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BSB 966

The REDACt project Educational Hub

From earthquake focus to induced damage

Deliverable No: D.T3.5.1d (EN)

GA T3 Implementation of REDA system (pilot studies)

Created by:
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1. Background of the document

1.1. Scope and Objectives

Earthquake imposed crises, invoke the entire community including all of its structural components. They put into test the operational capacity of services, their response efficiency and the response of the population, which strongly affects the dynamics and progress of response actions, both during the event and after that.

The right knowledge of what happens after an earthquake of moderate to large magnitude is of great importance. Citizens would like to know what is the magnitude and the epicenter of the event. If it is in the proximity of their living place to respond accordingly. However, they would like to know the level of the intensity measure in their location as well as in the broader epicentral area. In addition, Civil Protection authorities would like to have an estimation of distribution of possible damage and losses especially in urban environment to appropriately respond towards mitigation of seismic risk within the first minutes/hours after the earthquake. Scope of the deliverable is to provide information to the public about the Shakemaps and to the Civil Protection stakeholders about estimated damage distribution in urban built environment and infrastructure.

The document is a part of the REDACt Educational Hub (Edu-Hub). It capitalizes on respective material published by competent Authorities at National and Regional Levels and is based on research carried out during the project and on internationally recognized and widely acceptable principles. The International Hellenic University led this effort and partners contributed with data, information and translations.

1.2. Related Documents

1.2.1. Input

Table 1. List of former deliverables acting as inputs to this document

Document ID	Descriptor
D.T.3.5.1	The REDACt project Educational Hub

1.2.2. Output

Table 2. List of other deliverables for which this document is an input.

Document ID	Descriptor
D.T3.1.	

2. INTRODUCTION

The first important information we have immediately after a strong earthquake in our area is its epicenter and magnitude. Today, this is provided as a preliminary automatic solution by the seismological centers of the country (Geodynamic Institute of the National Observatory of Greece https://www.gein.noa.gr, Seismological Station of the Aristotle University of Thessaloniki http://geophysics.geo.auth.gr) within approximately 2 minutes from the earthquake occurrence. This information has its value, since citizens who felt the earthquake want to know its epicenter (where it happened), and what its size.

This level of information, although important, cannot answer questions such as: (a) to what extent the earthquake was felt and (b) how any possible damage to constructions and natural environment is spatially distributed. These two issues are directly related to any possible consequences of an earthquake and are of interest to both citizens living in the area around the epicenter as well as the civil protection authority. In this way they can have an image of what happened and where, as well as how they should react, to mitigate the consequences of the event. The answer to these questions can today be given satisfactorily and in almost real time (within about 5-10 minutes of the event origin) through the production and dissemination of Shakemaps.

3. WHAT IS A SHAKEMAP

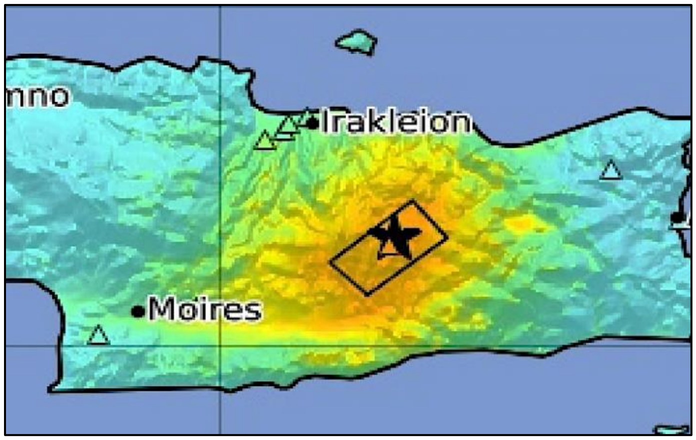
Strong earthquakes can cause injuries and loss of life, as well as significant damage to buildings and other infrastructure. Immediately after a major earthquake it is difficult to quickly get an overview of the situation in the wider area so that to take appropriate measures. Shakemaps can support crisis management during this very first phase by indicating likely areas that are particularly affected. In this way they serve as a key source of information helping civil protection and rescue teams to focus development of their efforts primarily in these areas. They can also estimate where and how strongly the seismic ground motion was felt, as well as whether damage is expected. The concept of Shalemaps maps originated in California in the 1990s and is now routinely used in many seismically active countries around the world.

Generation of a Shakemaps include the following processing steps: (a) the epicenter and magnitude of the earthquake are determined automatically in real time at the seismological centers based on data of the unified network of seismographs in Greece, (b) this information is then combined with ground motion predictive models derived from accelerometer data in the area of Greece as well as with observed maximum ground accelerations at stations of the national accelerometer network. Before processing the data to determine the macroseismic intensity it is necessary to filter them to adjust in local amplification effects.

4. HOW TO READ A SHAKEMAP

The Shakemap of Figs. 1 and 2 presents various useful information about the earthquake and the ground motion caused, both near and far from its epicenter. In these maps the epicenter and magnitude of the earthquake is displayed, and with the graduated color scale the estimated macroseismic intensity (Intensity) caused by the earthquake, up to the distance at which the vibration is no longer felt, i.e. where the macroseismic intensity has values smaller than II.

In addition, if one wants to examine the estimated horizontal ground acceleration (%g) the acceleration iso-contours are given which are a very useful element of the estimated seismic actions imposed on structures (see Figure 2).



SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0464	0.297	2.76	6.2	11.5	21.5	40.1	74.7	>139
PGV(cm/s)	<0.0215	0.135	1.41	4.65	9.64	20	41.4	85.8	>178
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Figure 1. Shakemap of the M6.0 earthquake in Arkalochori, Crete, in terms of estimated macroseismic intensity, with graduated color scale. The accelerometer stations recorded ground shaking are given by triangles, and the matching of macroseismic intensity to peak ground acceleration (PGA [%g]) and velocity (PGV [cm/s]) is given at the bottom of the figure. The black rectangle shows the projection of the seismic fault on the surface and the star the earthquake epicenter(http://shakemaps.itsak.gr).

Figure 2. Shakemap of the M6.0 earthquake in Arkalochori, Crete, in terms of maximum ground acceleration (iso-contours of [%g], g: acceleration of gravity). Triangles indicate the accelerometer stations recorded the ground shaking(http://shakemaps.itsak.gr).

In this way, it becomes clear that additionally to the classic magnitude and epicenter of an earthquake, one can see the spatial distribution of seismic intensity in the wider region of the epicenter, thus having a complete picture of the seismic ground motion caused by the earthquake. Then, incorporating the vulnerability of structures, the Shakemap with appropriate correlations can be converted into maps showing distribution of expected seismic damage in the built environment. This information is extremely useful for the civil protection authorities and not only, to focus into actions reducing consequences immediately after the earthquake. From the above, the usefulness of Shakemaps in the wider epicentral area of a strong earthquake with magnitude M>4.0 becomes clear.

5. FROM SHAKEMAPS TO DAMAGE & LOSSES

5.1 Introduction

Shakemap is one of the two factors that determine seismic hazard. The second is the vulnerability of each type of construction exposed to the specific seismic risk, according to the simple relationship:

$$R = H * V,$$

where R: seismic risk, H: seismic hazard and V: vulnerability.
The * refers to the convolution of the two factors.

Vulnerability can be expressed through relevant curves, known in international terminology as fragility curves which have the general form given in Figure 3. The fragility curves give the probability that a structure has suffered a certain degree of damage (from zero to complete collapse) in function of the value of a variable that serves to describe the ground motion intensity caused by an earthquake at the location of the structure (e.g. maximum ground acceleration, spectral acceleration, etc.).

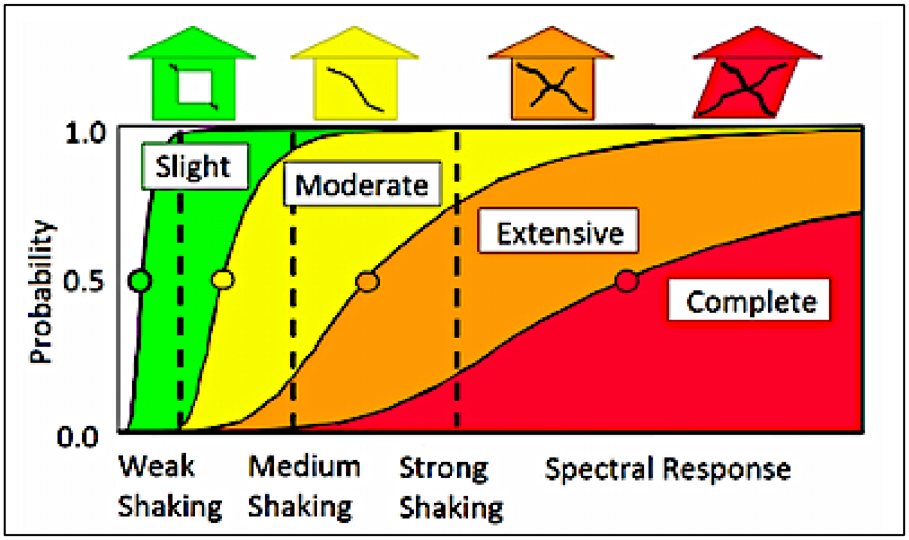


Figure 3. General form of fragility curves.

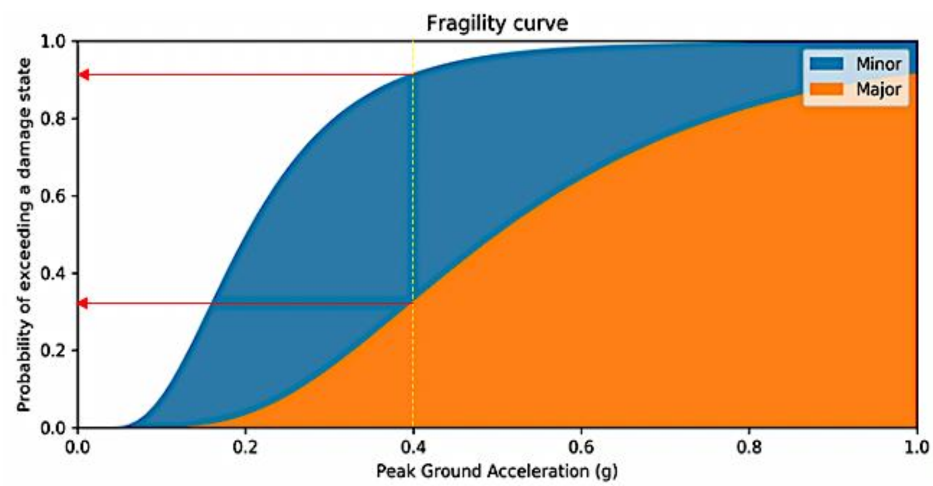


Figure 4. Example of a fragility curve for a specific pipeline construction.

Figure 4 shows two vulnerability curves of a pipeline structure. For example, if the maximum ground acceleration at the pipeline location is 0.4g, the probability of exceeding the major damage threshold is 33%. Accordingly, the probability of exceeding the threshold of the minor damage level is 93%.

5.2 Example of a Risk Scenario for the city of Thessaloniki

In the case of residential buildings, five (5) damage levels have been established. More specifically, the categories No Damage (D1), Slight Damage (D2), Major Damage (D3), Extensive Damage (D4) and Complete Damage (D5) (Figure 5).

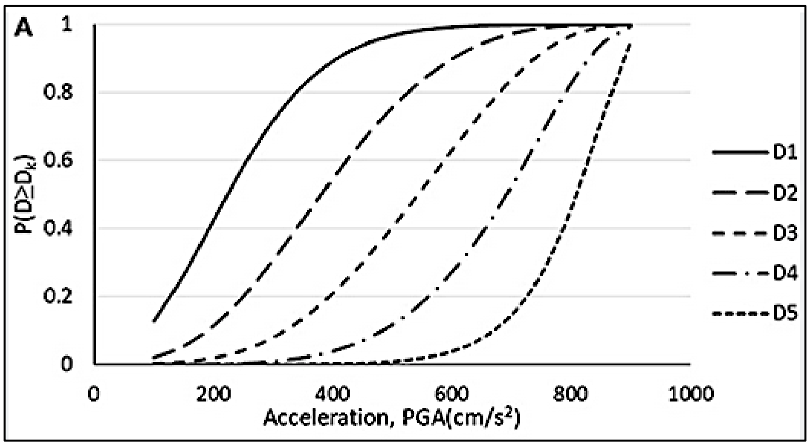


Figure 5. Example of fragility curves of reinforced concrete residential buildings.

Fragility curves used in seismic risk studies of extended areas, such as an urban metropolitan center, correspond to typologies of buildings defined based on characteristics that influence their seismic behavior (e.g., construction material, building height, age of construction etc.). In particular, the age/period of construction is directly linked to the seismic regulation with which the buildings were designed. For the city of Thessaloniki, Figure 6 shows the spatial distribution of the building stock per building block and in the form of a "pie-like". The percentage of buildings that have been constructed without seismic regulations (before 1959), with the first seismic code (period 1959-1984), with the additional provisions of the seismic code (period 1985-1995) and with the modern seismic regulations (period after 1995), are shown.

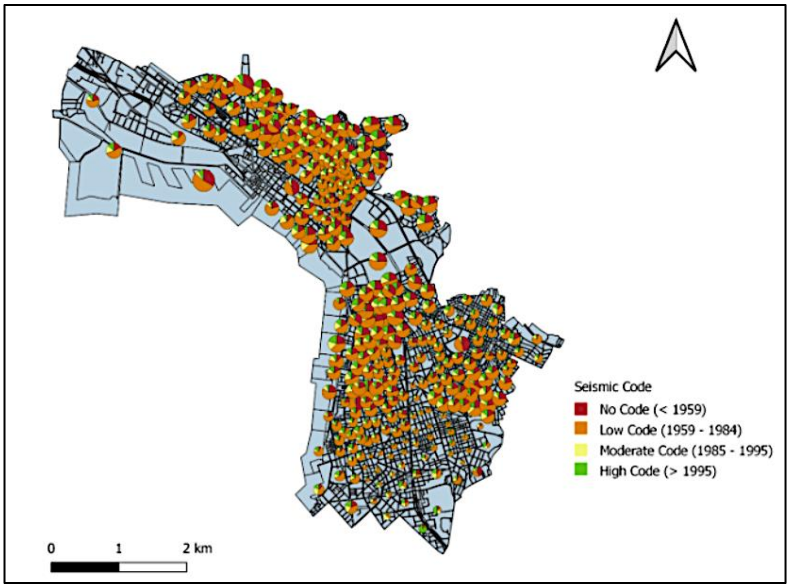


Figure 6. Distribution of the buildings of the city of Thessaloniki by building block, in relation to their seismic design codes.

For the earthquake scenario corresponding to that of June 20, 1978 (M6.5), about 20km east of the city of Thessaloniki, Figure 7 shows the expected values of the maximum ground acceleration (PGA cm/sec2) per building block of the city.

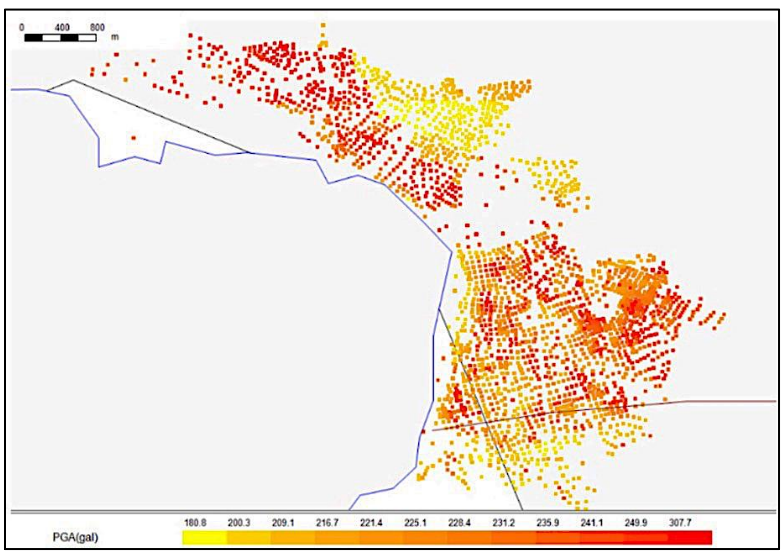


Figure 7. Distribution of the maximum ground accelerations per building block of the city of Thessaloniki, from the seismic scenario corresponding to the earthquake of 20/6/1978 (M6.5) 20km east of the city.

Then convolution of the expected maximum ground accelerations per building block with the fragility curves follows and the seismic risk from the specific scenario is derived (Figure 8).

Figure 8. Estimated spatial distribution of the damage level of buildings within the building blocks of the city of Thessaloniki for the scenario of the earthquake of 20/6/1978 (M6.5), 20km east of the city.

In this way, the state authorities can have an estimate of the spatial distribution of the expected damage, in case of a specific seismic scenario, that can be used to mitigate consequences of a possible future earthquake on the built environment and on citizens. It is understood that the rational estimation of the expected seismic actions (e.g. maximum ground acceleration) and the accuracy of the databases on building stock of a city are decisive factors for a reliable estimation of seismic risk parameters and results. In the direction of enriching the relevant database, cooperation of scientists with Civil Protection and public services updating the databases is deemed necessary and decisive.

In addition, in the case of real-time Shakemap generation, the above building inventory databases can also be used towards rapid damage assessment of an urban environment from a specific earthquake in the wider area. The usefulness of this information for the response of Civil Protection in the first minutes and/or hours after the event is evident, so that the actions to reduce consequences of the earthquake would be rationally focused.