SOME CONSIDERATIONS ABOUT SITE EFFECTS DURING THE IRPINIA EARTHQUAKE OF NOVEMBER 23,1980

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SUMMARY

This paper presents an analysis of some typical situations observed after the Irpinia earthquake of November 23,1980, in which the damage distribution could have been affected by local site effects. The analysis is carried out by means of simplified finite element models hypothetically representative of geomorphologic conditions encountered at the site. The parametric studies presented in this paper show that local amplification phenomena can effectively take place in situations similar to the ones considered herein.

INTRODUCTION

During the activity of damage evaluation and seismic zoning carried out by the Authors after the Irpinia earthquake of November 23,1980 under the auspices of the Italian National Research Council, several more or less highly damaged sites were inspected. In some cases very particular situations were observed in which the morphological nature of the site or the geological conditions of the subsoil seemed to have played a significant role on the distribution of seismic damage.

For example, in the Lioni area several collapsed r.c. buildings were located over a lithological discontinuity; the collapse was complete without showing any evidence of foundation or soil failures while surrounding buildings suffered limited damages. Analogous conditions were also associated with a generalized high state of damage at Senerchia and Valva.

Another interesting situation was observed in Calabritto and Rapolla were in the subsoil a very large number of grottoes was excavated during the centuries. This fact, typical of southern Italy, is associated in Calabritto with a very intense level of damage.

In other cases, like Conza della Campania and Melfi, the structures were built over a very rigid deposit placed upon softer layers of soil.This condition, common to many other places, is not always associated with a severe degree of damage.

Finally, very often, old towns were observed to be built upon shallow alluvial deposits with poor geomechanical properties.

The influence that situations like the ones described above may have on the local seismic intensity and damage distribution is quite controverse in the literature (Ref.1). In fact, the complexity of the phenomena is such that

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oversimplified models can very often give erroneous conclusions.

Field observations as well as appropriate analytical or numerical studies show however that the problem can be very important in the interpretation of seismic damaging and in the assessment of the expected earthquake intensity at a particular site.

Among the various situations referenced above, three cases are treated in some detail in the present paper, by means of numerical models. The first one is representative of the interaction effects which can develop when a horizontal layer of soil, underlain by a rigid bedrock, bears a large number of very closely and irregularly fabricated stone masonry buildings. This situation is typical of many hystorical cities in Italy and, generally, in southern Europe. The ensemble of buildings can be idealized as an upper layer of appropriate dynamic characteristics. Although soil structure interaction problems are extensively treated in the literature, and amplification phenomena are well known from both analyses (Ref.2) and field observations (Ref.3), detailed considerations concerning interaction effects in densely fabricated areas are still lacking.

The second one consists in the combination of the effects of morphology and subsoil stratification. The effects are studied with particular reference to the areas in which inclined ground surfaces intercept planes of geologic discontinuity separating layers of different geomechanical properties.

Finally, the third case considers the effects caused in a hill by horizontal holes naturally or artificially produced along its flanks.

The role played by the surface morphology is, again, relatively assessed by many studies (Refs.4 and 5). Nonetheless, combined subsurface and surface effects are seldom treated in the literature.

DESCRIPTION OF THE NUMERICAL MODELS

The three cases described in the introduction are schematically represented by the two-dimensional profiles respectively drawn in Figs. 1a, 1b and 1c. Fig. 1a shows a homogeneus layer of height H, resting on a rigid bedrock, supporting an indefinite array of buildings, characterized by an average height h. The analyses were carried out for two layer heights: 10m and 50m; in both cases the soil was supposed to present a shear wave velocity of 200m/sec. For each layer two average building heights (6m and 9m) were considered. The presence of the buildings was simulated by a layer the height of which was equal to the height of the buildings, and possessing mechanical properties derived from the average mass and stiffness of stoney buildings.

Fig. 1b shows a smoothly sloped hill rising above a horizontal layer, underlain by a rigid bedrock. The hill includes a horizontal layer composed by a material which is different from the one constituting the remaining part of the deposit. The assumed shear wave velocities were: 200m/sec for the deposit, 400m and 800m/sec for the intermediate layer.

Fig.1c shows a similar geometry in which the hill and the base layer are both homogeneous and the slopes are steeper. Along the flanks of the hill three rows of holes are present at three different elevations. The zones interested by the holes are indicated in the figure by the dotted areas. In the analysis, a shear wave velocity of 800m/sec was assumed for the soil. The presence of the holes was simulated by reducing the unit weight and the elastic modulus in the dotted regions. The reduction was effectued on the basis of the two following percentages of holes: 50 and 75 percent.

All the problems were idealized into finite element models and analyzed by the computer program FLUSH, assuming a uniform damping ratio of 5 percent. All the models were subjected to three real time hystories of the horizontal acceleration given at the free-field. These time hystories, denoted in the following as earthquake No. 1,2 and 3, correspond to the NS component of the records, scaled to 0.3g, taken at Bagnoli Irpino, Sturno and Ancona-Rocca, respectively. The response spectra of the input motions are plotted in Fig.2.

DISCUSSION OF RESULTS

The results, in terms of absolute spectral acceleration are presented in Fig. 3, for the case described in Fig.1a. In all the plots the solid line indicates the response in absence of buildings, the dashed line indicates the response for an average building height of 6m, and the dash-dot line indicates the response for an average building height of 9m.

From the plots of the right-hand side of the figure, it can be seen that the layer height of 50m is not critical for this problem and that there is no practical evidence of significant interaction effects, apart from the case of earthquake 3,characterized by a narrow-band frequency content. The layer height of 10m shows more remarkable effects for both the building heights of 6 and 9 meters. These effects consist,for earthquakes 1 and 2, in a relevant increase of the response in the 3 to 8 Hertz range, accompanied by a shift in the frequency of the peak response acceleration while,for earthquake 3, the response is generally deamplified by the presence of the buildings.

The absolute spectral accelerations obtained at points A and B of the profile depicted in Fig.1b are represented in Fig.4. In all the diagrams the solid line indicates the response at the specified points for a completely homogeneous profile; the dashed line indicates the response for a shear wave velocity of 400m/sec at the intermediate layer, and the dash-dot line refers to a shear wave velocity of 800 m/sec at the intermediate layer.

The effect due to the presence of the intermediate layer is clearly more relevant at point B than at point A. As concerning point A, regardless from the shear wave velocity of the layer, earthquakes 1,2 and 3 show an amplified response in the 4 to 6 Hertz range; earthquakes 1 and 2 show a reversed tendency in the 8 to 10 Hertz range, while earthquake 3 continues to give a slightly amplified response.

At point B, for a shear wave velocity of 400 m/sec earthquakes 1 and 2 generally give amplified responses; for a shear wave velocity of 800 m/sec, the amplification is limited to the 2 to 4 Hertz range with very high peaks, particularly in the case of earthquake 2. The response spectrum of earthquake 3 is generally amplified by a shear wave velocity of 400 m/sec and deamplified by a shear wave velocity of 800 m/sec.

Finally, the effect of the holes is limited to an increase of the value of the spectral peak acceleration without modification of the shape of the spectrum itself. Fig.5 shows, for the three earthquakes, the increase in percent of the peak acceleration due to the presence of the holes. The percentage hystograms are plotted at various points on the hill shape. All spectra show a peak for a frequency of approximately 6 Hertz. The results obtained are not substantially different for the three earthquakes. Qualitatively there is no difference between the two hole percentages examined. Amplification is practically limited to the upper flank and to the top of the hill. A maximum increase of about 30 percent was recorded.

CONCLUSIONS

It should be pointed out that the results herein presented are tightly related to the geometries and soil profiles analyzed; conclusions cannot be therefore stated in general terms. The cases examined were suggested by really observed situations but they are not specifically meant to interpret the effects of Irpinia earthquake of November 23,1980 at those sites.

The third earthquake used in this study, as concerning the frequency content, can be considered representative of typical near-field earthquakes.

For the case of hystorical towns founded on alluvial strata it can be concluded that interaction effects can effectively take place and cause anomalies in the seismic forces acting or structural typologies eventually inserted in the hystorical context.

The effect of heterogeneities in geologic formations like the one considered in the second problem can be locally significant at least under certain conditions. Microzoning studies seem therefore necessary in the assessment of the seismic risk at similar sites.

Finally, the presence of diffused man-excavated grottoes seems not to be responsible, at least through the modelization considered, of significant increases in the seismic damaging. However, a quantitative influence was detected in the study, and more detailed investigations could be necessary for a more clear understanding of the phenomenon.

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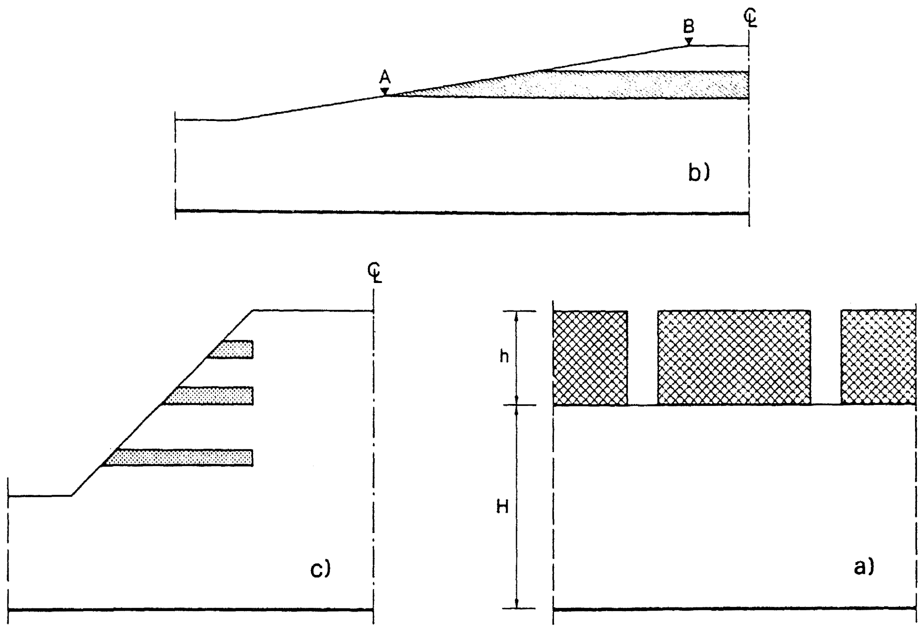

Fig.1 - Cases analyzed

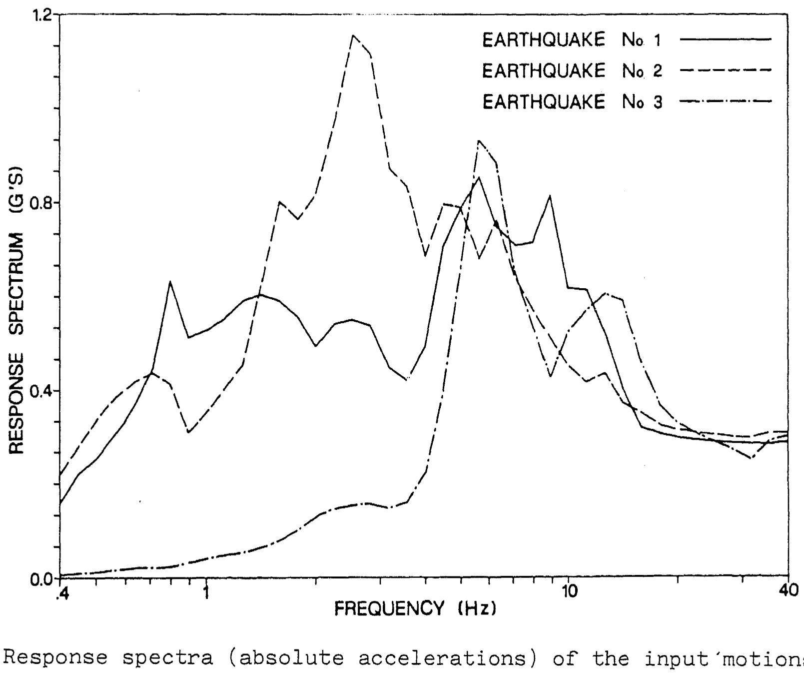

Fig.2 - Response spectra (absolute accelerations) of the input motions at 5 percent damping.

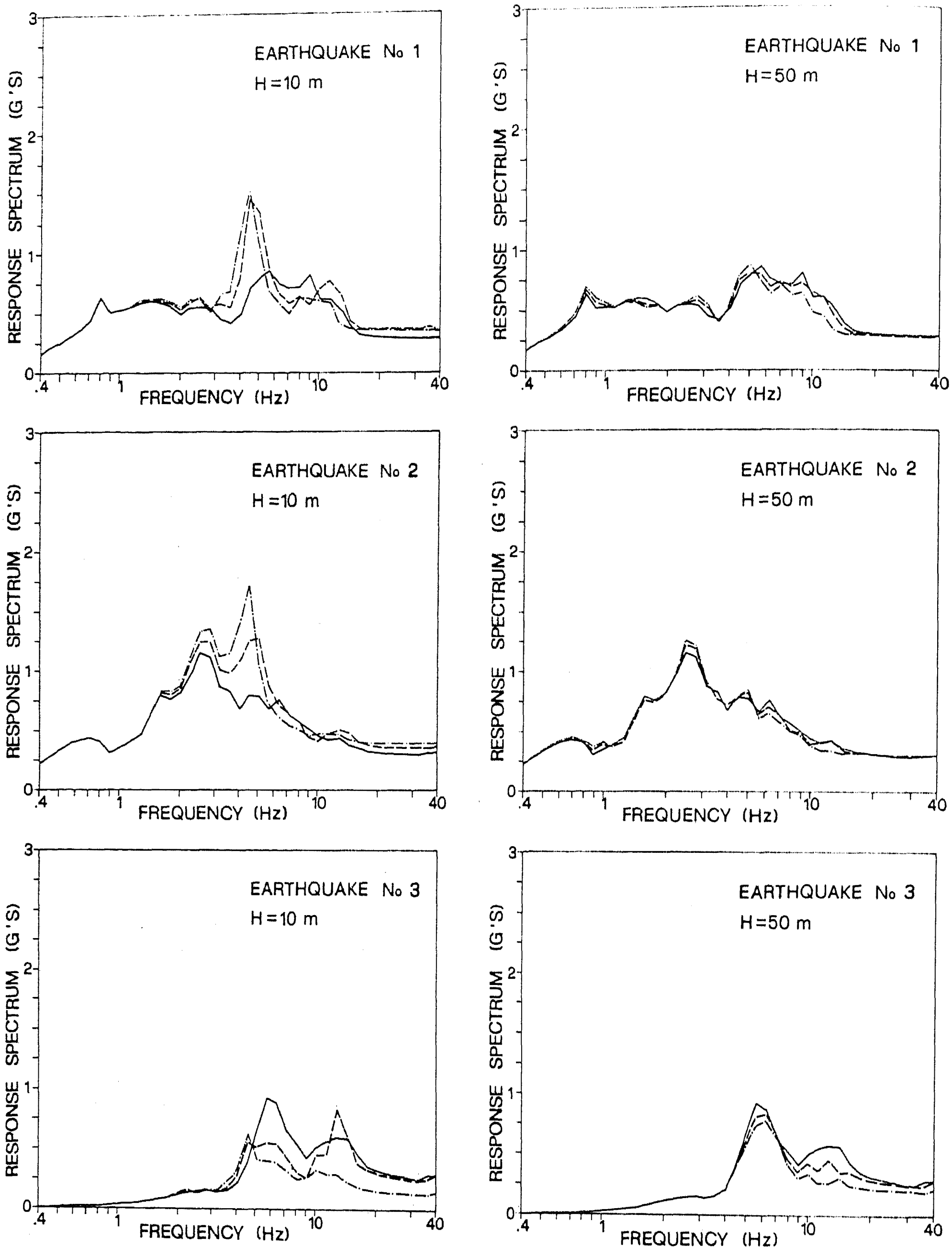

Fig.3 - Case a - Dense buildings on alluvial strata - Response spectra (absolute accelerations) at 5 percent damping.

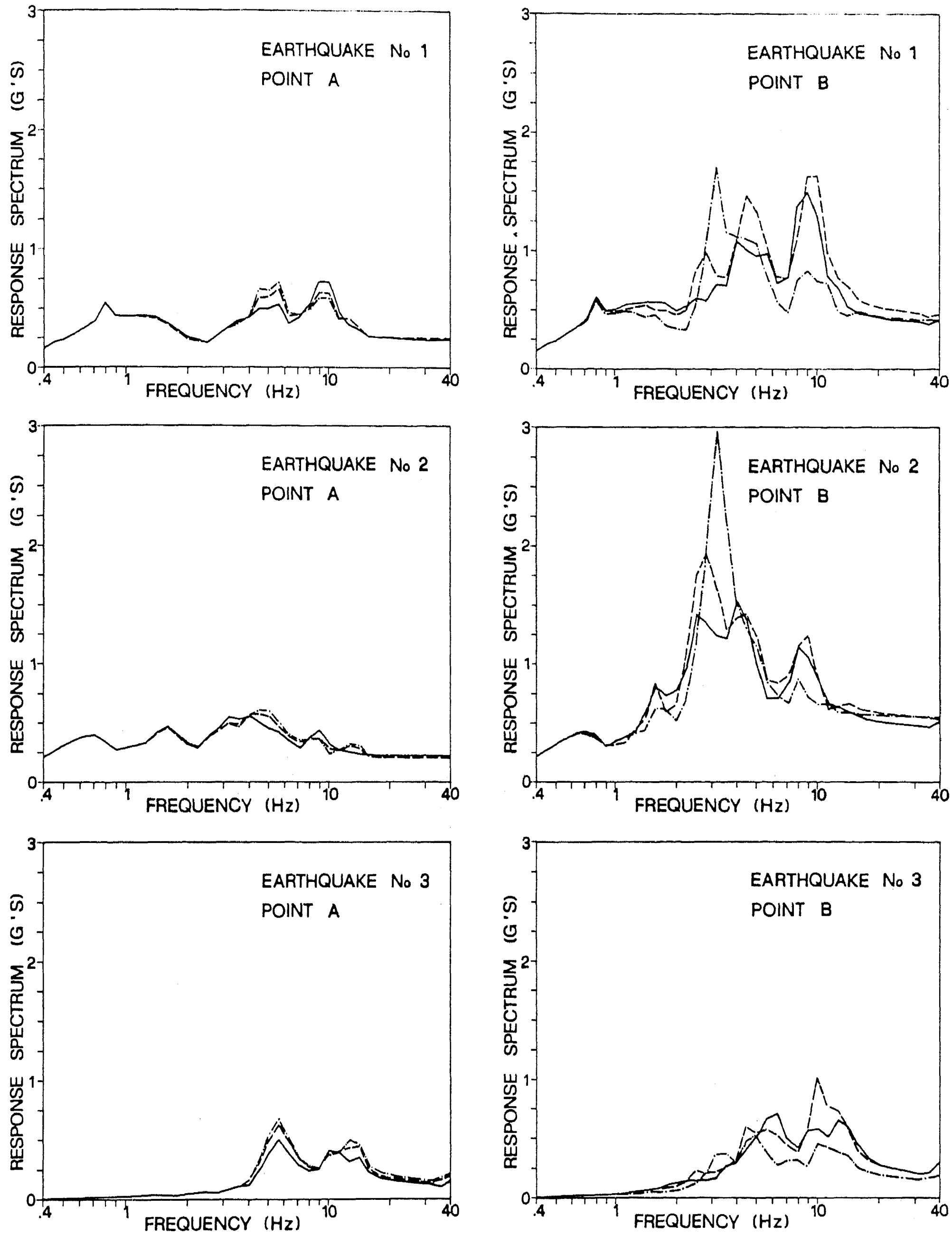

Fig.4 - Case b - Influence of stiff layers - Response spectra (absolute accelerations) at 5 percent damping.

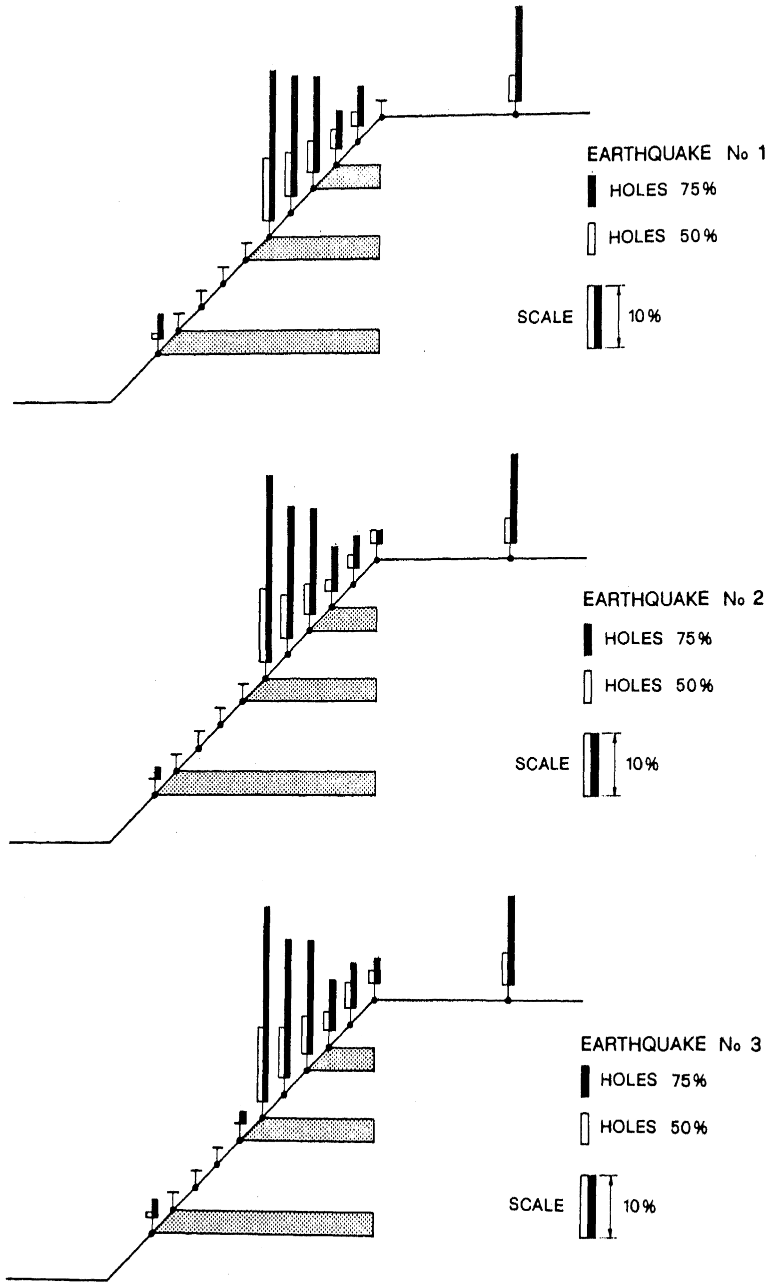

Fig.5 - Case c - Influence of holes - Percentage hystograms of peak response accelerations increase (from response spectra at 5 percent damping)