**Infrastructure**

**Telecommunications**

| | |
|---|---|
| Did you have access to radio broadcasts? | O yes O no O intermittent |
| Did you have access to television broadcasts? | O yes O no O intermittent |
| Did you have access to telephone land lines? | O yes O no O intermittent |
| Did you have access to mobile phone voice lines? | O yes O no O intermittent |
| Did you have access to mobile phone text messaging? | O yes O no O intermittent |
| Did you have access to internet information or email? | O yes O no O intermittent |

**Electricity and Fuel**

| | |
|---|---|
| Was electricity supply interrupted? | O yes O no O don't know |
| If yes, for how long: | |
| Were generators used to supply electricity? | O yes O no O don't know |
| Was water supply interrupted? | O yes O no O don't know |
| If yes, for how long: | |
| Were there problems getting fuel for transportation? | O no O yes |
| If yes, please describe: | O petrol pumps damaged O general destruction O roads damaged O Other... |

**Transportation**

28. Did road damage or closure affect your normal route of transportation out of the area? O no O yes

If yes, please describe:

29. Transportation between your location and relief help was by:

O walking O taxi O helicopter O jeep O carried
O private vehicle O bus service O mules O bicycles O Other...

if applicable, secondary mode of transport:

O walking O taxi O helicopter O jeep O carried
O private vehicle O bus service O mules O bicycles O Other...

**Thoughts**

30. What are your hopes and concerns for the future?

hopes

concerns

31: Any thoughts on when their family/ the community will/ did recover:

| | | |
|---|---|---|
| Get back home | | weeks/ months/years after the earthquake |
| Children back to school | | weeks/ months/years after the earthquake |
| Working again | | weeks/ months/years after the earthquake |

# Chapter 17
# Estimating Human Losses in Earthquake Models: A Discussion

**M.A. Ferreira, C.S. Oliveira, and F. Mota de Sá**

**Abstract** Several studies and methodologies have been developed in recent years to model the number of victims and injuries caused by natural disasters such as earthquakes. Unfortunately, models and simulations developed up to now show substantial variability in the numbers of victims when compared with real values, because they do not consider a multi-parameter analysis including variables such as seismic intensity, degrees of building damage, percent of occupancy at the time of the event, individual behaviour (age, gender, mobility within the house during the shaking, etc.) or emergency response (effectiveness in response). When dealing with this topic we should separate the situation of estimation of human losses for emergency preparedness from the estimation right after a given event. In this paper the second of these issues will be analysed. People's reactions prior to and during the shaking together with the building behaviour cause great differences in the number of deaths and injuries for a given earthquake. The European Macroseismic Scale (EMS-98) provides five grades for damage classification from "Negligible to slight" damage (D1) to "Collapse" (D5). While D5 class includes total or near total collapse of the buildings, we propose a class D5[+] to represent "totally collapsed" structures separately from "almost collapsed" so as to establish a direct relation between damage grade and death rate. Data from a few events in Portugal and Italy illustrate the difficulties in estimating human losses.

## 17.1 Background

Outcomes of models and simulations developed to estimate casualties (fatalities and injuries) caused by natural events like earthquakes show systematically large differences between modelled and observed values. This paper examines some

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factors that lead to earthquake casualties as well as some conclusions obtained from recent earthquakes that can be incorporated into epidemiological studies in order to contribute to an improved rapid casualty assessment. Note that when dealing with this topic, the estimation of human losses for emergency preparedness should be separated from the estimation done immediately after a given event, such as we do in this paper.

Accuracy of the model for earthquake casualties depends clearly on the rate of occupancy and on the damage state of a building. We cannot advance with any reliable estimate if these two ingredients are not present. A more adequate description of the building damage, especially considering total collapse as well as the rate of occupancy at the time of the event are crucial elements for a more realistic estimation. For the first point, census information on building classes should be always updated especially on new construction and replacement of old construction. Totally collapsed reinforced concrete buildings may be responsible for up to 100% of the occupants' deaths. For this reason we propose a new damage level, 'D5$^{+}$' which corresponds to this damage level, solving the controversy in language between collapse in structural analysis which means "imminence of collapse", and real total collapse as we should have in estimating the death toll.

In relation to the population inside the building, a "building occupancy" indicator is proposed, which measures the percentage of the population inside the building at the time of the earthquake. Census information is very crude and possibly misleading. For instance, in the Algarve, the southernmost significant region in mainland Portugal, where important active faults exist and the most important Portuguese earthquakes (1755, 1969, etc.) were felt and severely damaged this region, we see that the Census does not have a count of population that includes, for example, seasonal fluctuations and mobility. This region is a very popular destination for tourists (mainly from Britain, Germany and other North European countries), which suggests that there are real differences in the demography during the year, once tourism and related activities increase in summer. In fact, the Algarve population during summer in some towns, like Albufeira or Portimão, is almost three times the Census values.[1] Another example is related to tourist centres where population numbers could easily double, as for example in Faial Island (Azores) during the Sea Week Festival (between the first and second Sundays of August) where more than 12,000 people are present, while the Census indicates only 5,000 residents (Oliveira et al. 2008).

But the problem of getting the "building occupancy" indicator at the time of the event is much more complex than simply having a good estimator of mobility. It also has to do with anticipation of the event which can disperse the population from their houses to other places where they feel safer, as has happened in recent events where foreshocks were felt.

[1]A recent study on dynamics of population was made within a Project for the Algarve [ERSTA], sponsored by the ANPC, the Portuguese Authority for Civil Protection, in which investigations of population mobility were carried out.



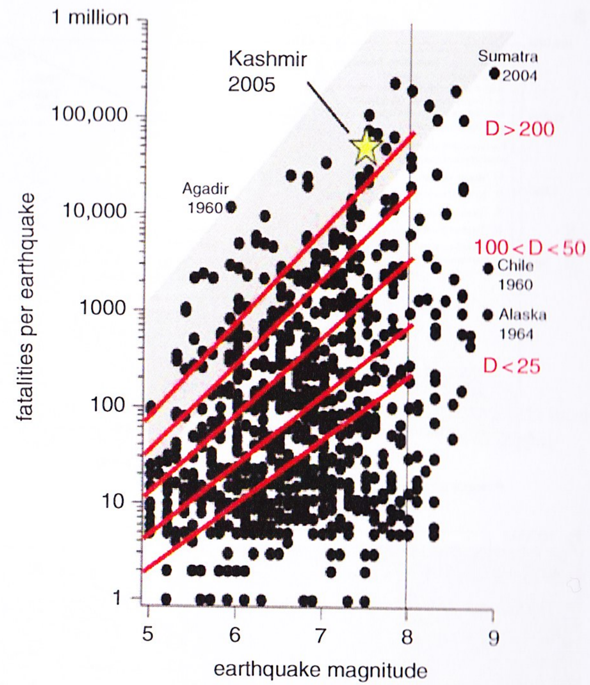



**Fig. 17.1** Relation between earthquake magnitude and numbers of fatalities for all earthquakes since 1900 (Hough and Bilham 2006) with lines adapted from Samardjieva and Badal 2002 (D is population density per km$^2$)

Figures 17.1 and 17.2 illustrate different measures of the distribution of the fatalities in earthquakes in the last century. Figure 17.1 shows that fatalities grow with magnitude starting with M5, but with such a wide dispersion that many variables need to be considered in the process to reduce uncertainties to a reasonable value. One improvement has been made by Samardjieva and Badal (2002), introducing the population density of the affected locations. Correlation with heavily damaged buildings is slightly better (Fig. 17.2) but dispersion is still so large (in some cases attaining almost five orders of magnitude) that those values are of no use in simulation. In fact, the simplified approach (Bramerini et al. 1995) that proposes a mean value of victims – casualties and severely injured – (e.g. 30% of the occupants of collapsed buildings) does not represent a reasonable rule for estimating victims, even though Fig. 17.2b) may support this assertion in average terms.

Although the fatal consequences of large earthquakes depends on their proximity to urban populations, the vulnerability of dwellings including the construction type and quality and population density (Hough and Bilham 2006) (Fig. 17.3), it is also certain that some variables like "building occupancy" and "population dynamics" during the day, weekends and for different periods of the year, cannot be discarded in these studies and estimations.

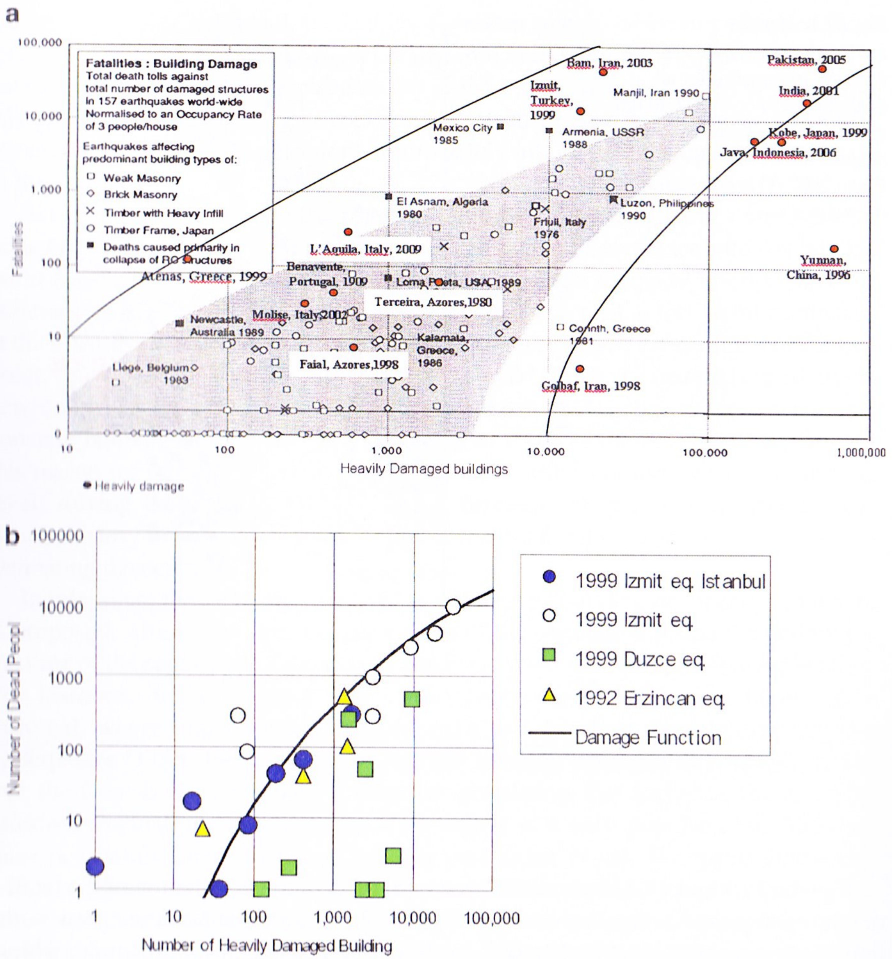



**Fig. 17.2** Relation between heavily damaged buildings and the number of resulting deaths: (**a**) adapted from Coburn and Spence 2002; (**b**) Erzincan and Izmit earthquakes (Mouroux and Le Brun 2006)

## 17.2 Results from Recent Earthquakes

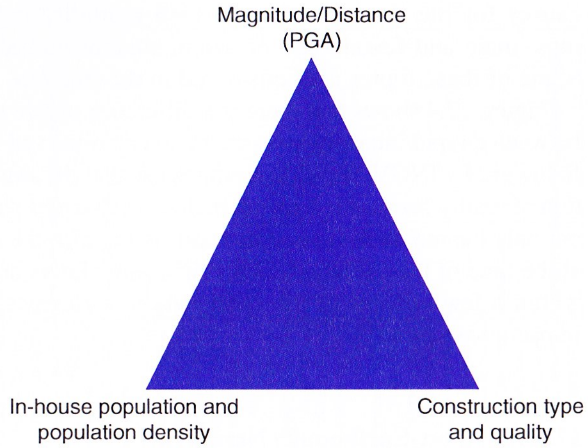
### *17.2.1 L'Aquila Earthquake (Italy)*

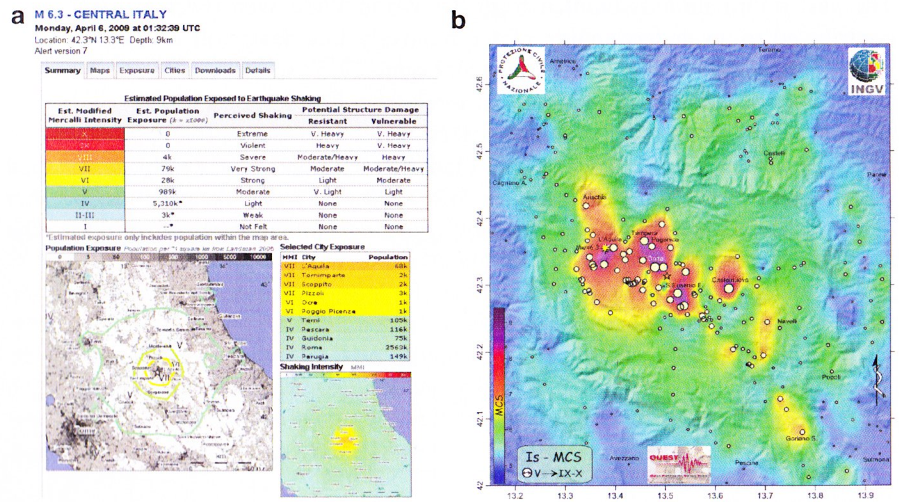
On 6 April, 2009 at 03.32, an earthquake ($M_L$ 5.8) rocked the mountainous Abruzzo region of central Italy reaching a maximum intensity of IX–X on the Mercalli-Cancani-Sieberg scale (Fig. 17.4).

Obituary data from the regional newspaper (www.ilcentro.it) were analysed and a database was constructed with all the related information: place of death (sometimes with the exact address), age, nationality, gender, and other variables



**Fig. 17.3** Main variables influencing human losses estimations




PAGER (Prompt Assessment of Global Earthquakes for Response), Imax=VII (www.usgs.com)

Real intensities obtained after some analysis (Galli and Camassi, 2009) Imax=IX-X

**Fig. 17.4** Comparison between estimated and real L'Aquila intensities

(Ferreira 2009). On 20 May the estimated number of victims was 306, including 22 children (from 4 months-old to 14 years old). The earthquake also caused 1,500 injuries (10% severely injured). According to Italian Civil Protection reports, around 62,200 persons were homeless: 24,300 were being housed in hotels near the Adriatic Coast, 9,400 found accommodation with friends or relatives, and 28,500 were living in tent villages (www.protezionecivile.it, 21 May, 2009). Once the large amount of data has been compiled and analysed, a wide range of discussion opportunities were made available on certain topics from causes for the discrepancies between mortality in masonry or concrete buildings, male and female age of death, student mortality causes and much more. Some of these topics are considered in this section.

Figure 17.4 shows that there is a difference of two or three intensity scale points between a rapid intensity assessment and an observed intensity value obtained after fieldwork by INGV. We should emphasise that the simulation is a crude representation of reality because it does not include the various circumstances that characterise not only the real fault rupture mechanism but also the distribution of the population at the time of the earthquake. Of course, simulators are important to give an idea – within a few minutes of the earthquake's occurrence – about the potential of the impact consequences.

#### 17.2.1.1 Post-Earthquake Numbers

The vast information assembled from the World Wide Web (Ferreira 2009) has contributed to an understanding of the relatively low death toll as well as other information freely available and updated. Figure 17.5 summarises the evolution of the number of fatalities during the first week from 6 to 13 April, 2009.

According to the 2007 Census (www.comuni-italiani.it) the population of L'Aquila province is 72,500; if we divided the total number of deaths by the total population we obtained a mortality rate of 0.42%. It is also clear that the number of female casualties is higher than male, suggesting a different behaviour during the earthquake shaking.

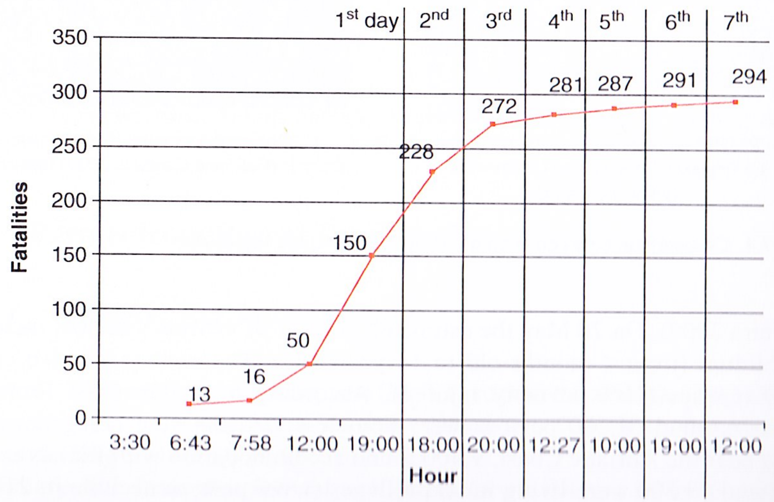



**Fig. 17.5** Estimates of the number of victims during the first week (Ferreira 2009)



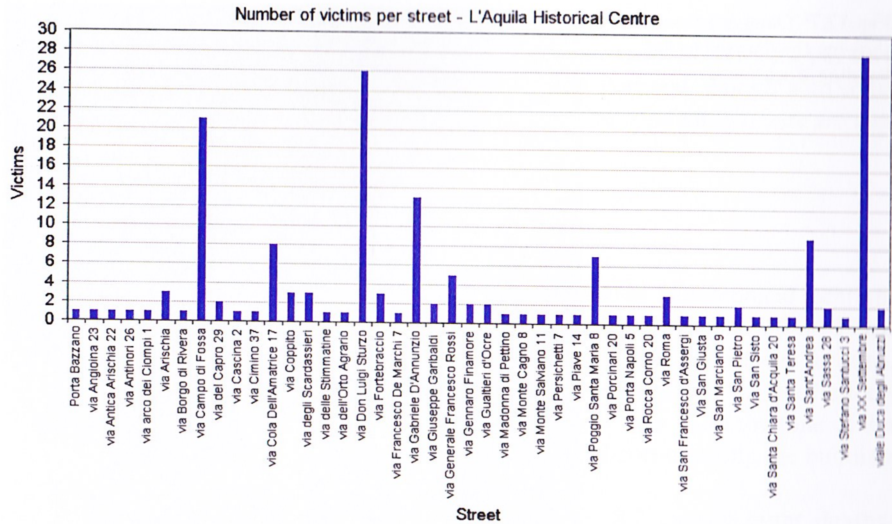



**Fig. 17.6** Number of victims per street – L'Aquila Historical Centre ("Il Centro" newspaper)

In L'Aquila historical centre where 199 people died, the pattern was essentially 6–8 deaths per totally collapsed building, here identified as D5⁺ damage level. Counting only these, one arrives at about 30–40% casualty rate for buildings having D5⁺. The worst conditions were 10–14 fatalities per building, which occurred on Via Campo di Fossa 6–6B, Via XX Settembre (Casa dello Studente – dormitory of the University of L'Aquila – with 11 fatalities) or at Via Don Luigi Sturzo, 39, where ten victims were found. Figure 17.6 illustrates the number of victims per street. The other 100 deaths were groups of 1–2 persons spread throughout the region. The number of deaths in localities situated in the valley (near the fault trace) was about 1–3 per locality (rural areas) with the exception of Onna and Villa Sant'Angelo where the death toll must have been 1–3 per collapsed building.

#### 17.2.1.2 Understanding the Death Toll

Despite the considerable destruction that has occurred in L'Aquila province, relatively low casualty rates were verified and could be explained by:

1. Felt seismicity in the 2 months before the earthquake frightened many people and some of them had decided to sleep outside. On 30 March 2009, for example, some panic occurred among the L'Aquila population due to several shocks, forcing the closing of four schools after a technical inspection which demonstrated moderate damage to these structures. L'Aquila University was also closed and the *Casa dello Studente* was evacuated for 3 hour after the 30 March event. The warning announced by Giampaolo Giuliani from Laboratori Nazionali del Gran Sasso (although the earthquake occurred about a week later than he had

**Fig. 17.7** Onna aerial view showing the damage to the building stock

predicted and at another locality – Sulmona about 70 km south of L'Aquila) and the foreshock 4 hour before the main event also contributed to saving a great number of lives (Ferreira 2009). A few families moved house in order to feel more secure close to their relatives or were camping in their own gardens or sleeping in the cars near their homes.

2. Many houses in L'Aquila are second homes used only at weekends. The earthquake occurred on Monday at 03.32 h when many such people were in their main homes out of L'Aquila.

By contrast, high mortality was verified among young people, students that returned back from the weekend to L'Aquila and were caught by the earthquake in their apartments or *Casa dello Studente*. Also, high mortality was observed in highly vulnerable rural or semirural areas with a poorly built environment like Onna, where among 350 inhabitants living in 150 houses (1–3 storeys) there were 40 deaths, corresponding to a death ratio of 11%. A preliminary Onna assessment (aerial view) indicates that about 50% of the building stock suffered total collapse (D5⁺) (Fig. 17.7).

### 17.2.2 *Azores and Benavente Earthquakes (Portugal)*

In this section we present casualty information on a few earthquakes that shook mainland Portugal and the Azores islands during the last century. In Portugal, for low rise masonry buildings the rate of mortality according to historical data is very



small, either on the Continent or the Azores, with the exception of the 1755 Lisbon event. In rural and historical urban areas analysed, the construction typology is very similar throughout the different geographic regions of Portugal, though with some differences in materials which are region-dependent; the population habits are also very similar throughout Portugal.

#### 17.2.2.1 Azores Earthquakes

The Azores archipelago is a high seismicity region due to its geographical location, near the triple junction of the Euro-Asian, African and American plates (Fig. 17.8). The $M_w$ 7.2 Azores earthquake that occurred on 1 January 1980 devastated Terceira, São Jorge and Graciosa islands at 16.42 h causing a death rate of 0.1% of a total population of 60,000 affected by Intensity(MMI) greater than V. At the time of the earthquake, many people were outside in the streets and consequently the building occupancy was very small. Sixty-three people died.

The 1998 Faial earthquake which measured $M_w$ 6.2 caused eight deaths, hundreds of injuries, and 2,500 homeless. In Faial 35% of the buildings were affected (at damage grade from D1 to D5); in Pico 10% of buildings were affected. The housing stock is predominantly one to two-storey stone masonry houses. Death and injury rates were very low (death rate: 0.05% of the population of 15,000) considering the immense damage observed.

The authors believe that the following factors may have been responsible for this low death rate:


**Fig. 17.8** Main seismicity in Azores Archipelago Central Group with epicentral locations of earthquakes from 1757–1998

1. As a direct consequence of emigration a high number of houses are secondary homes (seasonal), with no occupants during July. Some buildings have been abandoned for years and an old and vulnerable housing stock appeared to be contributing to the damage.
2. The outwards collapse of outer walls, leaving in place the inner partition walls which protected the inhabitants from the fall of roofs (the earthquake occurred at 05.00 h when most of the inhabitants were sleeping or still in their homes).
3. A foreshock took place 20 min before the main shock, which probably initiated some individual escape action.

#### 17.2.2.2 The Benavente Earthquake

Benavente is a municipality of continental Portugal where the $M_w$ 6.2 1909 earthquake, caused by rupture in the Lower Tagus Valley Fault Zone, destroyed a few villages. A maximum intensity of VIII–IX (EMS-92) was felt in Benavente and VI–VII (EMS-92) in Lisbon (Fig. 17.9).

Benavente municipality in 1909 had a population of 3,557 inhabitants and about 400 buildings (950 dwellings). The earthquake killed 30 people, 0.8% of this total population, and 40% of housing stock was demolished.

The authors believe that the apparent low impact in lives was caused by:

1. Time of day. At 17.00 h a majority of the inhabitants, mostly agricultural workers, were out in the open, working on their land.
2. Roofs and partition walls survived, with no collapse, though the outer walls of buildings collapsed, killing a few children that were playing near the houses (Rodrigues D'Azevedo 1926).

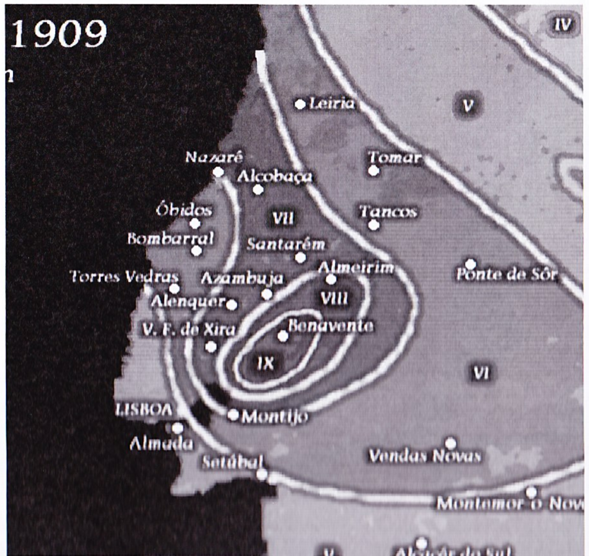



Fig. 17.9 Benavente isoseismal map (Moreira 1984)



## 17.3 Human Casualty Models: Making the Count Right

Ensuring a fair and accurate population count is one of the key components developing human casualty models. Human casualty models should be looked fr two different perspectives:

1. To design a system for civil protection, insurance, urban planning, etc., wher population scenario has to be developed, population dynamics have to included for a more adequate model.
2. For rapid casualty assessment and emergency response in the case of a gi earthquake, it is important to develop a human behaviour model in order produce better results than the ones obtained with current scenarios/mod Apart from the population dynamics by time of day and season, to give m consistent information the model should include, among others, the follow "building occupancy" indices:

- Signs of prediction
- Early-perception
- Panic reaction

These indices are very difficult to determine, but the examples presented Section 17.2 show how critical they may be for a more accurate estimation human casualties.

When analysing complex topics, we have to avoid over-simplification of problem, losing sight of the relevant aspects of it and losing sight of the ta problem. Thus, mortality rate computations cannot be explained in a strai forward manner using only the Census data due to the fact that mobility, example, is not taken into account in many cases. In addition, as referre above, other factors can significantly influence the "building occupan index.

In a tentative effort to give indications of human losses for masonry and r forced concrete buildings, after a simplified analysis of damage grades obse during several earthquakes we concluded that:

1. For masonry buildings the chances of survival for D5⁺ look higher than in buildings.
2. For RC buildings, total collapse (D5⁺) means a small chance of survival consequently, very high values of mortality rate (as high as 70%) as is well d onstrated in the recent Haiti M7.0 earthquake (12 January, 2010 –http://w telegraph.co.uk/) that has occurred without any warning.

Thus, we propose a qualitative graph (Fig. 17.10) which tries to explain evolution of mortality rate taking into account the type of structure and dam grade. To become of quantitative value, this proposal requires an analysi more data in a homogenised way; and this data collection can only be don investigation immediately after the event.

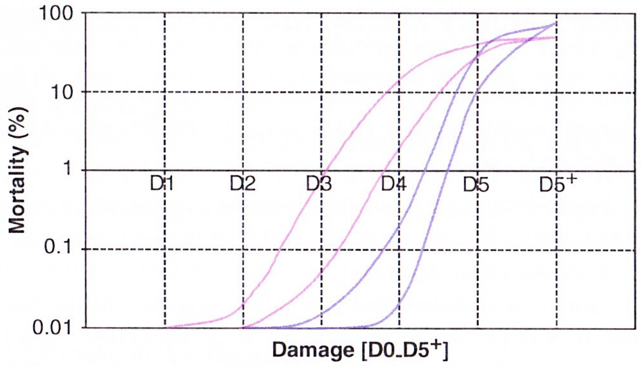



**Fig. 17.10** Proposed qualitative relationships between building damage grade (masonry – magenta; reinforced concrete – blue) and percentage of deaths

## 17.4 Conclusions

Casualty estimation is a very uncertain issue; it depends on a variety of parameters among which are the damage level and the occupancy rate at the time of the event. It also depends on the population's behaviour during and after the event especially to avoid the consequences of aftershocks. It is very important to be aware of these parameters for a better understanding of the behaviour of the population prior to an earthquake, carefully separating the different variables affecting the process. We cannot be satisfied with the results of present models. In this chapter several topics have been discussed and some suggestions have been made which it is hoped may lead to an improvement of casualty estimation models for future application.

**Acknowledgments** Mónica Amaral Ferreira is grateful for a research grant provided by Fundação para a Ciência e a Tecnologia (*SFRH/BD/29980/2006*).

Web links:

http://www.comuni-italiani.it/ (consulted in May 2009)

http://racconta.kataweb.it/terremotoabruzzo/index.php (consulted in April 2009)

http://portale.ingv.it/real-time-monitoring/quest/lavori-recenti-sull-area-aquilano-teramana/2009-08-06.8806198646/download (consulted in October 2009)

http://www.protezionecivile.it/ Emergenza sismica in Abruzzo, 6 Aprile 2009. Assistenza alla popolazione. Aggiornamento ore 08.00 del 21-5-2009 (consulted in May 2009)

http://www.telegraph.co.uk/news/picturegalleries/worldnews/6987916/Haiti-earthquake-aerial-and-satellite-photos-of-Port-au-Prince-from-the-air-and-space.html (consulted 17 January 2010)

# Chapter 18
# Trends in the Casualty Ratio of Injured to Fatalities in Earthquakes

**M. Wyss and G. Trendafiloski**

**Abstract** The worldwide ratio of injured to fatalities in earthquakes, $R = \text{Inj/Fat}$, has increased over time. This shows that it is more likely by approximately a factor of 2 that a person survives an earthquake today than 50 years ago. However, any meaningful analysis of R requires (as a minimum) separation by type of country and by location of epicentres (land or offshore). R in earthquakes beneath land is typically half of that for events offshore. R in the industrialised world is about two to three times larger than in the developing world. The countries that have made the greatest progress in protecting their population are Japan and China. Countries where R has not increased with time include Iran, Turkey, and Greece. The basic trends are clear, but the data sets for some individual countries are too small for the averages to be considered firm. We propose to use R to adjust the casualty matrices for estimation of human losses due to earthquakes worldwide.

## 18.1 Introduction

Estimating human losses due to earthquakes in real-time and scenario mode is becoming more necessary as the world population increases dramatically. Methods and data sets for estimating losses have been improving. However, they are still rudimentary for many parts of the world and for many aspects of the problem. We think that progress can be made in estimating human losses in earthquakes by modifying collapse rates of buildings and casualty matrices such that the historically observed casualty ratio, $R = \text{Injured/Fatalities}$, is correctly calculated. There are approximately 300 earthquakes since 1950 for which the numbers of fatalities and injured is known, after excluding events for which the data are not useful for one of the reasons given below. We are in the process of preparing and analysing this data set in such a way that we can use it for calibrating casualty matrices for earthquakes in developing countries.

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