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EFFECTS OF GEOLOGY AND SOILS ON DAMAGE CENTRAL CHILE EARTHQUAKE OF MARCH 3, 1985

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SUMMARY

A detailed field study of intensities in the Central Chile earthquake of March 3, 1985 was developed in the damaged area, 450 Km. North-South by 120 Km. East-West, approximately, analyzing the damages of one story adobe and masonry dwellings. Relations between seismic intensity and geology, geotechnical properties of soils, water table level and distance to the dislocated area for this subduction earthquake were established. The methodology and main results are described and future applications mentioned.

INTRODUCTION

The March' 3, 1985 earthquake in the central region of Chile had a magnitude 7.8. The epicenter was located at the sea between Valparaíso and Algarrobo, Fig.1, 20 Km. away from the coast with a focal depth of 15 Km. approximately. The length of rupture was 170 Km. in North-South direction and its width was 100 Km. The earthquake belongs to a series of destructive earthquakes of magnitude larger than 7 1/2 that occur in the same epicentral area with a remarkable periodicity of 85 +/- 6 years. The area affected by the earthquake has about six millions inhabitants, half of total population of the country. It was destructive enough to originate a considerable number of damaged houses reports in the cities and villages of the macroseismic area, which were the base of this study.

METHODOLOGY

The methodology consisted in the study of the reports, identifying the cases of one story adobe houses, which were assimilated to the type A of ref.1, and those of one story unreinforced masonry houses, which were supposed to belong to the type B of that scale. In case of lack of buildings of these characteristics, type C houses of reinforced masonry were also considered. A degree of damage was assigned according to the description in each report: 1 for small damage, 2 for moderate, 3 for severe, 4 for partial collapse and 5 for total collapse. All the houses with degree 4 or 5 and many with degree 3 of damage were checked at the field. A more detailed definition can be found in ref. 2.

The main cities were divided in sectors of approximately one square kilometre, each of them located on a same kind of soil. Since the determination of the degree of intensity is based on the statistical behaviour of houses of the

same type, the size of the group is important : fifty or more houses were considered sufficient; twenty was the minimum acceptable. Furthermore, since the reports may not include houses with minor damage, a complete survey of all the houses was carried out in a 10% to 20% of the sectors in order to check if the samples were representatives of the whole universe.

The degree of intensity is defined in ref.1 by Table 1, in which the intensity degree is related to the degree of damage. This degree was computed according to the statistical behaviour of each sample and adjusted later comparing the degrees obtained in the complete survey of some sectors with the preliminary estimation. The degrees were obtained by interpolation within the values specified in Table 1 and rounded to 1/4 of degree. A detail of this process can be found in ref.2.

Table 1. Determination of intensity degrees, ref.1.

Degree of Intensity	Buildings of Type A	Buildings of Type B	Buildings of Type C
V	Few (5%) : 1	----	----
VI	Few (5%) : 2 Many (50%): 1	Few (5%) : 1	----
VII	Few (5%) : 4 Many (50%): 3	Many (50%) : 2	Many (50%): 1
VIII	Few (5%) : 5 Many (50%): 4	Few (5%) : 4 Many (50%) : 3	Few (5%) : 3 Many (50%): 2
IX	Many (50%): 5	Few (5%) : 5 Many (50%) : 4	Few (5%) : 4 Many (50%): 3
X	Most (75%): 5	Many (50%) : 5	Few (5%) : 5 Many (50%): 4

Several available reports on geology, soil mechanics and underground water table levels on the zone of interest were gathered.

RESULTS

Fig. 1 corresponds to the area close to the epicenter and Fig. 2 shows the city of Santiago. Both cover about one fourth of the area under study, but the results take into account the observations in the whole area. The geology of quaternary deposits is shown in those figures. In addition, in Fig. 2 the iso-seismal curves are drawn. The main results are :

Rock Cities founded on rock have a low degree of intensity, for instance, $7\frac{1}{2}$ in the hills of Valparaíso and 7 in Cartagena, at epicentral distances of 25 and 52 Km., respectively. At Papudo, 98 Km. to the North of the epicenter, the degree was 6 and at Pichilemu, 133 Km. to the South, $6\frac{3}{4}$. In the ski fields at Farellones, 144 Km. to the East, no damages were observed in weak buildings built with stone without reinforcements that correspond to type A, so the degree must have been below 6.

Gravel In gravel deposits from the main rivers the degree of intensity varies between $6\frac{1}{2}$ and 7. These sites are usually located in the middle course of the main rivers, as can be seen for instance in Fig.2, with epicentral distances of

125 to 200 Km. Where fine soils with depth of about 1.6 meters cover the gravel an increase of up to 7 1/2 was observed; for thickness of 3 to 4 meters, it attained the value 8. The one-story buildings of the types A and B are founded at depths of 1 meter or less; this explains the influence of the upper layer.

Some gravel deposits are found near the epicenter. One case was Rapel, on the Rapel river, where the degree of intensity was estimated as 7 3/4. The epicentral distance was 90 Km.; another case was El Monte, at 100 Km. with degree 7 1/2

One exceptional case is the town of Puente Alto near the Maipo river, Fig.2, with an epicentral distance of 140 Km. and a degree 8. There are important changes of levels in the riverside sectors of this place and the gravel is intercalated with lenses of sand and fine soils.

Fine fluvial deposits The range of intensities is very wide in this case, from 7 1/2 to 9 1/2. One case can be seen in Fig.2, in the Northwest zone of the city of Santiago, where two small rivers flow into the Mapocho river. Due to the deposition of gravel, the main river has been increasing his bed level during the geological time. The velocity of flow of the small rivers has diminished and fine sediments have been deposited. Periodical floods have been observed in the areas covered by fine soils. The degree of intensity in this zone is 8 1/2, much higher than the value of 7 in the gravel deposits of the main river.

Fluvio-lacustrine deposits In areas with fine soils of this type, located North and South of the areas shown in Fig.1 and 2, high values of intensities were found. In an old disecated small lake South from San Vicente de Tagua Tagua, at 145 Km. to the Southeast from the epicenter a degree of 9 1/2 was established. In this case, as well as in the case of fine fluvial deposits, the underground water table is very close to the ground surface.

Colluvium Soils formed by dejection cones have in their apical zone about 1/4 of degree higher than neighbouring gravel deposits and in their lower zone, where fine soils are predominant, 1/2 of degree higher. These deposits are located at the foot of the Andes, at 135 Km. from the epicenter.

Talus deposits In Santiago, at the same epicentral distance as the dejection cones, talus deposits showed a degree 7 1/2 to 8. Very few constructions are founded on this type of soil.

Pumice tuff deposits These soils constituted by cemented volcanic ashes are found in a wide area. Pumice tuff deposits are considered by geologists to be a good foundation soil. The degree of intensity ranges from 8 in Santiago, Fig.2, at 125 Km., to 8 3/4 in areas closer to the epicenter, Fig. 1.

Dunes They are found at the coast near epicenter. At San Antonio, Fig. 1, 56 Km. to the epicenter, a degree 9 to 9 1/2 was found in slopes from 18% to 27%, while in gentler slopes it was about 8. The higher damage in the first case is caused by the failure or displacement of retaining walls parallel to the street (3 meters in height) and by the settlement of the fill sand behind them.

Artificial soils The highest degree of intensity was found in downtown San Antonio, exceeding the value of 10, in a zone where a small stream that passes through the city had been channelized and covered by an uncontrolled fill. Several settlements of foundations were observed, that led to the demolition of reinforced masonry buildings.

Slope slides At Cartagena, San Antonio, Fig. 1, and Reñaca, which is located about 10 Km. North of Viña del Mar, small slides occurred at sand dunes or creeks. Due to the small number of houses involved, no estimation of intensity was made at these sites.

Soil liquefaction Two cases of soil liquefaction were found in San Antonio with settlements of 1.0 and 0.4 meters. Other cases of liquefaction may have also occurred at the port installations of San Antonio and in a pier of the bridge over the Maipo river that connects Llolleo and Rocas de Santo Domingo (Fig. 1).

FUTURE APPLICATIONS OF THE RESULTS.

By using empirical formulae that relate maximum ground acceleration, degree of intensity, magnitude and hypocentral distance to a site it is possible to estimate how much the degrees of intensity increase for a given source when the magnitude increases. According to the historical earthquakes that have occurred in front of Valparaiso, the largest probable earthquake to consider for a construction with a life-time of 30 to 50 years is one of magnitude $M=8.3$. For this magnitude, the degree of intensity should increase in $1/2$ degree over the values of the 1985 $M=7.8$ earthquake.

The hypothesis that both earthquakes will have the same source is conservative for the areas shown in Fig. 1 and 2, which are near the epicenter. In effect, the seismic history of Valparaiso shows that stronger earthquakes have had a larger dislocation area that includes northern and southern portions of the plate not activated during the 1985 event. Their epicenter were close to that of the recent earthquake. If one supposes that all the energy of the larger earthquake is concentrated in the dislocation area of 1985, his effects should be larger. Cities or seismic microzones of cities where the degree for 1985 earthquake was $6\ 1/2$ should have 7 in the $M=8.3$ earthquake. For a degree 7, type A adobe buildings should attain the limit of an acceptable behaviour, resulting about 5% of them with partial collapse and 50% with severe damage; in a similar way, this condition should be attained by type B buildings for a degree 8, that is at zones where the intensity degree in the 1985 earthquake was $7\ 1/2$. City planners should keep this in mind when they establish the priorities for the reinforcement or substitution of old schools, hospitals and other public buildings or the remodelling of old parts of cities.

Though the intensities can be established for a given earthquake using only the observation of damage, the knowledge of relationships between seismic intensities and geological and geotechnical characteristics is important for the estimation of seismic effects in other regions where earthquake are expected to occur.

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