THE SEISMICITY OF CENTRAL GREECE IN THE LATE 19TH – EARLY 20TH CENTURY AS ENGRAVED ON VARIOUS HISTORICAL BUILDINGS

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ABSTRACT:

Design of historical structures is based on the earthquake macroseismic intensities expected to occur at the broader area to be erected. For the engineers, critical parameter is usually the peak ground acceleration of the earthquake, expected to affect the structure during a time period representing the real life time of the structure. When the structure is a historical monument, this period is projected to the past. As reliable instrumental measurements of earthquake parameters exist only for the 20th century and the life time of a monument goes much behind this limit, for the estimation of the characteristics of the past earthquakes, the use of historical sources recording these earthquakes or their damage is of primary importance. In these sources, descriptions, when discovered, may allow the estimation of the appropriate macroseismic parameters of past earthquakes and lead to integrated information on the area considered. By extrapolating this information, one can also get, on a probabilistic basis, an idea on expected future earthquake activity. In this paper, this methodology is presented in terms of a forward-inverse problem: historical earthquakes of the area of central Greece during the second half of the 19th century are investigated and macroseismic historical earthquake data are evaluated with respect to specific monumental buildings of the area. Inversely, these monuments may also act as servers of new, yet undiscovered information on earthquake effects, which would lead to an improved picture of the historical seismicity of Central Greece.

KEYWORDS: monumental buildings, macroseismic intensity, Central Greece

1. INTRODUCTION

It is common practice in earthquake reports that special reference is given to buildings of importance to the local community, as well as to monuments, as opposed to ordinary houses. These buildings are more important to the writers because of their social, economic, symbolic or cultural value. They also present a structural and non-structural complexity, so that they may be more likely to be damaged than ordinary buildings.

In an effort to quantify the degree of damage to historical buildings during the period 1850-1900 in central Greece, an extensive survey of the documentary data describing the effects of the earthquakes was performed. The selected area of central Greece incorporates all types of historical buildings during a long time span, from antiquity to the present. The reasons for selecting this time period were, that after the rehabilitation of the Hellenic State following the revolution of 1821, the administration was established and the National Observatory in Athens organized a network of local observers for natural disasters due to earthquakes, volcanoes, extreme weather conditions, etc. In addition, important facts were recorded by the consular authorities of foreign countries and by newspapers, which appeared in the mid 19th century. The purpose of this survey was to document the seismic history of monumental buildings and, subsequently, to evaluate the damage grade expected to occur in future earthquake scenarios. To demonstrate the potential applications of such a procedure, a case study on a specific important building is presented.

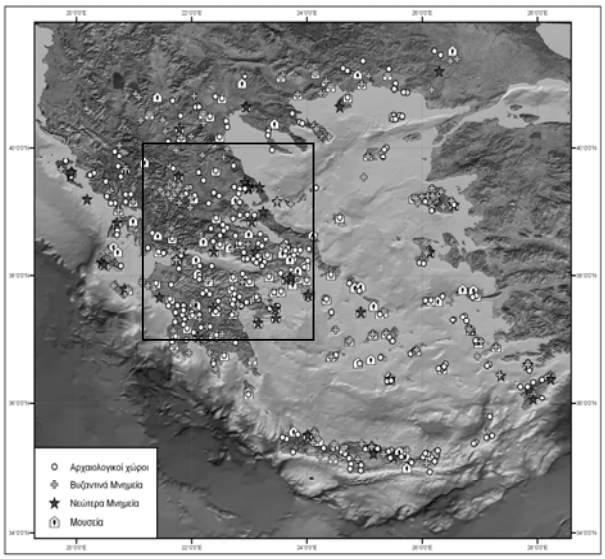

Figure 1. Distribution of monuments in the area of Greece. Archaeological, Byzantine, recent monuments and museums are distinguished (source: Ministry of Culture, Greece)

2. HISTORICAL EARTHQUAKES AND BUILDINGS SURVEY

The survey of historical earthquakes followed the procedure of retrieving information from documentary records, which can be seismological compilations, historical literature, the press, etc. From a large number of earthquakes in the period of study, a small number of damaging or destructive events was selected, with the criterion that they affected historical buildings of the area. The earthquakes studied, as well as the sources of information are listed in table 1.

Identifying the historical buildings from the amount of buildings quoted within the earthquake reports is sometimes a rather subjective procedure, taking into account that the variety of earthquake accounts does not allow for a homogenous listing of those affected by the earthquakes. Detailed professional reports (compiled by geologists appointed by the ministry, local historians, local earthquake observers appointed by the National Observatory, etc.) on damage to specific buildings exist only from a small number of strong earthquakes of late 19th century, e.g. the 1861 Aigion or the 1894 Atalanti events. In these reports, the effects of the earthquake to the important buildings of the area are described in detail and in some cases it is stressed which building did not suffer any damage at all. In very few cases photographic material or engravings are available (figure 2).

Event	Area	M	Source	Type of historical building								
				AR	BY	MR	PU	CH	MO	IM	OT	UN
1853Aug18	Thiva	6.5	AMJ1997	1		6	1	3		3		5
1858Feb21	Corinthos	6.5	KOU1858 DAM1928 AMJ1997	4		6	4			4		1
1861Dec26	Valimitika	6.6	STA1954 TRI1959 AMJ1997	3		2	2	6	2			2
1870Aug01	Phokis	6.7	SCH1879 AMP1989	1		1		9	4	1	1	
1873Jul25	Epidauros	6.0	SCH1879	1								
1874Mar18	Eretria	6.0	AMB1994	1								
1880Jan	N.Sporades		PAP1993d						1			
1886Aug27	Filiatra	7.3	MIT1899					1				
1886Oct22	Volos		PAP1993d						1			
1887Oct03	Xylokastro	6.4	AMJ1997				3		1			4
1888Sep09	Aigio	6.1	AMJ1997				3	1				4
1889Aug25	Aigio	7.0	GAL1953					3				2

			AMJ1997									
1899Jan22	Athens		AMB1994		1							
1892Jan09	Larisa	5.8	PAP1981 PAP1993d KSK2001				7			1		1
1894Apr20	Martino	7.0	AMB1994 AMJ1997	2					1			
1894Apr27	Atalanti	7.2	MIH1897 AMB1994 AMJ1997	1			1	2				1
1895May14	Paramythia	6.3	AGA1895		2		2	1				3
1898Jun02	Tripoli	7.0	MIT1899 SAK2008				3	1			5	1
1898Jul31	Ioannina	6.3	LAM1913					1				
1899Jan22	Kyparissia	6.5	MIT1899 SAK2008				2	4				1

Table 1. Historical earthquakes, their sources and distribution of categories of historical buildings affected

The historical earthquakes listed in table 1 are mainly located in the broader area of the gulf of Corinth, which is the most active in central Greece. However, strong events form Thessaly, Epirus to the north, Atalanti to the east and Tripoli and Kyparissia to the south also seem to have affected the historical buildings of the area. Out of the 20 events listed, three are not included in the parametric earthquake catalogues and seismological compilations (1880 N. Sporades, 1886 Volos and 1889 Athens). The first two events were discovered through the damage they produced in historical buildings, according to contemporary written records from monasteries of Thessaly. The latter damaged the Byzantine monastery of Dafni, near Athens, and was perceptible in Athens and Piraeus, according to the contemporary press.

The total number of historical buildings affected is 138, two of which have reported damage twice in this period (the Acropolis in Athens and the church of Agia Triada, due to the 1874, 1894 and 1886, 1899 earthquakes, respectively). As these buildings belong to different age, use, strengthening and importance, it was considered necessary to arrange them into various categories, i.e. Archaeological monuments (AR), Byzantine monuments (BY), Medeival, Venetian, Turkish, etc. (MR), Public buildings (PU), Churches (CH), Monasteries (MO), Important buildings (IM), Other/Unidentified (OT, UN). The distribution of these categories with respect to the earthquakes is also presented in table 1.

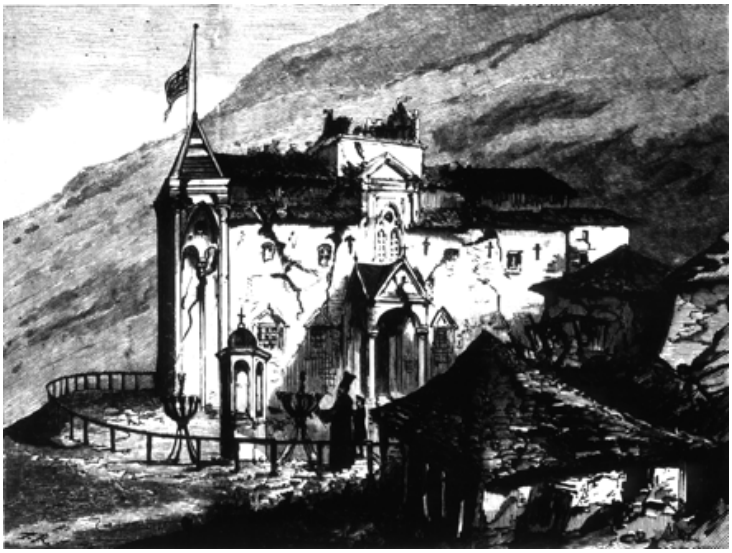

Figure 2. Main church damaged at Atalanti due to the 1894 events, drawn from a sketch by W. C. Bourchier (Albini & Pantosti 2004)

Damage evaluation was performed according to the European Macroseismic scale (EMS98), taking into consideration the restrictions concerning monumental buildings, when necessary. In many cases information was adequate for assessing the grade of damage; when information was minimal, a range of damage grades was given to the building (figures 3 and 4). It is observed that for each earthquake magnitude, historical buildings are affected in a range of epicentral distances, thus showing the perceptibility of each event (figure 3). In the same figure, the squares represent the range of distances, within which each earthquake magnitude may damage heavily or destroy the historical buildings. This range is analogue to the magnitude of the earthquake.

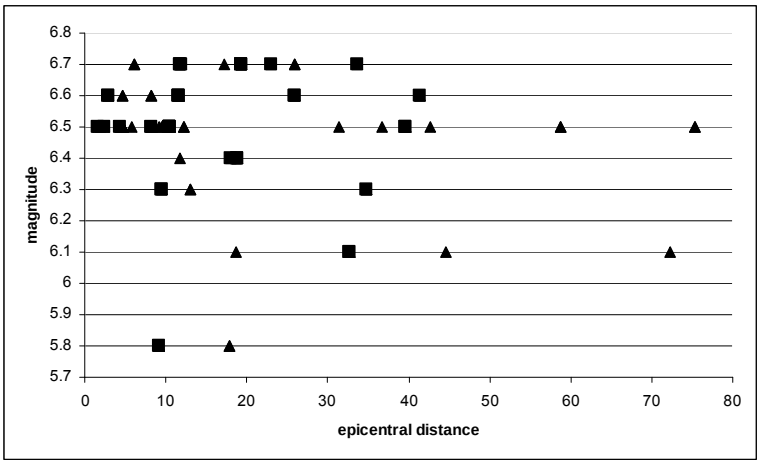

Figure 3. Distribution of affected (triangles) and destroyed (squares) historical buildings

Figure 4 presents an example of distribution of grades of damage to the different types of historical buildings, for the earthquake of 1870 in Phokis, near Delfi. Archaeological sites present a variety of damage, probably due to the fact that they have suffered repeatedly from earthquakes in the past, and therefore they are the most vulnerable. The same stands for the Venetian, Turkish and recent monuments. In this earthquake, a considerable number of buildings that were not identified, together with other historical buildings, also present a variety of damage grades. However, the identified churches and the other important buildings of the area show lower grades of damage, a fact proving that in the local communities of the time, special care was given during the construction of their churches, schools and other public buildings, as the earthquakes in these areas are not a rare phenomenon.

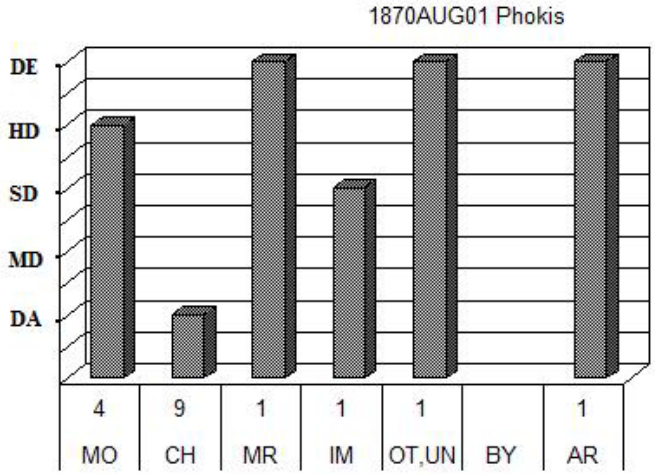

Figure 4. Severity of damage vs various types of historical buildings of table 1 for the earthquake of 1870 (DA: damage, MD: moderate damage, SD: substantial damage, HD: heavy damage, DE: partial or total destruction)

5. CASE STUDY: IDENTIFICATION OF A HISTORICAL BUILDING

In this section the detailed procedure of the background of a historical building is demonstrated. By researching historical archives, the information as to when it was built, its use, its damage due to previous earthquakes, etc. may be retrieved. Old maps may also show the actual location of the building.

In his report on the 1861 Aigion earthquake (table 1), Julius Schmidt, director of the National Observatory of Athens at the time, notes: "… during the 1861 earthquake, the walls of the primary school in Galaxeidi opened and the roof started falling, and it would have killed all the scholars who happened to be inside, unless the walls returned to their initial location and withstood the falling roof one meter from the heads of the intimidated children…".

Skiadas (1999), in his historical compilation on Galaxeidi, lists the various important buildings of the town through its history, amongst others, the old primary school. The topographic diagram of figure 5 gives the position of the building.

" … The old primary [school]
The first preoccupation of the Galaxeidians immediately after their return to the country and the rehabilitation of the Hellenic state, was to build a school. They raised funds between them, collected 4.389 grosi and in 1830 they built the Mutual Teaching School of 34 piks length and 14 piks width. It is located at the site Koukounas, an area out of town, at this time. It is one of the five schools built in liberated Greece at the time of Ioannis Kapodistrias [the first governor of Greece]. As a building, it is architecturally presentable, with stone arches. It operated as primary school until 1932. Since then it was abandoned and one school board sold it after public auction. And the school became private property, declared as national heritage."

Τοπογραφικό διάγραμμα του Γαλαξειδίου.

Figure 5. Topographic diagram of Galaxeidi, showing the location of the primary school damaged during the 1861 event

6. CONCLUSIONS

The historical earthquake survey showed that the historical buildings of the area of central Greece experienced in the second half of the 19th century at least twenty damaging earthquakes, 17 of which had magnitudes M≥5.8. The area is known for its high seismicity, which extends up to the preset. These buildings have repeatedly suffered from earthquakes, although the detailed information on damage and rehabilitation or strengthening is not always available.

In the present study, an inventory of the existing monuments, based on their response to earthquakes, is attempted, through evaluation of damage to each building. There was no apparent selectivity of the damage due the earthquakes, as to a specific type of buildings. However the age of the buildings seems to be the most prevailing factor of vulnerability of the structure. Historical studies inform that churches and schools were constructed with special attention, as opposed to ordinary houses. On the other hand, the monasteries were well kept, as well as military and public buildings.

As an illustration of an application of the procedure for building an inventory of the monuments of the area for engineering purposes, the history and location of a public building in Galaxeidi is presented. The school was built in 1830, operated in the period 1830-1932 and the first information on damage derives from the 1861 Aigion earthquake.

It is concluded that the time period selected in the present study, although provided ample information on earthquake effects to historical buildings, is not enough for the study of the effects of more than one earthquakes from the same seismogenic zone to these buildings. It is therefore suggested to expand the time period of study, giving special emphasis on the cases when, the same buildings identified in this study, have been affected by past events or will be affected in the future.

REFERENCES

1. Agamenone G., 1895. Tremblement de terre de Paramythia (Epire) de la nuit 13-14 mai 1895. Bolletino della Societa Sismologica Italiana, vol. 1, fasc. VI, 121-130. (AGA1895)
2. Albini P. & D. Pantosti The 20 and 27 April 1894 (Locris, Central Greece) Earthquake Sources through Coeval Records on Macroseismic Effects *Bulletin of the Seismological Society of America*; August 2004; v. 94; no. 4; p. 1305-1326;
3. Ambraseys, N.N., 1994. Material for the investigation of the seismicity in Central Greece. RHISE, vol. 2, 1-10. (AMB1994)
4. Ambraseys N.N. & J.A. Jackson, 1997. Seismicity and strain in the gulf of Corinth (Greece) since 1694. Journ. Earth. Engin. vol. 1, n. 3, 433-474. (AJ1997)
5. Ambraseys N.N. & P. Pantelopoulos, 1989. European Earth. Engin. vol. 1, 10-18. (AMP1989)
6. Damaskinos, 1928. The tragedy of a historical town. Corinth, 113 pp. (DAM1928)
7. Gruenthal G., 1998. European Macroseismic Scale 1998. Cahiers du Centre Europeen de Geodynamique et de Sismologie, vol. 15, 99 pp.
8. Kouskouna V., 2001. The earthquake of (28 December 1891) 9 January 1892 in Larisa. Proc. 9th Int. Congr. Hellenic. Geol. Soc., vol. 34/4, 1425-1432. (KSK2001)
9. Koustas G., 1858. The earthquake in Corinthos. Pandora, vol. 9, iss. 202, 15-8-1858, 225-229. (KOU1858)
10. Lambros S., 1913. Epirotika. Neos Ellinomnimon, vol. 10. (LAM1913)
11. Michas, K., 1978. Martino (Loutsi) of Boiotia. 128-141. (MIH1978)
12. Mitzopoulos, C., 1899. The earthquakes of Tripoli and Triphylia in the years 1898 kai 1899. Publ. Dept. of Federal Economy of the Ministry of Interior, March 1899, Athens, 179-254. (MIT1899)
13. Papaioannou I., 1981. The earthquake of Larisa in 1892. Eleftheria, Larisa, n. 21110, 15-3-1981. (PAP1981)
14. Papaioannou I., 1993d. The seismic activity in E. Thessaly and N. Sporades in the 19th century. Thessaliko Imerologio, vol. 24, 257-266. (PAP1993d)
15. Schmidt, J.F., 1879. *Studien ueber Erdbeben*. 1-136, 316-360, Leipzig. (SCH1879)

16. Sakellariou N., 2008. Historical earthquakes of central southern Peloponnese. MSc thesis (in press). (SAK2008)
17. Skiadas A., 1999. Galaxeidi. Athens, 365 pp. (SKI1999)
18. Stavropoulos A., 1954. History of Aigion. Patras, 699pp. (STA1954)
19. Triantaphyllou, K.N., 1959, 1980. Historical dictionary of Patra. Patra. (TRI1959)