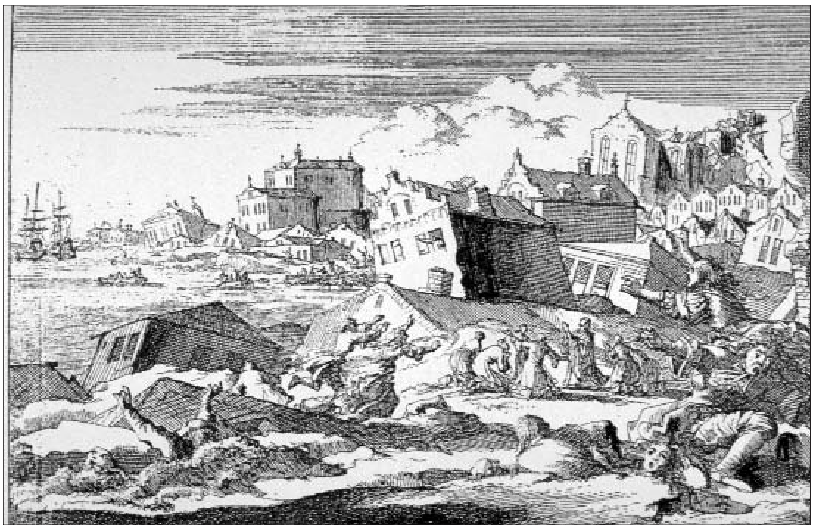
Seismic hazard awareness – a historical perspective

The 250th anniversary of the 1755 earthquake that hit Lisbon fell on 1 November 2005. Denis Camilleri (F) looks at how this event influenced the way we approach seismic hazards



Dramatic scene of Lisbon with buildings tilted and fallen, people falling into fissures, etc. (C18 Copper engraving) ***All engravings Courtesy Kozak Collection, EERC, University of California, Berkeley, and The British Historical Society of Portugal***

The earthquake occurred at around 9.40h on the morning of 1 November 1755 devastating the city of Lisbon, in Portugal, killing between 90 000 of the 275 000 population. It was strongly felt in the south of Spain and Morocco, where 10 000 were killed, and in almost all of Europe, in the Azores and Madeira Islands.

It was followed at 11.00h by a tsunami which covered the harbour and downtown areas, its flow and reflux covering a distance of 250m with the waters raised by 5m. Besides the damage caused by the seismic movement, a great fire burned for 6 days, increasing the number of deaths and material damage. 85% of Lisbon's buildings were destroyed either by the earthquake or the fire.

This earthquake and others in Europe, particularly those which occurred in Calabria 1783 and Messina in 1908, stimulated renewed interest in the phenomenon of earthquakes and provoked an intellectual debate which helped scientific explanation finally to divorce itself from religious dogma. The Lisbon earthquake was a devastating event which stimulated intellectual cross-disciplinary discussion from the likes of Voltaire, Rousseau and Kant. It took place when churches were full of the devout attending All Saints' Day mass. This helped contemporary intellectuals to ridicule prevailing beliefs that earthquakes and other natural disasters were 'divine retribution'. Voltaire's '*Poem on the Lisbon disaster*' pointed out the irony of the effect on the devout city, whilst dancing continued in vice-ridden Paris.

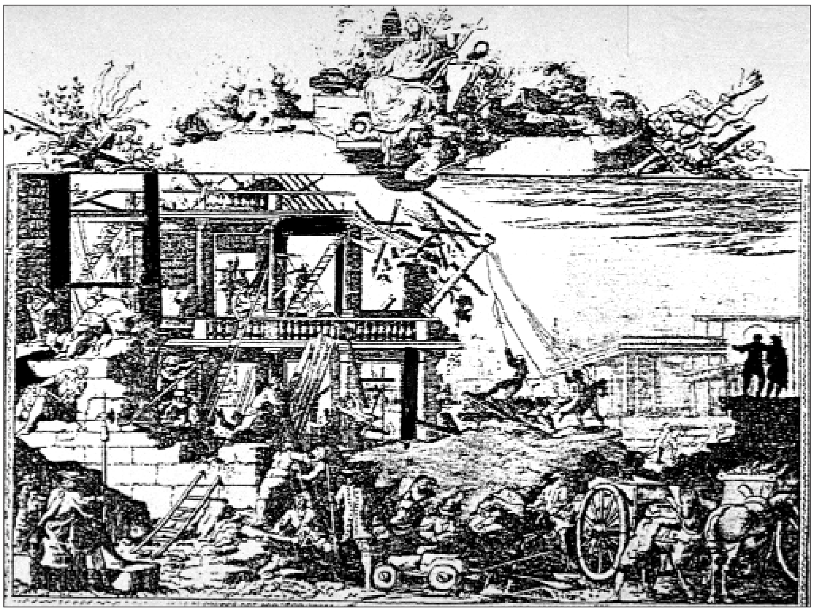
Lisbon a few days after the earthquake. Camping outside the damaged town, executions of robbers and looters (Copper engraving, Germany, 1755; Lisbon)

Politicians, risk managers and emergency relief agencies still have much to learn from the pragmatism and efficiency demonstrated in the aftermath of the Lisbon seismic event. King Joseph I's Prime Minister, Sebastião de Melo was completely in command from day one of the earthquake. The first tasks were to dispose of the dead and feed the living. The stagnant pools were drained, with troops from the provinces helping to stem the tide of survivors swarming out of the City. Able-bodied men and skilled workers were ordered back to help with fighting the flames, clearance of streets and demolition or repair of damaged structures. Tents, huts and other temporary shelters were erected for the homeless, profiteering in wood was stopped and available supplies of timber were commandeered. Landlords of lodgings which had survived the earthquake were not allowed to raise rents, allowing existing tenants to return to their properties. Assessment of the effects was undertaken with questionnaires being sent out asking people how many shocks were felt and what kind of damage was caused. Some of the questions are the same as those asked nowadays. These reactions are in marked contrast to the relief organisation following the recent Hurricane Katrina in the United States.

A starting point

The Lisbon earthquake had a tremendous impact on the development of seismology and indeed has been characterised as the starting point of modern seismology. Differences between deep, intermediate and shallow earthquakes were identified and their ground effects were described mainly in a qualitative fashion. Earthquake catalogues were compiled in the aftermath of the Lisbon disaster.

It was recognised that the rebuilding should be supervised and unauthorised building in stone or brick was stopped. Engineers and architects were given charge of the subsequent planning and



Left: Ruins of the Carmo convent preserved in memory of the earthquake

Right: Repairs and new construction after the Lisbon earthquake (C18 Copper engraving)

rebuilding of new Lisbon. The earthquake was also responsible for one of the earliest recorded building laws. It was proposed that no building should be taller than the street width and that they should be limited to two storeys. Similar rules for structural configurations of masonry buildings have been recently implemented in modern seismic standards, as in the Italian seismic code 2003, where specific rules account for building heights (H) with respect to street widths (L) in zones of high (0.35g) and moderate (0.25g) seismicity. EC 8 *Design of structures for earthquake resistance*, defines a high seismicity zone (0.1g), a low seismicity zone (0.05g – 0.1g) and no seismic design necessary for 0.04g, where the probability of exceedance of a failure stands at 10% over the design life of the building at 50years, i.e. a return period of 475 years. A so called timber cage, *gaiola* using flexes at each corner to withstand lateral forces has been described as the first recorded development of a method for reinforcing masonry buildings to resist earthquakes. Mortared stone provided another form of bracing and a shear wall was also designed to resist lateral deformations.

A few decades later in 1783, during the Calabrian earthquake in Italy, it was noted that the only building left standing in the village of Filogaso was a wooden planked structure built according to the Lisbon regulations. Following this event the authorities recommended that timber members should link the roof to the foundation, with transverse reinforcements in the form of diagonal members and light timber shingle roofs replacing the traditional heavy tiling system. Lightweight shingle roofs replaced the traditional tiles. The common adobe buildings were limited to a single-storey and the use of small stones, good quality bricks and a suitable mortar was advised. A timber framework was further prescribed encased in the masonry. This predates later earthquake-resistant design principles of tying the building together as a unit which, together with symmetric construction demonstrated optimal building configuration. There is even evidence that those not adhering to the rules had their buildings demolished, at least in the following years. This demonstrates that checks and quality control were undertaken.

Following ground shaking in Calabria in 1854, the Government of Naples developed a plan for iron reinforcement of buildings. They were the first to adopt the use of iron for earthquake resistant construction. Following the 1908 Messina earthquake an engineering professor recommended that the first storey be designed for a horizontal force equal to 1/12 the weight above, whilst the second and third storeys be designed for 1/8th of the building weight above. This method, which still survives today, was the first example of seismic design implementing the equivalent static method.

After the 1923 Kwanto earthquake in Japan (M=8.3), the design shear force coefficient was increased to 1/10th. In 1933 and after many severe earthquakes, the Los Angeles City Code in the US introduced the same formula, but specified a range of values from 0.08 up to 0.01. Not until 1943 was it realised that the height of the building had an influence on this coefficient and account was taken on the flexibility of the structure.

In 1959 the Structural Engineers Association California developed the equivalent static forces method taking note of the ductility and natural frequency of the structure, which with further modifications found its way in common global practice as the equivalent static analysis[1].

Approaches to protection

In 1913 two types of protection were discussed. The first, compensation through insurance of property owners and the second, inspections and quality control of buildings to prevent structural damage and loss of life. The present cover in Europe for natural disasters is as follows:

- Countries where the state intervenes or participates in the insurance arrangements include – Spain, France, Norway, Netherlands, Switzerland and Turkey.
- Countries where the state does not intervene include – Germany, Austria, Belgium, Denmark, Finland, Italy,

The old town, Lisbon

Poland, Portugal, Czech Republic, United Kingdom and Sweden.

- The prevention of vulnerability for these natural hazards is mostly catered for by the provision of building codes and by a mandatory requirement for property to be covered by an insurance policy for damage caused by natural catastrophes.

Earthquakes do not kill people, it is the buildings that do. In 1990 there were 90 super cities around the globe, with populations exceeding 2M. At the turn of the new century there were 160 super cities, of which 70% are in seismic zones, likely to experience damaging intensities of seven or more. With the doubling of estimated global population in 75 years, the growth of super cities will outstrip population growth, as the magnet of economic earning power draws people into the urban areas[2].

The design of buildings for seismic action is a major challenge to the structural engineer for the 21st Century. Earthquakes should roll under our buildings as the weather rolls above them without any loss occurring. Presently the reduction in earthquake losses is low, as research activity focuses on sophisticated engineering, with most losses suffered in developing countries and in non-engineered or low-engineered structures. It is claimed that only 2% of all the world's R&D is directed towards the problems of the developing countries[2].

The historic centre of Lisbon today; 85% of the town's buildings were destroyed in the 1755 'quake

Acknowledgment

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REFERENCES

1. 1. Beckett, A. A. *Introduction to Eurocode 2, Design of concrete structures* (including seismic actions)', E &FN Spon 1997
2. Coburn, A., Spence, R. *Earthquake protection,* John Wiley & Sons, Ltd 2002