INFLUENCE OF THE GEOTECHNICAL PARAMETERS ON SEISMIC LOCAL EFFECTS IN BARCELONA

A. Barchiesi[1,2,4], J. Cid[1,2], S. Figueras[1], T. Susagna[1,3], J. Fleta[1] and X. Goula[1]

[1] *Servei Geològic*
Institut Cartogràfic de Catalunya
Parc de Montjuich, s/n
E-08038 Barcelona
SPAIN

[2] *Dept. d'Enginyeria del Terreny*
Univ. Politècnica de Catalunya
Campus Nord (Edifici D2)
E-08034 Barcelona
SPAIN

[3] *Observatori Fabra*
Rambla dels estudis 115
E-08002 Barcelona
SPAIN

[4] *U.N. de Cuyo, Facultad de Ingenieria*
Instituto de Geotecnia
5500 Mendoza
ARGENTINA

SUMMARY

The city of Barcelona (2.000.000 inhabitants) is situated on the Mediterranean coast, occupying the pediment (6 km length) of the Catalan Coastal Ranges. The main part of the town is constructed upon a quaternary layer that lies above a basement composed of palaeozoic slates, granitoids or miocene marine marls, depending on the district. Barcelona is classified by the national seismic code ("Norma de Construcción Sismorresistente, NCSE94") with a peak acceleration of 0.04g. The values given in this code correspond to a "medium rock" site.

To take into account possible amplification effects due to the presence of sediments, transfer functions are computed by a one dimensional equivalent-linear method for different soils, taken as representatives of different districts. For the detailed characterization of the dynamical soil properties, a methodology based in empirical correlations between these properties and other more usual parameters obtained from geotechnical drillings has been applied.

1. INTRODUCTION

In the process of elaboration of the seismic micro-zonation of Barcelona, preliminary studies have been produced [1] and geotechnical information collected [2], generally related to the construction of civil works. Upon undertaking the stage of generation of the transfer functions associated to diverse lithological profiles, a deficiency in the available information was detected.

Face with the necessity, on the one hand, of evaluating the possible influence on the results of the insufficiently known parameters, and of relying on criteria in order to collect new information, we have performed a sensitivity study related to the influence of the geotechnical parameters on the seismic local effects in Barcelona. The main advances and results obtained are presented in this paper.

2. GEOLOGICAL CHARACTERIZATION

The main part of the town is constructed on a Quaternary layer that lies above a basement composed of Paleozoic slates, granitoids or Tertiary sediments discordant over the granitoids (Miocene marine marls and Pliocene sequence), depending on the district (see geological map in figure 1), [3], [4], [5].

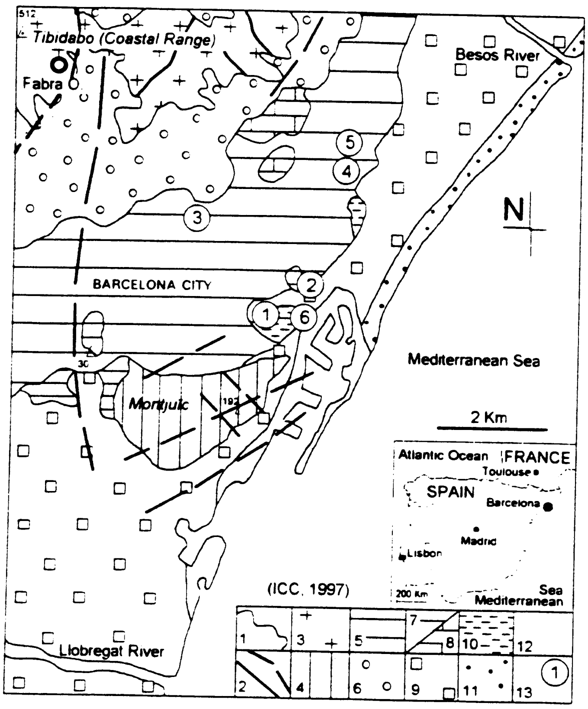


Fig. 1 : Geological map Legend: 1. Lithological contact ; 2. Faults and suppossed faults; 3. Metamorphic and granitoid rocks (Paleozoic basement). 4. Siliceous and bioclastics sands, marls and conglomerates of Montjuic (Mid-Upper Miocene); 5. Clays, marls, sands and conglomerates (Pliocene); 6. Gravels and clays (Mid-Upper Pleistocene); 7. Clays, sands, silts and gravels ("Triciclo", Mid-Upper Pleistocene); 8. Calcareous crust and calcareous muds ("Triciclo", Lower Pleistocene); 9. Sands, muds and gravels (Holocene); 10. Muds and sands (Holocene); 11. Sands (Holocene); 12. Anthropic soils; 13. Studied sites (Modified from LOSAN, 1978; IGME, 1977; SGC, 1989).

The Barcelona plain, where most of the city was built, is set up by two geomorphological units separated by a 20-30 m high scarp corresponding to the contact between pediment plain and deltaic terrains of the Besos and the Llobregat rivers. The pediment plain (ancient Quaternary age so called "Triciclo" deposits) is composed by red clays, eolian muds, calcareous crust and gravels; the deltaic terrains (recent Quaternary age) are made up by sands, muds and rounded gravels.

3. COMPILATION OF GEOTECHNICAL DATA

The absence of accurate experimental values of dynamical soil properties for Barcelona has lead us to use empirical correlations between values of dynamical parameters and standard geotechnical ones. Geotechnical data is available from drillings carried out extensively in civil works as parking lots, special buildings, etc.

In the first step we have collected information concerning geotechnical studies of six projected parking lots located on different soils (figure 1) furnished by the City Council. For each one of these sites information concernig several drillings is available. For each drilling a profile with the description of the different materials in depth is known. Results of SPT and equivalent tests (N) are also furnished.

For each site a representative column is obtained interpolating vertical and horizontal N values of the different drillings. The empirical correlations used in order to determine Vs from N value of the average column are: $V_s = 97 \cdot N^{0.314}$ [6] and $V_s = 62 \cdot N^{0.6}$ [7], $\rho = 1.5 \cdot N^{0.052}$ [6] and Gmax deduced from the expression $G_{max} = V_s^2 \cdot \rho$. Relatively low and high values for Gmax and V_s are obtained from [6] and [7] respectively.

4. MODEL

Due to the fact that the city is constructed on a pediment area, with the main topographical singularities located in their perimeter, we use an unidimensional mechanic model, that represents the propagation of shear waves in a vertical direction, through horizontal layers.

Moreover we want to consider an increase of the damping **D** and a decrease of the module of shear deformation **G**, with the shear deformation γ. These are the main reasons to use the program SHAKE91 [8].

5. PARAMETERS SELECTION

After a general evaluation of the characteristics of the problem, the study was concentrated in two sites, where systematic investigations were performed.

Within the studied depths, the lithologies are considered well-known. Nevertheless, when the tertiary substractum is not reached by the drilling, the additional depth necessary to reach this formation is uncertain.

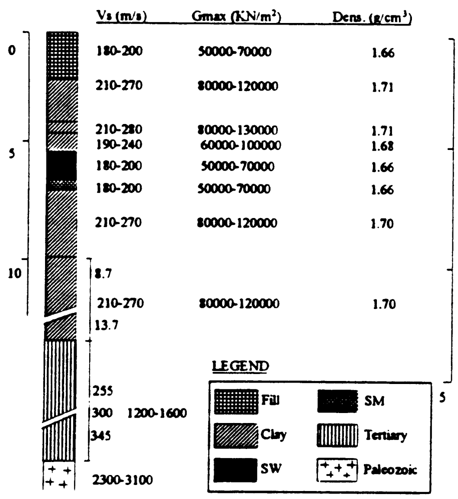
The geological knowledge of the area, guided us to consider two options: 5 m and 10 m of additional thickness of soils, with characteristics similar to the previous layers. Although a general profile is relied on [3] which allows us to estimate the thickness of this formation, there still exists a great uncertainty, particularly in Sant Pau street. In this context we decided to work with three sets of thickness of Tertiary: 300m ±15% for Sant Pau street; and 0, 5 and 10 m for Josep Tarradellas street.

Two sets of velocities were taken:

- Velocities obtained through the correlations of Imai- Tonouchi [6] for the soils, and the values used in [1] for the basement. These criteria establish relatively low rigidities.
- Velocities obtained through the correlations of Kanai [7] for the soils, and values a 30% greater than those used in [1] for the basement. These criteria establish relatively high rigidities.

In figures 2 and 3 one can observe the selection of the dynamic parameters considered for the sites of Sant Pau and Josep Tarradellas streets. The decay of **G** and the increase of **D** with the shear deformation γ, were estimated through the hyperbolic model of Hardin & Drnevich [9], [10].

In synthesis, 24 basic possibilities were evaluated: 12 for each site, assembled into two groups of six each, corresponding to two sets of velocities of shear waves. Each group of six cases corresponds to the combination of one of the two possibilities of additional thickness of soils, with one of the three thickness of Tertiary.



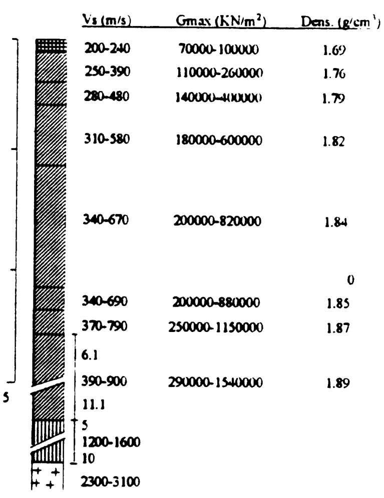


Fig. 2 : Soil column of the Sant Pau street (location 1 in Fig. 1).

Fig. 3 : Soil Column of the Josep Tarradellas street (location 3 in Fig. 1).

6. RESULTS

In figures 4 and 5, the obtained results for Sant Pau and Josep Tarradellas streets, corresponding to the twelve basic studied cases are presented.

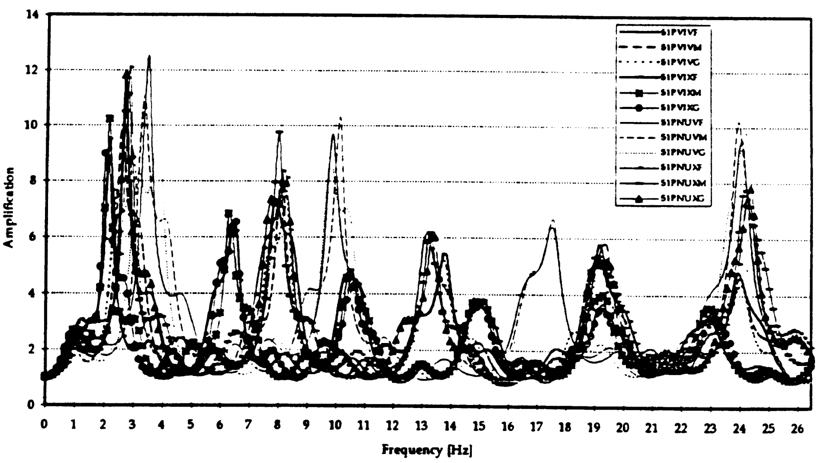


Fig. 4 : Transfer functions of Sant Pau street. *[(S1P: average drill in Sant Pau), (VI: Imai-Tonouchi correlations), (NU: Kanai correlations), (V,X: 5 or 10m additional soils depth), (F,M,G: 255m or 300m or 345m of the entire tertiary serie)].*

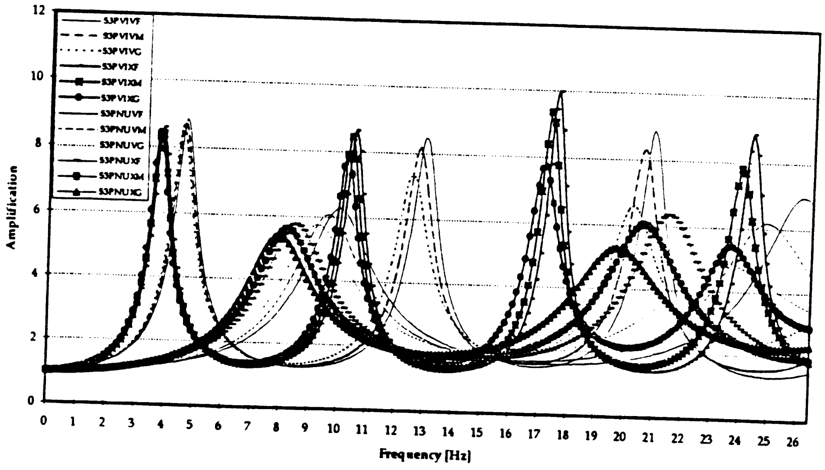


Fig. 5 : Transfer functions of Josep Tarradellas street. *[(S3P: average drill in Josep Tarradellas street), (VI: Imai-Tonouchi correlations), (NU: Kanai correlations), (V, X: 5 or 10 m additional soils depth), (F, M, G: 0 or 5 or 10 m de of the entire tertiary serie)].*

The following remarks can be noted:

⇒ In Sant Pau street, the peaks corresponding to the fundamental frequency, form a singular group, while in Josep Tarradellas street, they are clearly differentiated into two groups, each one of them corresponds to different velocities of shear waves.

⇒ Considering the geometries concerning the maximal amplifications obtained, and taking into account the average velocities V_s, determined by Imai Tonouchi correlation [6], fundamental frequencies are estimated (**fn = V_s / (4 * h)**) to be equal to 2.8 Hz and 3.5Hz for Sant Pau and Josep Tarradellas streets, respectively. With Kanai correlation [7], the values obtained are 3.4 Hz and 7.0 Hz. These values correspond to the fundamental frequencies plotted in the figures 4 and 5.

⇒ If the average shear velocities determined by means of the correlations of Kanai [7] are compared with the obtained by Imai-Tonouchi [6], quotients of 1.24 and 1.97 for Sant Pau and Josep Tarradellas streets are obtained. This explains, the bigger difference observed in Josep Terradellas street.

⇒ The greatest amplification recognized in Sant Pau street, is due to the major contrast of rigidity in the boundary between rock and soil.

These observations point out the necessity to determine more precisely shear wave velocities of the materials in each site.

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