

EARTHQUAKES AND PREVENTIVE MEASURES

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Abstract

The most important natural hazard in Greece is earthquake. The earthquake phenomenon can be explained using the theory of Plate Tectonics. Greece lies in the middle of the collision between two major tectonic plates, the Eurasian and the African, resulting in a very fragmented geotectonic regime. From the point of energy released, half of the European seismic energy is released within the Greek territory. Thus, the ways and means of reducing the seismic risk, that is the consequences from an earthquake, is for Greece of vital importance. The seismic risk is the convolution of the seismic hazard and the vulnerability of the specific area. From those factors, the vulnerability, which expresses the weakness or the sensitivity of the system and the value at risk during an earthquake, is the only parameter that can and should be minimized. The accomplishment of such an important task requires a combination of top-down and bottom-up approaches. In terms of the top-down approach, the Earthquake Planning and Protection Organisation's, (E.P.P.O.), main target is to plan the national policy for earthquake protection, as well as to coordinate the public and private resources for the implementation of this policy, through issuing regulations, guidelines for emergency situation or for strengthening existing buildings including monuments of cultural heritage value e.t.c. EPPO also has a strong educational/training focus, targeting inter alia schools and hospitals. Of importance are also bottom up approaches, often at the personal level, which include useful measures concerning the proper behaviour before, during and after a destructive earthquake. These approaches are also part of the EPPO mandate and focus.

Key words: *Greece, earthquake, seismic hazard, vulnerability, risk, preventive measures, E.P.P.O.*

1. Introduction

Earthquake is a natural phenomenon that occurs without warning and does not respect cities, nations or borders. It is a judge of the efficiency of the antiseismic measures that are applied to each construction, to the planning of a city and to the state level. When a large earthquake occurs, mistakes and incautiousness which were hidden under glamorous building facades are revealed and are, unfortunately, often accompanied by loss of human life. Experience of destructive earthquakes in Greece conforms to its long history, with evidence dating back to 550B.C.

On the other hand, the earthquake is a message of life, a sign that our planet is and will remain alive, keeping mankind alive as well. This is because the earthquakes are the result of the continuous deformation and movement of the earth due to endogenous forces caused by gravity, rotation, and heat from within the Planet. The extraterrestrial forces coming from sources like solar radiation and the gravitational pull of the Moon and the Sun causing the tides etc., try to extinguish all anomalies of the surface of the Earth and, if it weren't for the endogenous forces that cause the

earthquakes, the surface of the Earth would be covered by water of equal depth at all points. Therefore, the earthquake is indeed a message of liveliness for our Earth.

In the present study the effort will concentrate to the, brief, explanation/answer of the following question: why Greece had, has and will continue to have high seismicity. Subsequently, given the intense seismic activity of our country and the lack, to date, of a reliable earthquake prediction model, the attention will focus on measures to reduce the consequences of an earthquake to constructions, environment and, most importantly, to people.

2. Greek seismicity and Plate Tectonics

The main natural hazards are earthquakes, volcanic eruptions, floods, intense meteorological phenomena, fires, desertification phenomena, coastal hazards and landslides. Among these natural hazards, earthquake is the one that causes the most severe destruction in Greece since the antiquity.

The occurrence of an earthquake can be sufficiently explained by the Theory of Plate Tectonics. From the moment we could identify the earthquake by analyzing the seismogram, an effort began to study its origin and answer questions such as: why did it strike in this area and not the other. Such questions were explored by mapping the epicentres, calculated with ever increasing accuracy as the seismographs became more numerous and sensitive. The mapping showed that the distribution of sources on the Earth is not random. They are concentrated on narrow zones dividing the surface of the Earth in six big pieces that comprise the six main lithospheric plates (Fig. 1) namely the Pacific, American, Eurasian, African, Indian, and Antarctic plate.



Fig. 1: The six main tectonic plates

Greece lies in the middle of the collision between two tectonic plates, the Eurasian and the African, the latter sinking under the former at a rate that exceeds 3-4 cm per year south and east of Crete (Fig. 2). Greece, apart from the collision front, and due to its relatively small size, is broken into pieces, with many seismic zones. As a result of this complex seismo-tectonic regime, Greece has the greatest seismicity in the whole of Europe (Makropoulos and Burton, 1981; Ambraseys & Jackson 1990; Papazachos, 1996; Papazachos and Papazachou, 2003). Half the energy of all the earthquakes occurring in Europe is released in Greece. There is no Greek province that doesn't host seismic sources (Fig. 3). Fortunately, approximately 75% of Greek earthquakes occur either under the sea, away from inhabited areas, or in several kilometres depth and do not cause major disasters.

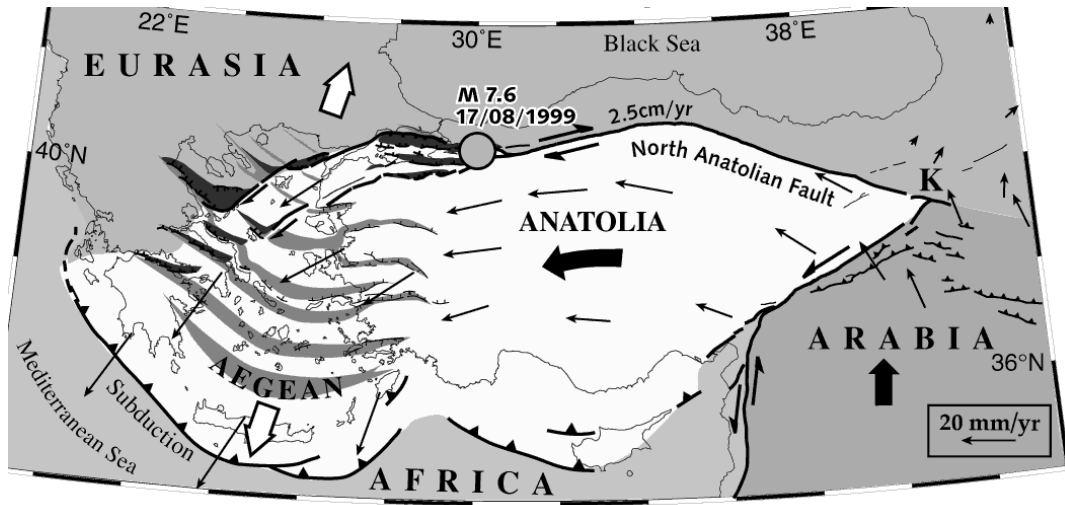


Fig. 2: Tectonic plates in the broader area of Greece (after Armijo et al., 1999).

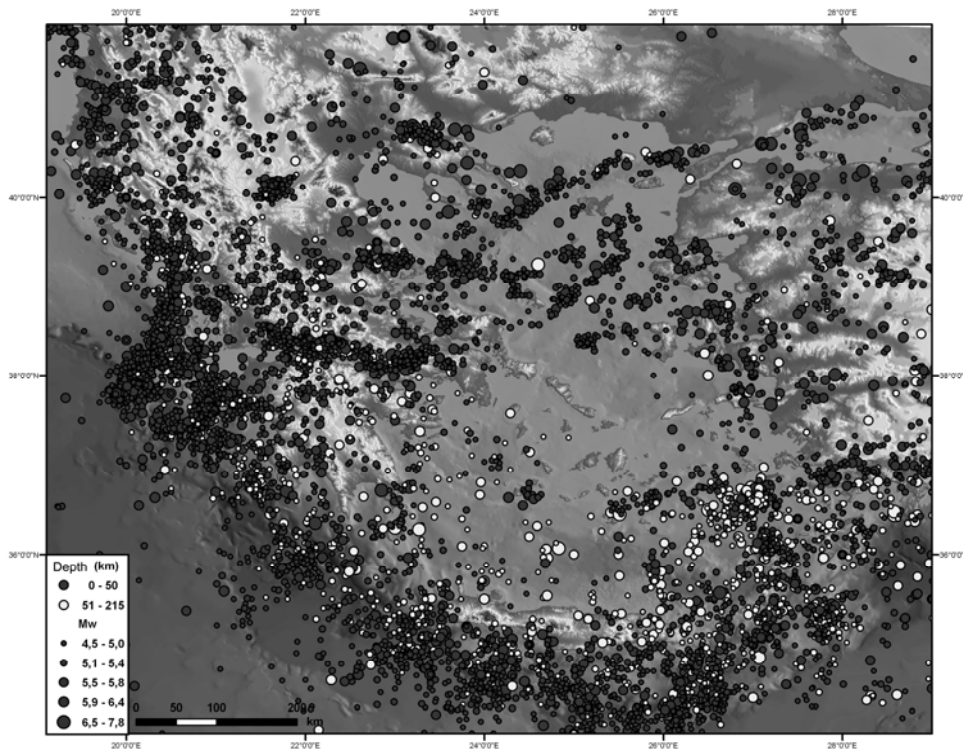


Fig. 3: Seismicity in Greece for the period 1900-2009

Apart from the high level of seismicity in Greece, due to its position between the Eurasian and African plates, resulting in a very fragmented geotectonic environment, the risk from an earthquake, despite modern technical advances, especially for the big cities, continues to be substantial and even rising. This is because of the overcrowding in large cities and the rising

demand for land development, factors which force construction on inappropriate grounds. Even within the same city, the differences in damages can be huge, since the ground factor plays a decisive role.

Another, equally important reason that today the consequences of an earthquake (risk) are greater than before, is the height of the buildings. Whereas 40 or 50 years ago in Greece there existed primarily low rise houses, today many buildings are multi-store high-rise ones. This fact made our cities more vulnerable to both, local and distant earthquakes. As it is well known, a structure will suffer great damage and may collapse if its eigenperiod becomes equal or very near to the predominant periods of the seismic waves arriving at the foundation of that building (resonance phenomenon). But the more distant the earthquake, the richer its seismic waves are in long periods. Thus, a high-rise building is more at risk by a relatively distant earthquake than by a local event. Example of increasing vulnerability is the case of Athens, our capital city. Most of the apartment buildings (six to eight stories), built after 1960 in Athens have an eigenperiod very close to the periods of the seismic waves arriving at Athens from seismic sources 60 and 70 kilometres away, i.e. from the well known from the antiquity seismic sources of Corinthos and Atalanti. The 1981 Corinth earthquake with an intensity around 7 degrees of MM in Athens, was the undeniable proof of this newly introduced vulnerability.

Since the geological phenomena that cause the earthquakes hardly change within 100 or 200 years, **the only certainty is that earthquakes will continue to test man's labors and expose our mistakes or inconsideration.**

Before going into specific *ways* and means of reducing the consequences from an earthquake by introducing certain preventive measures, the definition of the terms involved will, briefly, be described next.

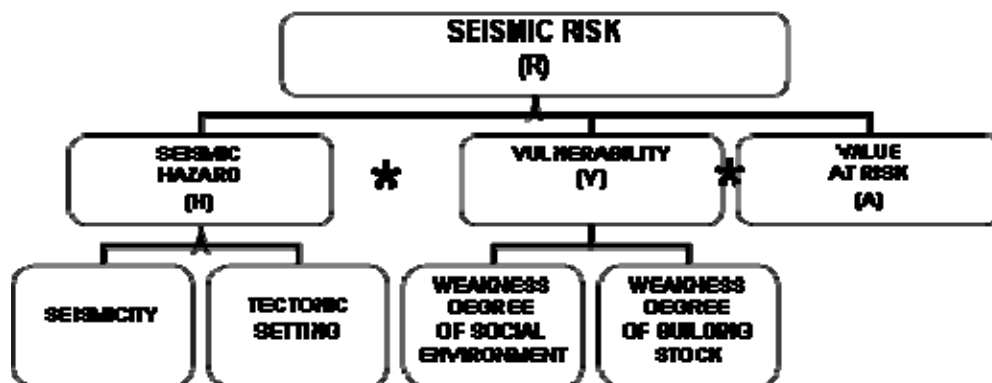
3. Seismic Hazard, Vulnerability and Risk

Seismic risk (R) has been defined as the potential economic, social and environmental consequences of hazardous seismic events that may occur in a specified period of time. It is the combination, the convolution in mathematics (Fig. 4), of the **seismic hazard (H)** of a region, which is defined as the probability P of an event of certain magnitude M to occur within a specific area in the next T years, and the **vulnerability (V)**, which expresses the weakness or the sensitivity of the system and the value at risk in the area, during an earthquake.

Among the three factors that determine the level of seismic risk and consequently the level of the possible disaster, seismologists and geoscientists try to determine the seismic hazard using the seismic history of the area, its geology and tectonics. This effort aims at providing Engineers with all the data they need for a proper and realistic earthquake resistant design. An earthquake resistant design is crucial, since even if earthquakes could be predicted in the future (which is far from the state of the art today), they cannot be avoided.

Therefore, **the reduction of seismic risk is mainly possible through reducing the vulnerability**, or the sensitivity of both technical and social structures and of their reinforcement in order to face large earthquake with the least possible damage.

Next, practical measures of strengthening the technical and social structures and thus reducing their vulnerability and consequently the seismic risk, at the national and individual levels will be presented as these emerged from the activities of the Earthquake Planning and Protection Organisation (E.P.P.O. or as is more commonly known, O.A.S.P.).



$$R=H*V*A$$

Fig. 4: Definition of Seismic Risk

4. Protective Measures

4.1 National level

Prevention measures should be taken at both the national (top-down) and individual (bottom-up) levels. Concerning the national level the responsible institutions in Greece are the Secretariat General of Civil Protection (SGCP), and the E.P.P.O. The latter is a legal entity and operates under the supervision of the Ministry for Infrastructure, Transport and Communications.

The aim of E.P.P.O. is to process and plan the national policy for earthquake protection – as well as to coordinate the public and private resources for the implementation of this policy. For this reason E.P.P.O. makes up all the necessary programs, leads and coordinates the earthquake protection policy of the country during the pre-seismic period while the SGCP is responsible for the co and post-seismic period, in close cooperation with other public and private organizations that participate in relevant subjects.

In the prevention sector, E.P.P.O.'s policy mainly aims at five (5) fundamental directions:

1. The prompt and reliable briefing of the State and the citizens from the scientific institutions that study seismic events and the seismic danger, so that planning and confrontation of the danger are feasible.
2. The improvement of regulations for strengthening the antiseismic behaviour and the antiseismic capacity and safety of structures and especially of buildings and bridges, so as to minimize the damage caused by the earthquake.
3. The cultivation of an “earthquake-aware” conscience and behaviour of the citizens through continuous training and briefing, so that they know what to do before, during, and after an earthquake in order to protect effectively their lives and wealth.
4. The prompt and rational planning of the State’s readiness to confront emergencies and aid the affected i.e. immediate mobilization, sufficiency of forces and means, co-ordination of all the organizations involved in the case of an earthquake.

5. The production and exploitation of up-to-date scientific knowledge and technology in Greece in subjects that are related with the seismic danger and its confrontation, so that permanent and sufficient scientific support to the State is ensured and the seismic defence of the country is achieved.

The main activities of E.P.P.O. are:

1. Strengthening of the seismic capacity of the structures, through regulations such as the Greek Seismic Design Code (EAK –2004), Greek Design Code of Reinforced Concrete (EKOS – 2000), Regulation of Repair and Strengthening of Buildings, Pre-earthquake Inspection of Public Buildings and Pre-earthquake Inspection of Bridges
2. Study and estimation of the seismic danger (through the disciplines of seismology and seismotectonics), including ensuring the existence of reliable seismological data, enactment of specifications and recommendations for the elaboration of studies related to seismic hazard and emphasis in the local ground conditions
3. Briefing of citizens, including School Educational Programs, Educational Seminars to school teachers, briefing of the citizens in subjects related to earthquakes, forming and training of groups of volunteers
4. Emergency Planning, including the design of the Plan «Xenokritis- Earthquakes» and the Construction of rescue equipment for trapped persons

4.2 Individual level

Some prevention measures that should be taken at the level of the individual, taken from F.E.M.A. (2010) and E.P.P.O. (2010), are the following:

4.2.1 Check for hazards in the home.

Fasten shelves securely to walls. Place large or heavy objects on lower shelves. Store breakable items such as, bottled foods, glass, and china in low closed cabinets with latches. Hang heavy items such as pictures and mirrors away from beds, couches, and anywhere people sit. Brace overhead light fixtures. Repair defective electrical wiring and leaky gas connections. These are potential fire risks. Secure a water heater by strapping it to the wall studs and bolting it to the floor. Repair any deep cracks in ceilings or foundations. Get expert advice if there are signs of structural defects.

4.2.2 Identify safe places in each room.

Under sturdy furniture such as a heavy desk or table, against an inside wall. Away from where glass could shatter—around windows, mirrors, pictures, or where book-cases or other heavy furniture could fall over.

4.2.3 Locate safe places outdoors.

In the open, away from buildings, trees, telephone and electrical lines, overpasses, or elevated expressways.

4.2.4 Make sure all family members know how to respond after an earthquake.

Teach all family members how and when to turn off gas, electricity, and water. Teach children how and when to call emergency services, the police, or fire department and which radio station to tune to for emergency information.

4.2.5 Contact local emergency management office or Red Cross chapter for information on earthquakes.

4.2.6 Have disaster supplies on hand.

Flashlight and extra batteries, portable, battery-operated radio and extra batteries. First aid kit and manual, emergency food and water, non-electric can opener, essential medicines, sturdy shoes.

4.2.7 Develop an emergency communication plan.

In case family members are separated from one another during an earthquake (a real possibility during the day when adults are at work and children are at school), develop a plan for reuniting after the disaster.

Ask an out-of-state relative or friend to serve as the “family contact.” After a disaster, it’s often easier to call long distance. Make sure everyone in the family knows the name, address and phone number of the contact person.

4.2.8 If indoors:

Take cover under a piece of heavy furniture or against an inside wall and hold on. Stay inside. The most dangerous thing to do during the shaking of an earth-quake is to try to leave the building because objects can fall on you.

4.2.9 If outdoors:

Move into the open, away from buildings, street lights, and utility wires. Once in the open, stay there until the shaking stops.

4.2.10 If in a moving vehicle:

Stop quickly and stay in the vehicle. Move to a clear area away from buildings, trees, overpasses, or utility wires. Once the shaking has stopped, proceed with caution. Avoid bridges or ramps that might have been damaged by the quake.

4.2.11 Stay out of damaged buildings. Return home only when authorities say it is safe.

Use the telephone only for emergency calls. Clean up spilled medicines, bleaches or gasoline or other flammable liquids immediately. Leave the area if you smell gas or fumes from other chemicals. Open closet and cupboard doors cautiously. Inspect the entire length of chimneys carefully for damage. Unnoticed damage could lead to a fire.

4.2.12 Be prepared for aftershocks.

Although smaller than the main shock, aftershocks cause additional damage and may bring weakened structures down. Aftershocks can occur in the first hours, days, weeks, or even months after the quake.

4.2.13 Help injured or trapped persons.

Give first aid where appropriate. Do not move seriously injured persons unless they are in immediate danger of further injury. Call for help.

Remember to help your neighbours who may require special assistance — infants, the elderly, and people with disabilities.

4.2.14 Inspection Utilities in a Damaged Home

Check for gas leaks: If you smell gas or hear a blowing or hissing noise, open a window and quickly leave the building. Turn off the gas at the outside main valve if you can and call the gas company from a neighbour’s home. If you turn off the gas for any reason, it must be turned back on by a professional.

Look for electrical system damage: If you see sparks or broken or frayed wires, or if you smell hot insulation, turn off the electricity at the main fuse box or circuit breaker. If you have to step in water to get to the fuse box or circuit breaker, call an electrician first for advice.

Check for sewage and water lines damage: If you suspect sewage lines are damaged, avoid using the toilets and call a plumber. If water pipes are damaged, contact the water company and avoid using water from the tap. You can obtain safe water by melting ice cubes.

5. Concluding remarks

From the above discussion it should be clear that, due to its unique seismotectonic regime, Greece had, has and unfortunately will continue to have earthquakes. However our knowledge about the phenomenon and today's advancements in earthquake engineering, allows us to deal with it more effectively. How?

First of all, by building in such a way, as to minimize the effects of an earthquake, which, even if we could predict it, we cannot prevent it from happening and, **second**, equally important, a change of culture that can be summarized in the following motto: **We have to learn to live with the earthquakes**, which means we have to learn as much as we can about the earthquake as a phenomenon, since our understanding of it, as well as the knowledge of practical ways of protection, such as those described above, are decisive factors in mitigating the indirect or secondary effects and panic, which, sometimes, are worse than the disaster caused by the earthquake itself. Thus, education of the citizens, starting from the primary school, is of vital importance and is among the main preparedness measures at both national and individual levels.

Finally, one thing should be clear by now, that earthquakes **are unavoidable and certain to recur**. Therefore, it is up to us, individual citizens, civil society and the state, to plan ahead and prepare for the unwelcome but inevitable future events, especially in Greece which has such a long experience of building and rebuilding what Poseidon's or Enceladus, wrath has left behind in ruins.

6. References

- Ambraseys, N. N. and Jackson, J. A., 1990. Seismicity and associated strain in central Greece between 1890 and 1988. *Geophys. Jour. Inter.*, 101, 663-708.
- Armijo R., Meyer B., Hubert A., Barka A., Westward propagation of the North Anatolian fault into the northern Aegean: timing and kinematics, 1999, *Geology*, 27, 267-270.
- E.P.P.O., 2010. Earthquake Safety Measures, <http://www.oasp.gr/default.asp?11=3&12=2#A>, in Greek.
- F.E.M.A., 2010. What to Do Before an Earthquake, During an Earthquake, After an Earthquake. <http://www.fema.gov/hazard/earthquake>.
- Makropoulos, K. C. and Burton, P. W., 1981. A catalogue of seismicity in Greece and adjacent areas. *Geophys. J. R. Astron. Soc.*, 65, 741-762.
- Papazachos, B. C., 1996. Large seismic faults in the Hellenic Arc. *Ann. Geofisica*, Vol. XXXIX, N. 5, 891-903