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SOIL CONDITION EFFECTS ON SEISMIC STRUCTURE DESIGN

L'EFFET DE LA CONDITION DU SOL SUR LE PROJET SISMIQUE DES OUVRAGES

WIRKUNG DES BODENBESTANDS AUF DER SISMISCHE ANSCHLAG DEN BAUWERKEN

by Michele Maugeri, Ass.Professor of Soil Mechanics University of Catania - Faculty of Engineering.

Abstract

The influence of soil condition on the behaviour of buildings is now being considered in Italy after the Friuli Earthquake by means of extensive area microzonation. .

But sometimes microzonation methods cannot be applied successfully and a direct evaluation of the interaction of soil layer characteristics with structural features cannot be avoided.

In this paper the effect of two different soil layers of variable depth is evaluated on eighteen different structure patterns.

Lastly the reduction of the seismic shaking by means of a deep pile foundation is quoted.

Resumé

En Italie, après le tremblement de terre en Friaul, on est en train de considérer l'influence de la condition du sol sur les bâtiments par une vaste microzonisation des zones.

Pourtant il arrive quèlquefois que les methodes de microzonisation ne peuvent pas être appliquées aved succès, donc il est impossible d'éviter une directe évaluation de l'intéraction des caractéristiques des couches de sol avec les configurations structurales.

Ici on évalue l'effet de deux differentes couches de sol, ayantes une profondeur variable, sur dix-huit différents modèles d'ouvrages.

Enfin on cite la réduction des vibrations sismiques par des fondations profondes à piliers.

Zusammenfass

Die Einfluss des Bodenbestands auf dem Bauwerkshalten wird jetzt in Italien, nach dem Friaulischen Erdbebens, in Betracht gezogen, vermittelst einen ausgedehnten der Bodenfläche.

Manchmals, aber, ist es nicht möglich die Methoden mit Erflog anzuwenden, deswegen ist es nötig eine direkte Auswertung des Wechselwirkungs des Kennzichnungs des Bodenbestands mit den Besonderheiten des Bauwerken anzuwenden.

Hier wird die Wirkung von zwei veschiedenen Bodenschichten mit veränderlicher Tiefe an achtzehn vèrshiedenen Bauwerkmustern ausgewertet.

Zuletzt die Reduktion von der seismische Eigenschwingung vermittelst ein tiefes Stoßfundament wird angeführt.

1. INTRODUCTION

The usual way of evaluating seismic forces when designing structures is to multiply the weight of the construction by a series of coefficients (Tezcan 1972). Two of these take the soil effect into account.

- the reduction factor, reflecting the effect of epicentral distances in relatively soft soils;
- the amplification factor due to soil layers and their interaction with the structure.

In many countries, particularly Japan (Ohsaki, 1969, 1972; Kobayashi and Kagami, 1972), this way of approaching the question has led to the microzonation of extensive areas. Italian researchers are also doing the same for the districts hit by the recent earthquake in Friuli (Giorgetti, 1977).

However microzonation methods are not fully successful when the local soil conditions present one of the following characteristics :

- vicinity to hills which disturb the soil amplification response (a very frequent case in Italy);
- presence of deep foundations of various types and depths;
- vicinity of the (largest or mean) period of microtremors to the predominant period of the soil layer and/or vicinity of the predominant period of the soil layer to the natural periods of the structure;
- vicinity to the epicenter of the examined zone.

In the last case the soil amplification technique (Idriss and Seed, 1969; Hayes et all., 1971) which sometimes gives an amplification coefficient of up to 20 - 25 for velocity (Kobayashi, 1977; Kobayashi and Nagahashi, 1975) cannot be successfully applied to plasticization and/or soil rupture in the epicentral areas. A great impulse in the direction of measuring slip vectors in the field during earthquakes (Papastamatiou, 1976) is that many collapses are due to unacceptable structure deformation. The influence of the microtremor period and of the predominant period of soil layer is so remarkable that different methods of microzonation, as shown in fig. 1, are based on the largest and the mean microtremor period (fig. 1a) the largest amplitude and predominant microtremor period (fig. 1b) and on the predominant period for each zone (fig. 1c).

During the recent Friuli Earthquake, for a series of caisson piers of variable height which will allow the motorway to cross the Cavazzo Lake, the velocity spectrum was near the oscillation periods and some piers were severely damaged at their bases (Bo et all., 1976).

2. SOIL STRUCTURE INTERACTION

The complex interaction of soil layer characteristics and its consequent predominant period with structural features, particularly, rigidity and ductility, can be carefully predicted if the design spectrum for a given structure resting in a given soil layer is known. This process of integral design for each case cannot be avoided for very large strctures or for simple structures with a high degree of repetitivity both on the structural pattern and in the condition of the subsoil.

In fig. 2 three typical structures, the last of which (diagram C) is very commonly used for residences in Friuli, are taken into consideration. The design spectrum is visible in fig. 3 in terms of maximum acceleration, in fig. 4, in terms of velocity and in fig. 5 in terms of displacement. The spectra shown are those of the May 6th Friuli Earthquake at Tolmezzo, as representing rock substratum, and at Codroipo as typical for soft ground, both with a damping coefficient of 10% (CNEN - ENEL, 1976). The displacement effect, severer at Codroipo than at Tolmezzo, is evident.

In fig. 6 the influence of rigidity is plotted, and in fig. 6a on the natural periods of the structures, fig. 6b the maximum acceleration and fig. 6.5 the displacement from which it is derived.

At this stage, differences in rigidity are due to six different pier dimensions (fig. 2d) and different pillar reinforcement percentage making a total of eighteen (18) different patterns. It is obvious that each pattern also has different ductility characteristics.

From the point of view of soil characteristics for different layer depths and different shear wave velocities, a particular predominant period, quoted in fig. 7a (Maugeri, 1976), corresponds and consequently various maximum ground accelerations (fig. 7b).

When the predominant period of soil layers of different depths reaches the field of the natural period of structures, the maximum accelerations are amplified as shown in fig. 8 for a shear wave velocity of 36 m/sec, corresponding to very soft soil, and in fig. 9, for a shear wave velocity of 480 m/sec, corresponding to stiff soil. It is clear from the graphs that stiff soil amplifies accelerations more than soft soil (though the latter demagnifies accelerations in the epicentral areas). The seismic stability of pattern C (fig. 2c) 9.80m high and 4.00m wide with 40 x 30 cm pillars and a 4.02 cm^2 reinforcement is not reached in the elastic field, but requires plasticisation of the section with a ductility factor of 2.7 in the case of structures resting in a rock and of 3.2 in the case of structures based on 10m of stiff soil. The ductility required was less than the 5.5 offered by the structure alone in the ultimate state, which can usually be reached in r.c. structures of this type (Benedetti and Vitiello, 1976).

3. CONCLUSION

From the preceeding section the strong influence of geotechnical soil characteristics is clearly evident on the structural safety requirements, particularly in terms of strength, deformability and then ductility.

When the predominant period of the soil layer is near the natural period of the building considered, the soil structure interaction reaches its maximum effect consisting in a magnification of acceleration and/or displacement which affects the structure (Maugeri, 1971; Bo et all. ; 1978). When the predominant soil period is different from the period of structures the interaction effect diminishes and can be negative, as results from fig. 8 (except in the case of a soil layer depth of 5m. when a small acceleration magnification still remains).

On the other hand, when the subsoil is formed of rock and the predominant earthquake period is very different from the period of structures the soil structure interaction effect is practically absent.

This is the case of the house of the keeper of the Ambiesta dam (fig. 10), a few metres away from where the maximum acceleration value was recorded (Tolmezzo station) during the Friuli earthquake.

The natural period of the construction resting on calcareous rock (Martinis, 1977) and made of both concrete and the bearing masonry was 0.023 sec. (taking into account the reduction in the stiffness due to the presence of the windows in the masonry).

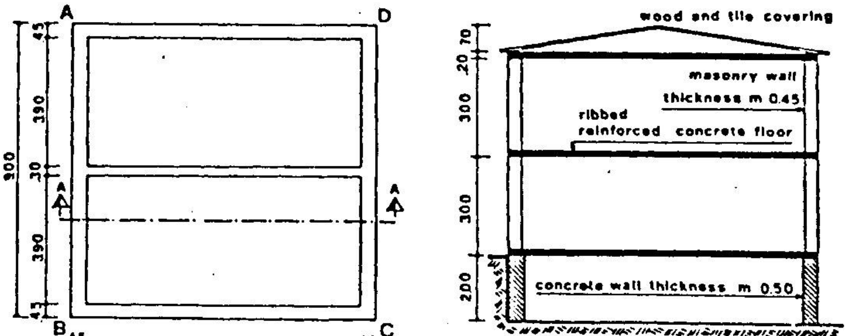

Fig. 10: Structural sheme of the house near the Ambiesta dam.

As a result, there was no appreciable amplification in the structure and it was virtually undamaged (small signs of damage which appeared during the second shock on 15th September 1976 could have been favoured by the increase in the original natural period due to the plasticisation during the main shock of 6th May 1976).

Lastly the relevance of a deep embedment as a measure to reduce the seismic shaking must be quoted.

In the case of the new terminal at Catania Airport, which will be built in a so far non seismic area above a clay soil deposit described by Maugeri (1977), when the response spectra of Codroipo (see figs. 3, 4, 5) is imposed, the seismic effect was reduced by 16% of that of a surface foundation, by taking the embedment due to the pile foundation depth of 40m into account.

Acknowledgement

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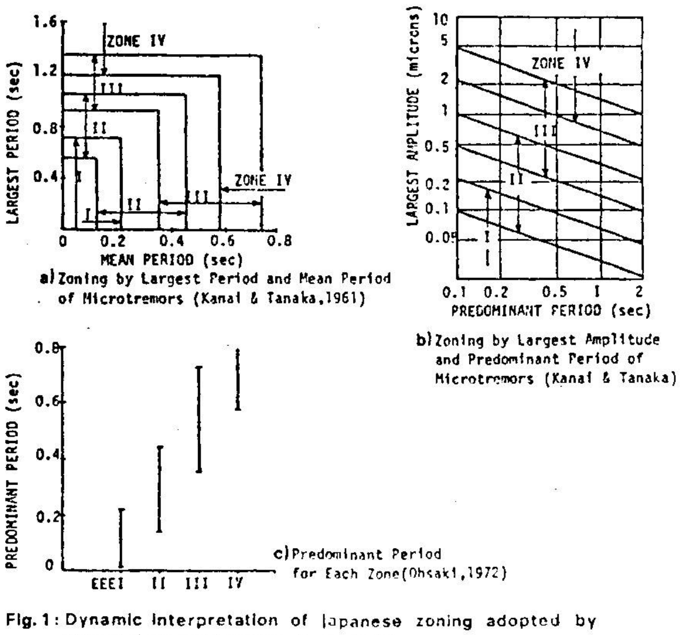


Fig. 1: Dynamic interpretation of Japanese zoning adopted by Ministry of constrution since 1951.

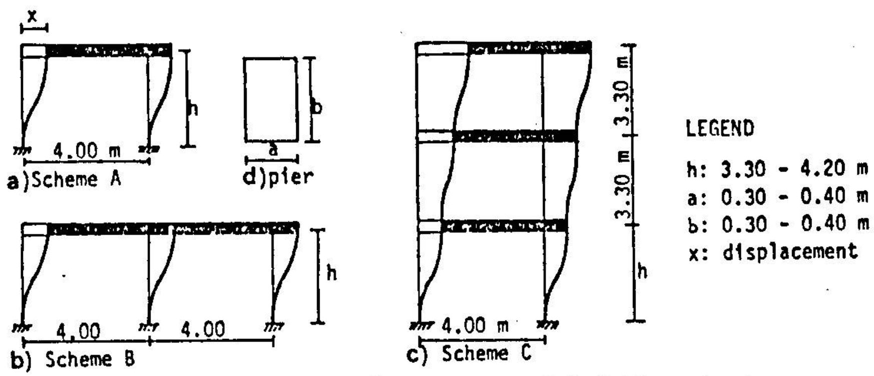


Fig. 2: Strctures examined with several height and pier dimensions.

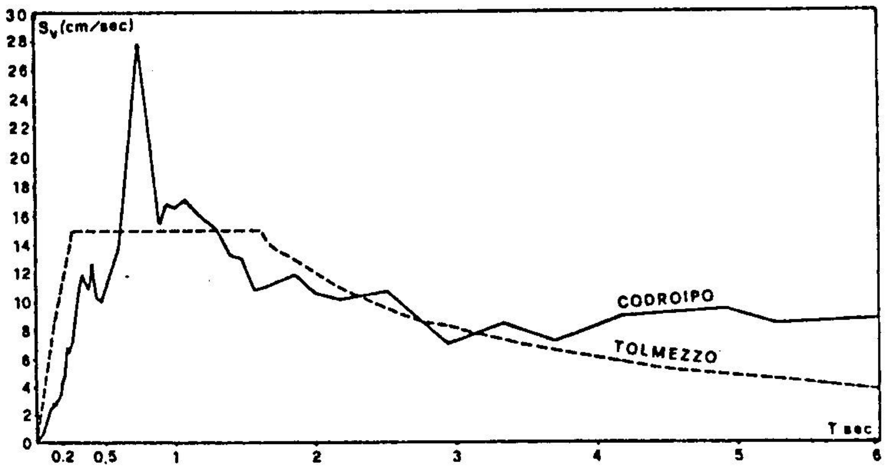


Fig. 4: Design velocity spectrum; Friuli Earthquake 1976.

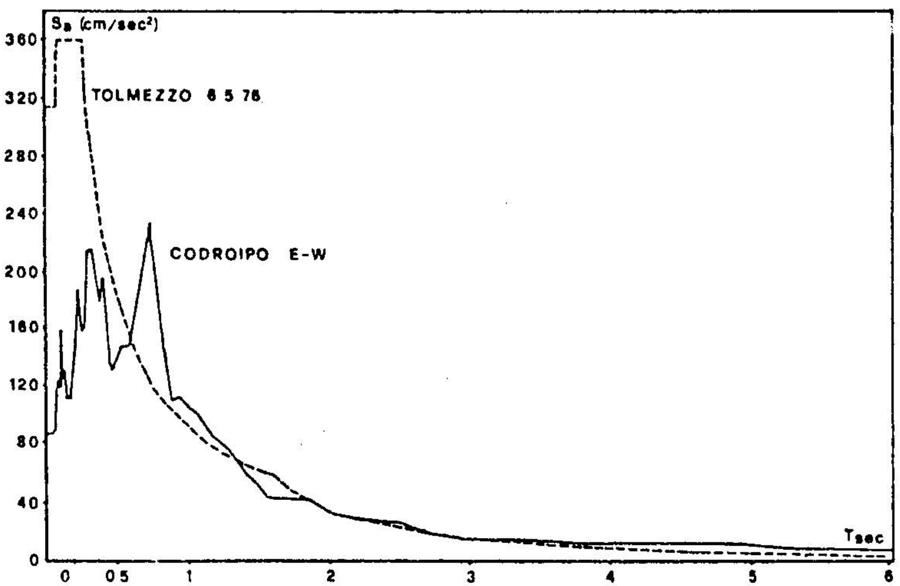


Fig. 3: Design acceleration spectrum; Friuli Earthquake 1976.

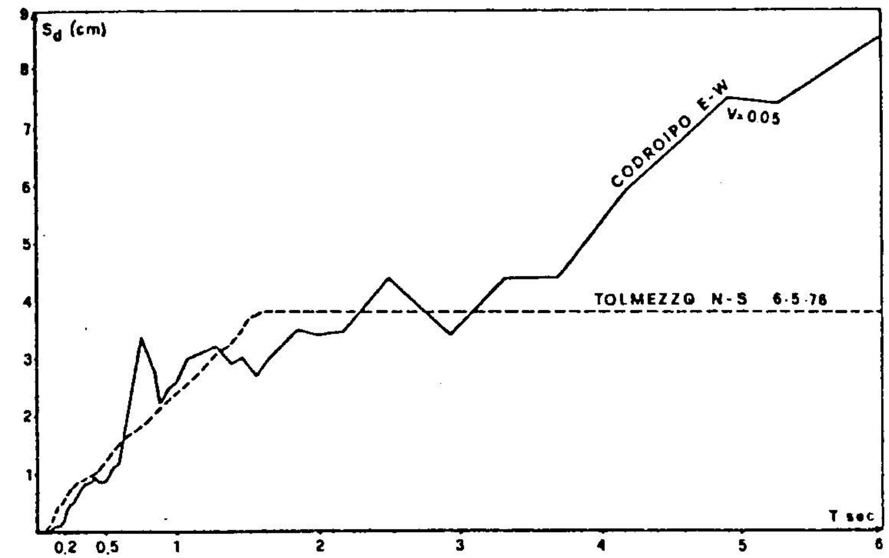
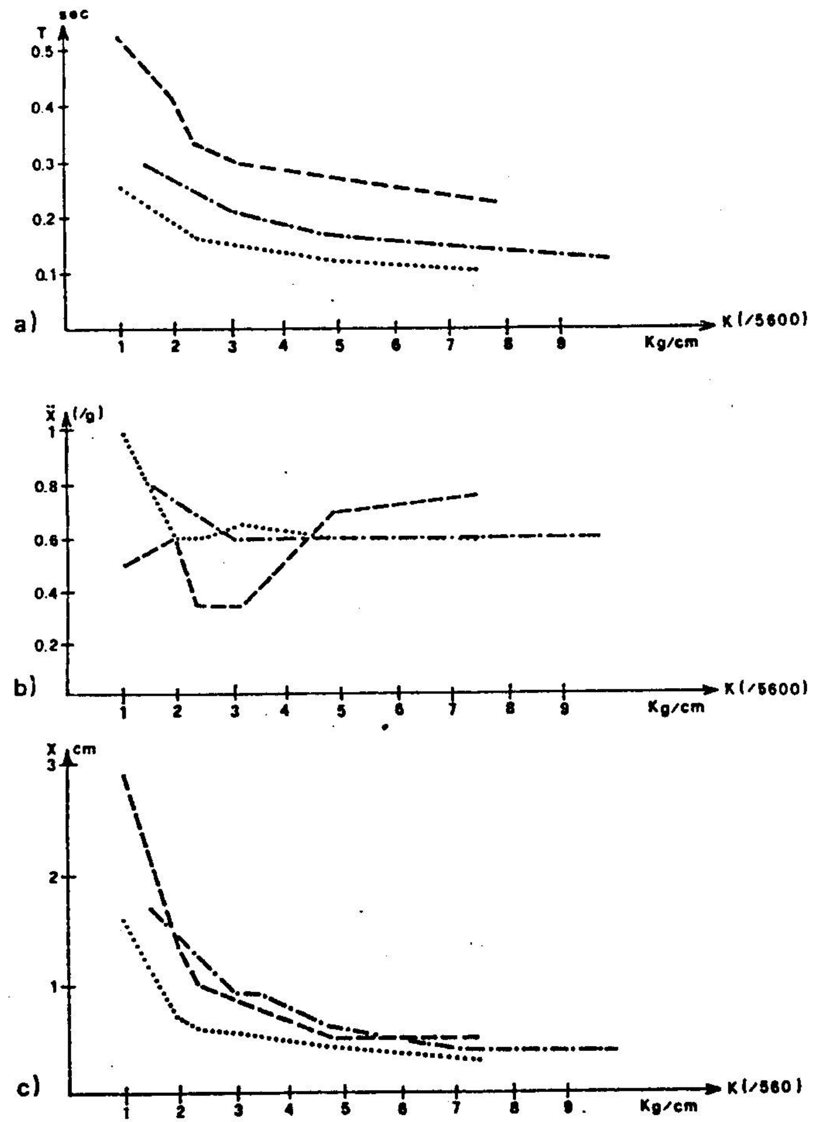


Fig. 5: Design displacement spectrum; Friuli Earthquake 1976.



LEGEND
.... SCHEME A
—·—·— SCHEME B
— — — SCHEME C

K = rigidity
T = natural period
Ẍ = acceleration
X = displacement

Fig. 6: Influence of rigidity on the natural periods, max structure accelerations and displacements.

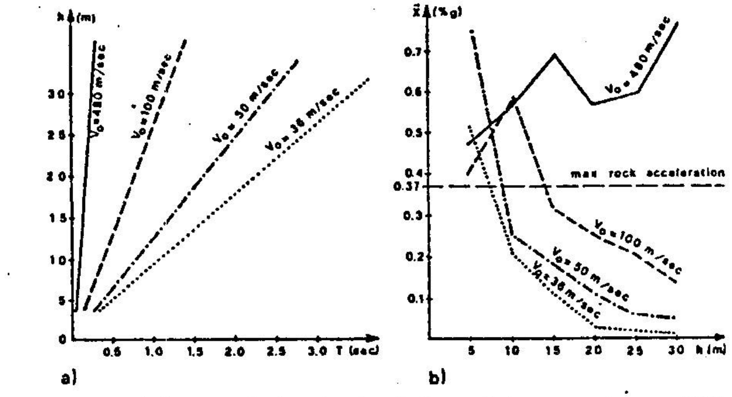


Fig. 7: Influence of the depth of the soil layer on its predominant period and on the max ground acceleration for a given sheor wave velocity.

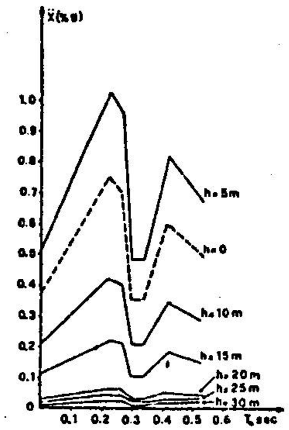


Fig. 8: Influence of structural natural period on its max acceleration resting on soft soil layer of different depth.

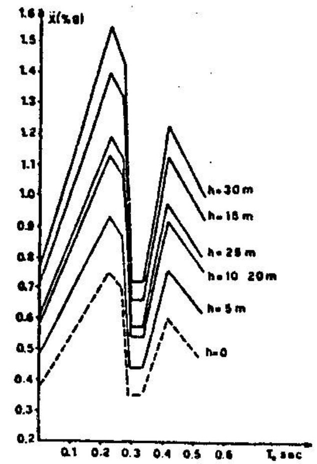


Fig. 9: Influence of structural natural period on its max acceleration resting on a stiff soil loyer of different depth.