APPLYING MICROTREMOR, GRAVITY ANOMALIES AND NUMERICAL MODELLING METHODS FOR THE EVALUATION OF SOIL EARTHQUAKE RESPONSE IN BARCELONA, SPAIN

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ABSTRACT

Two different techniques have been applied to evaluate the potential seismic site effects in the city of Barcelona. Transfer functions have been computed in different sites, through a unidimensional linear-equivalent model using the available dynamic parameters of soils obtained from drillings for building and infrastructure public works. The depth of the basement and the structural framework have been determined from the inverse solution of the residual gravity anomaly. Microtremor measurements using Nakamura's technique are also available for these sites.

The results of these techniques have been compared. We prove that the predominant frequencies obtained by Nakamura's technique agree with the fundamental frequencies in the computed transfer functions, but for complex structures these fundamental frequencies are not the frequencies for which largest amplifications appear. In our case, the fundamental frequency is related with the post-Palaeozoic deposit thickness, which is defined by the results from inversion of a detailed gravity survey, while the maximum amplification depends more on the uppermost soft soils.

LOCAL GEOLOGICAL SETTING

The city of Barcelona is located between the Llobregat and Besòs deltas, on a plane slightly sloping from the Collserola ridge to the sea. Two geomorphologic units can be recognised (figure 1). First, the mountainous profiles which consist of Palaeozoic shales, carbonates and granitic rocks (the Collserola ridge) and Neogene sediments (mainly sandstones and marls of Miocene age exposed on the Montjuic hill). Second, the plain of Barcelona, which is divided into two geomorphologic units, separated by a steep talus that presents an unevenness of approximately 20-30 m: Pleistocene terrains composed of a cyclic series of red clays, eolian silts, calcareous crusts and gravels; and Holocene deltaic materials from the mouths of the Besòs and Llobregat rivers.

SEISMIC SOIL RESPONSE

In order to estimate the seismic soil response for an area of the city of Barcelona, we compare the results obtained from two different techniques applied to different sites. The first results correspond to predominant frequencies that were obtained by the application of Nakamura's technique (Nakamura, 1989) to environmental noise (microtremors) measurements (Alfaro, 1997). The second results are the transfer functions computed with a unidimensional linear-equivalent method (Idriss & Sun, 1992) using a Ricker wavelet with a predominant period of 0.15 s (Goula et al., 1998). To compute the transfer functions, it was necessary to estimate the dynamic parameters of the existing materials between the basement and the surface. This model requires the estimation of parameters such as the shear wave velocity, the maximum dynamic shear modulus, the density and the thickness of the layers. To determine the depth of Paleozoic basement an inversion solution of the residual gravity anomaly was applied.

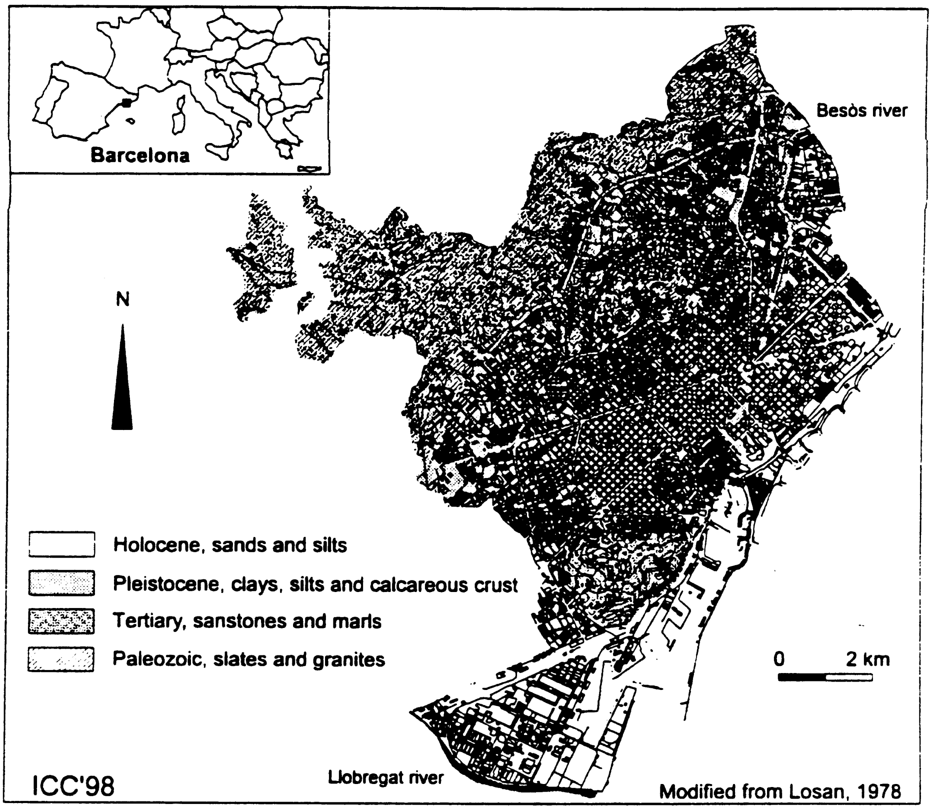

Figure 1. Geological map of the city of Barcelona

The gravity map of Barcelona has been produced by the compilation of 935 gravity stations on a high precision topographic network identified by a metallic nail. Data were terrain corrected to a limit of 167 km. Likewise, the effect of nearest artificial structures were controlled in order to obtain an accurate gravity map. After the usual corrections and extraction of the regional anomaly, the residual gravity map shows one negative anomaly of –3 mGal. The inversion of the gravity low has been attained by adjustment of a model of vertical prisms of fixed top (surface) and variable base (Palaeozoic basement). The algorithm that gave a better adjustment and convergence and has led to a more realistic model was those developed by Granser (1987) using an exponential density variation of $-0.42 \exp(-0.65z)$ taking into account the density log of some regional wells. The isobath map delineates the presence of small basins, near the coastline (figure2), under the sedimentary cover, not distinguished at surface (Lázaro et al., 1998).

COMPARISON OF RESULTS

It is presented the comparison of the results from microtremor measurements and modelling in the area where gravity data show the presence of small basins. In figure 2a, the frequency of the first peak of the computed transfer function (Goula et al., 1998) together with the predominant frequency of Nakamura's technique (Alfaro et al., 1997) are shown together with isolines from the gravity survey. From the analysis of the figure 2a the following conclusions can be pointed out: the computed frequencies and the predominant frequencies of Nakamura's technique show similar values, in agreement with the results of the gravity survey, that is to say, these frequencies are related to the depth of the Post-Paleozoic deposit. In figure 2b it can be seen that the computed frequency for the maximum amplification and the predominant frequencies of the Nakamura's technique show different values. The frequencies for which maximum amplification occur seem to be related to the Quaternary deposits or the superficial thin layers with higher impedance contrast (Goula et al., 1998). Therefore the predominant frequencies of the Nakamura's technique, which are well correlated with the Post-Paleozoic deposit, do not give information on the maximum amplification of the soil response.

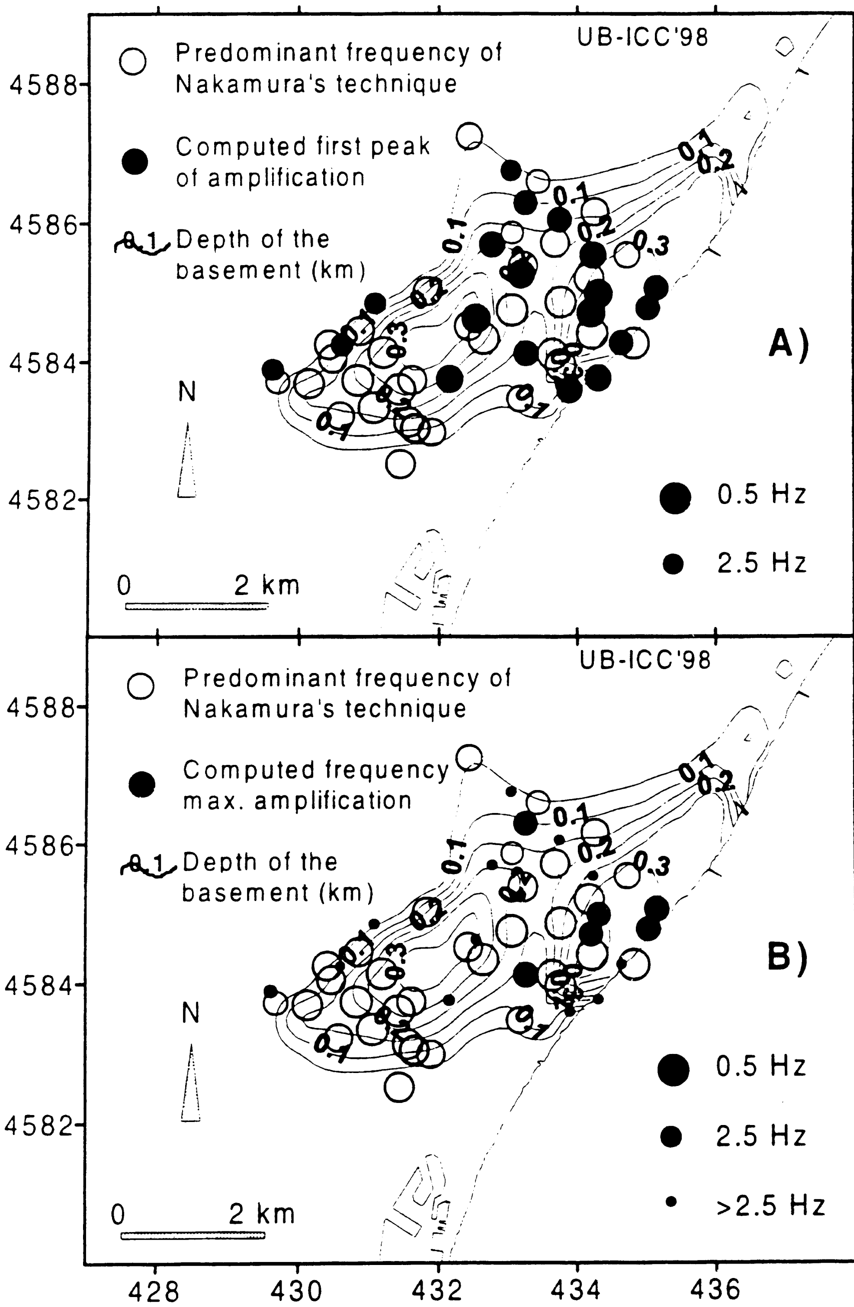

Figure 2. Comparison of results from microtremor, gravity and numerical modelling methods

These last conclusions are illustrated in figure 3. Figure 3a show the comparison (in bar chart) between the predominant frequency of Nakamura's technique -white bars- and the frequency of the first amplification peak in the computed transfer function (soil fundamental frequency - black bars-). It can be seen a significant agreement between these two parameters although Nakamura's frequencies tend to be a little lower.

Figure 3b show the comparison between the predominant frequency of Nakamuras's technique and the frequency for which the maximum amplification occur in the computed transfer function (so-called soil predominant frequency). A high divergence between these two parameters is observed. This conclusion may have strong implications for seismic risk and earthquake engineering as many of the microzoning studies that are carried out are mainly based on the Nakamuras's technique.

A warning should be given in the sense that although Nakamura's technique can give good approaches in some cases, in several other situations will not well estimate the soil predominant frequency. In fact, the validity limits of applicability of this technique have not yet been well established. Therefore, Nakamura's technique should always be applied together with other experimental technique as SSR (Standard Spectral Ratio) and numerical modelling using as more real geotechnical data as possible.

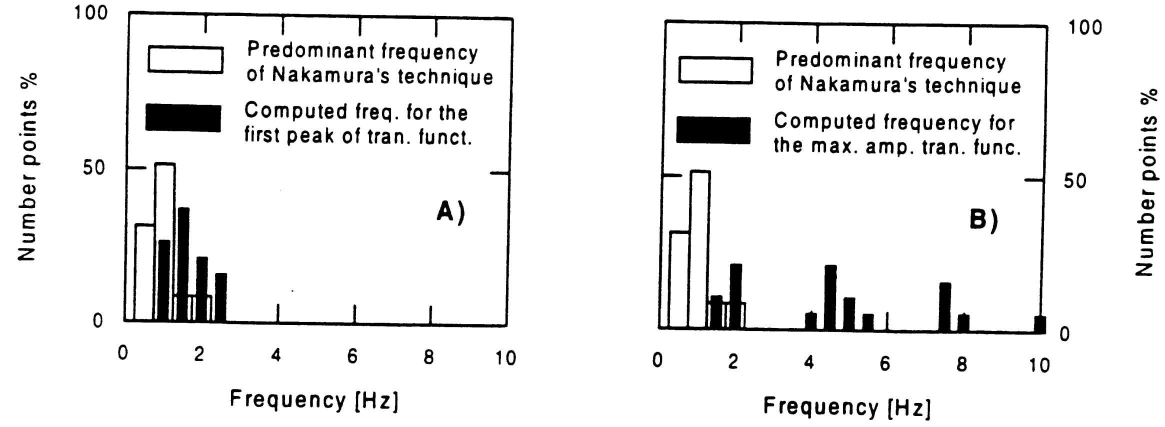

Figure 3. Comparison of results from Nakamura's technique and numerical modelling methods

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