



EARTHQUAKE ENGINEERING  
RESEARCH INSTITUTE

## NEWSLETTER

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### News of the Institute

#### Have You Received the *Spectra* Northridge Report?

An overly aggressive mail processing machine ripped several hundred mailing labels off the *Earthquake Spectra* edition containing the Northridge Earthquake Reconnaissance Report that was mailed last month. If you have not received your copy of the report by the time you receive this newsletter, your label was probably one of those destroyed. Contact the EERI office, BY FAX please, and a copy of the report will be sent to you immediately.

### News of the Institute

#### EERI/FEMA Graduate Fellowship Awarded

Jonathan Paul Stewart, a Ph.D. candidate in Geotechnical Engineering at the University of California at Berkeley, has been selected as the NEHRP Graduate Fellow in Earthquake Hazard Reduction awarded by EERI under a cooperative program funded by the Federal Emergency Management Agency. The fellowship is designed to foster the participation of capable individuals in working toward the goals and practice of earthquake hazard mitigation. It provides a nine-month stipend of \$12,000 and \$8,000 for tuition, fees and research expenses.

Jonathan P. Stewart, chosen from a group of 16 applicants, received his B.S. and M.S. degrees in Civil Engineering at U.C. Berkeley in 1990 and 1992 respectively. He is currently a licensed professional engineer and has worked as a consultant in seismic analysis.

Applications were reviewed by a Subcommittee of the Traditional Education Committee, composed of Mason T. Walters, Forell/Elsesser Engineers, Inc.; Stanley Scott, Institute of Government Studies, and Ricardo Dobry, Rensselaer Polytechnic Institute. Candidates came from 13 different

universities in 12 states and from the fields of structural, civil, geotechnical, and environmental engineering, geophysics, geography, seismology, and sociology.

Stewart is currently working on an empirical study of soil-structure interaction effects on foundation level earthquake motions. The review committee noted that this research project concerns an important frontier area of great interest to both the geotechnical and structural engineering disciplines, and that soil-structure interaction is currently not well understood by those who design foundations and structures and needs educational promotion.

#### 5ICSZ Travel Info

Remember to make your reservations for the Fifth International Conference on Seismic Zonation, to be held Oct. 17-19 in Nice, France. The Scan the World travel agency, which EERI is using, quotes the following round-trip fares: from New York, \$635-650; from Washington, \$655-690; from Miami, \$740; from Dallas, \$760; and from SF/LA, \$840. For info, call Maria at 1-800-775-0200.

### News of the Institute

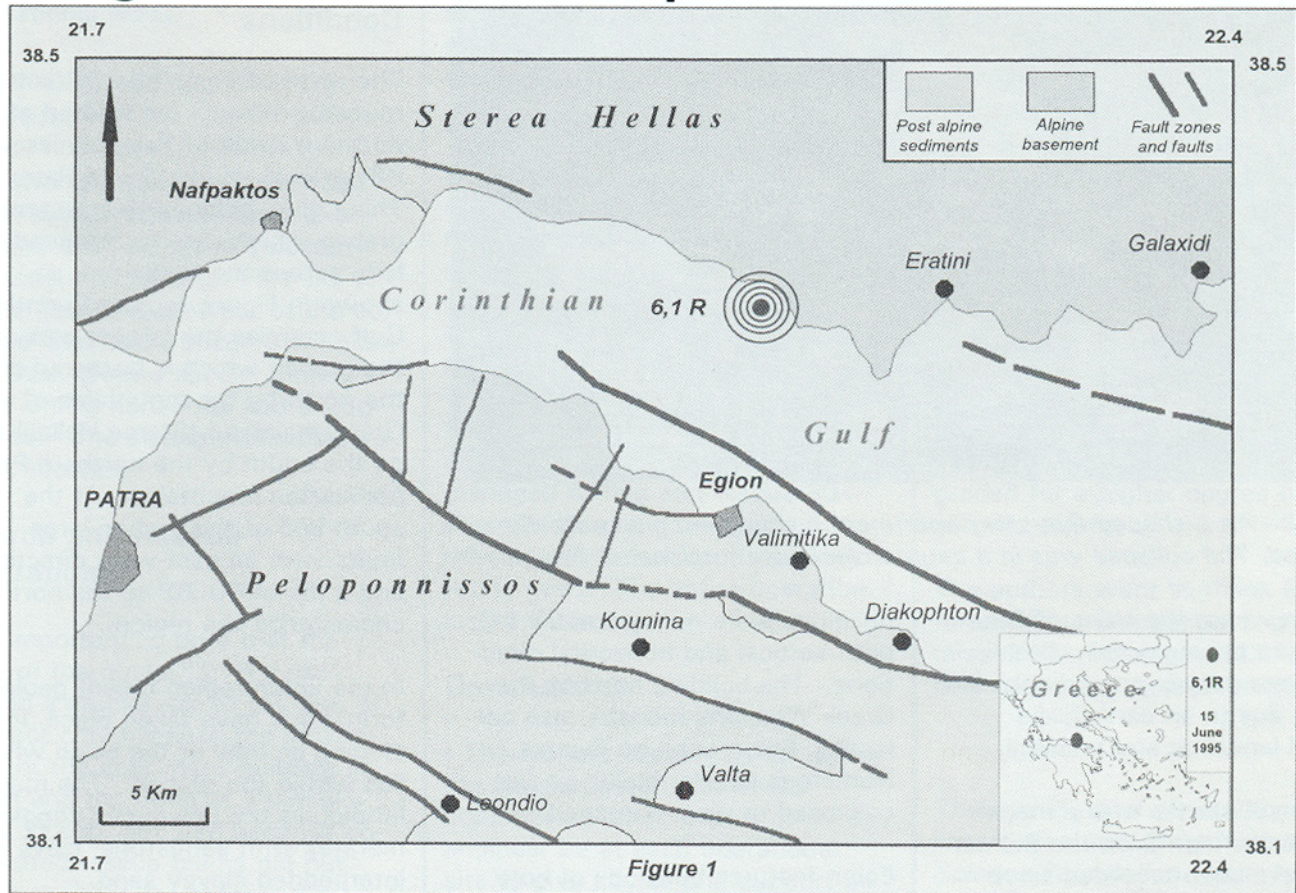
#### Nominees Sought to Serve New Madrid Chapter as Interim Directors

The newly formed New Madrid Chapter of EERI is seeking nominations for at least four interim directors. In order to be appointed director, at least two letters of nomination need to be received for each director by the chapter nominating committee. The directors will elect the first year's officers from within their ranks. Note that this is a temporary expediency, and the formal procedures for nominating and electing officers will be established once the chapter by-laws are approved by the membership. Please send nomination letters to: Brad Cross, Chair, Nominating Committee, Box 1800, Science Building, Southern Illinois University at Edwardsville, Edwardsville, IL 62026.



## 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.

The authors of this report, Pan. G. Carydis, Professor of Earthquake Engineering, NTUA; Konst. S. Holevas, Civil Engineer, Emergency Response Department, EPPO; Efth. L. Lekkas, Geologist, Assistant Professor, Athens University; and Tax. D. Papadopoulos, Geophysicist, Assistant Professor, Athens University, are members of the scientific emergency committee advising the interministerial coordination board of Greece. The authors visited the stricken area three hours after the main shock and stayed on site for two days. The mission was initiated and supported by the Earthquake Planning and Protection Organization (EPPO). This report was written

five days after the quake on June 20, 1995.

### 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  $38.36^\circ\text{N}$ ,  $22.15^\circ\text{E}$  (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 Valimika, 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 Peloponnesian 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 Egon, 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 Egon Telecommunications building. This site is about 300 m southwest of the collapsed apartment building in Egon. 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 Egon 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 Egon 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 re-examined, and if necessary, upgraded for a higher degree of seismic safety.

The authors want to thank EPPO for initiating and supporting this mission, and Georgakis C. for his help in the manuscript preparation.

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