

ENGINEERING ASPECTS OF THE JANUARY 1ST, 1980 AZORES EARTHQUAKE

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SUMMARY

A destructive earthquake struck the Azores Islands in the afternoon of the January 1st, 1980. Sixty people were killed and 20 000 remained homeless due to the total collapse or severe damage in poor masonry traditional construction dwellings. Recent small size reinforced concrete (R.C.) structures behaved well although a few require repair. A technical mission of LNEC visited the affected area in the week after the earthquake. This paper presents the preliminary available information, focusing the engineering aspects of the earthquake.

GENERAL DESCRIPTION

A destructive earthquake of Richter magnitude 7.0 occurred in the northern mid Atlantic ridge at 16: 42: 39 GMT on January 1st, 1980 and affected the Central Group of Azores Islands. According to the determination of the Boulder University in Colorado (USA) the epicenter was located at 38.76° N-27.73° W and the focal depth was 10 km (Fig 1). The earthquake was followed by a large number of aftershocks with epicentral locations in four different areas (Fig 1). The tectonic mechanism of this earthquake is still under study but the available information suggests that it had a strike-slip faulting generation.

The main event caused 60 deaths and severe damage in Terceira and S. Jorge islands and moderate damage in Graciosa. It was clearly felt in Pico and Faial islands where it triggered a strong-motion instrument. Overall damage is estimated at US \$ 100 million. 22 000 out of a 55 000 inhabitants in the 3 islands remained homeless. Even though the final isosseismal map is not yet available, preliminary estimation of intensities anticipates a maximum MMI = VIII occurring in small areas of Terceira and S. Jorge islands. A brief inspection along the peripheral road where the population lives provided a first evaluation of the damage distribution (Fig 2). In the town of Horta, 80 km from the epicenter, the accelerogram recorded (Fig 3) shows a peak horizontal acceleration, a_{max} , of 50 cm/s² and a slightly smaller vertical component. Preliminary response spectra are presented in (Fig 4). Based on that a_{max} and taking into account the different epicentral distances, a value of 100-150 cm/s² seems a credible estimation for the a_{max} in Terceira Island. These values are in agreement with the observed MMI.

According to a seismic hazard study for the Azores Islands (Ref.1), a_{max} for 100 and 1000 years return periods in the Central Group Island are respectively 100-120 cm/s² and 180-240 cm/s². Thus, it seems that the Jan 1st, 1980 earthquake is quite likely to occur in the islands during a standard lifetime.

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EFFECTS ON BUILDINGS

The constructions in the islands can be classified into the following four categories: a) recent R.C. structures of small to medium size; b) recent small size buildings with some degree of modern construction technology; c) old monuments (churches mainly) and d) traditional construction dwellings up to three floors either in urban or in rural areas. The behaviour of each of these categories during the earthquake was clearly different from each other. The more important aspects of their performance are briefly presented below. For a more detailed description see (Ref.2).

In general terms, the few R.C. structures existing in the island behaved satisfactorily. The relevant exception are the high school building and the hospital both in the Town of Angra. The former is a T shaped three storey building. Its two wings have approximately 110 x 20 m and 45 x 20 m plan dimensions and are separated by several expansion joints. These joints are formed by a small R.C. cantilever simply supporting the adjacent beam. Almost every joint shows evidence of relative motion between the adjacent zones and in some cases present light to moderate damage (Fig 5). The hospital has a R.C. structure and is formed by three parallel wings. One of the wings is a "soft storied" three storey building with 80 x 15 m plan dimensions (Fig 6) sectioned by three expansion joints into four totally independent blocks. In one of the central blocks there is an eccentric masonry infilled staircase. Columns are disposed in three rows, the external ones having 35 x 35 cm cross section dimensions and the central 45 x 45. Longitudinal reinforcement is formed by $\varnothing 20$ and $\varnothing 25$ mm diameter cold worked steel bars. Total sectional steel contents are very high, reaching in some cases 8%. Transversal reinforcement is formed by $\varnothing 6$ or $\varnothing 8$ mm peripheral hoops 20 cm apart. In some cases hoops are missing originating unconfined concrete portions up to 60 cm long. Ground floor columns present severe damage (Fig 7) either at their top or base but not simultaneously. Damage may be described, in an increasing order of severity by: general spalling of the cover concrete; crushing of the column core concrete; slight buckling of very few longitudinal bars. The damage pattern suggests in almost every case a flexural mode failure although for two of the internal columns, diagonal and even spiral cracking is clearly visible. The referred infilling masonry presents severe diagonal cracking. In spite of the damage suffered by the ground floor columns no permanent displacements in the building are apparent.

In a factory with a R.C. structure some damages occurred. One section of the factory has a five storey high infilled framed peripheral structure. There are no floor slabs leaving an open space for tall machinery. Structural elements present only slight cracking (mainly in beams). However, due to the great flexibility of the structure, important damage occurred in the infill non-structural elements (diagonal cracking in masonry and breakage of glasses). Inside an adjacent storehouse with a steel structure which had no damage, metallic racks having no seismic resistant provisions and supporting 160 000 liters of milk toppled (80 000 liters were lost).

Similarly to R.C. structures, recent small size buildings behaved very well. This type of buildings may be described as having: rectangular plan with dimension up to 15 m; one or two storeys; solid concrete block walls; light wooden interior partitions and roof structure; peripheral R.C. lintels at the floor and roof levels; in some cases corner R.C. columns.

Contrasting with the good performance of the two first categories of

constructions the behaviour of the other two categories was very bad. Old monuments, mainly churches suffered large destructions. Damages consists of severe wide spread cracking in the thick, poor masonry, peripheral walls and collapses of the towers (Fig 8). Roofs in almost all cases are made by ceramic tiles resting on wood structures. No roof collapse was reported but they suffered damages caused by the impact of falling debris.

Finally, constructions in the fourth category, consisting of poor masonry dwellings, were heavily damaged. This type of construction, generally two storeys high in urban areas and one storey high in rural zones has very heavy and thick (60 - 70 cm) peripheral stone masonry walls with mortar of poor quality. Generally, orthogonal walls have no tying-in at the corners. Floors and roofs, as well as internal partitions have light wooden structures. Damage was very heavy, mainly in the masonry walls (Fig 9 and 10) which suffered complete desaggregation. In some locations over 90% of the houses were damaged beyond repair. Comparatively, the light elements behaved better. In some instances, in spite of the total collapse of the external walls, the roof rested on the internal partitions. Furthermore, in most cases the collapse of the masonry walls seems to have been triggered by transverse forces (upper floors), instead of by excessive in-plan shear (lower floors).

OTHER ASPECTS

Other engineering facilities affected are retaining walls, light-houses and small old bridges. The most illustrative example of damage inflicted to a life-line system is the complete disruption of the aerial power distribution network in Angra. The total or partial collapse of city dwellings where the electric wires were attached, originated such destruction. In other cases the fixing system were pulled out by the wires themselves.

ACKNOWLEDGEMENTS

Colaboration of Dr C.S. Oliveira who visited also the Azores is thankfully acknowledged. The accelerogram was obtained from Instituto Nacional de Meteorologia e Geofísica. Response spectra were computed by Dr. R.T. Duarte.

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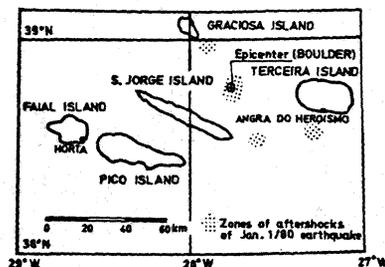


Fig.1 - Jan 1st, 1980 earthquake epicenter

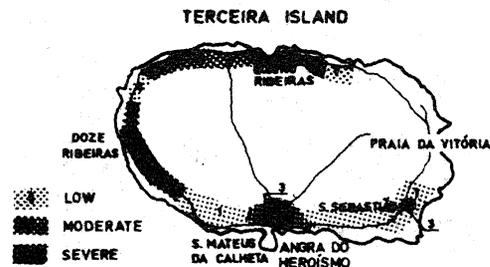


Fig.2 - Damage distribution

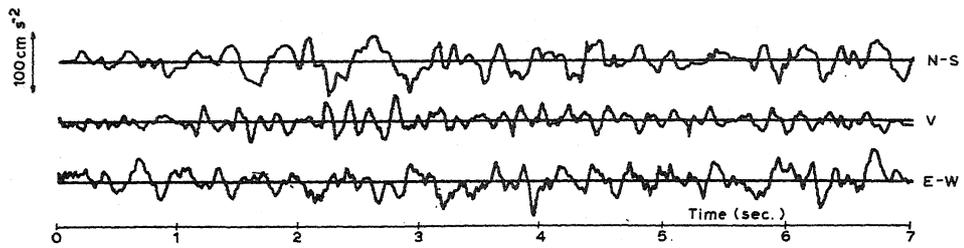


Fig. 3 - Main portion of accelerograms recorded at Horta

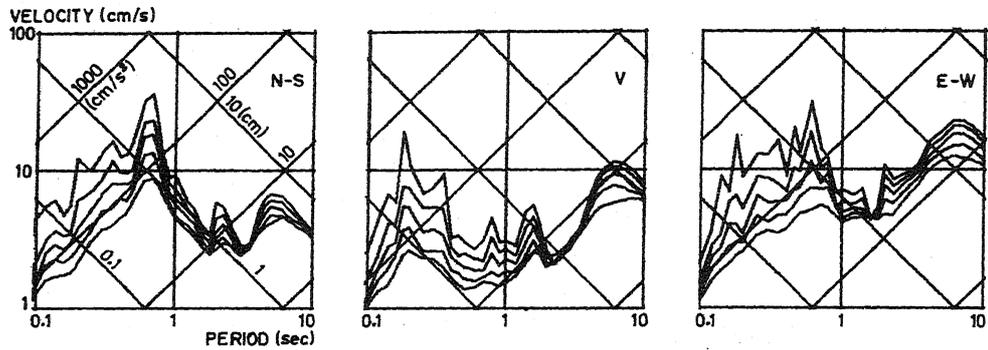


Fig.4 - Computed response spectra for 0,0.02,0.05,0.1,0.2 damping (preliminary)



Fig.5-Damage at expansion joint

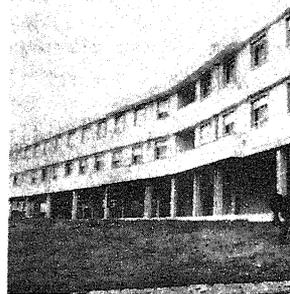


Fig.6-General view of Angra Hospital



Fig.7-Detail of column hinging



Fig.8-Damage in old church



Fig.9-Damaged traditional rural dwelling



Fig.10-Damaged urban construction (Angra)