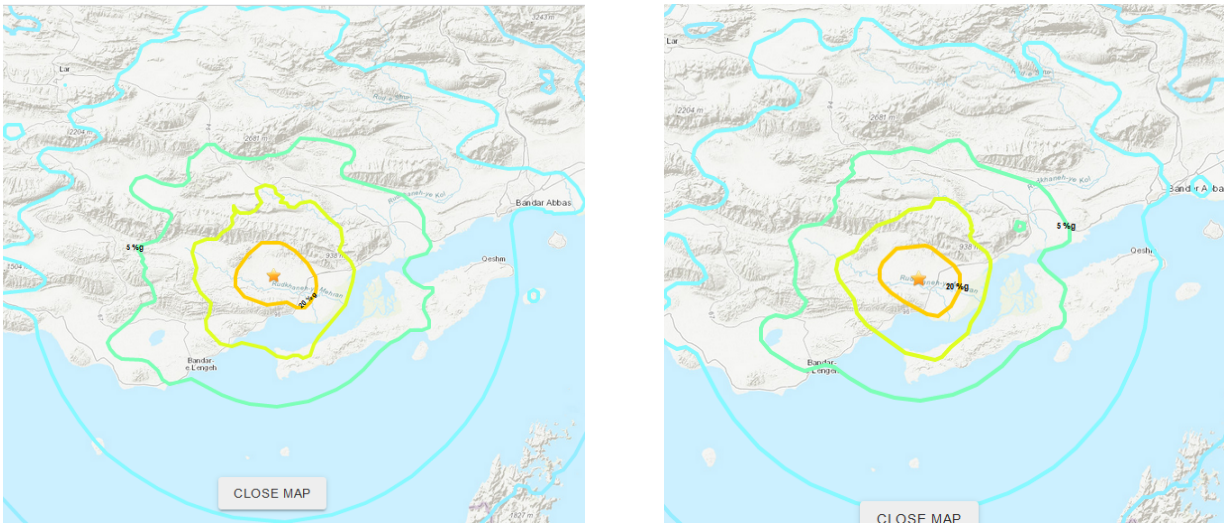
Key Lessons

- An earthquake sequence of three events with comparable magnitude of Mw 6.0 at the same location, three hours apart, is a unique case from a seismological perspective. Had the energy from these events released with a single fault rupture, it could have led to a larger magnitude earthquake with more severe consequences affecting a wider region.
- From a structural engineering and design perspective, this is a reminder that strong aftershocks (even with the same magnitude) can occur after the mainshock and should be considered in building codes for the design of buildings and other infrastructure.
- Similar to the Afghanistan earthquake on 22 June 2022, this earthquake sequence highlighted the significant vulnerability of non-engineered structures in rural areas across low-to-middle income countries even in moderate earthquakes, calling for renewed efforts towards improving the performance of non-engineered structures with cost-effective and contextually-appropriate solutions.
- All victims died in the first earthquake and there were no casualties or injuries in the subsequent earthquakes as people were already outside their homes. This highlights the potential benefits of Earthquake Early Warning systems in reducing fatalities and injuries and the need for wider access to these technologies to reduce/eliminate loss of life until the seismic performance of structures is improved to sufficient levels worldwide.
- Power failure in the heavily impacted Sayeh Khosh village hindered immediate emergency response and rescue efforts in this nighttime earthquake.

Event Description

On 2 July 2022, at approximately 2:02 am local time, a moment magnitude (Mw) 6.0 earthquake, with a depth of 16.0 km, struck the southern Iranian Gulf coast, with epicentral coordinates of 26.935°N, 55.254°E (USGS, 2022a, Fig. 1a). Approximately two hours later, this earthquake was followed by Mw 5.7 and Mw 6.0 earthquakes at the same origin. The 5.7 Mw earthquake occurred at 3:54 am with epicentral coordinates of 26.925°N, 55.247°E at 10.0 km depth (USGS, 2022b), and the second 6.0 Mw event occurred one minute after the 5.7 Mw earthquake at 3:55 am with epicentral coordinates of 26.899°N, 55.321°E, also at 10.0 km depth (USGS, 2022c, Fig. 1b). Such earthquake sequences are relatively common in this region, however, at this intensity, three earthquakes with such comparable magnitude at the same location three hours apart is a unique case from a seismological perspective. Had the energy from these three earthquakes released with a single rupture of the fault, it could have led to a larger magnitude earthquake having more severe consequences and affecting a wider region. From a structural engineering and design perspective, this is a reminder that strong aftershocks (even with the same magnitude) can occur after the mainshock, warranting consideration of aftershock impacts in building codes for the design of buildings and other infrastructure.

The nearest city to the origin of these earthquakes is the Iranian city of Bandar-e Lengeh, located 54-57 km NE of the earthquake epicenters. However, there are rural areas near the epicenter where building damage was reported, including five casualties in the Sayeh Khosh village (AP, 2022). The objectives of this Event Briefing are: (1) to provide details of the 2 July 2022 Mw 6.0 Southern Iran Earthquakes, (2) to describe damage to buildings and disruption to the community in terms of fatalities, downtime, and economic losses, and (3) to list key lessons learned from this international seismic event.



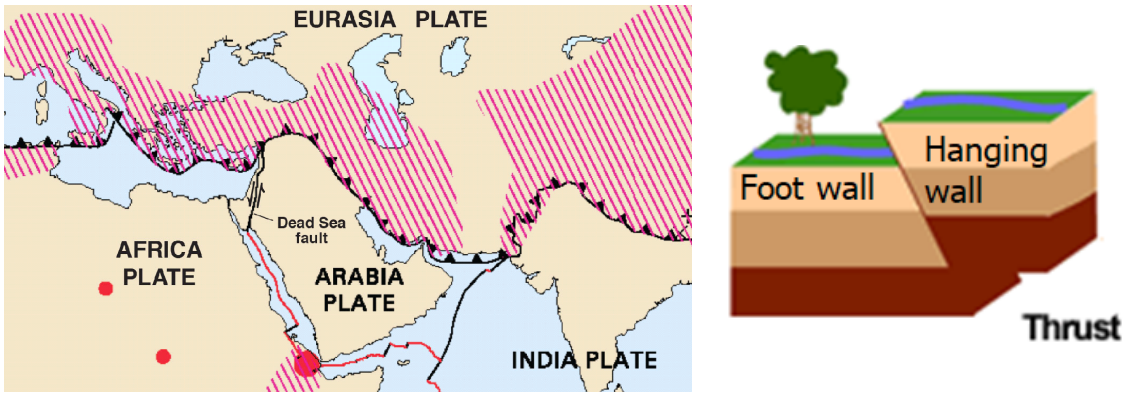
(a) (b)

Figure 1. USGS ShakeMap PGA estimates of the 2 July 2022 Mw 6.0 earthquakes with epicenters marked by stars: (a) first event, mainshock, (b) second event, aftershock (USGS, 2022a, c).

Hazard Description

Southern Iran is a highly seismically active region where earthquake sequences are relatively common. Regional tectonics in this area are characterized by the collisions of the Arabia plate with the Eurasia plate (Fig. 2a) that form the Zagros Mountains of southern Iran, adjacent to the Persian Gulf. At the location of these earthquakes, the Arabia plate is converging towards the Eurasia plate in the north and northeast directions at a rate of approximately 33 mm/yr, resulting in reverse faults (Fig. 2b). The Arabia plate lithosphere is subducted beneath the Eurasia plate at the Makran Coast of Pakistan and Iran and becomes progressively deeper to the north (USGS, 2022a).

According to the USGS, the faulting mechanisms for these three earthquakes follow the common seismicity in this region and indicate that slip occurred on reverse faults, either dipping to the north or to the south (USGS, 2022a). Occurring at shallow depths, these earthquakes reflect active deformation within the Zagros Mountains. Earthquake sequences similar to this one have previously occurred in the Zagros Mountains, including a similar sequence in November 2021.



(a) (b)

Figure 2. Hazard description: (a) plate boundary between the Arabia and Eurasia plates (WHCMSC, 2022), (b) schematic of a reverse fault (Earthhow, 2022).

Although moderate magnitude earthquakes (Mw 4-6) are common in this region, large magnitude (Mw 7 or greater) earthquakes are rare. There is documented evidence of only one surface-rupturing earthquake in the Zagros Mountains. Most of these earthquakes in the Zagros occur as the result of reverse faulting similar to this earthquake sequence. This prior seismicity includes a sequence on 14 November 2021 that included earthquakes of Mw 6.0 and 6.4. A Mw 5.6 reverse faulting earthquake occurred on 25 June 2022, approximately 100 km west of the 2 July 2022 sequence.

Ground motion data from recording stations are not available at the time this briefing was authored. According to the USGS ShakeMap, Peak Ground Acceleration (PGA) levels of up to 0.2g were estimated (USGS, 2022a, Fig. 1), which are reasonable for earthquakes of this magnitude. However, the earthquake sequence increased the number of cycles that the affected structures were subjected to and led to the corresponding accumulation of damage.

Damage to Structures

The earthquake resulted in damage to structures in the rural areas near the epicenter (Euronews, 2022). Several residential masonry buildings collapsed in Sayeh Khosh village (AP, 2022; Reuters,

2022, Fig. 3). Similar to the Afghanistan earthquake (Mosalam et al., 2022), this earthquake highlighted the significant vulnerability of non-engineered structures in rural areas across low-to-middle income countries to even moderate earthquakes. This emphasizes the need for renewed efforts toward improving the performance of structural typologies used in these regions, building on the current efforts of organizations like Build Change and GeoHazards International.

Figure 3. Collapsed masonry buildings in Sayeh Khosh village (AP, 2022; Reuters, 2022).

Community Impacts

Five people were killed and 44 were injured in this sequence of earthquakes (AP, 2022). All victims died in the first earthquake; there were no reported casualties or injuries in the following two events as people were already outside their homes (Reuters, 2022). This highlights the potential benefits of Earthquake Early Warning systems in reducing fatalities or injuries and the need of wider access to such technologies in order to reduce/eliminate loss of life until the seismic performance of structures is sufficiently improved. The Sayeh Khosh village also lost power immediately after the earthquake, hindering immediate emergency response and rescue efforts at night.

USGS PAGER tool estimates of fatalities and economic losses are shown in Figure 4. PAGER updates of fatalities and losses are the same for the mainshock and each subsequent earthquake. This is understandable for fatalities due to the aforementioned evacuation of homes after the mainshock (Reuters, 2022), though an increase in losses could be expected. PAGER's highest

probability casualty estimate was 10-100, an order of magnitude higher than the actual number of deaths, which fell within the PAGER range of 1-10 fatalities projected with 28% probability. PAGER estimated losses to be less than $1 million (52% probability) or $1-$10 million (40% probability).

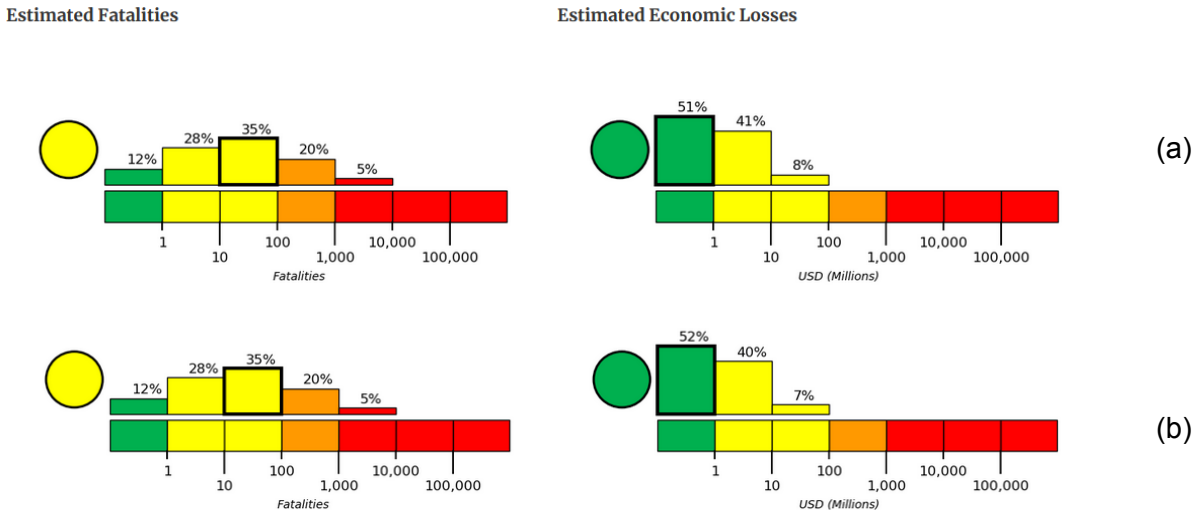


Figure 4. USGS PAGER loss estimates of the 2 July 2022, Mw 6.0 earthquakes: (a) first earthquake, mainshock, (b) second earthquake, aftershock (USGS, 2022a,c).

StEER Response Strategy

At present, StEER has assigned this event a Level 1 (virtual) response; based upon the information assembled in this briefing, StEER does not deem it necessary to form a Virtual Assessment Structural Team (VAST) or Field Assessment Structural Team (FAST) in response to this event. It is noted that, similar to the recent Afghanistan earthquake (Mosalam et al., 2022), this event reinforces the persistent vulnerabilities that manifest in the building inventory across low-to-middle income countries. StEER's present response takes the form of this Event Briefing to reiterate these observations. Information provided herein is based on various websites, news channels, and USGS. It does not include detailed field investigations. StEER will continue to engage its Virtual Assessment Structural Team (VAST) to collect and process additional public data relating to this earthquake. If warranted, these data may be used to develop a more detailed Preliminary Virtual Reconnaissance Report (PVRR) that will augment this Event Briefing.

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