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Published by Elsevier Science Ltd 1996
Paper No. 216. (quote when citing this article)
Eleventh World Conference on Earthquake Engineering
ISBN: 0 08 042822 3

INVESTIGATION OF EARTHQUAKE EFFECT ON BURIED BOX CULVERTS.

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ABSTRACT

The behavior of buried box culverts at different depths, under-earthquake-effect has been investigated. Linear and nonlinear dynamic analysis of models has been carried out using the finite elements method and results of the structural deformation and displacement, forces exerted on the slab and the wall have been presented.

1- INTRODUCTION

Knowing the high expense of Bridge and Tunnel constructions in road developments, the study of different applied loads including earthquake forces on these structures is of special importance. Depending on the geometric and topographic characteristics of the path, bridges and tunnels may be placed at different soil depths. Therefore, the effects of depth, adjacent soils and other forces on theses structures should be determined.

Due to considerable displacements resulted from earthquake forces, nonlinear models have to be used to explain the soil behavior. In the present paper, using various models, the effect of earthquakes on buried boxes with different geometric characteristics have been studied.

2- SELECTED MODELS AND ANALYSIS

The analysis have been carried out using the finite clement method with linear and non-linear models. due to the considerable length of the boxes, Asolid elements and plain strain has been assumed. the elements are four-sided (plane 42) and have four nodes. To study the behavior of the boxes, two models with dimensions of 8×15m and 8×5m placed at six different depths of 3.5, 7.5, 15, 20 and 30 meters have been selected.

To obtain the appropriate distance for adjacent soil layers in finite element mesh, four different distances of 90, 120, 150 and 220 meters have been studied, using the model analysis and it was found that accurate results can be obtained with the 90 m distances. The dimensions of the elements which are parallel and perpendicular to the direction of earthquake wave propagation are $\frac{\lambda}{5}$ and $\frac{\lambda}{2}$ respectively. Based on selected spectrum, these dimensions are respectively 12.5 and 31.25 meters. In addition, to eleminate the errors associated with wave reflections from soil border points, supplementary boundry elements have been applied.

Nonlinear analysis have been performed spectrally and through nojan spectrum (Fig.1). Various models of boxes and adjacent soil have been analyzed (Fig.2) with the following two assumptions for the soil-boxes system.

-Linear behavior
-Nonlinear behavior

In both conditions, three types of soil, dense sands, semi-dense sands and soft silty sand have been selected and their parameters have been calculated. Table 1 shows these parameters for linear analysis.

Type of soil	E (Mpa)	υ
Dense gravel & sand	135	0.35
Semi-dense sand	70	0.3
Soft silty sand	20	0.25

Tab.1

The Dracker-Prager elasto-Plastic model has been used to study the nonlinear behavior of soil where as the rupture surface in such a model is observed in terms of :

$$\alpha \; I_1 - J_2^{\,1/2} + K = 0$$

$$\alpha = \frac{2 \sin \Phi}{\sqrt{3}\,(3 - \sin \Phi)}$$

$$K = \frac{6C \quad \cos \Phi}{\sqrt{3}\,(3 - \sin \Phi)}$$

Perliminary soil data using the preceding parameters are shown in table 2.

Test No.	Confining Pressure	Pore pressure	$\sigma'_2 = \sigma'_3$	$\sigma'_1 (\frac{Kg}{Cm^2})$	I_1	$J_2^{1/2}$
1	1	0	1	6	8	2.89
2	0.3	0.29	2.71	12.71	18.13	5.77
3	4.5	0.61	3.89	3.89	28.87	9.93

Tab.2

Using the regression line for these three points, the rupture relation, is represented as:

$$0.3376\, I_1 - J_2^{\,1/2} + 0.005 = 0$$

3-RESULTS & DISCUSSIONS

3-1-Study of the effect of box rigidity. To study such a phenomenon, various box models in different depths and in two different conditions were analyzed and the vertical pressure and the tangential stress exerted on the box wall were obtained. As shown graphically in figure 3, the increase of rigidity of the box wall would cause an increase in vertical pressure and a decrease of tangential stress and such changes would be approximately similar in various depths

3-2-Study of box displacement in relation to bed-rock. In this part, models at different soils and various depths have analyzed in fifteen conditions and the results have been presented in figures 4 and 5. Results show that the amount of displacement have been increased up to a specified depth and diminishes thereafter. Such a limit depth for various models is based on the type of soil and changes between 7.5 to 15 meters. Also, by increasing stiffness of the soil (and its modules of elasticity) the amount of displacement is diminished.

It should be noted that the initial modes of the soil system for the box have played a major role in maximum relative displacement which are the corresponding displacement in the noted depth. Assuming non linear behavior for the soil, the relative displacement of the box is more than the corresponding displacement for linear behavior and the difference increases as the depth decreases. For the 3.5 m depth, the difference is 40% and when the depth reaches 30 m, the difference decreases to 25%.

From the results of analysis of different models, variation of vertical pressure and tangential stress of the slab, for three types of soils are presented in figures 6,7.

Results of linear analysis show that the tangential stress on the top and bottom of the box is uniformally distributed with small concentration at the corners. The amount of stress on the top is higher than the corresponding value on the bottom which is as a result of its relative displacement.

The tangential stress on the top increases with increase of depth upto a certain limit where it decreases with moderate slope after ward. In addition, as soil density increases, the amount of tangential stress increase and an average of 9 and 25% increase are observed as compared to the soft soil.

As the box rigidity decreases, the tangential stress on its top and bottom increases which is as a results of increase in surface deformation.

Fig. 8 shows that the amount of tangential stress on the top of box, assuming nonlinear behavior for soil which results increases of displacement, is about 18% higher than the corresponding value when linear behavior is assumed. This difference decreases with increase in depth and it almost diminishes at the depth of 30 m.

figs. 9 to 10 show variation of vertical pressure on the walls for different soils and depths. The amount of the pressure is significant and its distribution is relatively uniform. The location of the corresponding resulting pressure is at 0.5 to 0.6 of the height from the floor which is in agreement with dynamic soil behavior.

As soil density increases, the vertical pressure increases and this increase continues up to a depth of 7.5 m and then it decreases with a moderate slope.

With decrease in box rigidity, the vertical pressures on the walls are decreased. In nonlinear analysis, the soil hardness is decreased, but with increase in relative displacement, the resulting pressure is not changed significantly. In non linear analysis the location of the resulting pressure is lower than the corresponding location from linear analysis by 5 to 10%.

4-CONCLUSION

Consideration of the results of linear and nonlinear analysis of the buried box bridges under the effect of earthquake at different soil depths indicates that the amount of exerted loads and displacements of the box in some sections exceeds the static values and the loads and displacements of nonlinear analysis are generally more than the corresponding values for linear analysis.

The amount of vertical pressure on the wall and the box displacement increases upto a limit depth as compared to the earth surface and decreases after ward.

Variation of the vertical pressure on the box walls are limited and the location of the corresponding resulting pressure is higher than the corresponding position for the static load (about 0.5 to 0.6 of height from the floor).

The amount of tangential stress on top and bottom of the box is relatively uniform with small stress concentration at the corners. The amount of this stress on top and bottom of the box is higher than the tangential stress on the walls.

5-REFERENCES

1- Dungar, R. and studer, J. A. (1986); "Geomechanical modelling in Engineering practice", Balkema, Rotterdam.

2- Chen,W.F. (1984) "Constitutive Modelling in soil mechanics" - John Williey & Sons.

3- Suzuki, K. and Desai, C.S.(1985) " Finite element Analysis using an elastoplastic anisotropic hardening model "-Rotterdam.

4- J.P. Wolf (1985) " Dynamic soil-structure Interaction" Prentice Hall, Inc, Englewood Cliffs.

5- J.P. Wolf (1988) "soil-structure Intraction Analysis in time domain" Prentice Hall, Inc, Englewood Cliffs.

6- N.M. Newmark. W.D. Hall (1987) " earthquake spectra and design " Earthquake engineering research Institute.

7- Chanooni. S.M (1994) " Dynamic Analysis of soil Layer-Dam Systems subjected to strong Earthquakes" Imperial College. London. U. K.

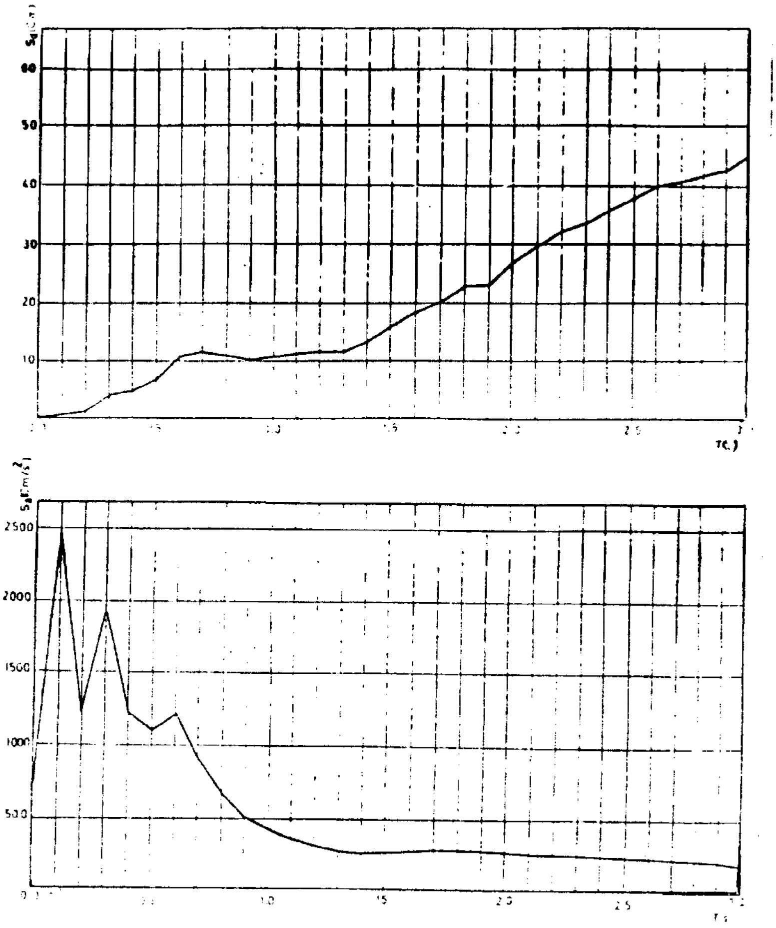


FIG 1 Accelaration and displacement spectrums of Naghan earthquake.

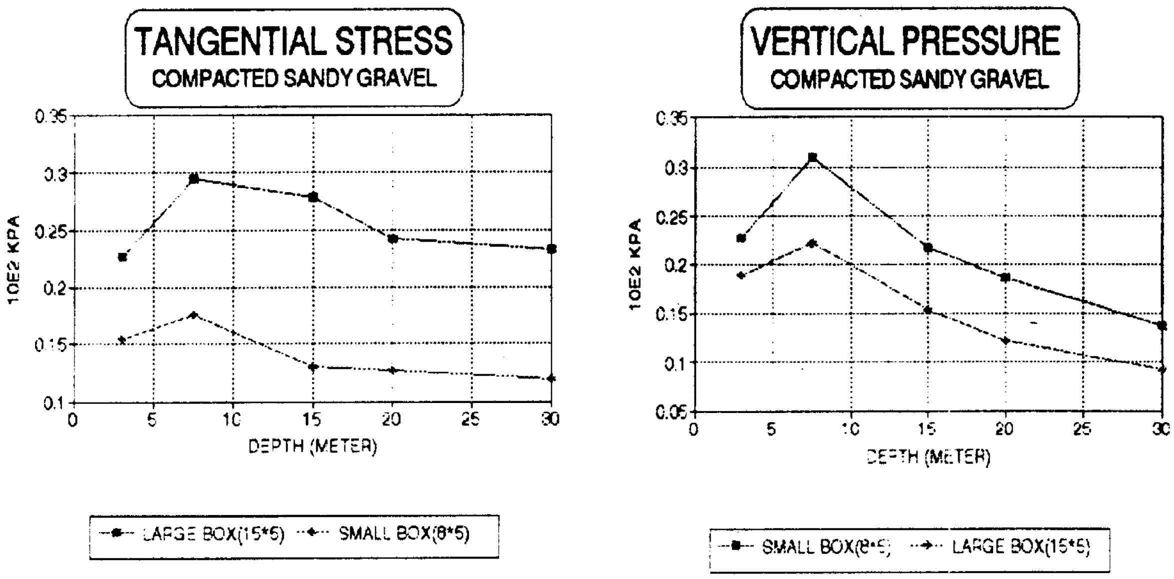
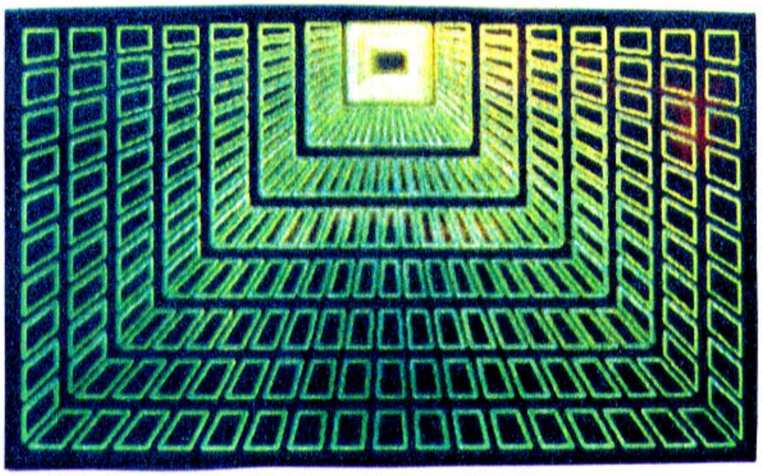
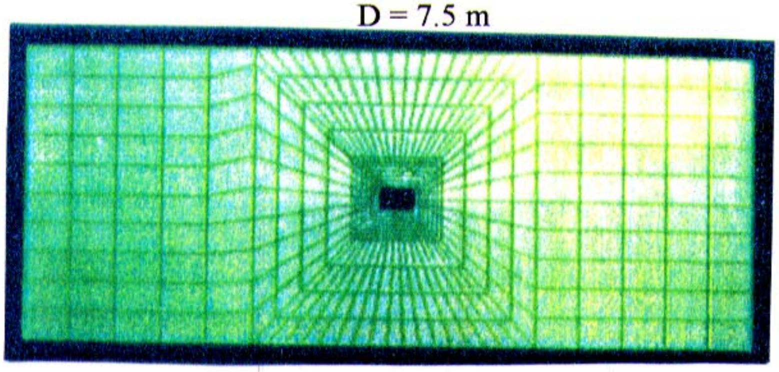


FIG 3 . Variation of Vertical Pressure and Tangential Stress for Different Boxes



D = 7.5 m



D = 30 m

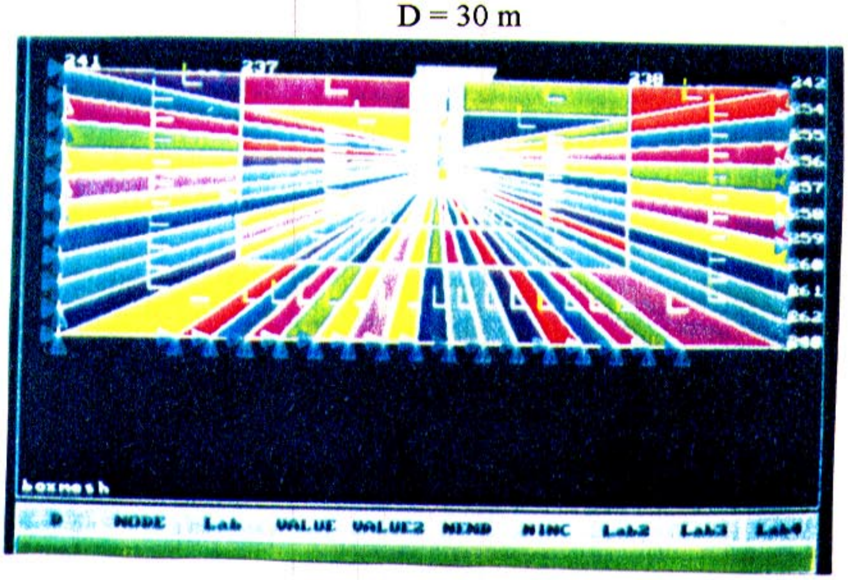


Fig. 2 Finite element mesh for linear and nonlinear analysis.

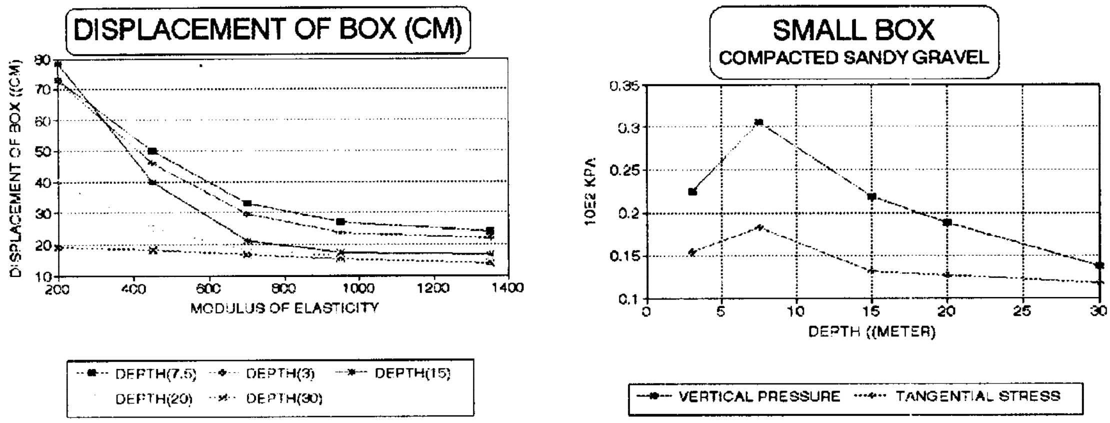


FIG 5 . Displacement of Box for Different Soils

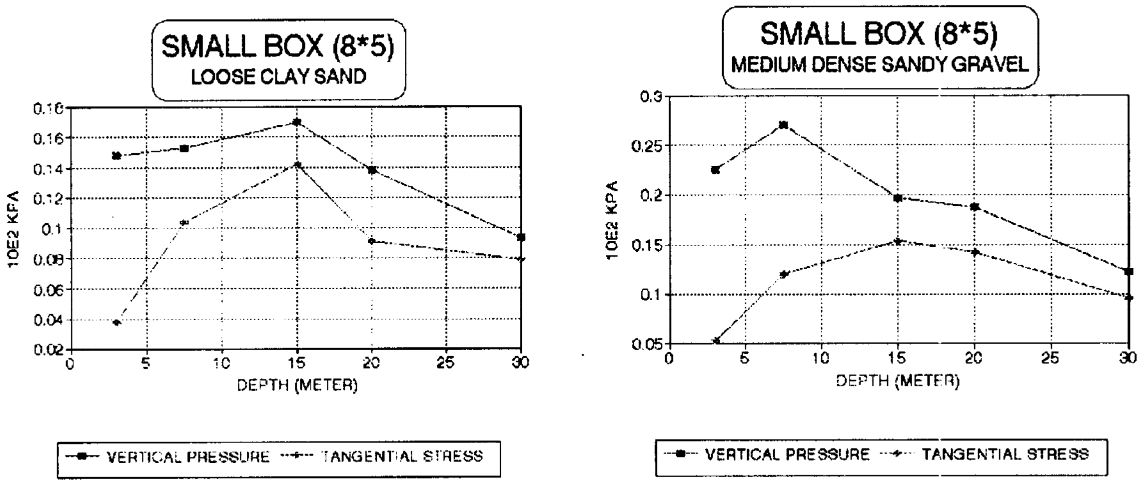


FIG 6 . .Variation of Vertical Pressure and Tangential Stress for Different Soils

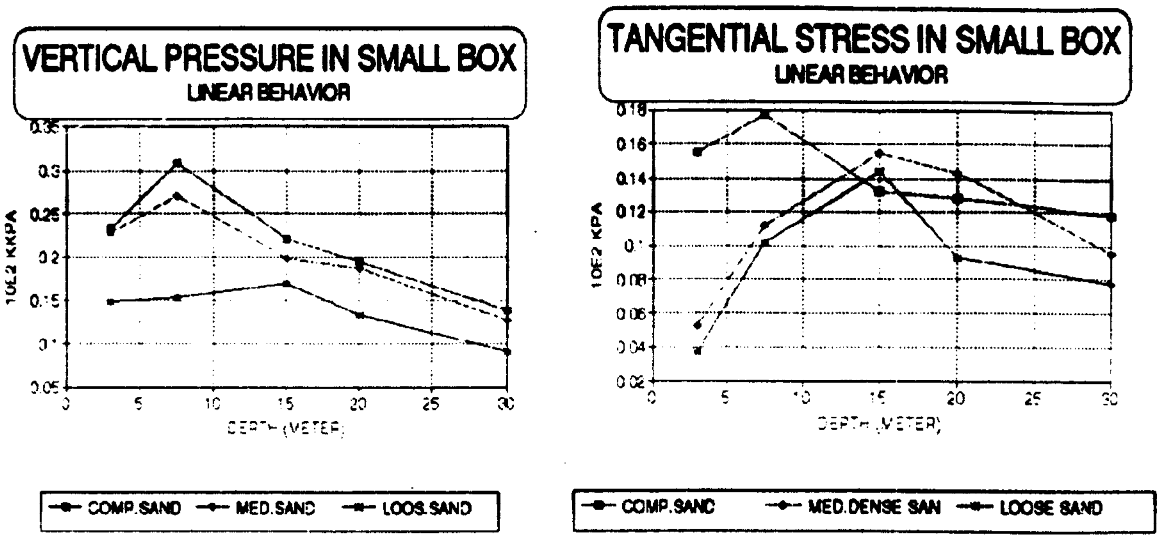


FIG 7 . Variation of Vertical Pressure and Tangential Stress for Different Soils

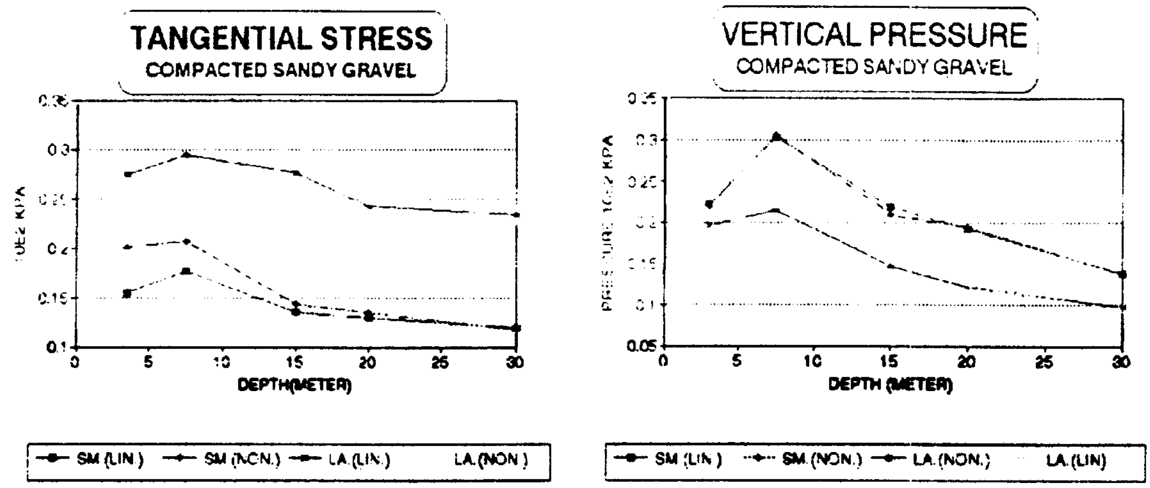


FIG 8 . Variation of Vertical Pressure and Tangential Stress for Different Conditions

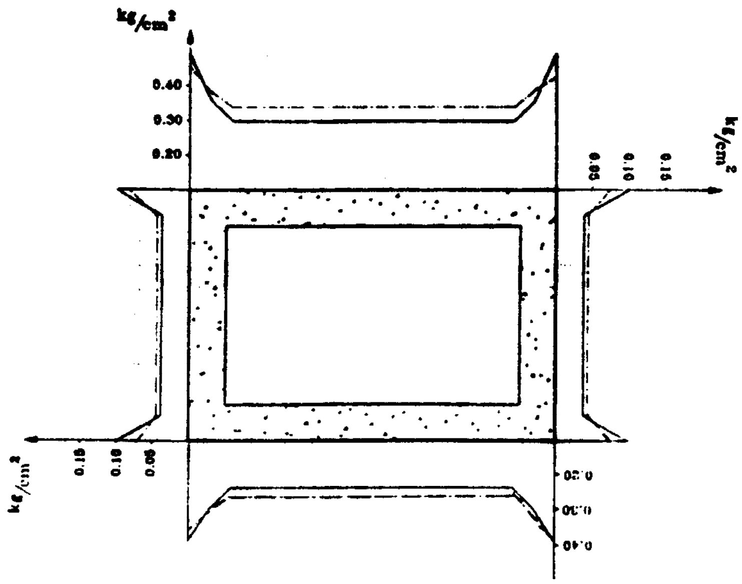
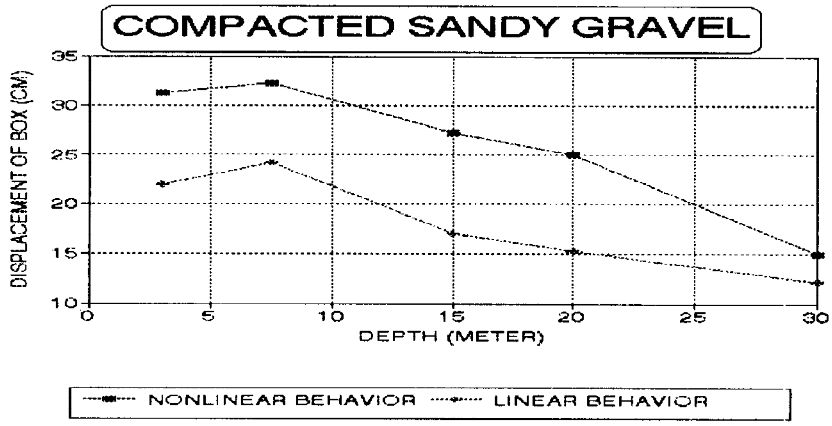
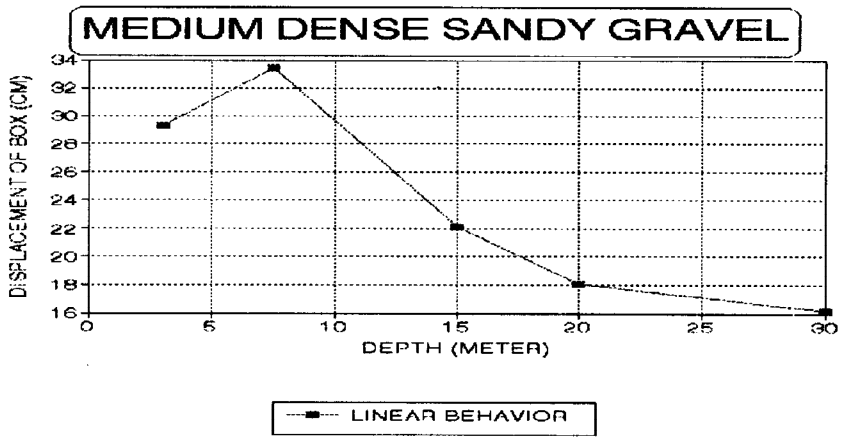


FIG 9 Variation of shear stress for Large Box





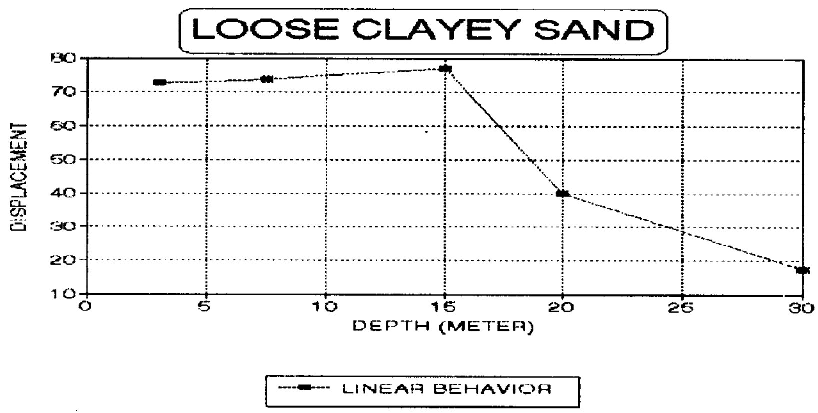


FIG 4 . Displacement of Box for Different Soils and Depths