OVERALL IMPACT OF JULY, 9 EARTHQUAKE. TEN YEARS LATER

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SUMMARY

The earthquake that struck Faial, Pico and S. Jorge in 1998 has allowed the collection of an unprecedented quantity of good quality data about damage in constructions, costs of repair and other variables. As an example, a total of 3909 buildings damaged were analyzed case by case which permitted to establish a damage classification using the European Macroseismic Scale 1998 and consequently draw the severity of ground shaking (macroseismic intensity).

A general overview about the impacts of the earthquake on population, housing and economy is analyzed ten years after the occurrence and is briefly reported in this paper. This paper present overall result obtained from different sources of information, mainly from the integrated database ("Base Integrada") assembled.

1. INTRODUCTION

The 1998 Faial earthquake which measured M_w 6.2 caused 8 deaths, hundred of injuries, 2500 homeless, 35% of the Faial buildings were affected and 10% in Pico (from the grade of damage 1 to 5, D1-D5) and a great impact on socioeconomics activities occurred during a long period. The main annual event of the Horta (Semana do Mar - Sea Week in August) was cancelled as earthquake consequence, with a clearly social impact in the island. Today marks the 10^{th} anniversary of the earthquake and many things in Faial and Pico Island are different now: increased the earthquake safety procedures for building construction, new urban areas, infrastructure and services were developed as well as some new urban planning measures were studied although an effective application was not yet implemented. This paper refers some direct and indirect impacts of the Faial earthquake.

2. POPULATION AND HOUSING STATISTICS

Figure 1 shows population and housing unit totals according to different Censuses years as well as other statistical information. The following charts illustrate a population decrease on the period 1950-2001 promoted by the emigration caused by Capelinhos volcano eruption in 1957 or due to lack of employment on the islands which forced people to leave. As a direct consequence of the emigration, buildings have been abandoned during these years and an old and vulnerable housing stock was induced, contributing to the damages (when occur an earthquake) due to structural deficiency in design and unsafe construction features. In fact this was visible when the 1998 earthquake devastated a large number of housings in Faial. One explanation to the difference between the high numbers of collapsed buildings and only the 8 death registered is that many buildings are abandoned or are seasonal houses, with none inside.

Figure 1 shows that there has been a moderate increase in the size of the population and housing between 2001 and 2007 due to the process of reconstruction and rebuild after the earthquake, creating a huge number of jobs for local population and immigrant workers, contributing to the islands economic growth.

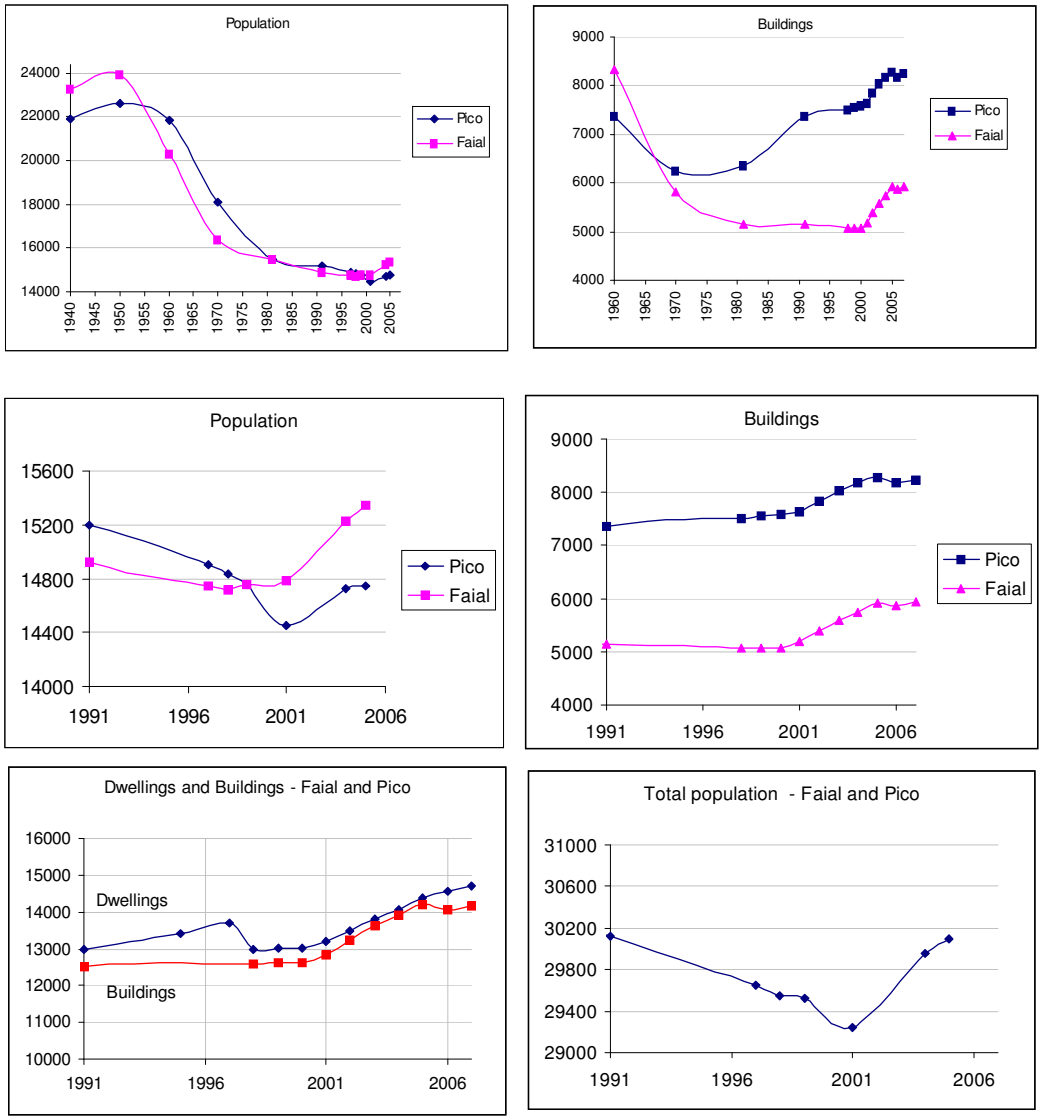

Figure 1: Evolution of population and housing between 1940 and 2007.

3. CLASSIFICATION OF DAMAGED BUILDINGS USING EMS-98 CONCEPTS

A post-earthquake survey named "Auto de Vistoria" was carried out in 1998 and further updated in 2007 (Neves *et al.*, 2008) which offered a strong potential to achieve damage assessment using the European Macroseismic Scale, 1998 (EMS-98). A total of 3909 buildings affected by the July 9, 1998 earthquake from Faial and Pico were analysed and characterized. The knowledge about typical damage types on buildings is necessary to interpret and classify those real damaged buildings so the AeDES field manual (Baggio *et al.*, 2007) and all the information contained on "European Macroseismic Scale" (Grünthal l *et al.*, 1998) were used as guidelines to the EMS-98 classification. Many complexity and heterogeneity exist in this process of classification due to the presence of great differences in damage over short distances; the presence of different grade of damage in similar typologies of construction or due to the impossibility of distinguish the global effects of earthquake in some buildings because the information or pictures are non comprehensive or doesn't exist. Finally, the database produced during this studies (Neves *et al.*, 2007) contain, beyond other information, a large number of addresses to match. 2151 buildings of Faial and 570 of Pico had been geo-referenced using GIS software, but unfortunately not all buildings are the correct addresses or complete street address (with house number) forcing us to distribute some buildings in terms only of their street name, decreasing the exactness and reliability of results. The

importance of geocoding all this information is to conduct to geospatial analyses and understand the distribution of buildings damage grade in a certain zone or know building-by-building locations near faults and landslide areas and consequently displays this information on maps.

3.1. Damage assessment

The state of emergency that was experienced after the 9 July earthquake brought the need for design a survey form named "Auto de Vistoria" to gather information regarding the damaged occurred in each single building combined with the economic situation of each family to determine the criteria for initialized the post-quake reconstruction and rehabilitation process and restore the normality. This survey was the base adopted to classify the damages observed using the EMS-98 concepts. Unfortunately this survey has a lack of information regarding:

- damage observed to structural and non structural elements
- damage occurred in the past, not associated with this earthquake,
- the percentage of the building affected by each damage grade (D1 to D5).It is very important to estimate the damage extension for each structural component (e.g. vertical structures, floors and roof) and non structural component (infills and partitions).

These factors contribute to a more difficult and not very realistic classification of damage in some cases.
A total of 2030 process/dwellings in Faial and 885 in Pico were classified using the EMS-98 concepts.Classification of building damage was done examining the following information:

- exterior house photography and damage descriptions contained in "Auto de Vistoria" database,
- damage classification obtained by Neves *et al.* (2007) – "Base Integrada".

3.2. Some examples illustrating the classification of damage to building types

Several examples illustrating the classification of building damage for masonry and reinforced concrete buildings are presented in Table 1.

Table 1 – Examples of grade of damage to masonry and reinforced concrete buildings

Level	Masonry	Reinforced concrete
D1	 Slight damage – cracks of width ≤ 1 mm.	 Slight damage – Slight cracks (≤ 2 mm).

D2	 Slight structural damage. Fallen of plaster.	 Separation between floor and wall.
D3	 Falling of tiles. Large and extensive cracks in the exterior walls.	
D4	 Partial failure of wall.	
D5	 Collapse of masonry walls.	

3.3. Results

The assessment of the damage suffered with regard to housing, revealed that 88% of the Faial houses contained in the database "Base Integrada", have suffered some kind of damage D1 to D5. Pico presents a total of 67% dwellings with damage (Figure 2).

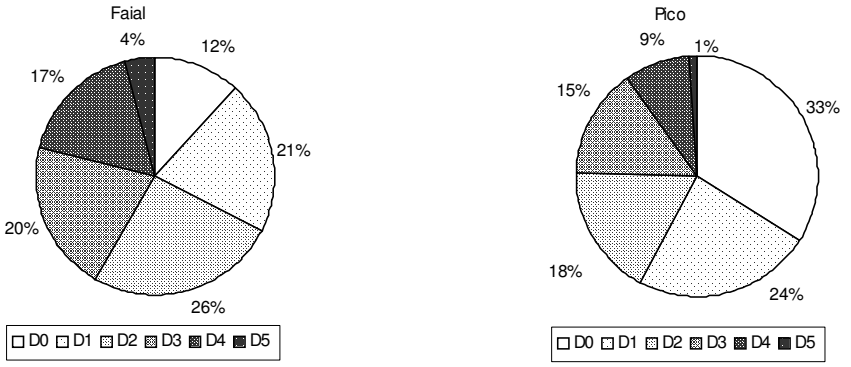

Figure 2: Faial and Pico grade of damage distribution ("Base Integrada").

If we introduce this values of structures damaged in the housing 1991 Census it is possible to infer that 35% of Faial building stock suffered damage (D1 to D5) and in Pico island nearly 10% of the total housing were damaged (D1 to D5). It is important to refer that not all housing damaged by this earthquake was analysed, due to the fact that some householders are immigrants and other houses are abandoned.

From the observed damage it had been possible assign macroseismic intensity to each parish from Faial and Pico (Ferreira, 2008). In order to assign intensity it is necessary to know not only how many houses were damaged but also how many were not damaged, and the not damaged houses was not collected by the survey "Auto de Vistoria", contributing to a lesser detail. Another problem detected was the fact that almost the damage descriptions contained in the "Auto de Vistoria" survey have poor quality, are incomplete or do not exist, so greater the error there is likely to be in assessment.

The EMS-98 scale exposed in Figure 3 reveals in some cases a problem of scale: in some localities is reasonable consider that intensities at individual block of houses could be one intensity unit higher or lower than the parish value depicted by the map, depending on the proportion and quantities of cases.

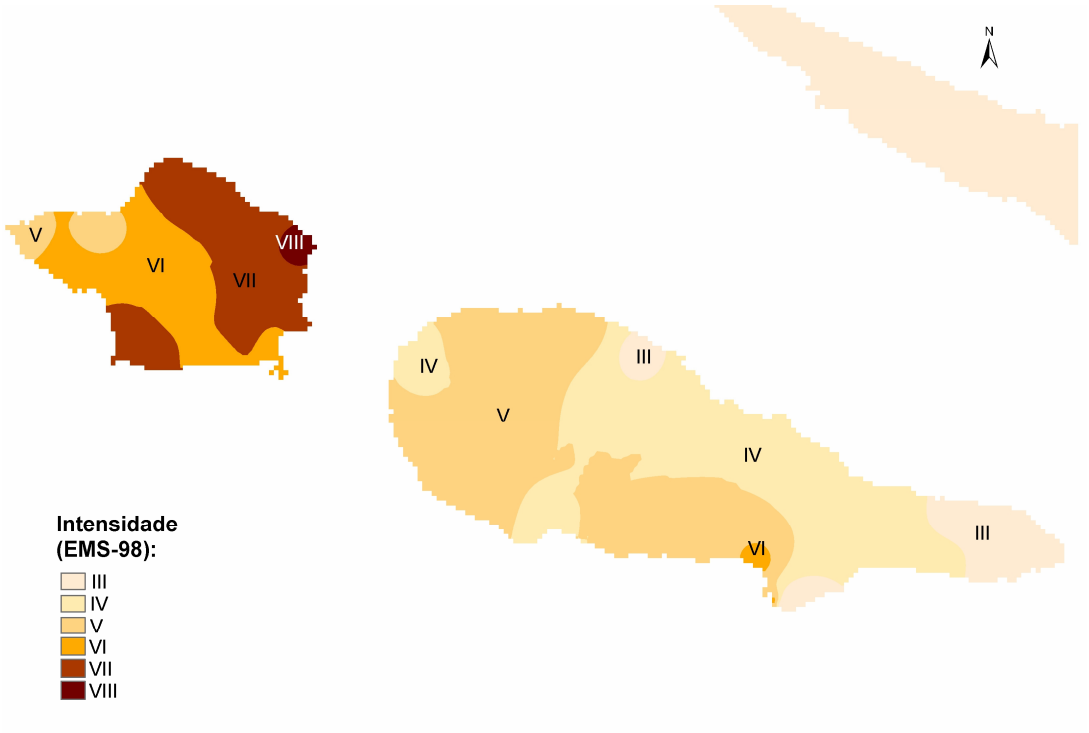

Figure 3: Faial and Pico macroseismic intensity.

4. HORTA DAMAGE EVALUATION IN 2000

A team of the Instituto Superior Técnico, TULisbon launched a field mission to the City of Horta on 2000. They carried out walkover surveys and took photos of a total of 2170 buildings in the city in order to identify the distribution and extent of damage to structures due to the earthquake. The information collated during the study enables not only to evaluate the different level of damages that occurred in this area but also the construction of a model to inform about the qualitative risk assessment. Figure 4 illustrates the building vulnerability according to a several factors:

- geological formation;
- fault presences;
- building characterization (type of material, number of storeys, state of conservation, etc.)

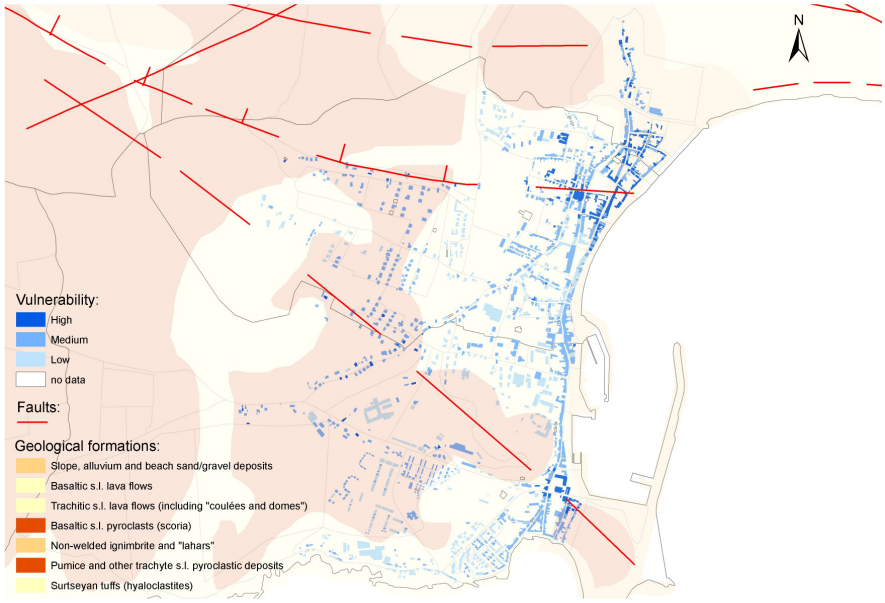

Figure 4: Horta vulnerability evaluation.

5. QUALITATIVE EVALUATION. MODIFICATIONS MADE IN THE HOUSINGS

After an earthquake people whose psychological, social and economic integrity were damaged needs to gain a new residential area with a similar (or even improved) integrity. However, after a disaster while the authorities are trying to provide the certain number of housing needed with the planning-programming process (design, construction and construction controlling) many times is difficult to supply all the quality in several stages due to restrictions depending on time, finance or other factors, reflecting in several problems to users and consequently is an indicator of the housing quality. It would be interesting develop a survey with information describing the housing and user satisfaction with housing, social, physical and natural conditions and analyse those information.

Modifications/improvements that have been made as consequence of reconstruction/rehabilitation were groups as follows:

- structural modifications/improvements,
- modifications/inclusion of the basic needs (bathroom, number and size of the rooms in the housing);
- introduction of new materials.

According to the data analysed for this study some statistics are shown in Table 2 and 3.

Table 2 – Analysis of a few variables of “Base Integrada” database - Faial

Variable	Mean	Mode	Standard deviation	Count
Family members	2.96	2	1.68	3002
Housing construction area - inicial (sq. m.)	144.14	40	113.01	2411
Housing construction area - final (sq. m.)	94.37	90	18.91	3003
Project area (sq. m.)	148.67	90	93.94	592
Number of floors	1.54	1	0.60	3003

Table 3 – Analysis of a few variables of "Base Integrada" database - Pico

Variable	Mean	Mode	Standard deviation	Count
Family members	2.78	2	1.59	904
Housing construction area - inicial (sq. m.)	125.82	120	61.59	904
Housing construction area - final (sq. m.)	92.86	90	17.81	904
Project area (sq. m.)	---	---	---	---
Number of floors	1.90	2	0.34	898

6. COSTS

Reconstruction costs were estimated to be about $12 million (€60 millions) right after the event and $25 Million (€ 125 million) after the first surveys. One year later this last estimative was kept. The final values in 2008 for the building stock were found 1.49 times the values at the time of detailing surveys (2001); while the cost for monumental structures were 2.2 times the estimates made at the same time.

The largest cost was for reconstruction, rehabilitation and housings repairs. The overall cost associated with the earthquake is estimated at approximately € 300 million (SPRHI, S.A., 2006), which includes estimated costs for reconstruction (Table 4).

Table 4 – Overall costs of the reconstruction

Category	€ Million
Reconstruction/rehabilitation of housing stock (Faial and Pico)	220
Infrastructures	30
Churches (rehabilitation)	27
New Churches (4)	10
Horta Municipality (infrastructures)	10
Schools rehabilitation	4
Total	**€ 300**

A large number of economic activities were affected by the earthquake like telecommunications, power and water supply, roads, services, commerce and tourism. The main annual event of the Horta (Semana do Mar - Sea Week) which begins on the first Sunday in August, and calls for more than 12 000 visitants (double the population of Faial), organized by various institutions connected to water sports and tourism, was cancelled as a consequence of the earthquake, with a clear social-economic impact in the island.

7. DIFFERENT IMPACTS

Soon after the earthquake the Azorean Government started the recovery program to restore normal life.

Although the region loses some economic activity quickly started with the reconstruction and redevelopment. Table 5 refers some negative and positive impacts of the earthquake during time (immediate and long-term).

Table 5 – Positive and negative impacts of Faial earthquake

Time	Positive	Negative
Immediate	--	Lives
	--	Housing
	--	Infrastructures (telecommunications, power, water roads)
	--	Services
	--	Tourism (Semana do Mar – Sea Week)
	Employment (debris removal, reconstruction and rehabilitation works)	--
	Identification of appropriate areas to live	--
	Identification of appropriate standards for reconstruction	--
	Tourism	--
	--	Cost of rebuild
Long-term	--	Lost of important natural and human landmarks

8. ACKNOWLEDGMENTS

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