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NEDIES PROJECT

Lessons Learnt from Earthquake Disasters That Occurred in Greece

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ABSTRACT

The NEDIES project is being conducted at Ispra by the Institute for the Protection and Security of the Citizen (IPSC), formerly the Institute for Systems, Informatics and Safety (ISIS), of the EC Joint Research Centre (JRC). The objective of the project is to support the Commission of the European Communities, the Member States and other EU organisations in their efforts to prevent and prepare for natural and environmental disasters and to manage their consequences.

A main NEDIES activity is to produce "lessons learnt" reports based on experience gained from past disasters. This report discusses lessons learnt from earthquake disasters that occurred in Greece. It is based on contributions from experts active in the field of earthquake disaster management.

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1. INTRODUCTION

NEDIES (Natural and Environmental Disaster Information Exchange System) is a project concerned with natural and environmental disasters, which occurred in EU Member States. It is carried out at the Institute for the Protection and Security of the Citizen (IPSC) of the EC Joint Research Centre (JRC).

This report considers four earthquakes that occurred in Greece. It is mainly based on the contributions at a NEDIES meeting in Athens, Greece on 27 June 2000, in collaboration with the Greek Earthquake Planning and Protection Organisation (EPPO). However, references regarding the first three earthquake disasters were also obtained from event forms, which were already compiled during the pilot phase of the NEDIES project.

Chapter 2 focuses on the description of the four earthquake disasters:

- Kalamata (September 1986),
- Grevena-Kozani (May 1995),
- Egio (June 1995),
- Mt Parnitha-Athens,(September 1999),

along with the lessons learnt in the various disaster management phases: prevention, preparedness and response, and also, those regarding the dissemination of information to the public during the above-mentioned phases.

Chapter 3 aims to identify and summarise common lessons learnt in the management of the four earthquakes.

This report was made for the European Commission Services, Civil Protection Authorities of the EU Member States and people involved in the management of any type of natural and environmental disaster. Although the report is concerned with earthquake disasters, the lessons learnt presented can also be of help in the prevention of, preparedness for and response to other types of disasters.

The report is included in the website (http://nedies.jrc.it) of the NEDIES project, thus it is also available to any interested public, and not only to experts in the area of earthquake management. To assist the non-expert reader, an annex is provided, which contains selected earthquake terms and seismic scale definitions, which are mentioned in the report.

Special acknowledgements are given to the following experts who have contributed to the compilation of the event forms, presented the earthquake events at the NEDIES meeting and assisted in finalising this lessons learnt report:

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2. LESSONS LEARNT

2.1 Kalamata Earthquake

2.1.1 Date of the disaster and location

13 September 1986, Kalamata, Messinia (Greece).

2.1.2 Short description of the event

On 13 September 1986, at 20:24 local time, the city of Kalamata (Prefecture of Messinia) and the surrounding settlements (34 major and small villages) was hit by a main shock of surface wave magnitude, MS=6.0 (Richter Scale) which resulted to an intensity of grade XI on the Modified Mercalli scale. The stronger aftershock of the series measuring MS=5.4 consequently occurred on 15 September, at 14:41 local time.

The very high spectral acceleration values for periods T ranging from 0.25 sec to 0.70 sec, the short duration, along with the significant vertical component of the strong motion were the dominant factors of the significant damages to the building environment. Eyewitness reports described a sudden, torsional ground motion, making it difficult to walk but not to stand, with the motion ending abruptly. Individual buildings within the city collapsed completely, but total collapse conditions were not wide spread. For the vast majority of the structures built according to the 1959 Hellenic anti-seismic code which suffered moderate to low damage, the demand for ductility factor was 4 to 10 times higher than the one acquired in comparison to the high numbers of collapsed and heavily damaged older masonry wall buildings.

The damaging seismic activity that hit the area posed a severe “strength test” for the population and had a significant impact to the regional and (to some extent to) the national economy. The demanding and complex character of the numerous problems confronted, urged for a multi-tasking mobilisation of the local, regional and part of state agencies and resources. The experiences from the emergency response, the relief phase, the post disaster rehabilitation and reconstruction of the hit area could be seen as a “milestone” for seismic protection and management in earthquake prone Greece.

2.1.3 Human consequences

There were 20 fatalities among the estimated 42 000 inhabitants of Kalamata. The inauguration of a new ferry on the harbour front was the reason of a large crowd gathering (estimated 15 000 people) in the open air, which saved many from possible injury. The relatively low death toll is also attributable to the low number of buildings that suffered complete structural collapse.

There were 330 people injured, 82 of whom needed hospitalisation, whilst the rest suffered serious psychological reactions (earthquake stress). Furthermore, 35 000 people were left homeless as a consequence of the earthquake.

2.1.4 Economic losses

Damages were recorded for about 22 000 resident, commerce and office units, out of the 9 800 buildings inspected. 22% of them were demolished, 21% suffered heavy structural damage, 26% with light structural damage and 32% with no or light non-structural damage. The condition was slightly better for public buildings and facilities (50% affected), although monuments and traditional structures (some of them old school buildings) were severely and extensively hit (80%). In the city of Kalamata, two multi-storey apartment buildings totally collapsed during the main shock and other five followed during the aftershocks. The downtown road network, especially in the historic centre, housing most of the city's economic life, was blocked by heavy debris. Moderate electric power supply failure was managed easily, while the OTE local telephone network suffered significant damage and demanded significant efforts to come back to full function.

The temporal failure of the telecommunication network, which was mainly due to overload caused by waves of simultaneous phone calls from panic-stricken citizens, obstructed the emergency response and aid actions. The city's transportation facilities (airport, national road network, railway and seaport) were only slightly affected and were thus able to readily respond to the increasing emergency demands. The earthquake triggered rockfalls on Mount Taygetos, which blocked the Kalamata – Sparti road and the road to Eleohori, the most destructed village in the area (113 out of 117 small houses were demolished).

It is not an easy task to quantify economic loss. However, the following estimated costs were incurred:

- 180 million Euro for response measures taken,
- 250 million Euro worth of material loss.

2.1.5 Prevention measures and related lessons learnt

In the area of prevention, the actual measures were: the anti-seismic regulation of 1959 regarding building construction starting from 1959 and the improvements and additional articles introduced in 1985, just one year before the earthquake.

Beyond of what the anti-seismic regulations defined, the earthquake confirmed the vulnerability of various structural choices applied in constructions such as low underpinnings and asymmetries, and defined them as critical parameters for the seismic behaviour of the buildings.

Lessons learnt

- ⇨ There is a strong need to re-examine the building code requirements, especially in high-risk zones. Usually after a destructive earthquake (Kalamata was not an exception) a higher seismic coefficient is proposed.
- ⇨ There should be a periodical checking of all building safety requirements.
- ⇨ Risk assessment and land use planning should also be incorporated as part of the prevention measures.
- ⇨ The extensive multidisciplinary microzonation studies conducted for the area after the earthquake could not have been proposed as the absolute tool for the rehabilitation and development policies for the hit area.
- ⇨ Anti-seismic urban planning and land-use regulations would be very useful.
- ⇨ An institutional framework for the recovery and reconstruction phases is greatly needed.

- ⇨ In the case of this event the recovery, rehabilitation and post disaster development issues were viewed through the strategic policy concept, not only of incorporating the disaster into the area's development but also as a good chance to promote upgraded urban, land use and investment measures on the basis of a new master plan.

2.1.6 Preparedness measures and related lessons learnt

With regard to preparedness measures, the so-called transitive plan was introduced in 1984, which dealt with the handling of the emergencies due to earthquake disasters. It was the entire turnover of the previous military and confidential type plan. This transitive plan had been implemented locally through the development of a regulatory plan, and evaluation procedures had been performed for testing its operability and the synergy of the community involved. The main idea behind this local plan was the strengthening of the role of the local authorities by providing them the possibility to mobilise central government services and forces as well as to co-ordinate the actions at local level.

Lessons learnt

- ⇨ This event urged a further revision of the existing emergency plan proposing elaboration on the dynamic character of its evaluation and respond features and the supportive training of the bodies and manpower involved.
- ⇨ The local degree of preparedness of the authorities and the population was significantly high because of the existing local plan. The active involvement of the local population in the process of its design and development was determinant for the efficiency of the emergency operations.
- ⇨ It would be useful to set up and implement training programmes that can be used in schools and communities to support public actions during and immediately after an earthquake.
- ⇨ There is also a need to document experiences and disseminate the results gained to the designated target groups.
- ⇨ International co-operation can be more sufficient if bilateral and multilateral agreements focus on response, relief and rehabilitation procedures.

2.1.7 Response actions and related lessons learnt

For the first time in Greece, organised search and rescue operations of trapped persons in collapsed buildings were carried out. This achievement was mainly due to the organising and training of an expert rescue team, which started two years prior to the Kalamata disaster. Since the scientific community could not predict a safe evolution of the phenomenon, the authorities issued cautions and warnings that prohibited the access even to those buildings that were considered safe after the rapid usability inspection and control operations. This made it even more difficult for the city of Kalamata to return to normal day-to-day activities for a period of 40 days.

Since the first hours after the event there was an international aid offer on rescue and technical support. As a result two small specialised rescue teams from the French Civil Protection and the Swiss Red Cross arrived in situ. A larger team from the German Red

Cross offered evacuation camping equipment (outdoor cooking and water piping system) along with medical care. Technical – scientific teams from the USA and the Italian Civil Protection also visited Kalamata.

During the temporary accommodation of the evacuees in organised tent camps, cultural manifestations and psychological support to the affected population highly contributed to the return of a sense of normality, despite the difficult and challenging conditions. At the same time research was launched to trail and register the characteristics of the psychological impact to the population of the hit area.

Eventually, prefabricate homes were set up in the region to accommodate the homeless. Special funding measures were provided to the owners of damaged buildings for repair and reconstruction.

EU awarded the special care given for the saviour of the local monumental heritage (traditional housing, monasteries, Byzantine churches that were severely damaged).

<u>Lessons learnt</u>

- ⇨ The responsibilities of all types of organisations involved in the response phase must be clarified in order to facilitate emergency operations. At the same time bureaucracy should not be considered as the only remedy to a clear response plan. Usually expert innovative work can better manage situations where the demands dramatically exceed the readily available resources as long as it is within a legislative frame for recovery operations.
- ⇨ Provision of communication lines to the population affected is needed.
- ⇨ Mobilisation time is always a critical parameter.
- ⇨ In addition, the strengthening of the role and resources available at a local level should be established.
- ⇨ The long-term (more than a few days) evacuation of a city is a complex project with two parallel facilities, social support and service networks functioning in interaction. This can be achieved after the prompt repair of the essential parts of the cities old network and the fast establishment of the subsidiary one for the city's evacuation camps.

2.1.8 Information supplied to the public and related lessons learnt

In the case of an Earthquake in Greece, information is usually disseminated by means of leaflets, pamphlets, TV broadcasting, educational activities including presentations to schools. The organisation responsible for providing information is the Earthquake Planning and Protection Organisation (EPPO), in collaboration with the local authorities. Positive public perception of the degree of preparedness of the authorities during earthquake disasters can limit the adverse effects of the public's behaviour immediately after the earthquake.

Official information and specialised recommendations for public safety were provided for the population affected by the EPPO and the Co-ordinate Prefecture Board. Local emergency services, police and fire services provided information about the general situation. The mass media and local FM radio also informed the public stations with programs covering search and rescue operations. International TV networks covered the event.

Lessons learnt

- ⇨ Cultural and artistic events such outdoor festivals, cinemas and music scenes and special recreation activities for children can serve as socio - psychological tool for stress relief.
- ⇨ The designation of a local radio station to disseminate instructions to the public in case of an emergency is a high priority.
- ⇨ Informative seminars should also be introduced to raise public awareness in earthquake-prone areas, and special workshops should also be carried out after an earthquake.
- ⇨ The promotion of a broad-based public awareness scheme, coupled with a better understanding of earthquakes is required, so as to obtain public support for actions to reduce the impacts of earthquakes.

2.2 Grevena-Kozani Earthquake

2.2.1 Date of the disaster and location

13 May 1995, Grevena, Kozani, Florina and Kastor, Western Macedonia (Greece).

2.2.2 Short description of the event

On Saturday 13th of May, 1995, at 11:47 local time a strong shallow depth earthquake (9 Km focal depth) of magnitude MS=6.6 on the Richter Scale took place in the Western Macedonia Region, and in particular between the cities of Grevena and Kozani (Epicentre Coordinates: 40.18N, 21.67E). A maximum intensity of grade VIII-IX on the Modified Mercalli scale was estimated. The epicentre was located at the Vourinos mount. The main earthquake was followed by two main strong aftershocks on May 15 (07:13:00 local time) and May 17 (07:14:00 local time) with magnitude 5.4 MS and 5.5 MS respectively. It is interesting to note that this sequence of events was preceded, minutes before the main shock, by five moderated events of magnitude 3.4-4.5 MS which made the alarmed population to abandon their households just in the night time.

It is important to note that the earthquake occurred during Saturday when no schools are operating and the most part of the population were involved with agricultural activities in the field, away from their houses. The two main cities, Kozani and Grevena were outside the rupture zone and the buildings were proven to be well standing. However, many villages like Chramio, Rimnio, Knidi, Dafnero, Paleochori, Kentro, and Ajapi were converted to ruins.

The post seismic sequence lasted for 5 months including events of a magnitude greater than MS=4.5. The area affected was 800 Km^2 with a population of 5 000. Extensive damage was recorded to schools and poor buildings. The timing of the earthquake conduced significantly to avoid victims.

Landslides were also associated to the earthquake event, along with liquefaction of the ground in the vicinity of the Rimnio-Skoumtsa road.

2.2.3 Human consequences

The consequences to the persons involved no fatality. 20 people claimed minor injuries, while 12 000 people remained homeless.

2.2.4 Economic losses

Approximately 3 million Euro was the cost of the immediate assistance given to 5 000 families.

2.2.5 Prevention measures and related lessons learnt

In 1995, minor changes to the anti-seismic regulation issued in 1992 were introduced. This was the main preventive measure for the seismic area.

Lessons Learnt

- ⇨ Immediate changes to the National Earthquake Building Code Map must be introduced.
- ⇨ Urban planning should be developed with the earthquake event in mind.
- ⇨ Microzonation studies and neotectonic mapping must be updated.

2.2.6 Preparedness measures and related lessons learnt

The earthquake was a surprise for the population and the local authorities concerned, a fact that was locally felt at the level of preparedness. No preparedness measures were taken for the particular area as no earthquake was expected. However, the usual "Xenokratis" disaster management plan has been in force since 1992 for the Grevena and Kozani prefectures.

Lessons Learnt

- ⇨ It is remarkable to notice that immediately after the earthquake there were not sufficient resources available for the accommodation of 12 000 homeless (there were only 100 tents available locally, out of 7 500 that were actually needed for the temporary accommodation of the affected population.
- ⇨ Preparedness measures such as monitoring and prediction systems should be considered.

2.2.7 Response actions and related lessons learnt

The first days following the earthquake measures such as propping of damaged buildings, removal of dangerous elements, emergency demolition of buildings damaged beyond repair were conducted hardly because of the lack of co-ordination and materials needed.

Lessons Learnt

- ⇨ Regardless of the co-ordinated attempts made by EPPO for the operation of organised settlements as an immediate support measure, the reaction of the people to remain as close as possible to their damaged homes complicated the response actions.

2.2.8 Information supplied to the public and related lessons learnt

The standard procedure of EPPO (distribution of information by means of leaflets, TV broadcasting, educational campaigns and detailed instructions) for providing the public with information before, during and after the event was followed and it was satisfactory.

Lessons Learnt

⇨ Measures to increase public awareness would be very useful. Methods of improving the communication to the public would be of great help.

2.3 Egio Earthquake

2.3.1 Date of the disaster and location

15 June 1995, Egio, Peloponnessos and Eratini, Sterea Hellas (Greece).

2.3.2 Short description of the event

On 15 June 1995 (03:16 local time) a strong superficial earthquake (depth 26 km) of magnitude 6.1 on the Richter scale hit the region of Egio (Northern Peloponnesos-Southern Sterea Hellas). The epicentre area lay offshore, in the Gulf of Korinthos between Erateini and Egio (38.26° N, 22.15°, E).

The mostly affected area of Egio was the densely built urban centre where several types of buildings, of different age and construction materials exist together. The time of occurrence of the main shock played a crucial role in the provocation of a high loss of life, compared with the magnitude of the earthquake. The inhabitants were at home and the rescue teams arrived in the disaster scene from Athens after, at least, 3 hours.

Local authorities as fire brigade, police and the municipality started immediately search and rescue efforts, by all the available means, with the support of relatives and neighbours into the debris, in a status of general confusion. The two partially collapsed buildings, where 26 lives were lost, became the scenes of very difficult search and rescue operations, due to instability and the aftershocks, continuing for four days after the main event. This was the worst earthquake affected Greece since 1980, in terms of loss of life.

Landslides were associated to the earthquake, along with liquefaction of the ground in coastal areas and small-size tsunamis were observed following the main shock.

2.3.3 Human consequences

This earthquake affected a total 150 000 people. There were 26 lives claimed by this earthquake. Furthermore, 200 people were injured and 2 100 were made homeless. In particular, about 2 000 houses were characterised inhabitable, 2 300 temporarily inhabitable and 3 400 slightly damaged. Extensive damages were observed to many monumental and traditional constructions in the area.

2.3.4 Economic losses

Approximately 5 million Euro was the value of response costs. No estimates of material loss are presently available.

Farmland along the coastal zones and livestock were severely affected. Three churches were severely damaged, along with other historical buildings.

2.3.5 Prevention measures and related lesson learnt

The main preventive measure was the anti-seismic regulation of 1992 with some changes, which were introduced in 1995. Urban planning in correspondence with the plan of Kalamata was at a lower level. When the earthquake occurred a program for the determination of land-use and a micro zoning study were in early stages of development.

Lessons Learnt

- ⇨ The appropriate use of building codes requirements should be checked on a systematic basis, especially in high-risk zones.
- ⇨ All buildings should be maintained and their safety requirements should be periodically checked.
- ⇨ There is a need to document experiences and disseminate the results gained.

2.3.6 Preparedness measures and related lesson learnt

There was a local emergency plan for the region called “Xenokratis-earthquakes” which was been elaborated by a small group of persons. The plan was not used during the emergency because it was not found! Educational campaigns to schools had been organised mainly by Earthquake Planning and Protection Organisation (EPPO) and initiatives had been started at local level regarding emergency planning.

Lessons Learnt

- ⇨ The existing emergency plan must be easily accessible and continuously updated, as preparedness is an important factor.
- ⇨ Although voluntary organisations are included in the National Emergency Plan, there is still a strong need to clarify their role in the preparation for a potential disaster and their interaction with all actors involved in responding to any major emergencies.

2.3.7 Response actions and related lessons learnt

Regardless of the timing of the earthquake a large mobilisation took place. Building collapses resulted in extensive search and rescue operations conducted by the Greek rescue team in collaboration with the assistance offered by the French and Swiss rescue teams. 17 persons trapped into the ruins were rescued successfully. The search and rescue operation lasted for many days after the earthquake under very difficult conditions. It should be noted that after 4 days of search operations a small boy was rescued from the ruins of the collapsed apartment building. Sanitary provisions, first care and psychological support were provided to the population affected to a great extent.

Lessons Learnt

- ⇨ The availability of reliable and timely information is vital for an efficient search and rescue. This information is essential for putting priorities on search and rescue actions and for allocating the available resources and means appropriately.
- ⇨ It is important to note that accesses and escape ways from buildings and towns must be ensured and be widely known to the population.
- ⇨ There is a necessity for testing the applicability of existing modern technology (information technology, remote-sensing applications) to emergency management so as to improve the current capacity of data transfer back and forth.
- ⇨ To facilitate emergency operations, competent authorities must assure that people should be conscious of staying away from the disaster places (e.g. collapsed buildings) during the emergency operation period.
- ⇨ The provision of communication lines to the population was also affected. Thus the role and resources should be strengthened at the local level, in order to re-establish the vital lifelines as soon as possible.
- ⇨ The creation of inventories and data bases on resources at a National Level, along with its continuous update, are important measures for an effective response.
- ⇨ International co-operation and bilateral agreements can improve the response, relief and rehabilitation procedures.
- ⇨ Furthermore, role identification of each actor taking part in the response phase, before the disaster occurs, is essential in ensuring a faster and efficient response.

2.3.8 Information supplied to the public and related lessons learnt

It lies among the responsibilities of the Seismological Institutions and Civil Protection Authorities to confirm the information on the seismic event characteristics, which will be consequently disseminated to the emergency services, the mass media and the general public.

Lessons Learnt

- ⇨ Media played a crucial role on the management of the emergency. Observed over-reactions of the population were influenced and exaggerated by broadcaster remarks mainly from seismologists on predictions for oncoming earthquake.

2.4 Mt Parnitha - Athens Earthquake

2.4.1 Date of the disaster and location

7 September 1999, Athens, Attica (Greece).

2.4.2 Short description of the event

On September 7th, 1999 14:56 local time, a moderate earthquake of magnitude 5.9 on the Richter scale occurred in Athens. According to the Institute of Geodynamics in Athens, the epicentre was located at a distance of about 18 km north of the city of Athens. The main shock was proceeded by some foreshocks starting at 11:38 with a small event of local magnitude M=3.2 followed by two other smaller shocks at 11:40 and 11:43. These tremors were followed by an intense aftershock sequence with magnitude range of MS≤4.7.

The Greater Athens area is part of Attica and has a population of about 3 million people. The administration structure in Attica reflects the fact that about 35% of the country's population lives there and that it accounts for around 50% of its GDP (Gross Domestic Product). The earthquake affected mainly the west part of Attica. Industry, as well as a series of critical facilities for all Attica is located there.

The earthquake occurred a few minutes before 15:00 local time when many people were at work or commuting. The population in all Attica was alarmed and emergency evacuation of buildings took place. The electric power system went off in several areas, thus contributing to huge traffic jams because the traffic lights were blacked out. The telecommunications system, both cellular and cable, was blocked for several hours due to overload (telephone panic).

2.4.3 Human consequences

After a week of search and rescue a number of 143 people were confirmed dead, either in collapsed buildings or by falling elements of buildings or by heart attacks, while 85 were extricated from the ruins by the SAR teams alive. About 750 people were injured. Hundreds of thousands of households became homeless, but a much greater number stayed outdoors for some days after the earthquake due to fear of aftershocks.

2.4.4 Economic losses

The Attica earthquake was the costlier earthquake ever occurred in Greece. According to an early estimation published by the Government (November 1999) the total cost is approximately 3.8 million Euro. That corresponds to about 3% of the GDP of Greece.

The earthquake caused extensive damage in the western suburbs of Athens. The worst affected areas, where intensities up to IX (on the Modified Mercalli Scale) were observed in the municipalities Ano Liosia, Acharnes (Menidi) and Thracomakedones. Severe and in some cases heavy damage was observed in scattered areas in the municipalities Adames, Metamorphosis (the western part), Ilion (Nea Liosia), Agaleo and others. The post-earthquake inspection of about 218 000 residence units and business premises in about 64 000 buildings resulted in characterising 3% of them as damaged beyond repair and about 41% as not to be occupied before been repaired. From the rest, a significant percentage suffered minor damages that should be repaired.

Most classical monuments survived the earthquake almost without damage. Serious damaged occurred to the Fortress of Fili (5th Century BC) and the Wall of Elefsina (5th Century BC). Some Byzantine monuments suffered damages. This is the case of the Monastery in Dafni (11th Century AC), which suffered significant damage. Damage to historical masonry buildings of the last centuries was reported also. Among them, the Metropolis (the Cathedral Church) and the National Lyric Theatre.

Serious damage and interruption of function was reported in several hospitals. Schools suffered some damage, but only a small number suffered structural damage. Nevertheless, they all stopped their function until repairs were made. It should be mentioned though that the severity of damage to public buildings was much lower than to private ones. No major damage was reported to bridges or to road or rail network. Also, the underground pipelines behaved well.

It seems that a main characteristic of this earthquake disaster is that both the production and business sectors of the economy were affected. The economic activities more affected were commerce, services and industry.

2.4.5 Prevention measures and related lessons learnt

The drawing up and enactment of updated building regulations, principally of the Greek Seismic Design Code, is the main prevention tool in Greece. The first Greek Code was enacted in 1959 and has been updated in 1984 after the 1981 Alkyonides earthquake, which affected also Athens. The New Greek Seismic Design Code was established in 1995 and was revised in 1999. The Concrete Technology Code and the Reinforced Concrete Code were also revised recently. The application of these codes is mandatory for all new construction.

Spectra comparison shows that earthquake accelerations surpassed the response spectrum adopted in the New Greek Seismic Design Code. Thus, buildings constructed under the 1959 Seismic Design Code, but also of the low and medium rise buildings constructed under the New Greek Seismic Design Code, were tested beyond the seismic design requirements. Taken this into account, buildings in Athens performed relatively well in the earthquake. Nevertheless, the "Greek Earthquake Design Code - 2000", which revises the previous Code, was published in the year 2000, whilst the Reinforced Concrete Code was also revised and published in 2001.

Lessons Learnt

- ⇨ More effort should be placed regarding land use and urban planning in respect to seismic safety. For this, geological and geotechnical studies as well as seismic micro zoning studies should be conducted in order to back up land use and urban planning.
- ⇨ The improvement of seismic risk assessment would also be a useful in order to obtain a clear view of the possible effects of future earthquakes in the significant area of Attica and to support decision making on earthquake protection.
- ⇨ The project on establishing criteria and procedures for vulnerability assessment of public buildings and of bridges, which was in progress when the earthquake occurred, should continue.
- ⇨ Requirements regarding seismic safety should be included in the General Building Code and the Code for the Design of Non-structural Elements, as seismic safety has much to do with the overall design of the building.
- ⇨ It would be advisable if more projects regarding earthquake mitigation conducted within a research framework programme (announced by the Earthquake Planning and Protection Organisation [EPPO], after Attica earthquake) were to be promoted and carried out.

2.4.6 Preparedness measures and related lessons learnt

National civil protection is organised under Law 2344/95 "Organisation of Civil Protection and other matters" (Gov.Gaz. 212A/11-10-1995). Hence, the General Secretariat of Civil Protection (GSCP), under the auspices of the Ministry of Interior Affairs, Public Administration and Decentralisation, was established. The GSCP aims to study, plan, organise and co-ordinate national policy in matters such as the prevention of, information about and the response to, catastrophes. It is also accountable for the co-ordination of operations insuring the necessary preparedness of the nation to respond to catastrophes. Nevertheless, EPPO, which was established in 1983, still runs as an independent body under the auspices of the Ministry of Environment, Physical Planning and Public Works (YPEXODE). EPPO is responsible for guiding the earthquake protection policy and has a long experience in earthquake planning and protection regarding all phases of an earthquake disaster (prevention and mitigation, preparedness and response, reconstruction).

The GSCP issued the General Plan of Civil Protection "Xenocrates" which sets in general terms the roles of agencies involved in civil protection in the country. The Plan also defines the composition of Boards for Civil Protection Planning and the Civil Protection Implementation Boards, at state, regional and prefecture level. It should be underlined that according to the Plan, a key role is assigned to the prefecture government, while the role of local authorities (municipalities) is minor. According to the General Plan "Xenocrates" the Ministry of Environment, Regional Planning and Public Works issues the Emergency Plan "Xenocrates-Earthquakes", i.e. the Plan for preparedness and response after an earthquake disaster. The Emergency Plan "Xenocrates-Earthquakes" was issued by EPPO on June 1999, only a few months before the earthquake. It defines the fields of responsibility of the ministries, the GSCP, the EPPO, the Regional Administration and the Prefecture Governments. It also assigns some role for the municipalities.

It is obvious that due to the short time until Athens earthquake occurred, this plan did not reach the Prefectures and the Municipalities in due time. Therefore response and aid provision at the Prefecture and Municipal Level preparedness and response, was guided either by the General Plan "Xenocrates" or by the previous Earthquake Emergency Plan "Xenocrates-Earthquake" enacted by the Resolution of YPEXODE.

<u>Lessons Learnt</u>

- ⇨ Metropolitan areas pose various differences that should be taken into consideration in earthquake emergency planning. These differences have to do with the complexities in the administration structure of Metropolitan areas and the actual continuity in space (functions, networks, flows etc.) regardless of the official limits of responsibility and administrative boarders between municipalities, prefectures and regions. The special features of such areas still remain a challenge in emergency planning and it is necessary to make the existing plans and actions compatible with them.
- ⇨ It is necessary to raise the awareness of Municipal authorities and administration and the training of their personnel involved in earthquake emergency response and relief should be intensified.

- ⇨ Volunteers played a significant role in aid provision after the earthquake. Their contribution would have been greater if there would have been planning for their co-ordination.
- ⇨ The emergency plan should provide for feedback procedures in order to record experience from this major disaster and integrate lessons learnt.

2.4.7 Response measures and related lessons learnt

Immediately after the earthquake, a series of functions were initiated. First of all the staff and the material resources of the key response services were mobilised. The National Emergency Operations Centre at the General Secretariat for Civil Protection was activated, as well as the Operational Centres for key response Services, such as the Fire Services, the EPPO, the Hellenic Centre for Emergency Care and the Police.

Search and rescue operations started immediately after the earthquake and lasted for about a week. A total of 150 rescue squads with more than 2 500 people, were operating in 32 sites of collapsed buildings, among them 6 factories. A number of 85 people trapped in the ruins were rescued while 115 were pulled out of the rubble dead. The operations were conducted by the Special Disaster Response and Rescue Unit (EMAK), the Fire Services, volunteers, engineers from the EPPO and medical staff from the Hellenic National Centre for Emergency Care. International collaboration in search and rescue was expressed and rescue teams from Israel, Turkey, France, Germany, Cyprus, Switzerland, Russia and Hungary, took part in the operations.

At the same time, a series of emergency operations were taking place such as: inspecting the lifelines and critical facilities, assuring that the key facilities of the city are safe to be occupied, first aid and emergency care, restoration of utilities, outdoor sheltering, water and food distribution, installation of portable toilettes, hygiene inspections and control, distribution of a series of items and first need supplies, management of aid.

On day two after the earthquake, the first-degree rapid safety assessment of buildings started. The aim of the inspections was to warn the occupants about the safety of the building after the earthquake. The standard method for rapid, first-degree safety assessment of buildings issued by EPPO at 1998 was used. Buildings were divided in three categories and posted accordingly.

Red:	**Dangerous. No entry.**
Yellow:	**Not safe. Limited entry at own risk.**
Green:	**Possibly damaged but not unsafe.**

The operation was huge. About 280 000 inspections of residence units and business premises were carried out and about 120 000 of them were inspected before September 18th. About 2 000 engineers of all disciplines, public servants and volunteers, participated in the operation. About 50% of the inspected premises were deemed not safe to occupy. Fifteen days after the earthquake, the second-degree damage assessment of buildings started. The inspection forms and procedures used were the same of the first-degree inspection, but the engineers who took part were experienced and the time pressure was less. A number of 218 752 residence units and business premises were inspected. The inspections were completed at the end of 1999.

One of the measures for financial support of households comprised a 580 Euro financial aid to cover immediate expenses, which was offered to every household whose residence was marked as “red’ or “yellow”. About 120 000 households had received this aid. Furthermore, 5 800 Euro were offered to families who lost a member in the earthquake. In addition, 230 Euro worth of dole money was offered to pensioners. Finally, a series of arrangements were made to postpone payments such as social security contribution, depth payment, electricity and telephone bill, tax payment. Since, many industries or workshops were damaged, special measures were taken for the people who remained jobless as a consequence of the earthquake.

Emergency propping of damaged buildings and removal of dangerous elements, emergency demolition of buildings damaged beyond repair were also conducted. Housing the homeless population until the reconstruction of new buildings is a significant challenge. Tent camps should not be used for many months and the forthcoming winter put pressure for creating more acceptable housing conditions. In order to tackle the problem combinations of measures were taken. That is:

a. Offering a rent subsidy to homeless households who will either stay with friends and relatives or rent an apartment, until their permanent residence is repaired or rebuild. The rent subsidy is 175 to 350 Euro (depending on the number of the members of the household) and it will be offered for two years to owners and for six months to renters of a damaged or collapsed residence. About 30 000 families applied the first trimester for a rent subsidy.

b. Housing in temporary units (prefabricated or containers), were offered to households who did not manage or did not want the rent subsidy. In four months about 6 800 units were set up in 100 settlements in 33 Municipalities. Out of them about 5 500 were distributed to the beneficiaries.

It is not often that an earthquake disaster strikes the capital of the country. In this case disaster management became a national priority. The National Government and the State played a dominant role in response and relief surpassing the role assigned to it according to the Emergency Plan.

After an earthquake disaster there are pressures for temporary housing in prefabricated units or containers, regardless of the problems associated with this policy (tendency of prefabricated units to become permanent, ghetto situations, illegal occupancy of units even after the reconstruction of permanent residence etc.). This was also the case after the Athens earthquake. Yet, in the case of Athens Metropolitan Area housing market could absorb at least some of the demand, thus limiting the number of temporary housing units required. Rent subsidence offered by the State to the homeless households was a wise policy for directing housing demand to the real estate market of Athens. As a result, the number of about 6 500 prefabricated units installed a few months after the earthquake, although being criticised during the emergency period as inadequate, they proved to be adequate in the aftermath of the disaster.

<u>Lessons Learnt</u>

⇨ A huge bulk of inspections of buildings was completed timely and successfully using the standard rapid first-degree usability assessment of buildings issued by EPPO in 1998. Yet, there is a difference between the rapid first-degree usability assessment of buildings and second-degree damage assessment of buildings. Therefore, it is important that different procedures and inspection forms should be issued. Furthermore, the spatial distribution of damage should be an outcome of the assessment in both inspections, but especially in the second degree.

⇨ A monitoring and management system of temporary settlements should be set up in order to help minimise the negative side effects, such as social degradation.

2.4.8 Information supply to the public and related lessons learnt

Of prime significance was to obtain information on the situation as soon as possible. Given that telephones were not working, initial information came from the police and the fire departments through their radio communication network. Helicopters performed aerial survey. The media also communicated a rough picture of the situation. Rapidly communications through hand radios were established. Volunteers were also used to facilitate the radio communication for the field people. Information feedback and management was a priority during all the emergency period.

Informing the population was also vital and urgent. The media were very helpful at informing people, however they put pressure on decision-makers and disaster managers requesting information constantly. An hour after the earthquake instructions for the population were disseminated through the media on what people should do and not do during the emergency situation.

<u>Lessons Learnt</u>

⇨ It is necessary that information technology be used in order to manage information. It is textbook knowledge that real-time, accurate information is vital in emergency respond and disaster management. An operational MIS (Management Information System) and GIS (Geographical Information System) would have made a difference in effectiveness of disaster management.

⇨ Earthquake education pays back. It is a common knowledge that children reacted during the aftershocks better than their parents, thanks to the training that they took at school. Therefore, more effort needs to be placed at seismic safety in schools involving all members of the school community.

⇨ New information technologies should be used to facilitate information dissemination. Members of the school community from all over Greece expressed this request during the emergency period.

⇨ Education and training regarding seismic safety of children with special needs and abilities should be addressed.

⇨ Information dissemination during the emergency period is an important and sensitive task. A series of matters arise regarding information dissemination: Relief and aid provision involves a bulk of information to the population in the disaster area. Rumours for impending earthquakes are to be tackled. Guidance and instructions to the public on what to do and not to do during the emergency period should be given. In some urban areas foreigners of various nationalities should be reached out.

⇨ During the emergency period, the public is sensitive and eager to know more. Working close with the media and with the scientific community before the disaster can facilitate protecting the public from rumours and unsound information after the event.

⇨ The earthquake has arisen the awareness and made people seek out earthquake education and information. This was proved during a train-the-trainers project for the Principals of schools of Attica on earthquake safety at a school level.

3 RECAP OF LESSONS LEARNT AND CONCLUSIONS

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Many lessons have been learnt, as it can be observed in the contributions of the experts collected in this report. This chapter aims to summarise the lessons learnt grouped according to the main disaster management phases: prevention, preparedness and response, and those regarding the dissemination of information during the three above-mentioned phases of disaster management. Furthermore, where relevant, the lessons learnt have been grouped into the following areas:

- improvement of the built environment,
- improvement of co-ordination,
- improvement on regulation and legislation,
- improvement of our knowledge and data on the social component of earthquake disasters,
- improvement of vulnerability knowledge,
- effectiveness of search and rescue operations,
- improvement of training.

It is important to bear in mind that the lessons learnt are not ordered according to their importance, but mainly according to "logical" considerations.

3.1 Lessons learnt concerning prevention measures

Improvement of the built environment

Almost all property damage, loss of life and socio-economic disruption associated with earthquake disasters occur as a result of the failure of the built environment (structurally, functionally, environmentally and socially) to cope with an earthquake hazard. The primary cause of casualties due to earthquakes is the collapse of buildings. The following needs were identified:

⇨ Seismic risk assessment and land use planning should also be incorporated as part of the prevention measures.

⇨ Microzonation studies and neotectonic mapping must be updated.

⇨ Seismic hazard assessment needs to be improved.

⇨ Immediate changes to the National Earthquake Building Code Map must be introduced.

⇨ All buildings should be maintained and their safety requirements should be periodically checked.

⇨ It is necessary to ensure total quality control of building construction (study, construction and materials used).

- ⇨ Special attention should be given to the control on the implementation of regulations, mainly regarding construction of private buildings.
- ⇨ It is necessary to increase the level of awareness of the wider engineering community with regards to building construction, safety requirements and regulation implementation.
- ⇨ More effort should be placed regarding land use and urban planning in respect to seismic safety. For this, geological and geotechnical studies as well as seismic micro zoning studies should be conducted in order to back up land use and urban planning.
- ⇨ The project on establishing criteria and procedures for vulnerability assessment of public buildings and of bridges, which was in progress when the earthquake occurred, should continue.
- ⇨ There is also a need for interventions for seismic retrofitting of buildings.
- ⇨ It would be advisable if more projects regarding earthquake mitigation.

Improvement on regulation and legislation

Regulations and legislation pave the way to a better co-ordination of earthquake disaster management. It is also very important to ensure that updated versions of regulations and legislation are available. The various improvements in the field of earthquake management have been observed:

- ⇨ It is necessary to establish an institutional framework on how to intervene and evaluate building safety.
- ⇨ There is a strong need to re-examine the building code and building safety requirements on a systematic basis, especially in high-risk zones.
- ⇨ Anti-seismic urban planning and land-use regulations are required.
- ⇨ Urban planning should be developed with the earthquake event in mind.
- ⇨ There is a need to document experiences and disseminate the results gained.
- ⇨ The improvement of seismic risk assessment would also be a useful in order to obtain a clear view of the possible effects of future earthquakes in the significant area of Attica and to support decision making on earthquake protection.
- ⇨ Requirements regarding seismic safety should be included in the General Building Code and the Code for the Design of Non-structural Elements, as seismic safety has much to do with the overall design of the building.

Improvement of our knowledge and data on the social component of earthquake disasters

- ⇨ Emphasis should be placed on technological perspectives, such as the design of monitoring and warning systems.
- ⇨ The social component in earthquake disaster management is crucial and is required for planning efficient mitigation programs, as the success or failure of mitigation programs is also strongly influenced by people’s perceptions of the earthquake threat and how to adjust to it, the organisation and cultural make-up of the community involved.

Improvement of vulnerability knowledge

While each disaster has its own characteristics, all disasters, whatever their types, present a number of common features. The previous mentioned potential effects of earthquakes can be in some way "tuned up" by local conditions, which determine the actual consequences and the type of information required for disaster management. Thus:

⇨ Local profiles should be established a priori, so as to help plan an effective management of disasters, from prevention and community preparedness to rescue and relief. A detailed matrix of earthquake impacts should be defined and refined on the basis of empirical experience and case studies in order to obtain a complete image of the extent and combinations of these effects. The extent and combination of the dominant effects of earthquakes on life, health, life support, housing, utilities, transport, and the associated secondary hazards depend on a number of local factors. These factors may be categorised in permanent variables (geographic, demographic, housing, resources, utilities, access routes and communications, potential parameters in propagating the effect) depending on the place of the disaster, and transient variables, related to the time of occurrence and the climatic conditions. The possibility of assistance will also vary according to these variables. Many of these factors can increase the vulnerability to earthquake hazard and thus initiate a disaster.

3.2 Lessons learnt concerning preparedness measures

Improvement on co-ordination

⇨ There is a need to have a co-ordination body that deals with volunteers (NGOs, charity organisations and individuals). Volunteers played a significant role in aid provision after the earthquake. There is still a strong need to clarify their role in the preparation for a potential disaster and their interaction with all actors involved in responding to any major emergencies. Experience shows that their contribution would have been greater if there would have been some form of co-ordination at either Municipal or Government level. It is imperative that the role of volunteers is taken into account in the Emergency Plan in order to tackle these matters.

⇨ It is essential that resources are available in the aftermath of an earthquake.

⇨ An attempt should be made at incorporating a prediction system in the updated emergency plan.

⇨ Although voluntary organisations are included in the National Emergency Plan, Metropolitan areas pose various differences that should be taken into consideration in earthquake emergency planning. These differences have to do with the complexities in the administration structure of Metropolitan areas and the actual continuity in space (functions, networks, flows etc.) regardless of the official limits of responsibility and administrative boarders between municipalities, prefectures and regions. The special features of such areas still remain a challenge in emergency planning and it is necessary to make the existing plans and actions compatible with them.

- ⇨ Municipalities should be taken into account in emergency planning. They should be assigned roles and they also should be accountable for disaster response and relief.

Improvement on regulation and legislation

- ⇨ The updating of the existing emergency plan is of extreme importance.
- ⇨ The emergency earthquake plan should provide for feedback procedures in order to record experience from this major disaster and integrate lessons learnt.

Improvement of our knowledge and data on the social component of earthquake disasters

- ⇨ The local degree of preparedness of the authorities and the population can be significantly high because an existing local plan. The active involvement of the local population in the process of its design and development can be determinant for the efficiency of the emergency operations.
- ⇨ There is also a need to document experiences and disseminate the results gained to the designated target groups.

Improvement of training

- ⇨ It would be useful to set up and implement training programmes that can be used in schools and communities can support public actions during and immediately after an earthquake.
- ⇨ It is necessary to raise the awareness of Municipal authorities and administration and the training of their personnel involved in earthquake emergency response and relief should be intensified.

3.3 Lessons learnt concerning response measures

Improvement on co-ordination

- ⇨ Role identification of each actor from all types of organisations taking part in the response phase, before the disaster occurs, is essential in ensuring a faster and more efficient response and to facilitate emergency operations.
- ⇨ Competent authorities must assure that people should be conscious of staying away from the disaster places (e.g. collapsed buildings) during the emergency operation period.
- ⇨ The provision of communication lines to the population was also affected. Thus the role and resources should be strengthened at the local level, in order to re-establish the vital lifelines as soon as possible.
- ⇨ Mobilisation time should be minimised.
- ⇨ In addition, the strengthening of the role and resources available at a local level should be established.
- ⇨ It is necessary to establish a monitoring and management system of temporary settlements in order to help minimise the negative side effects, such as social degradation.

Effectiveness of search and rescue operations

- ⇨ The availability of reliable and timely information is vital for an efficient search and rescue. This information is essential for putting priorities on search and rescue actions and for allocating the available resources and means appropriately.
- ⇨ It is important to note that accesses and escape ways from buildings and towns must be ensured and be widely known to the population.
- ⇨ It is important that different procedures and inspection forms should be issued. A huge bulk of inspections of buildings was completed timely and successfully using the standard rapid first-degree usability assessment of buildings issued by EPPO in 1998. Yet, there is a difference between the rapid first-degree usability assessment of buildings and second-degree damage assessment of buildings. Furthermore, the spatial distribution of damage should be an outcome of the assessment in both inspections, but especially in the second degree.
- ⇨ The living conditions in the temporary settlements need to be improved, along with facilities and services.

Improvement on regulation and legislation

- ⇨ An institutional framework for the recovery and reconstruction phases should be set up.
- ⇨ The creation of inventories and data bases on resources at a National Level, along with its continuous update, are considered important measures for an effective response.
- ⇨ International co-operation and bilateral agreements can improve the response, relief and rehabilitation procedures.

Improvement of training

- ⇨ There is a necessity for testing the applicability of existing modern technology (information technology, remote-sensing applications) to emergency management so as to improve our current capacity of data transfer back and forth.

3.4 Lessons learnt concerning dissemination of information to the public

Improvement on co-ordination

- ⇨ The designation of a local radio station to disseminate instructions to the public in case of an emergency is a high priority.
- ⇨ It is essential that the adequate use of the media be carried out. Media can play a crucial role in the management of an emergency. Observed over-reactions of the population were influenced and exaggerated by broadcasted remarks mainly from seismologists on predictions for oncoming earthquake.
- ⇨ It is necessary that information technology be used in order to manage information. It is textbook knowledge that real-time, accurate information is vital in emergency respond and disaster management. An operational MIS (Management Information System) and GIS (Geographical Information System) can make a difference in effectiveness of disaster management.

Improvement of training

- ⇨ Informative seminars should also be introduced to raise public awareness prior to and after an earthquake.
- ⇨ The promotion of a broad-based public awareness scheme, coupled with a better understanding of earthquakes is required, so as to obtain public support for actions to reduce the impacts of earthquakes.
- ⇨ Methods of improving the communication to the public would be of great help.

3.5 Conclusions

Earthquakes, like volcanoes, are linked to the tectonic movement within the Earth. Thus, they are very difficult to predict because it is difficult to quantify the strains and stresses that the tectonic plates are experiencing and to identify the exact threshold beyond which an earthquake will occur. Furthermore, they can also trigger other natural hazards such as landslides, tsunamis and ground liquefaction. This must also be considered in risk assessment processes.

It would be wrong to claim that an earthquake event can be prevented, as this is physically impossible. However, it would be wise to prepare for an earthquake event. It can be observed that there are **key lessons learnt** that the four analysed earthquake events have in common. In particular, improvements are required in the following areas listed below.

- **Forecasting, alert and warning systems**
- **Strategic co-ordination**
- **Role designation**
- **Task prioritisation**
- **Training and formation of all stakeholders**
- **Allocation material and human resources**
- **Availability of resources**
- **Inter-disciplinary collaboration**
- **Inter-organisational collaboration**
- **International co-operation**
- **Communication strategies**
- **Dissemination of information to the public**.

Annex: Selected Earthquake Terms and Seismic Intensity Scales

1. Selected Earthquake Terms[1]

USED FOR LOCAL EARTHQUAKES

ML (local magnitude): used to calculate the size of a local earthquake up to 600 km from the epicentre.

USED FOR WORLD EARTHQUAKES

Ms (surface wave): used to calculate the magnitude of world earthquakes, which occur at shallow depths (< 100 km) and measured at distances greater than 2000 km.

Mb (body wave): used to calculate the magnitude of world earthquakes at any depth.

Mw (moment magnitude): used to calculate the magnitude of any earthquake and is especially used for larger earthquakes (> 7.5) where other scales tend to underestimate the size.

2. Seismic Intensity Scales

The **Modified Mercalli (MM) Scale**[2] (Table A1) was developed in 1931 by the American seismologists Harry Wood and Frank Neumann. This intensity scale is composed of 12 increasing levels (in Roman numerals) that range from imperceptible shaking to catastrophic destruction. It does not have a mathematical basis, but is an arbitrary ranking based on observed effects. Generally, "*the lower numbers of the intensity scale generally deal with the manner in which the earthquake is felt by people. The higher numbers of the scale are based on observed structural damage. Structural engineers usually contribute information for assigning intensity values of VIII or above*".

The Richter Scale[3] (Table A2) was developed in 1935 by Charles F. Richter of the California Institute of Technology as a mathematical device to compare the size of earthquakes. The magnitude of an earthquake is determined from the logarithm of the amplitude of waves recorded by seismographs. Adjustments are included for the variation in the distance between the various seismographs and the epicentre of the earthquakes. On the Richter Scale, magnitude is expressed in whole numbers and decimal fractions. The Richter Scale has no upper limit and is not used to express damage, as opposed to the Modified Mercalli Scale.

3. References

1 - British Geological Survey Earthquakes Booklet
http://www.gsrg.nmh.ac.uk/quicklinks.html#BOOKLET

2 - **http://wwwneic.cr.usgs.gov/neis/general/handouts/mercalli.html**

3 - **http://wwwneic.cr.usgs.gov/neis/general/handouts/richter.html**

Other interesting earthquake websites:

United States Geological Survey	**http://geohazards.cr.usgs.gov/earthquake.html**
Euro-Mediterranean Seismological Centre	**http://www.emsc-csem.org/**
Federal Emergency Management Agency	**http://www.fema.gov/library/quakef.htm**
Global Seismic Hazard Programme	**http://seismo.ethz.ch/gshap/**

International Association of Seismology and Physics of the Earth's Interior — http://www.iaspei.org/

Observatories and Research Facilities for European Seismology — http://orfeus.knmi.nl/

Table A1 – The Modified Mercalli Earthquake Intensity Scale[2]

MM Value	Description of Shaking Severity	Summary Damage Description	Full Description
I			Not felt. Marginal and long period effects of large earthquakes.
II			Felt by persons at rest, on upper floors, or favourably placed.
III			Felt indoors. Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognised as an earthquake.
IV			Hanging objects swing. Vibration like passing of heavy trucks; or sensation of a jolt like a heavy ball striking the walls. Standing motor cars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV, wooden walls and frame creak.
V	Light	Pictures move	Felt outdoors; direction estimated. Sleepers wakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, change rate.
VI	Moderate	Objects fall	Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken. Knickknacks, books, etc., off shelves. Pictures off walls. Furniture moved or overturned. Weak plaster and masonry D cracked. Small bells ring (church, school). Trees, bushes shaken (visibly, or heard to rustle).
VII	Strong	Non-structural damage	Difficult to stand. Noticed by drivers of motor cars. Hanging objects quiver. Furniture broken. Damage to masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices (also unbraced parapets and architectural ornaments). Some cracks in masonry C. Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.
VIII	Very strong	Moderate damage	Steering of motor cars affected. Damage to masonry C; partial collapse. Some damage to masonry B; none to masonry A. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes.
IX	Violent	Heavy damage	General panic. Masonry D destroyed; masonry C heavily damaged, sometimes with complete collapse; masonry B seriously damaged. (General damage to foundations.) Frame structures, if not bolted, shifted off foundations. Frames racked. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground. In alluvial areas sand and mud ejected, earthquake fountains, sand craters.
X	Very violent	Extreme damage	Most masonry and frame structures destroyed with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. Rails bent slightly.
XI			Rails bent greatly. Underground pipelines completely out of service.
XII			Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into the air.

Table A2 – The Richter Earthquake Intensity Scale[3]

Richter Magnitudes	Earthquake Effects
Less than 3.5	Generally not felt, but recorded.
3.5-5.4	Often felt, but rarely causes damage.
Under 6.0	At most slight damage to well-designed buildings. Can cause major damage to poorly constructed buildings over small regions.
6.1-6.9	Can be destructive in areas up to about 100 kilometres across where people live.
7.0-7.9	Major earthquake. Can cause serious damage over larger areas.
8 or greater	Great earthquake. Can cause serious damage in areas several hundred kilometres across.