INFLUENCE OF GEOLOGICAL SOIL PROFILES ON THE AMPLITUDE OF SEISMIC WAVES

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SUMMARY

The amplification of seismic waves in subsurface soil layers has been evaluated by numerical analysis. Detailed laminated as well as appropriately simplified subsoil models have been used assuming horizontal stratification and vertical incidence of SH-waves. It is shown that the fine structure of the soft layer has a significant impact on the spectral amplitudes. Even small variations of only 10 - 20 % in the distribution of the elastic parameters in the soft covering layer of the models can cause a frequency dependent 150 % increase or decrease of the amplitudes observed at the surface.

INTRODUCTION

Detailed macroseismic investigations show that the isoseismals are frequently distributed in a rather spotty manner. This is related to significant changes of ground shaking over short distances. Although the damage patterns observed are partly caused by inhomogeneous distribution of settlements there is strong evidence that the ground shakings are strongly modified by the local ground conditions too. In general destruction is heavier on soft than on hard soils or rocks. The problem of seismic microzoning is to assess and predict such local effects in order to get reliable criteria for planning and earthquake design parameters.

The most important parameters of ground shaking are the amplitude, the frequency distribution and the duration of shaking. These characteristics are influenced by various factors such as the earthquake source mechanism, the orientation of the site with respect to the source, the surface topography, the subsurface configuration, and the physical properties of the media through which the wave propagates (Petrovski, 1978). What can be investigated most easily of the upper mentioned elements is the effect of the variation of soil properties for various simple soil layer configurations and assumptions on the incidence of seismic waves. Two important parameters for the assessment of the ground shaking characteristics within the interesting frequency range are the resonance period and the respective amplitudes of the seismic waves as compared to a reference location on hard rock.

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Numerous simple procedures are available and frequently used for the computation of the fundamental period of a soft soil cover overlaying hard rock (Dobry et al., 1976). But sufficiently accurate determinations of the amplification of ground amplitudes owing to soft covering soil layers are not less important. Amplitude estimations are easily when using single layer models, a simplification often used in microzoning computations. In the present paper the significant influence of the fine structure of subsoil models on the spectral amplitudes will be demonstrated.

METHOD

In order to estimate the soil amplification characteristics it is necessary to differentiate between low and high intensity ground shakings. In high intensity areas or those near to the epicentre of strong eartnquakes (near-field) the characteristics of shaking are strongly influenced by the earthquake source mechanism and nonlinear effects of ground deformations, while in more distant areas with lower intensities (farfield) the amplification of soil motion can be computed using linear theory and assuming that it only depends on the elastic properties and geometry of the subsurface layer. Only the latter case will be dealt in this study.

We restrict ourselves to computing the seismic response of horizontally layered sediments with reference to the responce of bedrock sites. Only vertically incident SH-waves are considered. This assumption does not truly reflect the real conditions but it allows to evaluate the maximum effect to be expected with regard to earthquake damage. This is true since buildings in general respond much more critically to horizontal shaking than to vertical components of ground motion.

The algorithm by Baranov and Kunetz (1960) was used for computing the transmission response of the models. Input function is a spike with the unit amplitude 1. The resulting output is a time series. Any form of seismic signals can be considered by convolving it with the output time series (Grünthal, 1978). The Fourier transform of the output time series yields the spectral response of the model, since the spectrum of the exciting spike is equal to one for all frequencies. The calculations were performed for periods between 0.2 and 4.0 sec. The absorption of the soil material was neglected for the goal of the paper was to show the influence of the degreee of refinement of the subsoil stratification model on the spectral amplitudes.

The amplification of a single layer model is shown in fig. 1. The exciting spike vertically incident from the bedrock halfspace and the output time series are depicted for illustration of the method. The first transmitted peak has a larger amplitude than the exciting peak owing to the transmission coefficient being larger than one between hard and soft rock. The multiple reflections within the covering layer produce the alternating peaks. Such alternating peak

series cause constructive interferences for waves with periods egual to the resonance period T_r. The response spectrum at the free surface shows the typical frequency dependence of the amplification factor with maxima at the resonance periods. Furthermore, the figure shows the amplification of a typical seismic wave train assumed to consist of SH waves.
For the dominating waves the amplification factor is about 3.

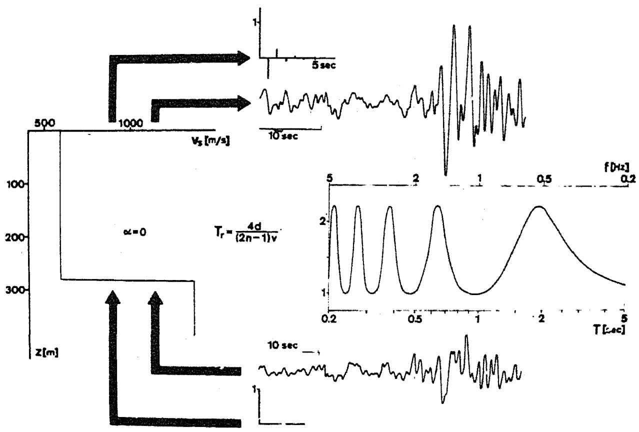

Fig. 1 Response of an one-layer model (without absorption, $\alpha = 0$) in the time and frequency domain

AMPLIFICATION SPECTRA FOR DIFFERENT FINE STRATIFIED SOIL MODELS

Very simple subsoil models are often used in microzonation practice. The question was to which extent a model could be simplified and still provide relaible amplification spectra. The influence of model simplification on the form of spectra was to be demonstrated by example of a subsoil model typical for large areas of the GDR. Therefore a basic model was used consisting of a soft covering layer of 190 m thickness underlain by hard rock. The soft cover is subdivided into 66 layers (model MA 66). This fine stratified model for the soft cover was systematically simplified getting models with 18, 6, 5, 4 and finally 1 layer. The velocity variations in the soft covering layer amount to 10 - 20 % of the velocity jump between the soft and the underlaying hard rock.

Fig. 2 shows on the left the shear wave velocity models with 1, 4 and 5 soft layers and on the right the corresponding amplification response spectra. The spectrum of the single-layer model shows the typical form with the same amplitudes at all resonance periods. The model with 4 layers produces larger amplitudes for the higher modes of the resonance period than the single-layer model. The model with 5 layers includes a low velocity layer. Compared with the former models it causes a quite different shape of the spectrum. The wave energy is shifted to periods of 0.45 - 1.5 sec, i. e. the low velocity layer acts as a low pass filter.

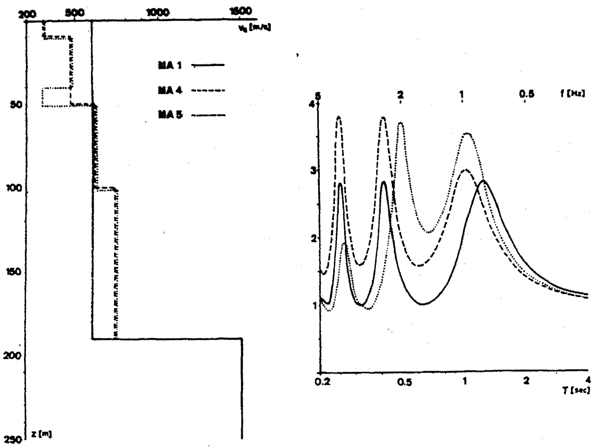

Fig. 2 Subsoil model consisting of 1, 4 and 5 soft covering layers with its appropriate amplification response spectra

Fig. 3 presents the results for the 6, 18 and 66 layer model all of them including low velocity layers. A comparison of the 3 spectra of this figure leads to the conclusion that with increasing finess of the stratification the energy shifts more and more to the first resonance peak at about 1 sec. The amplitudes of the higher modes get more and more unimportant. Concerning the amplitude of the first resonance peak we can see that for the models presented even small velocity variations in the soft covering layer produce an increase in amplitude by a factor 1.5, approximately.

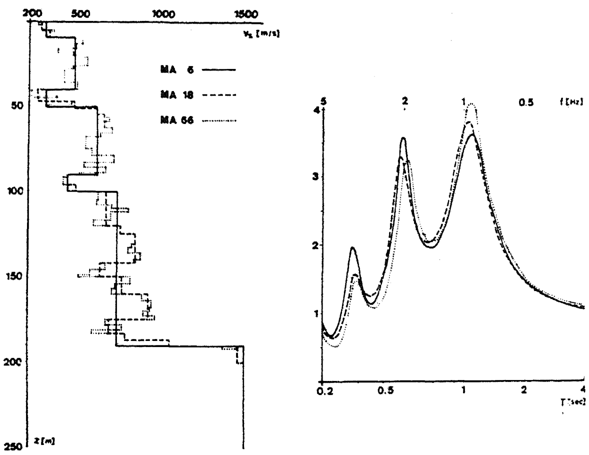

Fig. 3 Subsoil model consisting of 6, 18 and 66 soft covering layers with its appropriate amplification response spectra

From these results we conclude, that any reliable amplitude estimate in microzoning need to be based on detailed knowledge of subsoil profils considering, in particular, all existing low velocity layers. Since it might be difficult to fulfill this requirement in the geophysical or engineering field praxis one must be aware, that the spectral amplitudes computed for simplified single-layer models of the soft soil cover could be wrong by almost a factor 2. This error is considerable if compared with the absolute amplification effect of a soft soil cover which can be approximately a factor 5 for realistic models if compared with a reference site on hard rock.

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