The Earthquake of Oct. 30, 2020, M6.7 (11:51GMT) North of Samos Island (Greece): Observed strong ground motion on Samos island

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The Laboratory and the Computer Center of ITSAK actively participate in the operation of accelerometer network and its data transmission and storage.

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Intoduction

The earthquake of October 30, 2020 11:51GMT, M6.7, (or M_w7.0 according to EMSC-CSEM), took place in the sea between Samos island and western shores of Turkey, close to Izmir region). (37.91N, 26.84E). The focal mechanism of the mainshock was normal faulting with an almost E-W strike (see Fig. 1). At Samos island two teenagers were killed and several residents were injured, while according to recent information there were 116 victims and more than 1000 injured people in the city of Izmir as well (https://en.wikipedia.org/wiki/2020_Aegean_Sea_earthquake). A general description of the observed damage to the building inventory in the island of Samos can be found later in this report.

The accelerograph station of ITSAK-EPPO installed at the capital of Samos island with a station-to-epicenter distance R~15km (see Fig.2), recorded ground motion with a horizontal PGA=0.23g and strong ground motion duration ~7sec (bracketed duration including ground acceleration ≥0.05g).

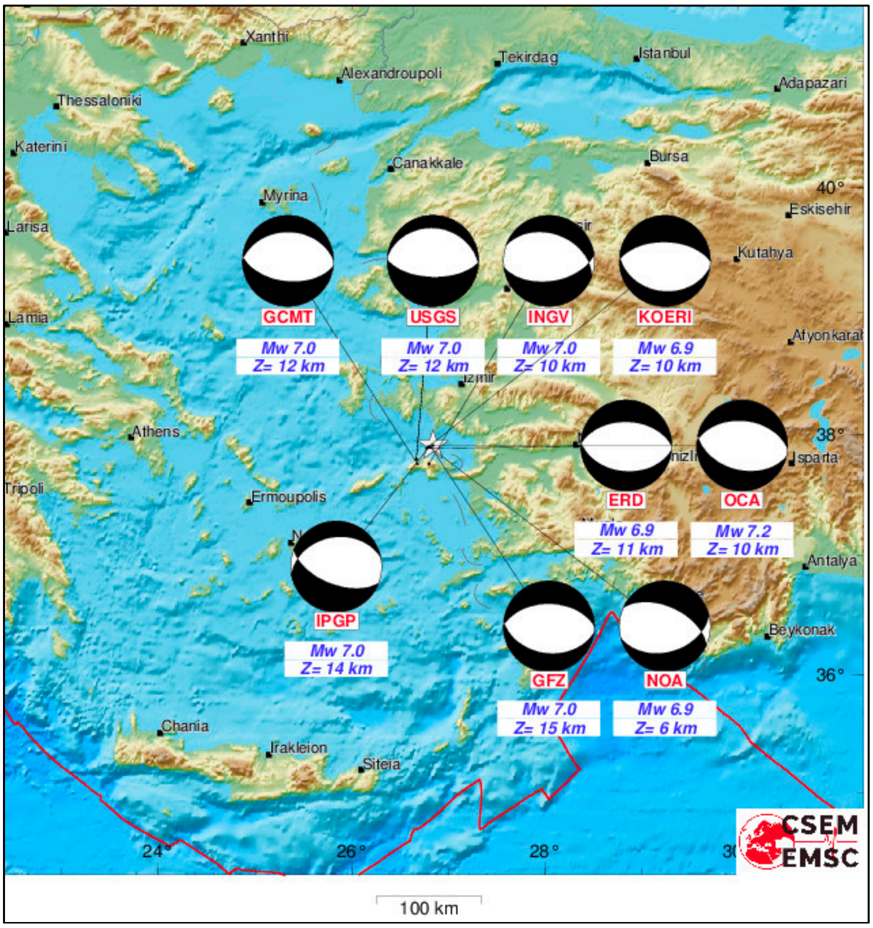


Fig. 1. Epicenter and focal mechanism of the 30/10/2020 11:51 earthquake.

Fig. 2. ITSAK accelerograph station SMG1 installed at Samos island (white triangle) and the epicenter of the mainshock (yellow star). The city of Izmir is also shown.

Strong Motion Data and Shakemaps

In Figs. 3, 4, 5 the recordings of the mainshock (3 components) are presented. In Figs. 7, 8, 9 the corresponding acceleration response spectra are shown. Higher spectral values of >0.4g are observed within the eigen-period window of 0.4sec<T<0.7sec. Such a period range according to seismic code provisions in Greece, corresponds to medium rise buildings (roughly between 4 to 7 storeys).

The shakemaps generated by ITSAK-EPPO (Fig. 6) demonstrated high intensity values (>VI) to be expected both on the northern part of the Samos island as well as on the western Turkey shore opposite the island.

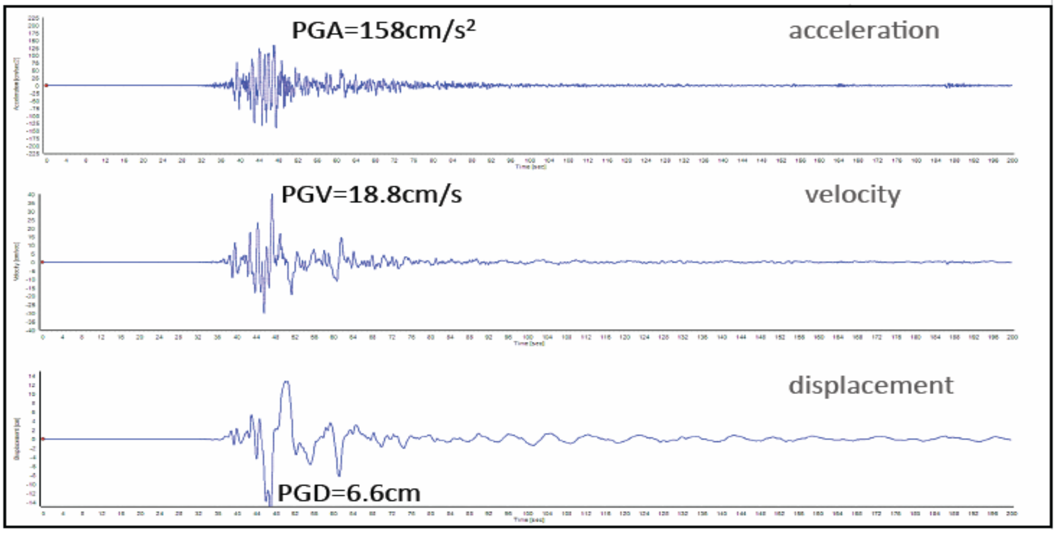


Fig. 3. Time histories of the horizontal component (direction N48W).

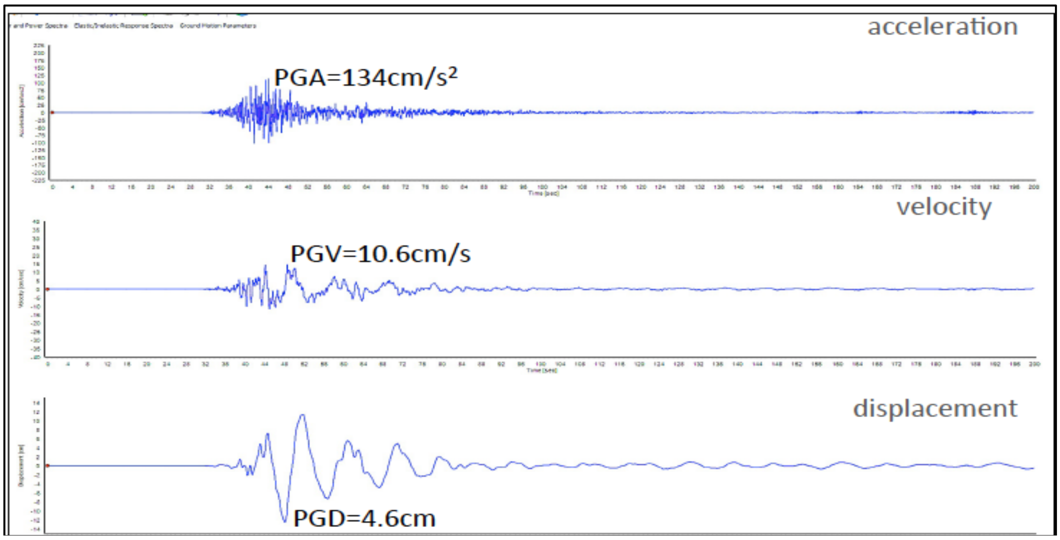


Fig. 4. Time histories of the vertical component.

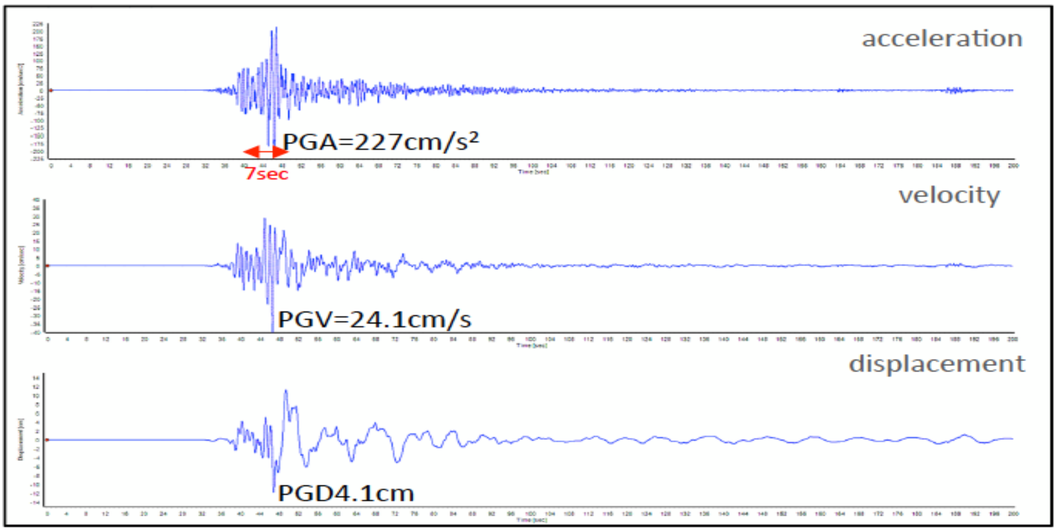
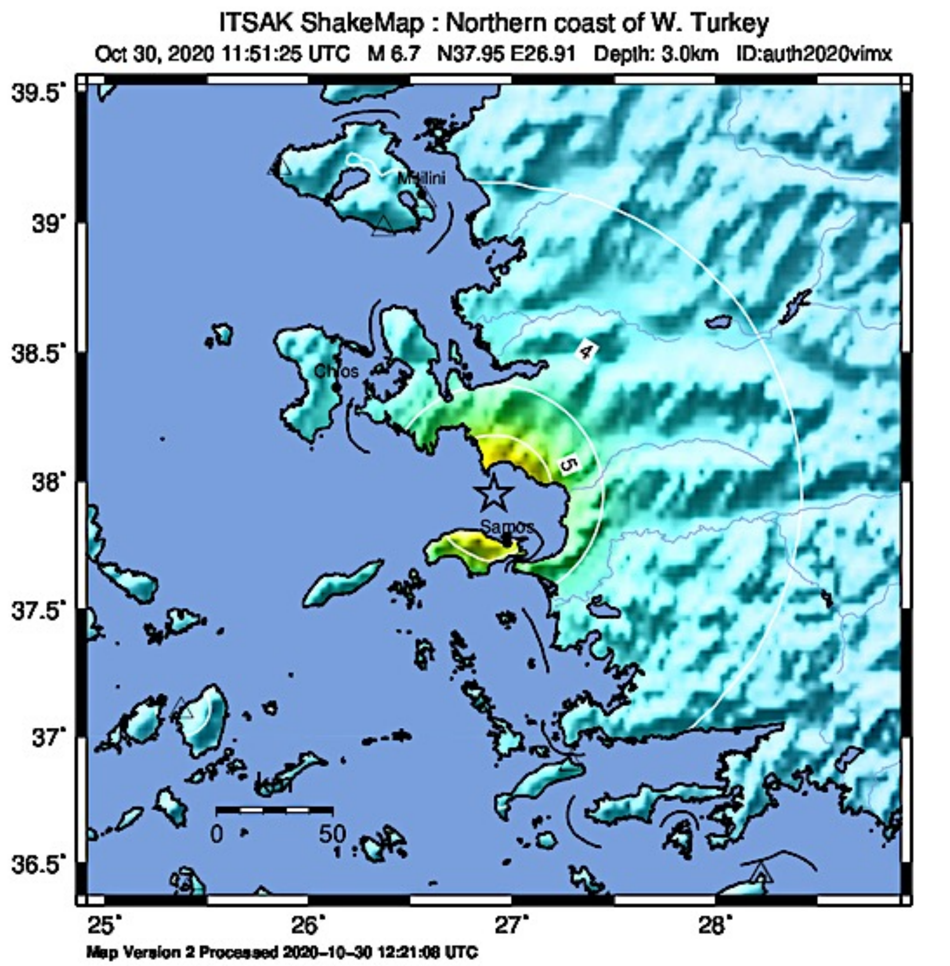


Fig 5. Time histories of the horizontal component (direction N42E).



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL.(cm/s)	<0.02	0.1	1.4	4.7	9.6	20	41	86	>178
INSTRUMENTAL INTENSITY	I	II–III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Worden et al. (2012)

Fig. 6. Shakemaps generated a few minutes after the mainshock (http://shakemaps.itsak.gr)

Acceleration Response Spectra and Elastic Design Spectra

Hereafter an effort to compare the observed response spectra at the Samos (SMG1 station, at the Vathi town) with the elastic design spectra of the EC8 and those of the national Hellenic seismic codes is presented. Figure 7 shows the comparison of the 5%-damped elastic acceleration response spectra between the earthquake record in Vathi, Samos and the Greek Aseismic Code (EAK2003) for the horizontal components of motion. For the code-specified spectra, those referring to soil type "B" and "Γ" are shown.

The corresponding comparison for the EC8-based elastic response spectra is shown in Figure 8 for soil type B and C. The above selection was based solely on the V_{s30} value (equal to 380 m/sec) at the location of the accelerometric station. The comparison between recorded and code elastic design spectra for the vertical component of the seismic motion is shown in Figure 9.

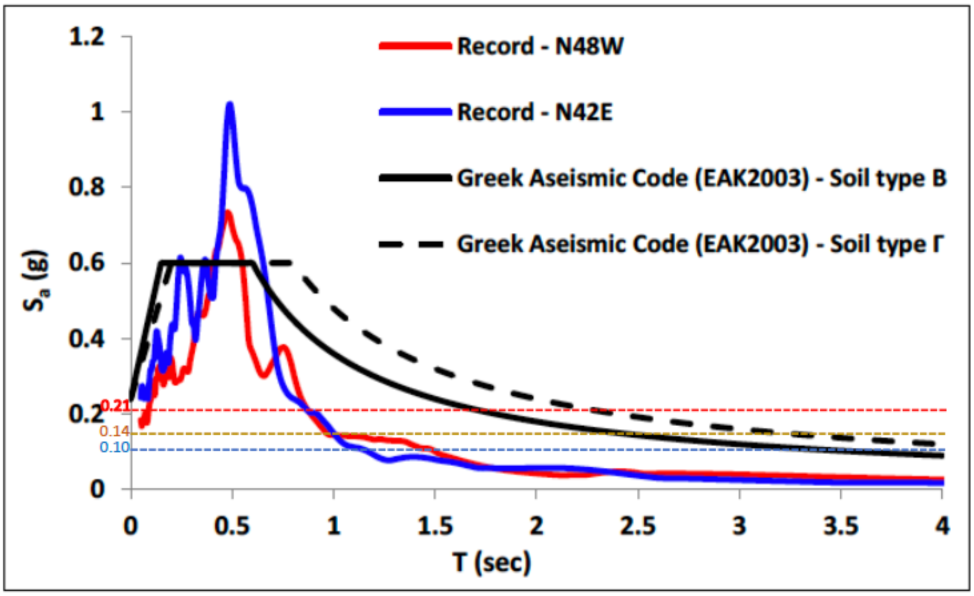


Fig. 7. Comparison of the 5%-damped elastic acceleration response spectra between the earthquake record in Vathi, Samos and the Greek Aseismic Code (EAK2003): Horizontal components of seismic motion. The horizontal lines anchored at 0.10, 0.14, 0.21g show base shear coefficients according to 1959 Greek Seismic Code for ultimate strength design.

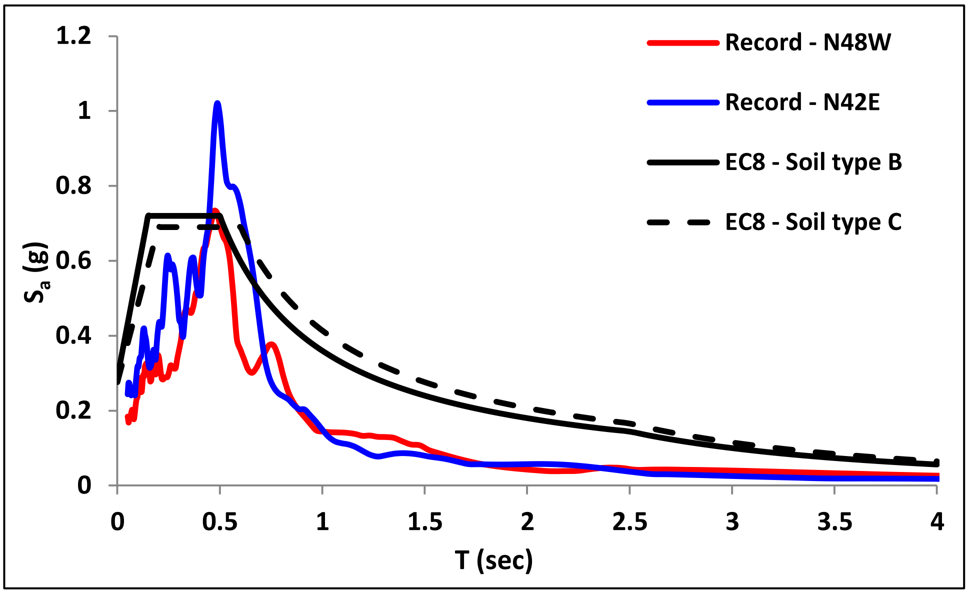


Fig. 8. Comparison of the 5%-damped elastic acceleration response spectra between the earthquake record in Vathi, Samos and the EC8 Code: Horizontal components of seismic motion.

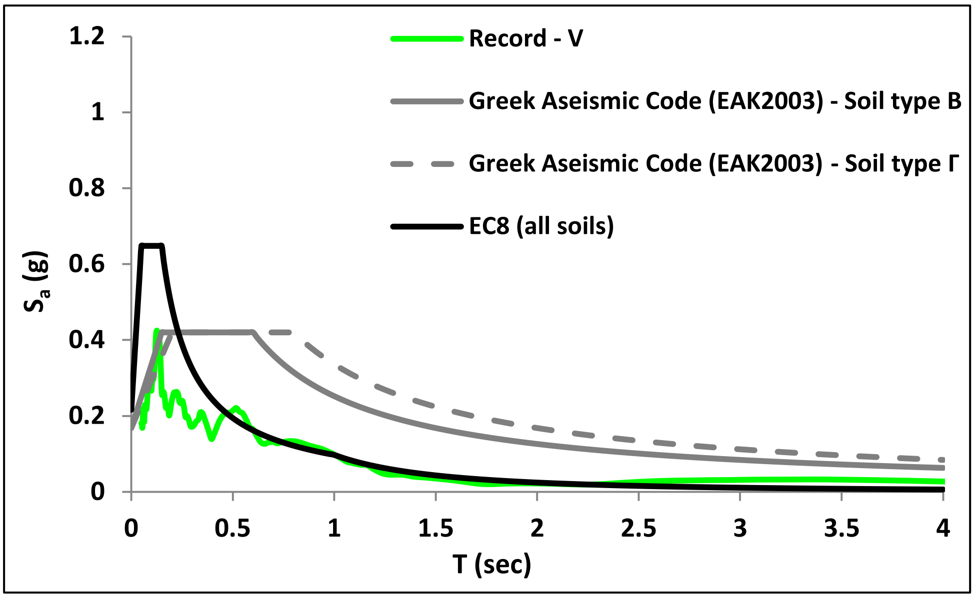


Fig. 9. Comparison of the 5%-damped elastic acceleration response spectra between the earthquake record in Vathi, Samos and the Greek Seismic codes (EAK2003 and EC8): Vertical component of seismic motion.

From the comparison between the observed and elastic design spectra of the seismic codes (EC8 , EAK2003) it is apparent that the latter satisfactorily cover the observed ones for almost the entire period range except for a rather narrow window between 0.5sec to 0.7sec, for the horizontal motion. This period range roughly corresponds to medium-rise R/C buildings (that is 5-7 storeys).

Site Effects

A preliminary idea of the fundamental period of the recording site SMG1 as well as a lower level of amplification amplitude can be obtained using the well-known Horizontal-to-Vertical spectral ratio (eHVSR). In Fig. 10 the eHVSR for both horizontal components is shown. A double peak is apparent on the eHVSR showing a fundamental period at around 2sec (0.5Hz) while a second dominant period appears at lower period around 0.5sec (2Hz). The corresponding amplitudes range from 3 to 5, meaning that the real site amplification would be possibly much higher. Such an observation implies that the role of soil layers in shaping the strong ground motion could be important. However, additional data and further investigation is needed to clarify this issue.

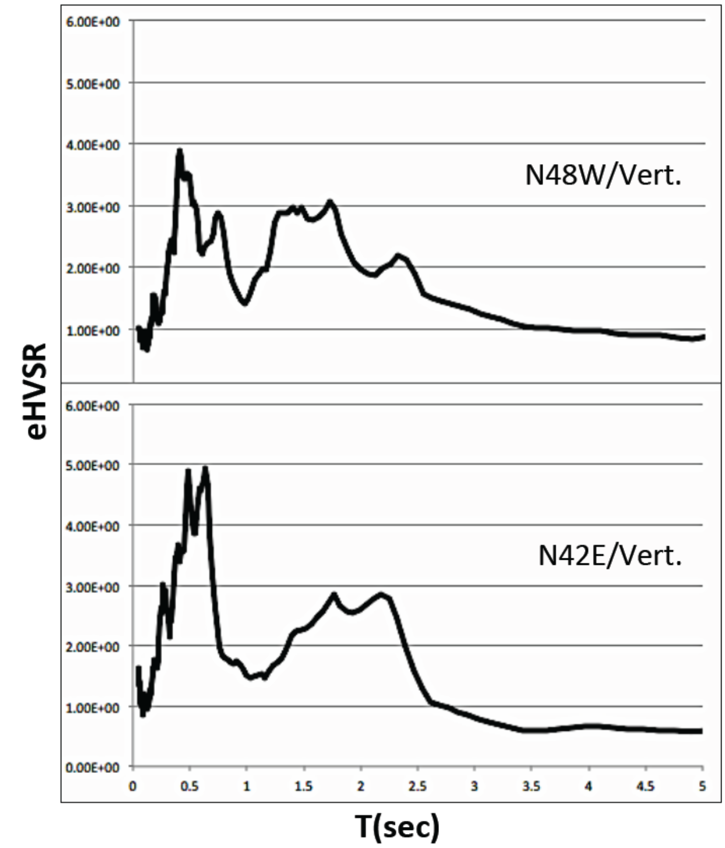


Fig. 10. Earthquake Horizontal-to-Vertical spectral ratio for both horizontal components based on the 5% damped response spectra at the SMG1 station.

Building Inventory-Seismic Codes & Structural Response at the Island of Samos

The types of structures that are located at the stricken areas are divided in four major categories in relation to the type of the load bearing system. In the wider meizoseismal area where structures were strongly affected by the 30/10/2020 earthquake the structural systems are grouped as follows:

- *One to two storey masonry buildings:* These buildings are further subdivided according location criteria. There are masonry buildings that were constructed by clay or stone or concrete bricks and by higher quality mortar. Also there are one storey masonry buildings that are located at small villages. These buildings have walls that are composed by roughly treated stones and low-strength clay mortar.
- *Reinforced concrete buildings:* These buildings are located at the whole island and were constructed mainly according 1959 and 1985 seismic codes. These buildings are of one to three storeys, they have well reinforced concrete frames, as well as shear walls.
- *Monumental and other cultural heritage masonry buildings:* These buildings serve mainly as churches or schools (at country villages) and have one or two storeys. They were constructed by adopting traditional aseismic techniques and in most cases their construction was financed by benefactors.
- *Other buildings:* Some wooden buildings were found, as well as some stone and reinforced concrete bridges.

The first Greek Seismic Code (AK) was issued in 1959, and was revised in 1984. A major new revision took place in 1992 (EAK1992) and 1995 (EAK1995), and upgraded versions were published in 2000 and 2003 (very similar to Eurocode 8). Until 1992, design was based on maximum allowable stresses, and thereafter on ultimate strength. For Samos Island, the base shear seismic design coefficient, according to the 1959 Greek Seismic Code was ε = 0.06, 0.08 and 0.12, for firm, medium and soft soils, respectively. This coefficient was constant, independent of the building's period and applied uniformly to all buildings. Since the 1959 Code was based on the allowable-stress design method, the coefficient is modified to correspond to ultimate strength design, multiplied by 1.7, leading to values of **ε' = 0.10, 0.14 and 0.21** (Anagnostopoulos et al.1986). In the 1985 revised code there were provisions which impose dense stirrups in joints and instead of one storey model analysis of the building (1959 code) impose frame analysis for a multi-storey building.

For structures constructed according to new seismic codes (1995, 2003, Eurocodes) there was satisfactory seismic performance. This can be explained through figures 7, 8 with response spectra comparisons. The problem is with old structures and masonry structures which were constructed with old codes or without any seismic provisions. To get an idea of the ductility demands imposed on the building of Samos (Vathi) by the earthquake, the spectral accelerations are compared with the three base shear coefficients applicable in Samos inland (Fig.7). As it can be seen, the ductility demands of the earthquake were quite high (4 to 8), mainly in the period range of 0.4-0.75 sec., above what is estimated to be the available ductility of the old buildings. Most damage in the island appears to *Monumental and other cultural heritage masonry buildings.*

The 2020 Samos earthquake, as well as previous strong events, has demonstrated the importance of several alternative factors towards a safe seismic behavior of structures. Among such factors, some of which may not even enter the design process, one could mention the configuration of the structural system, good material and workmanship quality, sensible use of infill panels etc. Due to these reasons, the overall performance of buildings properly designed and built in accordance with the 1984 and even 1959 seismic codes was quite satisfactory, despite the severity of the shaking.
First level buildings inspections from civil protection authorities (until 10^{th} of November) shows that from 500 buildings with damage, that were inspected, 150 were habitable (green) and 350 were not habitable and need extended evaluation.

Finally, it is necessary to stress that for all schools in the island, the second-level inspection for their seismic capacity will contribute to their restoration effort, where needed.