## Title

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## Journal

Bulletin of Earthquake Engineering, 20(14)

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## Publication Date

2022

DOI

10.1007/s10518-021-01212-y

Bulletin of Earthquake Engineering (2022) 20:7707–7712
https://doi.org/10.1007/s10518-021-01212-y

S.I. : THE M7.0 SAMOS ISLAND (AEGEAN SEA) EARTHQUAKE OF 30TH OCTOBER 2020

# Reconnaissance of 2020 M 7.0 Samos Island (Aegean Sea) earthquake

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Received: 21 June 2021 / Accepted: 21 August 2021 / Published online: 28 August 2021

**Abstract**

The Samos Island (Aegean Sea) Earthquake occurred on 30 October 2020. It produced a tsunami that impacted coastal communities, ground shaking that was locally amplified in some areas and that led to collapse of structures with 118 fatalities in both Greece and Turkey, and wide-ranging geotechnical effects including rockfalls, landsliding, and liquefaction. As a result of the global COVID-19 pandemic, the reconnaissance of this event did not involve the deployment of international teams, as would be typical for an event of this size. Instead, following initial deployments of separate Greek and Turkish teams, the reconnaissance and documentation efforts were managed in a coordinated manner with the assistance of international partners. This coordination ultimately produced a multi-agency joint report published on the 2-month anniversary of the earthquake, and this special issue. This paper provides an overview of the reconnaissance activities undertaken to document the effects of this important event and summarizes key lessons spanning topic areas from seismology to emergency response.

**Keywords** Reconnaissance · Fault rupture · Tsunami · Ground motion · Site response · Ground failure · Infrastructure · Seismic codes · Emergency response

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## 1 Introduction

On 30 October 2020, a moment magnitude 7.0 earthquake occurred on a previously mapped normal fault north of Samos Island (variously referred to as the North Samos Fault or the Kaystrios Fault) in the Aegean Sea (Fig. 1). Given the location of the event on the sea floor, the event produced damage (as a result of tsunami and strong shaking) in both Greece and Turkey.

The reconnaissance undertaken for this event faced two challenges—the international COVID-19 pandemic and the tensions associated with the long history between Greece and Turkey, especially in regard to the earthquake region that has been the subject of disputes (Aydin and Ifantis 2004; Heraclides and Çakmak 2019). As described in the next section, these challenges were overcome with a multi-national, multi-disciplinary approach for the reconnaissance and the dissemination of results. That outcome of that work was presented in a multi-agency report published on the two-month anniversary of the event (Cetin et al. 2020) and in the collection of papers in this special issue.

This paper describes the organization of the reconnaissance and highlights some of the most significant findings, which are explained in more detail in other papers within this issue. Those papers have been prepared to document what we believe to be the most significant findings of the reconnaissance.

## 2 Organization

As a result of the global COVID-19 pandemic, international travel was restricted following the Samos Island (Aegean Sea) earthquake, so U.S.-based reconnaissance organizations did not send teams to the region. Rather, reconnaissance was organized independently by groups in Greece (the Hellenic Association of Earthquake Engineering, HAEE/ETAM) and Turkey (Earthquake Engineering Association of Turkey and the Earthquake Foundation of Turkey, EEAT/EFT). HAEE/ETAM mobilized a 12-member team to Samos Island and neighboring islands in two successive missions. EEAT/EFT mobilized teams to affected regions of the Aegean coast, with the main focus being the highly impacted city of Izmir.

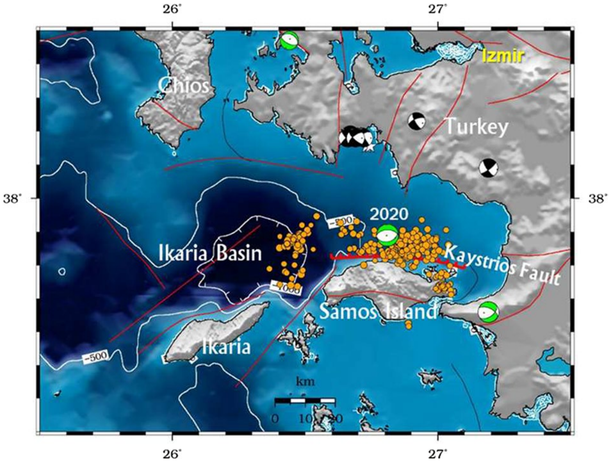

**Fig. 1** Location of October 2020 Samos Island (Aegean Sea) earthquake. Map adapted from Chapter 1 of Cetin et al. (2020)

While these reconnaissance missions were underway, discussions began to take place between HAEE/ETAM and EEAT/EFT, which was facilitated and encouraged by US-based international organizations (Earthquake Engineering Research Institute, EERI, and Geotechnical Extreme Events Reconnaissance Association, GEER). The information exchange led to a mutual understanding that the impacts of this significant event could only be captured in depth by mobilizing scientists on both sides of the fault, while integrating data and interpreting field evidence collectively. The outcomes of this coordinated work include a joint report (Cetin et al. 2020), a joint webinar organized by the collaborating scientific entities on 30 January 2021, and this special volume.

## 3 Summary of major findings

As described by Kiratzi et al. (2021), the Samos Island (Aegean Sea) earthquake occurred within a tectonic setting that is trans-tensional (both active extension and strike-slip deformations coexist). The event magnitude of 7.0 slightly exceeds the maximum magnitude provided for this fault in source models. Historical archives do not indicate an event of this magnitude on this or other local faults in the last 19 centuries (since AD47). Kiratzi et al. (2021) present two similar finite fault models derived from ground motion data and geodetic data, both of which show the rupture as occurring on a fault dipping 40–45° to the north, with an along-strike length of 32–38 km and down-dip width of 15 km. Several primary phenomena (e.g. coastal uplift of approximately 10 cm on west Samos footwall) were observed.

The fault rupture lowered the seafloor, which produced a tsunami that impacted nearby Samos Island as well as a series of Anatolian cities along the coast of Seferihisar Bay, with maximum run-up and inundation lengths of about 3.8 m and 2500 m measured in Akarca and along the Alacati Azmak stream, respectively, resulting in substantial property losses. Kalligeris et al. (2021) describe the tsunami as a sequence of sea level lowering and surge, which they document from post-event reconnaissance and eyewitness reports and videos. Due to short distances between the source and affected cities, wave travel times were relatively short for the affected coastal locations (10–30 min), challenging the ability of tsunami warning systems to alert the public, and contributing to substantial property losses and causing one fatality.

The mainshock was recorded by 11 and 66 stations in Greek and Turkish strong-motion networks, respectively, within 200 km from the fault rupture and by $>200$ accelerometers from both national networks (Turkey & Greece) for distances up to 600 km (Askan et al. 2021). Two of the Greek instruments were located in the near-fault region, about 10 km from the fault rupture plane, and provided the strongest recordings (PGA of approximately 0.23 g, PGV of approximately 22 cm/s). Overall levels of ground shaking, and their variation with distance, are consistent with expectation from global and regional ground motion models, and reinforce previous findings of relatively fast regional anelastic attenuation effects. The intensity of ground shaking was near design levels in Samos Island (design PGA being 0.24 g), but well below design levels for reference rock conditions in the Anatolian coastal regions due to large source-site distances (30–70 km). Where site conditions were favorable (rock or shallow stiff soils), these ground motions did not damage structures. However, pronounced site effects locally amplified ground shaking at site frequencies near 0.7–1.6 Hz throughout the Izmir Bay region for both stiff and soft soil sites. This amplification was particularly pronounced on soft soils in the Bayrakli district, which led to significant structural damage (Cetin et al. 2021). Cetin et al. (2021) also document an apparent localization of site amplification (possibly from surface topography and bedrock morphology) on Samos Island at Ano Vathy suggested by damage concentration in low-rise buildings.

Ziotopoulou et al. (2021) show that the earthquake produced isolated incidents of rockfalls and landslides, mainly in the northern part of Samos Island. They document these ground failures, as well as several "no-ground failure" case histories in Anatolia, where liquefaction was anticipated given the poor geotechnical conditions and high groundwater levels. Liquefaction was observed in different parts of Samos Island. Ports on the north side of Samos Island were damaged by displacements/rotations of quay walls towards the water, pavement cracks and backfill settlements behind the walls, and some signs of ejecta associated with liquefaction. The source of these movements (soil liquefaction, foundation deformations from wall inertial response) remains under investigation. On the Anatolian coast, despite tsunami-induced damage in port facilities, no geotechnical engineering related permanent ground deformations or failures of quay walls were observed.

The earthquake impacted a diverse inventory of structures on Samos Island and the Aegean part of Anatolia (Vintzileou et al. 2021; Cetin et al 2021; Yakut et al 2021; Binici et al 2021). In Samos Island, because of its proximity to the source, the strength of the shaking in the period range of the predominantly low-rise masonry structures was near the design level, however, damage was only observed in old buildings that were either designed before the 1980's or were not designed to resist earthquake loads. Vintzileou et al. (2021) document damage that occurred to these structures, although collapses were rare and the performance, particularly to buildings that were compliant to the codes issued after 1985, was generally good and consistent with expectation for the level of shaking. Disproportional damage was observed in several heritage and religious buildings as a result of poor connections between the domes and the walls.

Seismic damage in Anatolia was concentrated in Izmir, a city of 4 million with a range of geotechnical conditions. Structures of all types performed well in most of Izmir, with the notable exception of the Bayrakli district, which has soft soil conditions that amplified ground shaking in the 0.6–1.5 s period range (Cetin et al. 2021). As described by Yakut et al. (2021), structures in this same period range (7 to 10 stories) experienced much higher demands than what was typical in Izmir. Even though these demands were below the levels of design spectra in place at the time of structural design, they nonetheless produced a series of collapses and appurtenant loss of life (116 fatalities), suggesting the structural performance is below the level that would be expected, possibly because of design and/or construction process deficiencies. Based on this experience, Binici et al. (2021) argue that future earthquakes will produce strong shaking over a wider frequency range, which may cause many more structures to experience damage. This is an important observation that applies to all metropolitan cities in Southeast Europe and the Balkans (including Greece). As such, retrofit/replacement campaigns are needed to address this risk, including policies that provide financial incentives to property owners for the strengthening of structures to achieve enhanced performance (e.g., SismaBonus framework in Italy; Ministry Decree no. 58 28/02/2017). Further penetration of earthquake insurance is also important for loss mitigation, particularly in Greece, given that in Izmit the number of insured buildings was quite high.

In contrast to building structures, major lifeline systems in Anatolia, including dams and pipelines do not appear to have been damaged (Toprak et al. 2021). This is largely expected, because the modest ground shaking levels in the region did not produce ground failures (e.g., from liquefaction), which has been shown to be a principal cause of damage to such systems elsewhere.

The emergency responses in Greece and Turkey provided housing, food, and related assistance to residents displaced from their homes due to actual or perceived structural collapse risk (Mavroulis et al. 2021). In both regions, educational efforts with local government officials and residents had been undertaken prior to the event. Future research could investigate the beneficial impacts of these efforts on the responses of organizations and citizens during and immediately following the event, as well as other public policy measures including mandatory earthquake insurance (Turkey), building code enforcement, and retrofit policy.

**Acknowledgements** On behalf of the sponsoring organizations, we would like to express our gratitude to the coordinators of the individual chapters in Cetin et al. (2020), the authors of those chapters and the papers in this volume, and the reviewers of these documents. Any opinions, findings, and conclusions or recommendations expressed in this paper are those of the authors and do not necessarily reflect the views of the sponsoring organizations. Likewise, any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the sponsoring organizations and their governments. We thank the two anonymous reviewers of this paper.

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