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Influence of the dynamic properties on the characteristics of seismic amplification in the city of Concepción

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ABSTRACT: This is a study of the characteristics of the dynamic amplification in the city of Concepción, Chile. Two dynamic models for earthquakes of medium and great intensity for the soils in the center of Concepción are proposed, and they are used to analyze the soil behavior for Chilean and American earthquakes. It can be noted that the response of the soil is totally different depending on the intensity of the earthquake acting and that for strong earthquakes, the amplification phenomenon is relegated to a second place by the constitutive properties of the weaker layers, which set a limit to the maximum accelerations that they may transmit towards the surface.

LOCATION AND STRATIGRAPHIC CHARACTERISTICS OF THE SUBSOIL OF THE CITY

Concepción, with more than one million inhabitants, is the second most populated city in Chile and is located at 36 50 meridional latitude and 73 06 occidental longitude west from the Coast Mountains. The urban zone in its flat area is limited by Caracol and Lo Pequén Hills at the south, by a series of low hills and by Amarillo and La Pólvora hills at the north. The Biobío and Andalién rivers are the urban west and east limits respectively. The subsoil on which a great part of the city was built is formed by fluvial sedimentary fillings corresponding to Biobío sands coming from the Andes Mountains and consisting of clean to silty basaltic sands with silt and sand horizons with compactness varying from loose to dense. There is a silt layer between 23 and 28 mt. deep in the center of the city. The phreatic level is found at 5 mts. deep and has a yearly fluctuation of ± 1.2 mts. Figures 1 and 2 summarize these conditions.

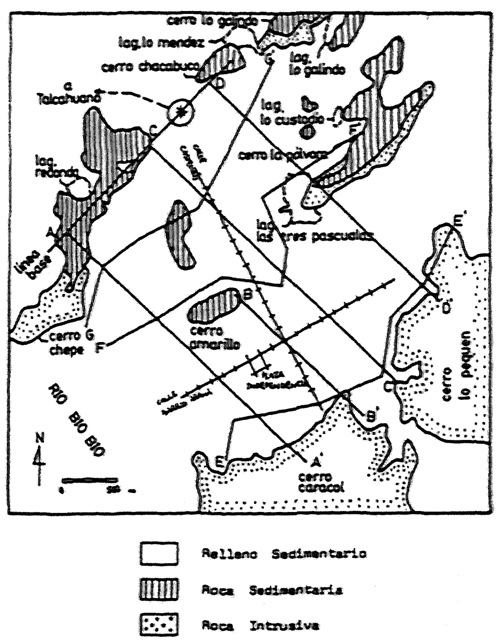

Figure 1. Reference diagram showing the profiles analyzed for the determination of the rock depth and the sediment thickness.

SEISMIC BACKGROUND OF THE CITY

The area of Concepción forms part of the seismic zone known as "circumpacific ring", one of the two zones of the greatest seismic activity in the globe. It has been proved that in Chile, between Santiago and Castro, in a period of 472 years as from 1520, there have been 47 strong earthquakes. From them, 7 have been of a magnitude comparable to the main shaking of May 1960 (8.4 Richter scale) and 8 have been associated with seaquakes or similar alterations in the sea.

A destructive earthquake may be expected to happen somewhere in the south of Chile every 10 years and a catastrophic earthquake and seaquake, every 60 years.

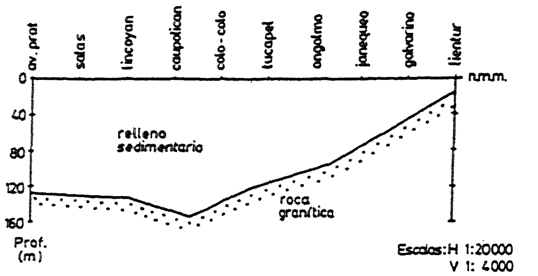

figure 2. Rock profile along Barros Arana St.

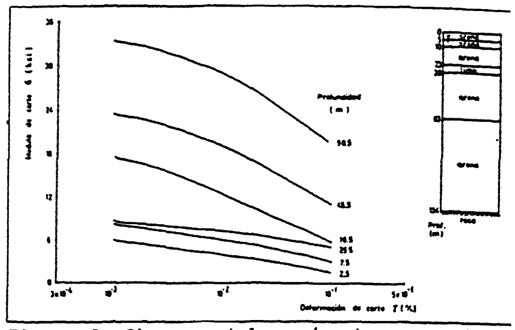

Figure 3. Shear modulus v/s shear strain, model 1.

DYNAMIC MODELLING OF THE SUBSOIL

The dynamic modelling of the subsoil has been made from the basal rock by means of gravimetric methods of electric resistivity and mechanical borings. The static parameters of the subsoil have been obtained from boring samples and statistical and probabilistic methods. The maximum shear modulus was obtained by means of wave propagation measurements made in situ and the shear and damping modulus for any strain was obtained from the proposition made by Seed and Idviss (1970). These properties of the models are shown in Figures 3, 4, and 5, where two models for the center of the city have been included in order to study in a better way the influence of the upper soils during the amplification phenomenon.

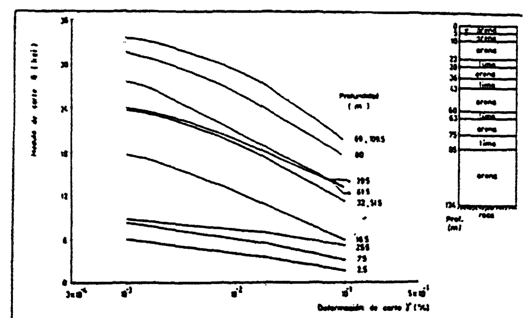

Figure 4. Shear modulus v/s shear strain, model 2.

INPUT EARTHQUAKES

The results below correspond to studies performed with the following accelerograms:
a) Pasadena, California, U.S.A. Rock record. Maximum acceleration 0,057 g.; average freguency 1.57 cps.
b) La Ligua, Chile, 1979. Rock record. Maximum acceleration 0,165 g., average frequency 6.93 cps.
c) Concepción, Chile, 1978. Modulus surface record. Maximum soil acceleration 0,091 g.; average frequency 4.57 cps (transverse component) and 4.04 cps (longitudinal component).
d) Valparaíso, Chile, 1985. Rock record. Maximum acceleration 0,145 g.; average frequency 5.61 cps.
e) Viña del Mar, Chile, 1985. Sand record. Maximum acceleration 0,3139 g.; average frequency 2.21 cps.
f) El Centro, U.S.A., 1940. Sand record. Maximum acceleration 0,3485 g.; average frequency 3.37 cps.

The records are put in the model as an excitation on the basal rock. For the case of the earthquake in Concepción 1978, it was previously reduced to the basal rock by using the proposed models. The seismic records for earthquakes d), e), and f) are

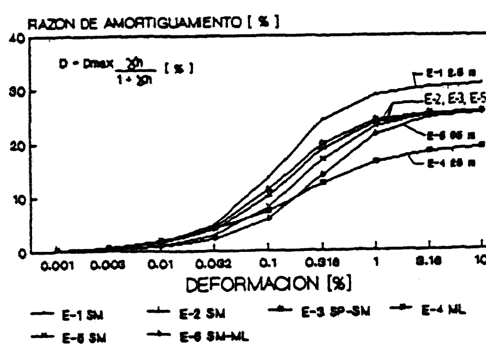

Figure 5. Damping ratio v/s shear strain for both models.

standardized for equal basal maximum accelerations corresponding to the earthquake in Valparaíso 1985. In order to have a greater variety of results, the records wer scaled so as to increase or decrease the accelerations.

ANALYSIS METHODS USED

Once the models of the subsoil of Concepció and its dynamic properties were defined, th

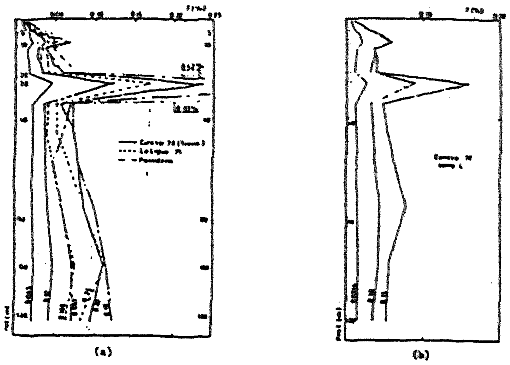

Figure 6. Maximum strain v/s depth.

the seismic wave propagation and its effects were studied. A simplified mathematic model (Kanai 1950, Duke and Mathieson 1963, and Schnabel, Lysmer and Seed 1972) was used, where the seismic waves had been idealized as waves SH propagating vertically through the horizontally stratified soil deposit. The soil is represented as a viscoelastic solid with non-linear constitutive properties. Thus a unidimensional propagation model described by a differential equation in partial derivatives in terms of horizontal displacement is obtained. In order to solve it, a Fourier decomposition was used assuming that the earthquake is a periodical function and the problem is solved in the frequency domain. The non-linearity of the constitutive properties is considered by means of an iterative process where a linear problem is solved in each iteration. In order to make the calculations, the Shake computing program was used (Schnabel, Lysmer, and Seed 1972).

EFFECTS OF THE INPUT EARTHQUAKES ON THE MODEL. RESULTS AND COMMENTS

The maximum strain distribution for the earthquakes considered has been graphed in Figure 6 a) and b) varying the maximum accelerations of the records on rock. It can be clearly observed that the greatest strain is produced in the strata of less rigidity and that when the basal acceleration is increased, the strain increases, though unproportionally, showing in this way the non-linear nature of the responses. The influence of the earthquake frequencyiis significant for equal maximum accelerations on the base, making evident that lower frequencies cause greater strains. It should be considered that Chilean earthquakes have higher average frequencies than Californian earthquakes.

Figure 7 a), b), and c) show the maximum acceleration distribution for the indicated earthquakes. For low intensity earthquakes, amplifications ranging between 2 and 3 are produced. As the acceleration on the rock is increased, the amplifications become lower and for earthquakes of greater intensity, they get reversed, being evident a rise in the surface acceleration as regards

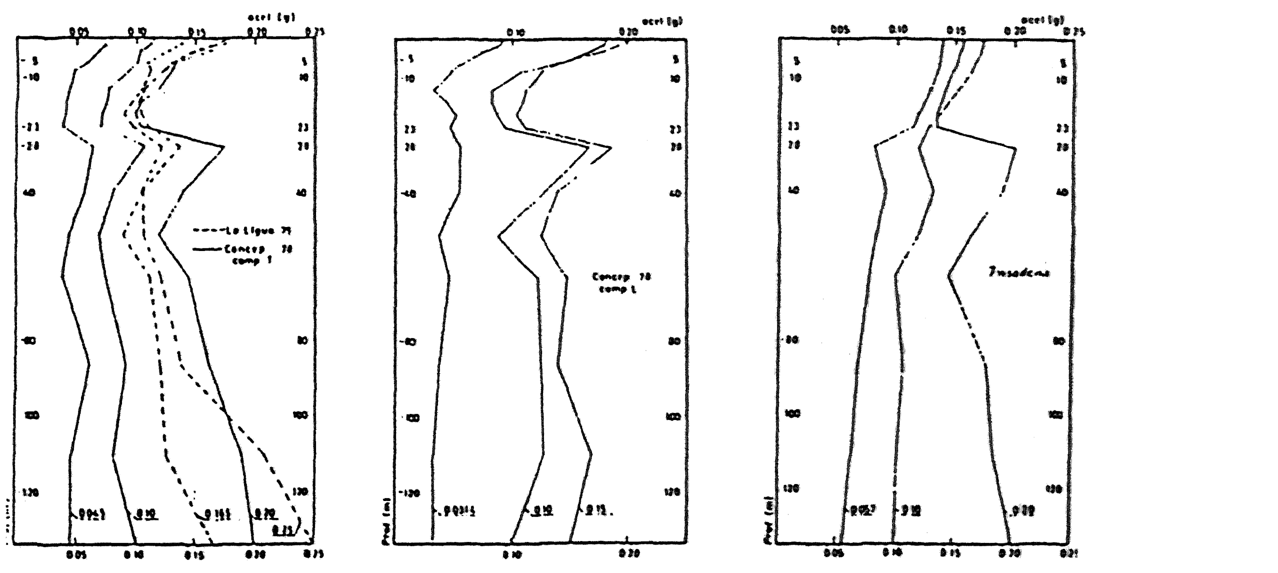

Figure 7. Maximum acceleration distribution v/s depth

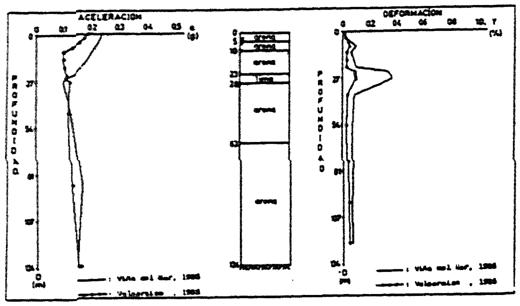

Figure 8. Acceleration variation and maximum strain with the depth of model 1 for the center of Concepción.

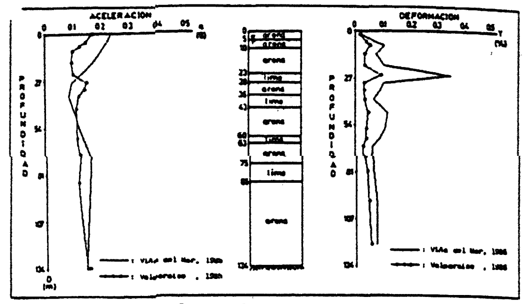

Figure 9. Acceleration variation and maximum strain with the depth of model 2 for the center of Concepción.

the basal ones. This is due to the silt stratum of the two models. The upper layers show important amplifications in all the cases and they are virtually responsible for the amplification. The seismic frequencies have influence on the phenomenon and they could be the reason for the different behavior observed between the transverse and the longitudinal component of the earthquake in Concepción.

Figures 8 and 9 show the effect of two different earthquakes on the two proposed models.

CONCLUSIONS

Two dynamic models for the subsoil in the center of Concepción for earthquakes of medium and great intensity have been proposed. In this area, during intense earthquakes, the accelerations on the surface would be superiorly delimited. The cause of this is a low rigidity silt stratum (low shear modulus) located between 23 and 28 meters deep. This phenomenon would be more important than others (influence of the earthquake characteristics) even for intense earthquakes of short epicentral distances.

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