Learning from Earthquakes

The Egion, Greece, Earthquake of June 15, 1995

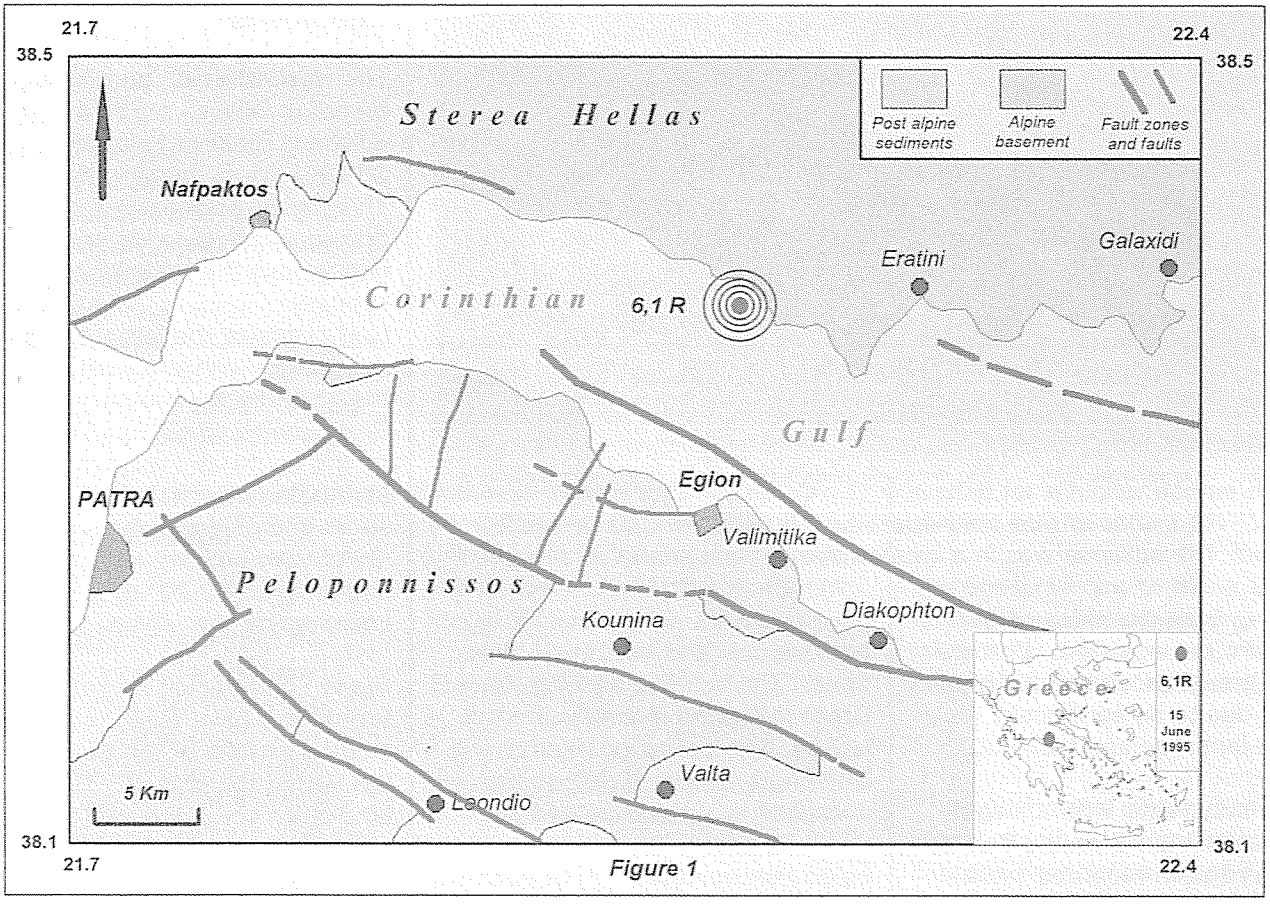

Figure 1 *- On June 15, 1995, a magnitude 6.1 earthquake struck off the northern coast of the Corinthian Gulf in western Greece. The town of Egion, 14 km south of the epicenter on the southern coast of the Gulf, was hardest hit.*

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Introduction

At 3:15 a.m. local time on Thursday, June 15, 1995, a strong ($M_S = 6.1$), shallow (26 km depth) earthquake occurred in western Greece, just off the north shore of the Corinthian Gulf, at coordinates 38.36°N, 22.15°E (figure 1). An aftershock of magnitude 5.5 hit 15 minutes after the main shock.

In terms of deaths, this is the worst earthquake Greece has had since 1980. This quake was more devastating than the May 13 magnitude 6.6 quake which struck near Grevena in central-north Greece. No one was killed in the May event, and losses are estimated at $520 million. The June 15 magnitude 6.1 quake caused 26 deaths in the town of Egion and surrounding villages and an estimated $600 million in damages.

Seismic History

Egion (also transliterated into English as Aegion, Aegio, and Aeyion) and the surrounding areas have suffered numerous destructive earthquakes. Records of earthquakes in the area go back as far as 371 BC, when a massive earthquake hit an area to the east

Figure 2 - An L-shaped five-story apartment building in Egion partially collapsed. The collapse was in a counterclockwise torsional direction.

of Egion where the cities of Elike and Voura once existed. Both cities were destroyed and submerged due to an earthquake induced landslide and tsunami.

Twenty-six events with a magnitude greater than 5 on the Richter scale have been recorded since 1960. The largest of these was a 6.6 event on March 31, 1965, near the recent epicentral area.

The Built Environment

The town of Egion was hardest hit. Situated on the south shore of the Corinthian Gulf, about 14 km south of the epicenter, Egion (population 28,000) is the economic and social center of the affected area (Aegialia, population 40,000). On the more lightly populated north shore of the Corinthian Gulf the damage was limited to a few collapses of unreinforced masonry warehouses.

The 26 persons killed were in two partially collapsed reinforced concrete buildings: 16 in a five-story apartment building in Egion, and 10 at a four-story hotel in Valimitika, 5 km to the east. The two buildings were nonsymmetric in both vertical and horizontal directions. The building housing the Greek Weapons Industry also collapsed, but caused no injuries. Numerous smaller buildings also collapsed or were damaged.

Egion features buildings of both historic and artistic value in the center of town, similar to those found in many other European urban centers. The city also contains many modern buildings, built according to contemporary requirements.

As of the date of this report, 8,155 damaged buildings had been inspected. Of these, 2,000 were found to have collapsed or suffered irreparable damage while 2,301 were rendered uninhabitable. The remainder suffered slight damage.

The distribution of damage in the city and surrounding areas does not seem to follow any obvious pattern. Only in a few areas is there a type of directivity and agglomeration. Several reinforced concrete buildings suffered extensive damage while adjacent buildings, some of which are old adobe, suffered minimal damage.

Geotectonic Regime and Soil Conditions

The town of Egion and the surrounding villages are located at the northern coast of Peloponnissos, 38 km east of the city of Patra. This region belongs to a tectonic graben which extends perpendicularly across the Hellinides, as shown in Figure 1. The Corinthian Gulf occupies the largest part of the graben which is bordered on the north by the mountains of the Greek mainland (Sterea Hellas) and on the south by the northern Peloponnissian mountains. At the south end of the graben large faults with an east-west direction and a dip of 60-70° to the north characterize the region.

In the Egion region recent geologic formations have taken place, including an infill of the basin which lies within the graben. The main lithologies are polymictic conglomerates with sandstone, clays and interbedded clayey sand.

Geologic Phenomena

During the earthquake a number of concomitant geodynamic phenomena occurred. A large number of east-west surface fractures were observed, coinciding with the average trend of the fault zones. The seismic fractures appeared south of Egion and their overall length exceeded 3 km.

Ground liquefaction occurred along the coastal zone for a distance of approximately 10 km east and west of Egion. The liquefaction phenomena occurred in coastal and river deposits and alluvials. They were accompanied by numerous ground fissures which caused damage to roads, squares, brick walls and light structures.

Coastal subsidence of about 0.5

meter also took place along the shoreline for a distance of about 10 km east and west of Egion, resulting in the flooding of seashore recreational areas.

Description of the Strong Motion

The strong motion was recorded by an instrument located in the basement of the Egion Telecommunications building. This site is about 300 m southwest of the collapsed apartment building in Egion. The peak ground accelerations were 0.49g horizontal and 0.25g vertical. The strong motion lasted eight seconds.

Search and Rescue Operations

It is important to note that the time of the quake (3:15 a.m.) played a crucial role in the loss of life, not only because the inhabitants of the apartment building in Egion and the hotel at Valimitika were asleep, but also because coordinated rescue teams did not reach the area for at least three hours.

The authors reached the area early in the morning only to find a state of general confusion and lack of coordination, even though an emergency plan existed. The two partially collapsed buildings which caused the loss of the 26 lives became the center of the search and rescue operations.

The partially-collapsed five story L-shaped apartment building in the center of Egion was built in 1978-1979. One leg of the L collapsed, blocking the exit stairwell. Most of the victims were later found around or in the stairwell. The collapsed section had 27 apartments (22 inhabited, 5 empty) and 3 shops. Fifty-four persons were trapped in the debris of this section, 38 of whom were rescued alive. Among the survivors was an eight-year-old boy who was rescued after a 21-hour operation carried out by the Greek rescue team in cooperation with a Swiss rescue team. Sixteen persons were found dead in the wreckage.

The Elikh Hotel, a four-story, three-section building in Valimitika, suffered a partial collapse of the middle section. That night, 167 persons were lodged at the hotel. After the quake, 127 managed to escape the damaged building; 40 remained trapped under the debris. The operations of the Greek rescue teams, supported by a French rescue team, were rigorous. They managed to find and rescue 30 persons alive; the remaining 10 missing, all French tourists, were found dead. The entire operation lasted 40 hours.

Conclusions

- The authors observed that, during rescue operations, it was imperative that an expert civil engineer be at each operational site to give advice and support on the stabilization and maneuvering of debris.

- Many of the damaged buildings appeared to have been previously weakened, due to the lack of maintenance, foundation settlement, and various modifications carried out by the owners.

- The shape of a building played a crucial role in the behavior of many structures during the strong earthquake shaking.

- The presence of a high underground water level contributed to damage in many cases.

- Buildings of social, industrial, and economic importance should be reexamined, and if necessary, upgraded for a higher degree of seismic safety.

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***Figure 3** - One wing of the Eliki Hotel in Valimitika partially collapsed, killing 10 tourists.*