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DYNAMIC TESTS PERFORMED ON LARGE PILES

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ABSTRACT

In order to have a better characterization of the soil dynamics behavior of a bridge foundation a 3D finite element model was developed for the interpretation of the behavior observed during a forced vibration test of a group of two piles.

The **soil-piles system** was discretized with 3D finite elements of the second degree (cubic with 20 nodal points). The numerical results are compared with the in situ observed results, in terms of displacement transfer functions.

KEYWORDS

Dynamic in situ test; Large piles; 3DFEM; Vibration modes; Transfer functions; Displacements; Strains.

INTRODUCTION

In order to have a better characterization of the dynamic behavior of the alluvial material for a bridge foundation a forced vibration test of a group of two piles was performed. A 3D finite element model was developed for the interpretation of the observed behavior.

The piles with 1.20 m of diameter and 60 m long were connected by a cap with 5.5 x 3.5 x 1.2 m (Fig. 1).

A simplified profile of ground material is also shown in Fig. 1.

The soil-pile system was discretized with 3D finite elements of the second degree (cubic with 20 nodal points). The numerical results are compared with the observed values, in terms of displacement transfer functions.

DESCRIPTION OF THE TEST

In the dynamic test a vibrator built in LNEC was used to impose on the pile cap, harmonic horizontal loads, with different amplitudes and frequencies.

The excitation frequencies were applied in steps of 0.1 Hz in the range from 0.5 to 20 Hz approximately. The dynamic response of the structure, for the various frequencies of excitation, was measured by means of velocity transducers and accelerometers. These equipments were placed in several points in order to monitoring the horizontal and vertical displacements.

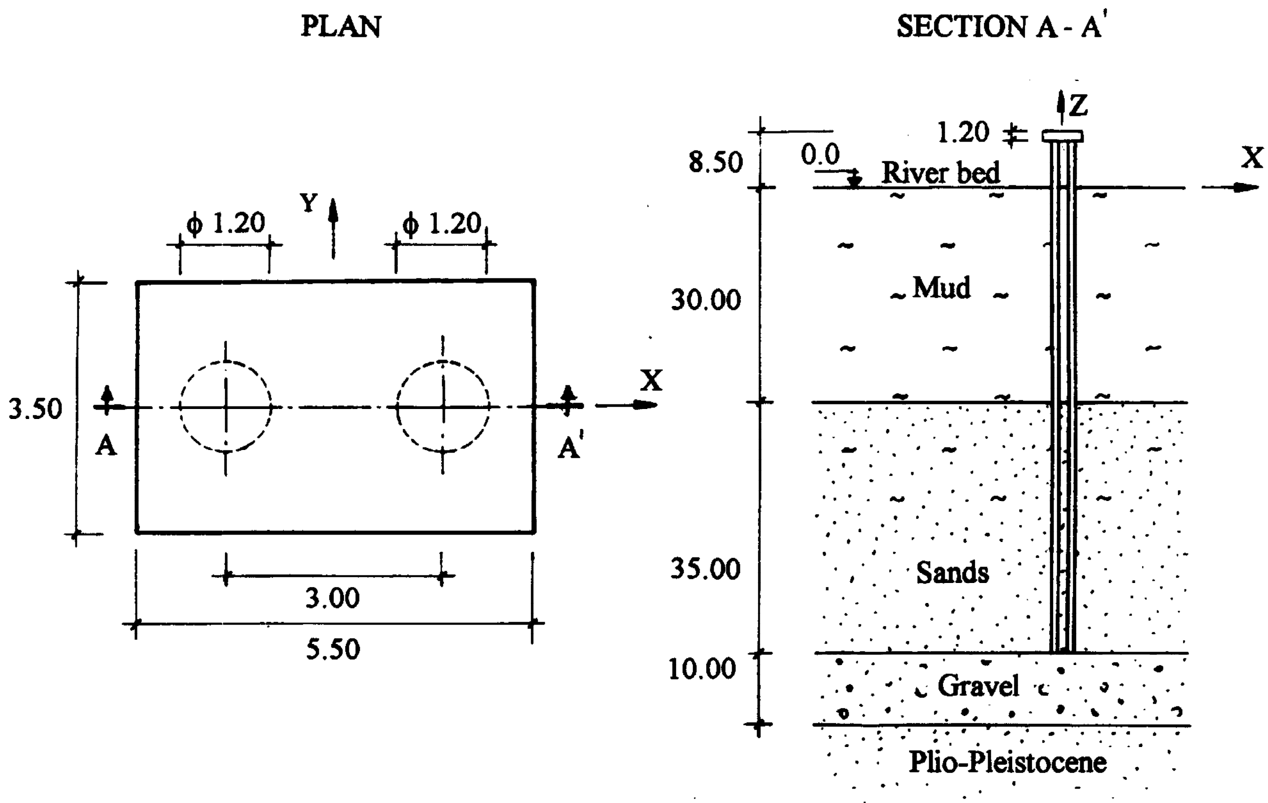


Fig. 1 - Group of two piles. Simplified geotechnical profile.

Time series of velocity were recorded on several points (Fig. 2), during the test. The digital treatment of this time series was performed by a computer program developed at LNEC (Portugal, 1990). Treated series are transported for frequency domain and the displacements were obtained by integration.

MATHEMATICAL MODEL

For the interpretation of the test results a 3D model was used, to represent the soil, the two piles and the cap.

It was assumed that the piles were composed of a continuous, homogeneous and isotropic material with a linear and elastic behavior characterized by an elasticity module E_p=50 GPa (about 50% higher than the values determined in static tests) and by the Poisson's ratio ν_p=0.2. The soil was considered as a continuous material, with elastic behavior, and composed of various homogeneous layers. The final values adopted for the thickness for each of those layers, the shear modules (G) and the Poisson's ratio (ν) are shown in Table 1:

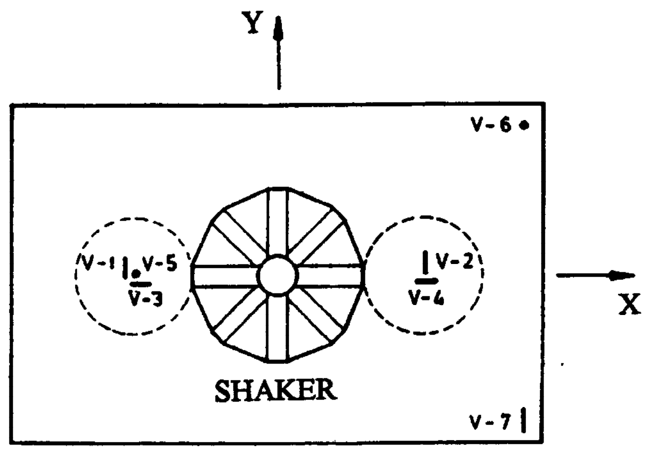


Fig. 2 - Schematic vue of the shaker and velocity transducers

Table 1 Characteristics of the soil materials

LAYER	G (MPa)	ν
Mud - surface zone, decompressed zone and submitted to erosion (from 0 to -2.5 m)	0	—
Mud - 1st layer (from - 2.5 m to -10 m)	10	0.45
Mud - 2nd layer (from - 10m to -20 m)	15	0.45
Mud - 3rd layer (from - 20 to -30 m)	20	0.45
Sands (from - 30 to -65m)	40	0.35
Gravel (from -65 to -75m)	50	0.30
Plio-Pleistocene	120	0.25

Those values were defined from an extensive geotechnical characterization of the soil materials to assess the static and dynamic properties. The following field tests were performed: SPT tests, CPTU tests, crosshole tests, vane tests, pressurometer tests and seismic cone tests. From undisturbed samples, the following laboratory tests were performed: identification tests, static triaxial tests, reasonant column tests, cyclic simple shear tests and torsional shear tests.

It must be pointed out that during the stage of calibration of the model it was verified that a zone of about 2.5 m with an almost nil shear modulus should be considered on top of the layer of mud. This fact indicates that the surface layer of mud in the vicinity of the piles is decompressed and disturbed due to the effect of tides in the channel zone.

There must also be pointed out that the response measured in the soil is essentially conditioned by the mechanical characteristics of the upper zone of the mud, therefore, the values presented for the other formations had minor importance in view of the values measured. The measurements that were to be obtained from the accelerometers would have a decisive importance for a better knowledge of the dynamic response in depth.

For the analysis, a computer program developed at LNEC (Oliveira, 1991) was used and the soil-piles system was discretized in 248 finite elements of second order, (20 node cubic elements) with nodal points in the vertices and in the middle of the edges, 1240 nodal points to which correspond 3720 degrees of freedom (Fig.3).

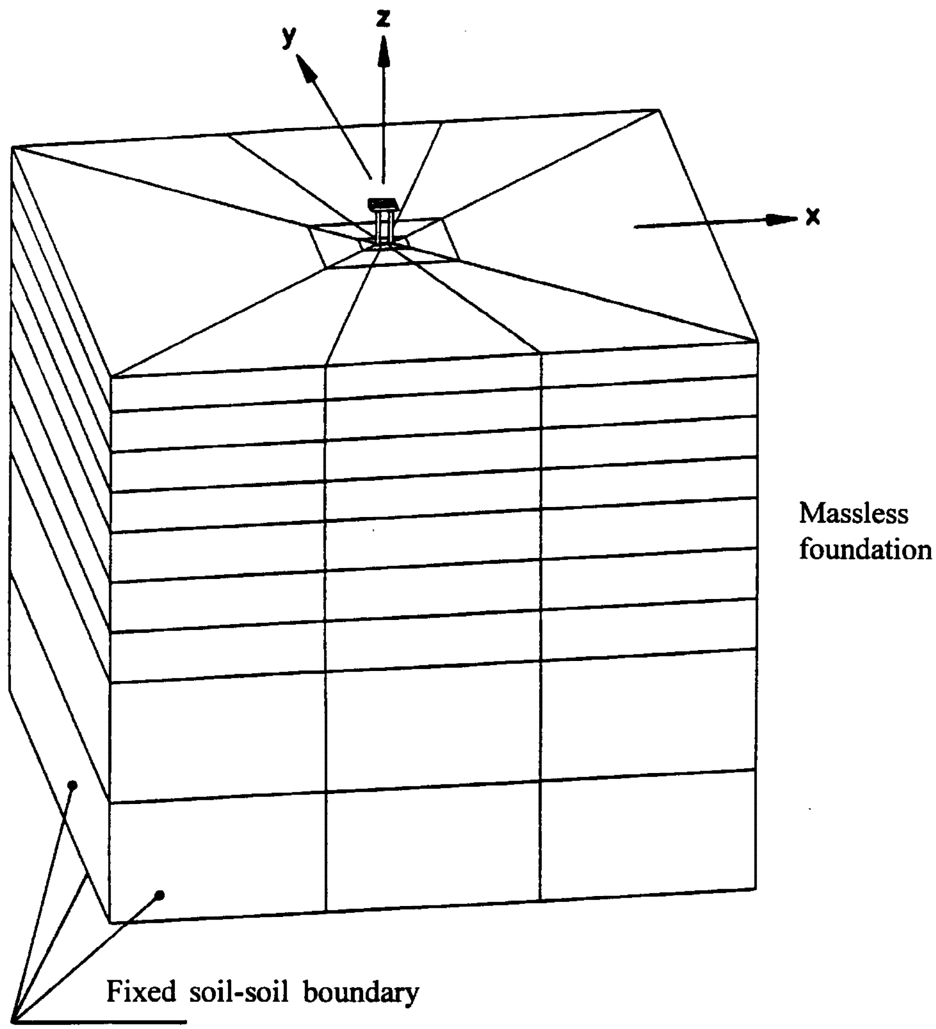
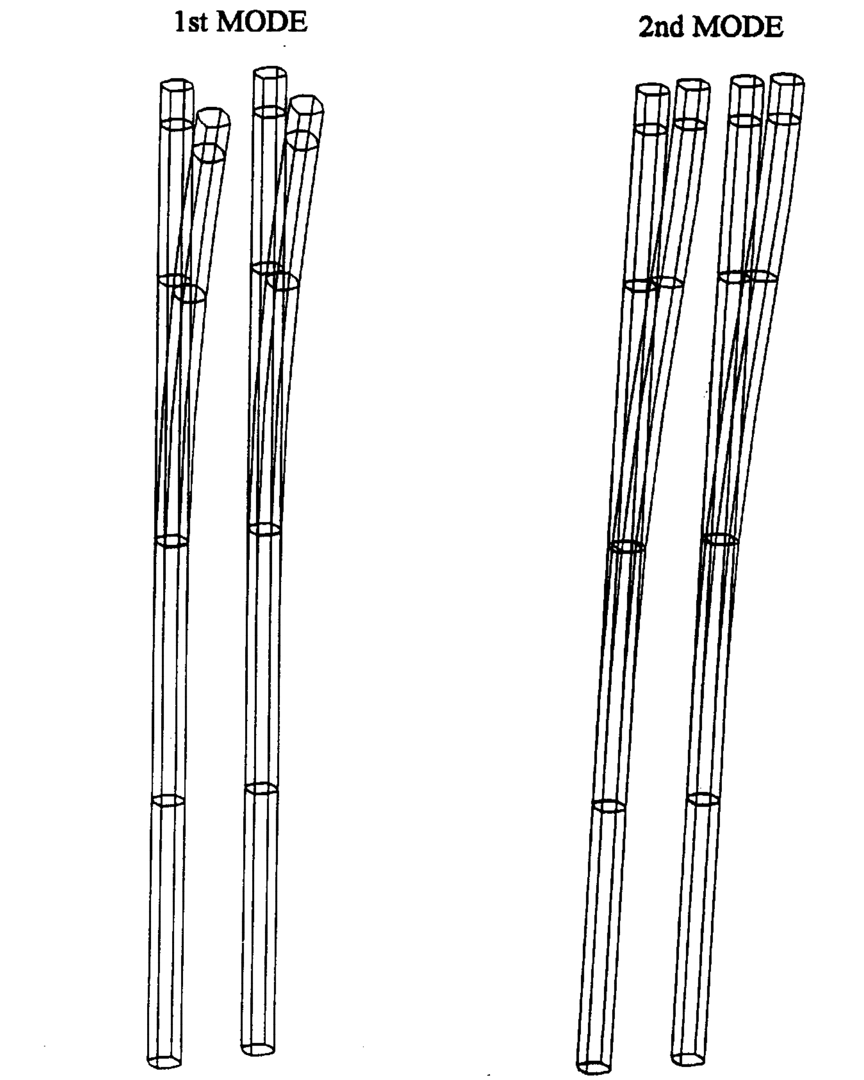


Fig. 3 - 3D Finite element model of soil-piles system

In these studies the soil mass was considered nil and the dynamic pressure of the water and of the mud material acting on the piles was disregarded.

The configuration of the two first modes of vibration and respective frequencies (observed and computed) is presented in Fig.4. The first vibration mode corresponds to the bending of both piles following a direction perpendicular to the vertical plan that encloses both of them. The second mode corresponds to the bending of both piles in the vertical plan that contains them.

The modal damping values used in the mathematical model were the ones that were best adjusted to the transfer functions observed in the test. The adopted values are presented in Table 2.



$f_1 = \begin{cases} 1.7 \text{ Hz (observed)} \\ 1.76 \text{ Hz (calculated)} \end{cases}$ $f_2 = \begin{cases} 2.7 \text{ Hz (observed)} \\ 2.79 \text{ Hz (calculated)} \end{cases}$

Fig. 4 - Configuration of the two first vibration modes. Observed and computed frequencies

Table 2. Modal damping values adopted in the mathematical model

Vibration Modes	1	2	3
Damping modal in % of the critical damping	7	13	20

COMPARISON OF RESULTS

The observed frequencies and the calculated frequencies by the mathematical model are presented in Table 3. For the two first vibration modes there is a good agreement between the observed and the calculated values. It must be stressed that the seismic behavior of the **soil-piles system** will be mainly conditioned by the response of the two first vibration modes because the power spectral density for seismic accelerations presents low values for frequencies of the same magnitude of the other modes.

Table 3 Frequencies of the first vibration modes

Vibration Modes	1	2	3	4
Observed Frequencies	1.7	2.7	—	—
Calculated Frequencies	1.76	2.79	8.78	11.70

DISPLACEMENT TRANSFER FUNCTIONS

The results observed in the test and those computed by the mathematical model in terms of displacement transfer functions of the force applied by the shaker (points V-1, V- 3 and V-5) are shown in Fig. 5.

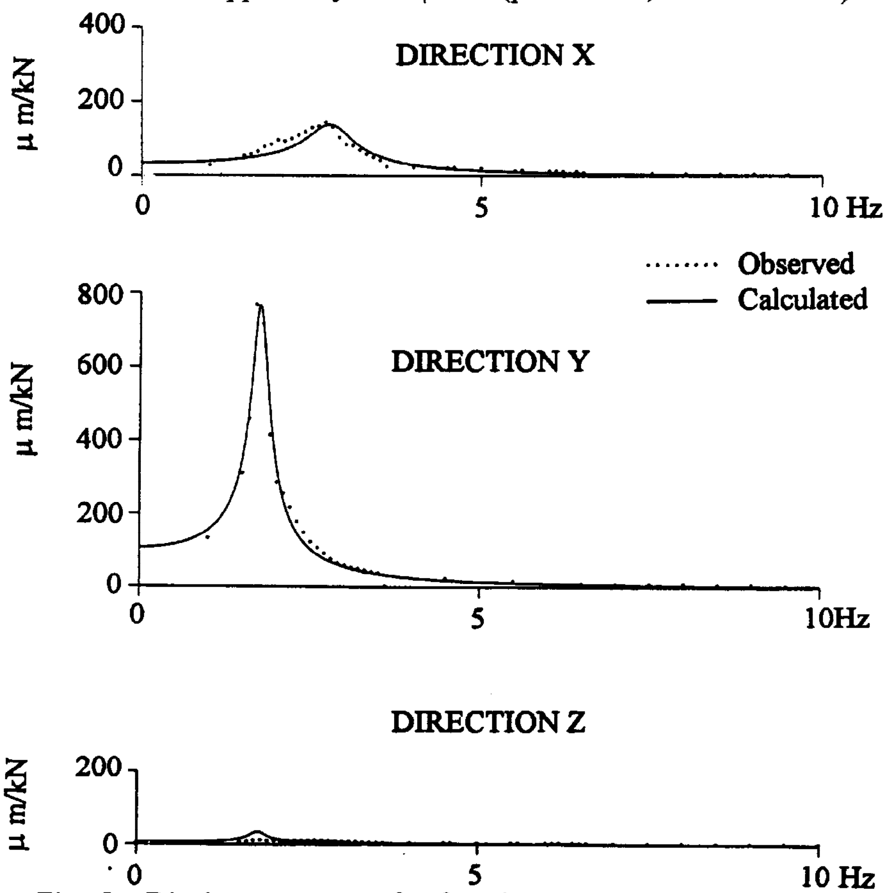


Fig. 5 - Displacement transfer functions (points V-1, V-3 and V-5). Comparison between computed and observed values

A good agreement between the observed values and the calculated curves was obtained, which makes it possible to conclude that the mathematical model is well calibrated for simulation of the behavior of the **soil-piles system** under the shaker forces.
The variation of maximum displacements of piles with depth according to directions X and Y, as well as some displacement transfer functions computed at different depths is shown in Fig. 6. This figure also shows that, during tests, for depths higher than 15 m, the piles displacements were almost nil .

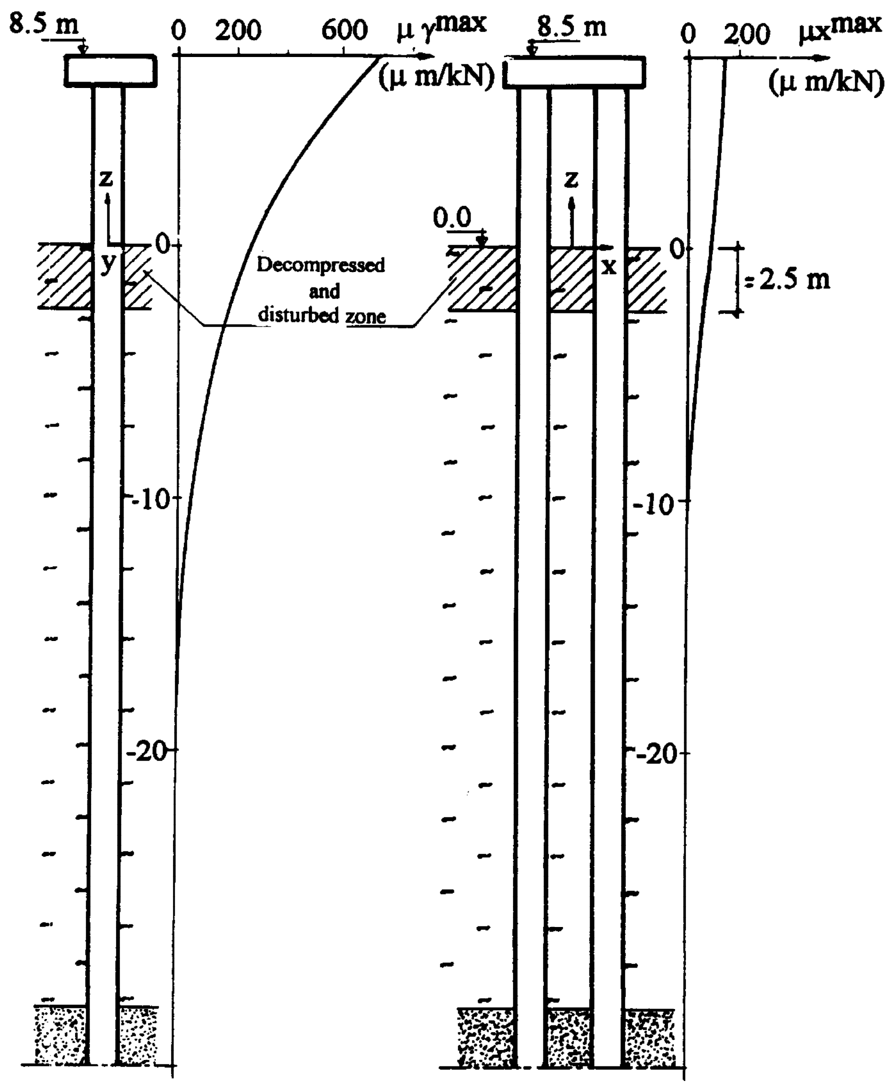


Fig. 6 - Variation with depth of maximum displacement of piles. X and Y directions

The variation of maximum strains of the soil in the neighboring of the piles with depth is shown in Fig 7. The strain level is low (the maximum value is 0.1%), which confirms the fact that the overall observed behavior is almost linear.

CONCLUSIONS

The implemented 3D mathematical model has shown adequate for the interpretation of the dynamic behavior of the soil-pile system for the forces applied by the shaker.

The observed and calculated values present a good agreement, both in terms of specific frequencies of the two main vibration modes (the observed values are 1.7 and 2.7 Hz and the calculated values are 1.76 and 2.79 Hz), and in terms of the amplitude of the response measured in the cap (compared in terms of displacement transfer functions).

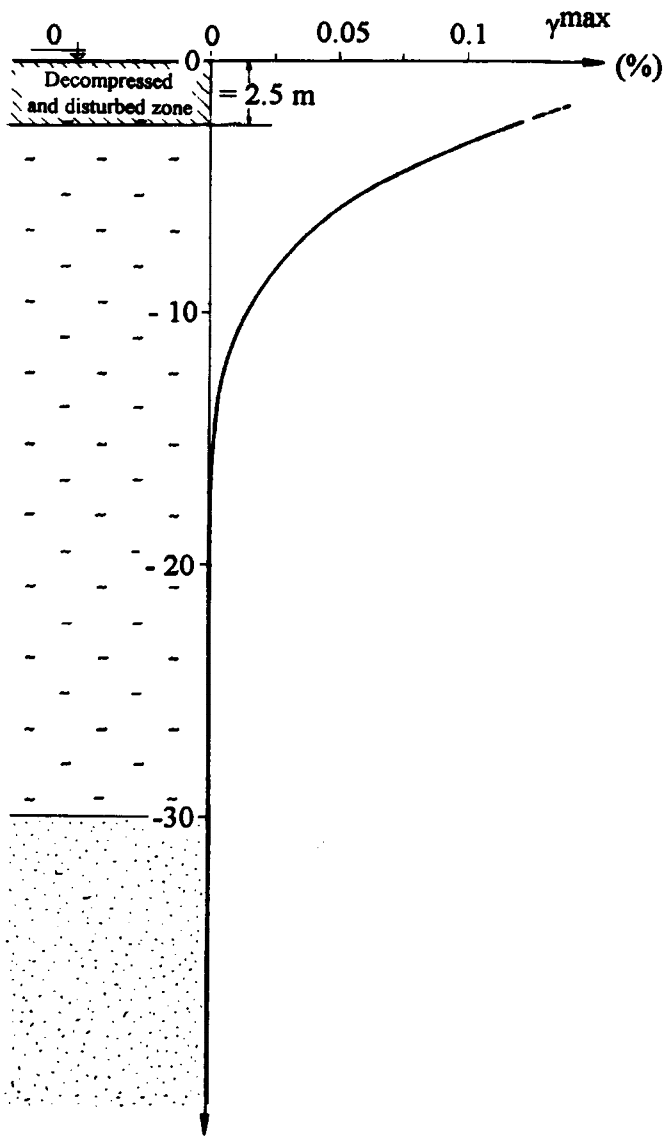


Fig. 7 - Variation of maximum strains with depth

The modal damping values of 7% and 13% used in the model, for the first and second mode, respectively, are values approximately equal to the observed ones.

The application of the mathematical model presented has validated the hypothesis of the existence of a totally decompressed and remolded surface layer of mud with a thickness of 1 to 2.5 m, exhibiting extremely low distortion modules.

In summary, it is considered that the tests carried out, even though they had been based only on measurements carried out on the top of the cap showed that the soil presents mechanical characteristics that agree with the geotechnical model defined from the in-situ and laboratory tests results.

REFERENCES

Oliveira, S.B. (1991) 3D Finite element for static and dynamic 3D equilibrium. Report submitted for the degree of Assistant Research (in portuguese).

Portugal, A.C. (1990) Characterization of the dynamic behavior of concrete dams by in situ tests. Master thesis (in portuguese).