ANALYSIS OF STRESSES IN PILE CAPS BY FINITE ELEMENT

BY

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SYNOPISIS:

The behaviour of normal and shear stresses inside the body of squared pile caps, are studied by finite element F.E. The aim of the study is to give insight into the parameters affecting the stress distribution parameters such as, geometrical properties of the cap, different loading conditions (concentric, inclined, eccentric in one two directions), and different supporting conditions (normal piles and large piles are considered). Three dimensional elastic body was used to represent the pile cap while point supports were used to represent the piles.

INTRODUCTION:

In recent years, tall buildings are widely used in our city centers because of the soaring land coasts. The use of pile foundations becomes important for such structures to transmit the loads to firm stratum using bearing or friction piles.

A reinforced concrete cap is necessary to distribute the vertical and horizontal loads and moments to all the piles in the group. Therefore there is recently a growing interest in studing the actual characteristics and behaviour of this type of foundation. This paper presents a study of the cap as three dimensional body subjected to different loading (concentric, inclined, eccentric in one and two directions). The effect of such parameters as: geometrical properties of the cap, different loading conditions and different supporting conditions, on the behaviour and distribution of stresses in the cap is studied.

The Problem:

Consider a square pile cap loaded with different loading conditions. The problem is to study the behaviour of normal and shear stresses inside the pile cap, study the deformed shape of the cap due to different loading, also to give indication for the acceptable limits of using the beam method in the design with the comparison with the analysis of cap as three-dimensional elastic body sample for the problem is shown in Fig.(1).

The Mathematical Model:

The pile cap is treated as a three-dimensional, finite element method is used in the analysis. The cap is considered hinged at base with the piles. The stiffness matrix of the cap is built by adding the stiffness of the elements surrounding each node

$$Kij = \sum kij \qquad .....(1)$$

where: Kij = term of the element stiffness matrix and is a function of size and thickness of the element.
kij = Cap stiffness

The equilibrium of the system is expressed by the following matrix equation:

$$F = K_c \delta_c \qquad .....(2)$$

where: F = external loading
K_c = stiffness matrix of structural system.
δ_c = nodal deformation system.

The method is fully described in reference (1).

The Parameter Study:

In the present study, caps with different loading conditions are analysed. The following parameters are considered:

1) widh of the cap 0,8, 1.0, and 1.5 ms.
2) loading conditions (concentric, inclined, eccentric in one and two directions).
3) supporting conditions (thin pile is considered as point support thic pile is considered as area support).

Discussion of Results:

The distribution of stresses in the pile cap according to the rigid beam method, is basically different from its behaviour when considered analysed as three-dimensional body connected with the piles. Reference (2), gives details for the analysis of cap with the rigid beam method.

1. Effect of the geometrical properties of the cap in different loading conditions.

1.1. Maximum Stresses in Pile Cap:

The effect of width depth ratio of the cap on the behaviour of maximum normal and shear stresses are studied. Figures (2, 3, 4 and 5), gives these dimensionless relations for concentric, inclined, eccentric load in one and two directions, respectively. The most important features of comparison between these cases can be summarized as follows:

1- The maximum normal stresses (σ_x, σ_y, σ_z), increase with the increase of B/d ratio for all cases of loading.

2- The maximum shear stresses ($_{yz}$, $_{xz}$), decrease with the increase of B/d ratio in case of eccentric loading applied on pile cap, but the value of $_{xy}$ increase in case of symmetric loading and reach its maximum value at B/d = 1.50

1.2. Maximum displacements in pile cap:

The effect of the B/d ratio of the cap on the maximum deformation in pile cap in X,Y,Z directions is illustrated a in figures (6), (7), (8), (9), for concentric, inclined, eccentric load in one and two directions, respectively. The most important features of comparison between these cases are:

1- The maximum displacement in Z-direction (Z), represent the main displacement due to applied loads for all cases loading.

2- The values of Z, X, Y, decrease with the increase of B/d ratio.

3- The displacement in Y-direction, is relatively small for all cases of loading.

2. Distribution of Stresses Inside the Pile Cap:

Distribution of normal and shear stresses are given in dimensionless graphical form on vertical planes at face and middle of the cap, as shown in Fig.(10). The case of symmetric loading is given as an example for the behaviour of normal and shear stresses by using three-dimensional finite element analysis.

3. Effect of Supporting Piles:

The supporting piles were considered in two conditions:

1- Thin piles (point supports).
2- Thick piles (area supports).

It is found that considering the area support piles gives less stresses and deformations for the cap, this leads to a more economical design for the pile cap.

Comparison between distortion of pile cap in case of point supports and area supports are shown in Figures (11 and 12).

4. Comparison Between Exact and Linear Distribution of Stresses:

Comparison between exact distribution of stresses obtained in the study and linear distribution in the riged beam method are given in Fig.(10-b). The most important features of comparison can be summarized as follows:

1- For hight to span ratios more than 0.6, the distribution of (x) diminishes fast, to the extent that in computation there can occur a serioue error if linear distribution is used in the analysis.

2- Below hight to span ratio of 0.5, there will not be serious error if the linear distribution of x is adopted in the analysis.

CONCLUSIONS:

The finite element procedure herein provides satisfactory predictions for behaviour and distribution of stresses inside the body of square pile caps. For a chosen set of loading conditions, geometrical properties of cap and supporting conditions, a serious of dimensionless curves and graphical forms were generated that can permit evalation of maximum stresses and displacements inside the square pile cap according to the B/d ratio-such important topics as variation of supporting piles (point and area supports), and different loading conditions (concentric, inclined, eccentric load in one and two directions), were examined and will require further investigation and previous studies it is belived that the finite element could be employed as a tool for analysis and design for pile foundations. This work has also shown the potential of the method for obtaining design curves that can prove useful for practical applications.

REFERENCE:

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3. Aschenbrenner, R., "Three-dimensional analysis of pile cap foundations" Journal of the structural division ASCE, Vol. 93, NO. STI Paper 5097 Feb. 1967.

4. E. Hinton and O.R.J. Owen "Finite element programming". Great britain by whitstable lintho Ltd. Whitstable Kent, 1977.

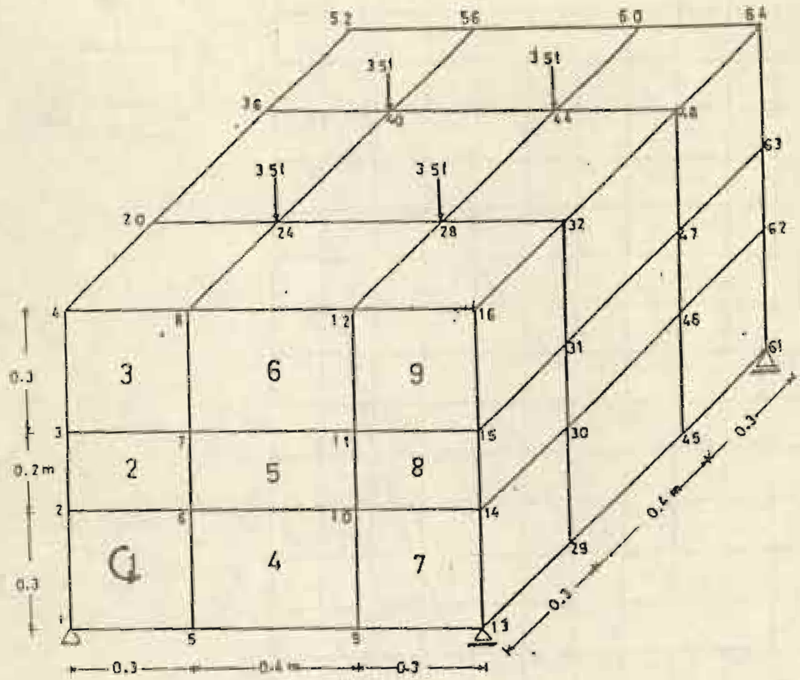
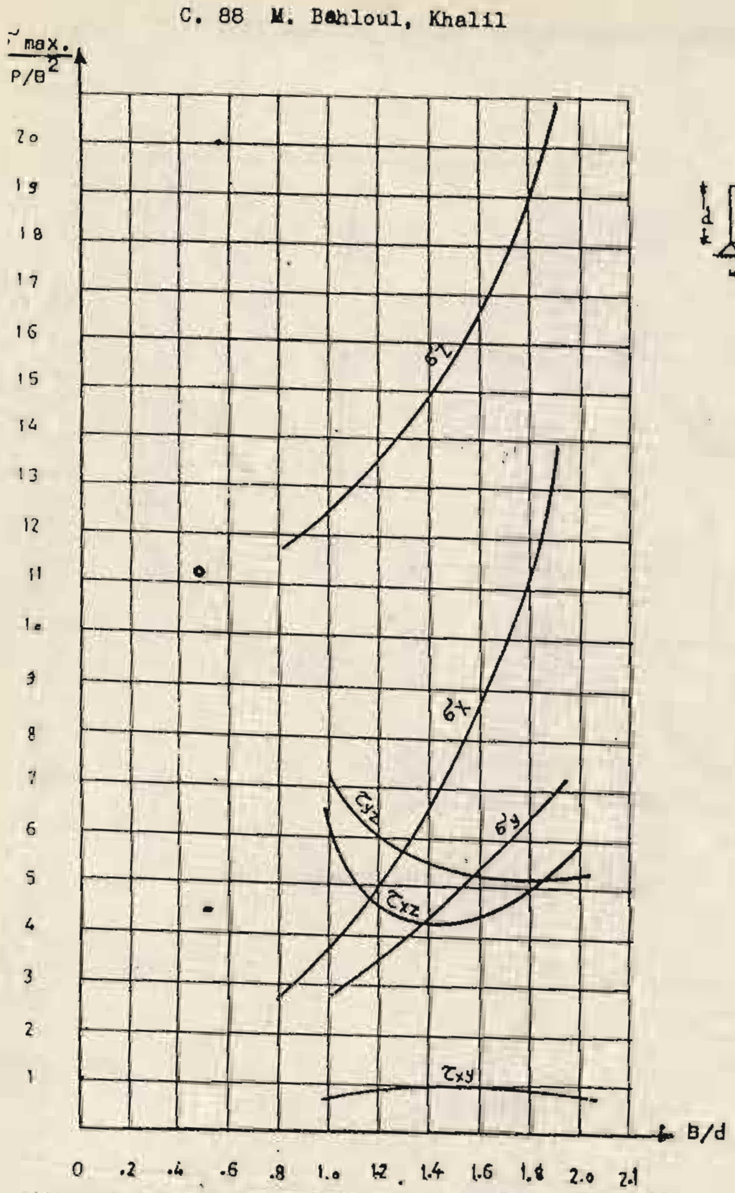


Figure (1): Illustrative Example.



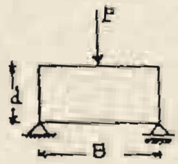


Figure (·21) Maximum stresses for axial symmetric loading.

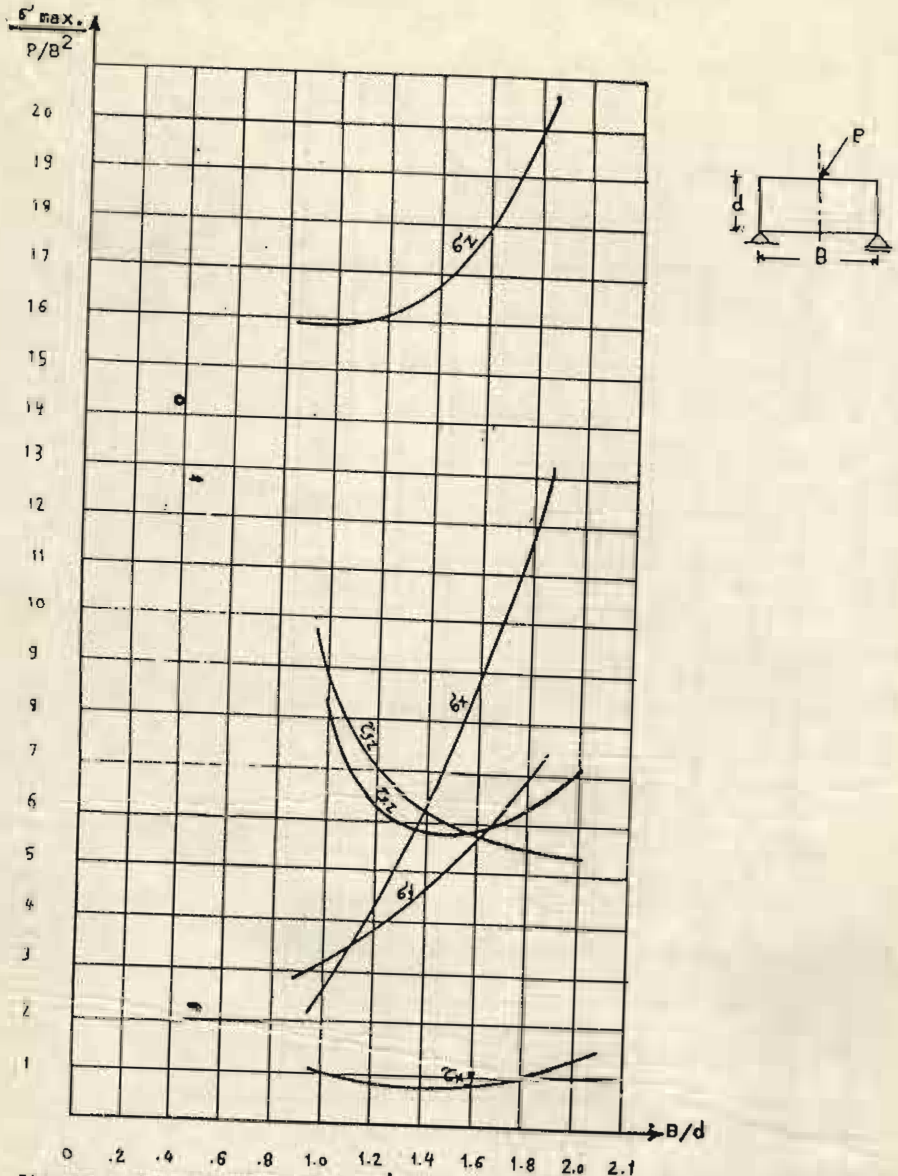


Figure (-3-) Maximum stresses for concentric inclined loading.

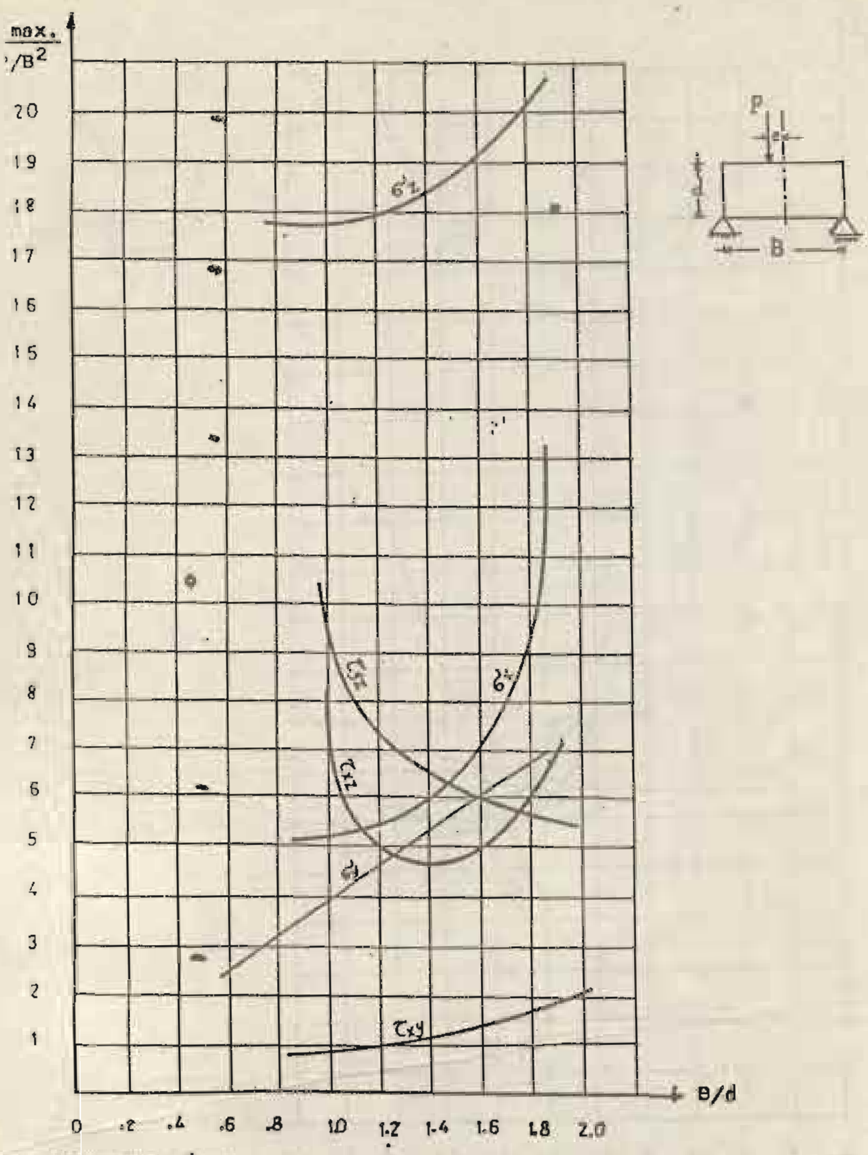


Figure (.4.) Maximum stresses for eccentric load in one direction.

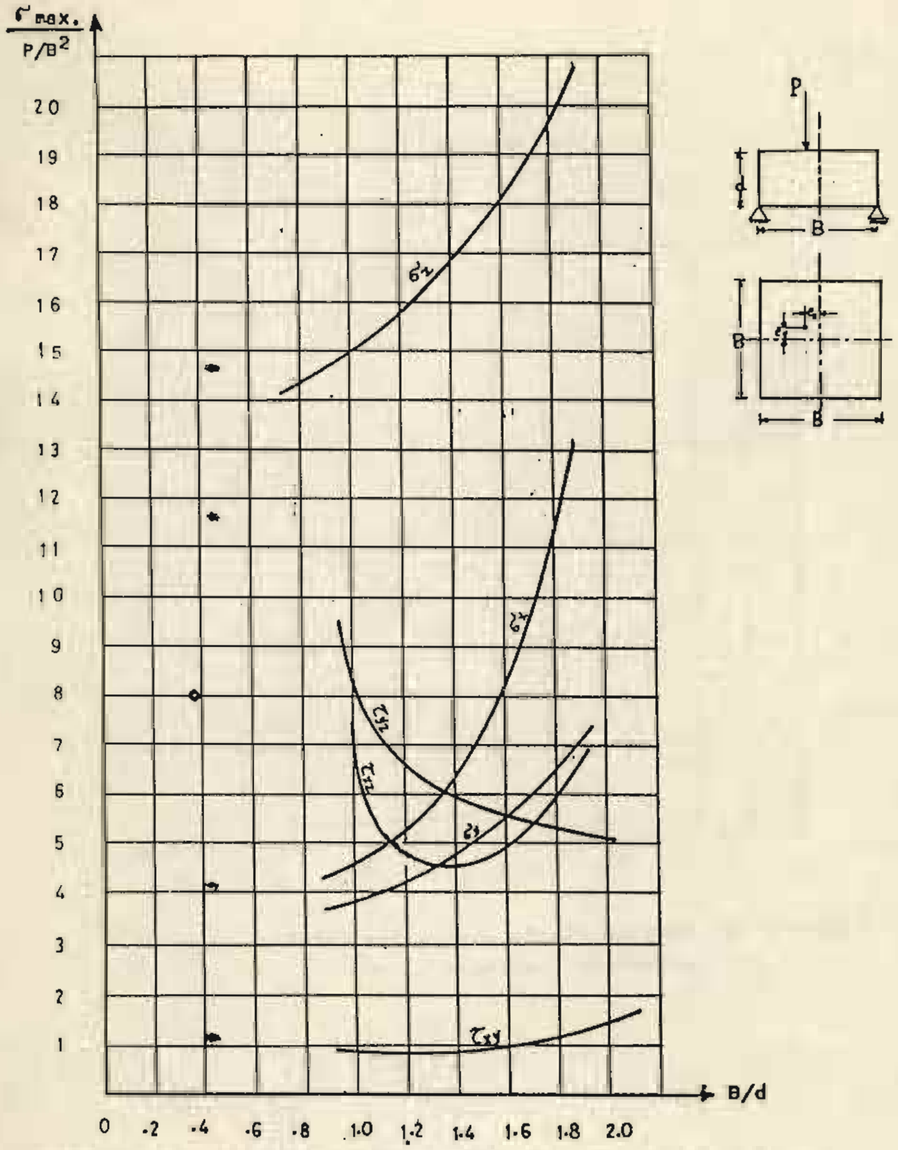


Figure (15) Maximum stresses for eccentric load in two directions.

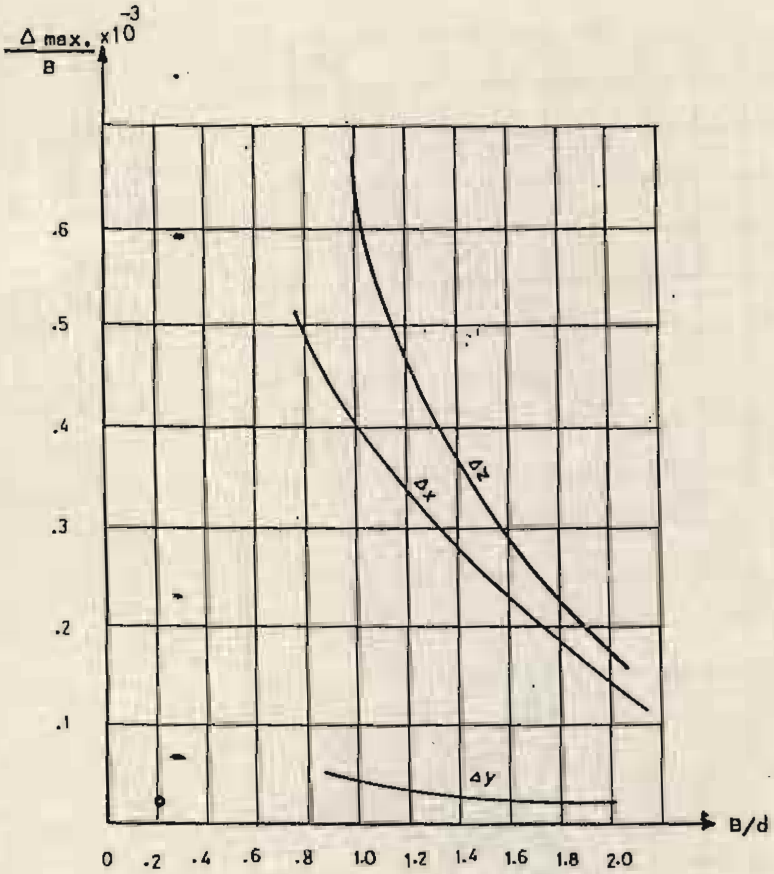


Figure ([illegible]) Maximum displacements for axial symmetric loading.

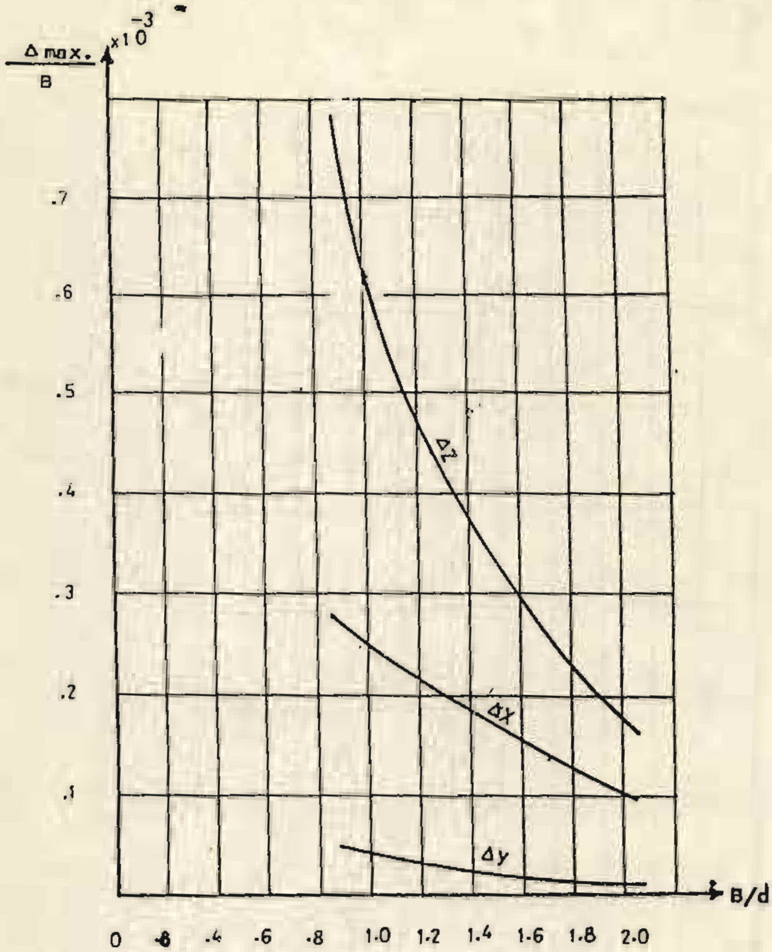


Figure (7) Maximum displacements for concentric inclined loading.

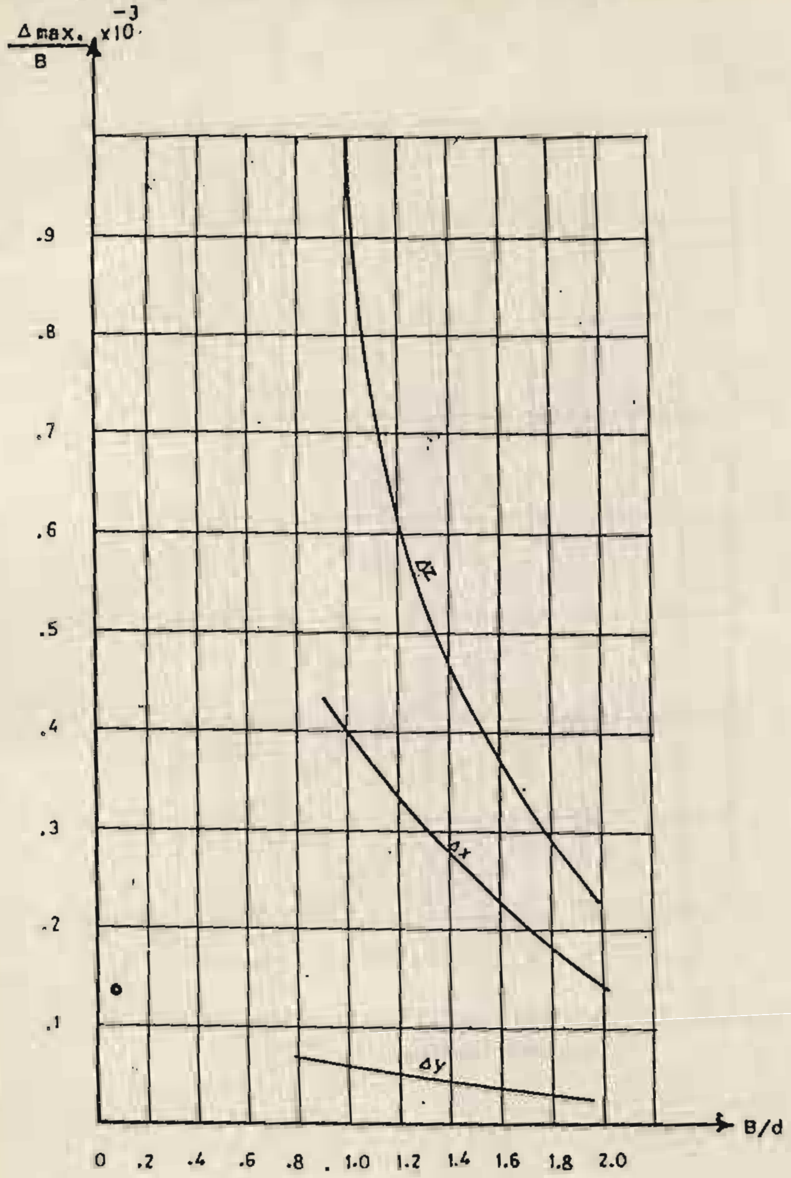


Fig.(8 , Maximum displacements for eccentric load in one direction.

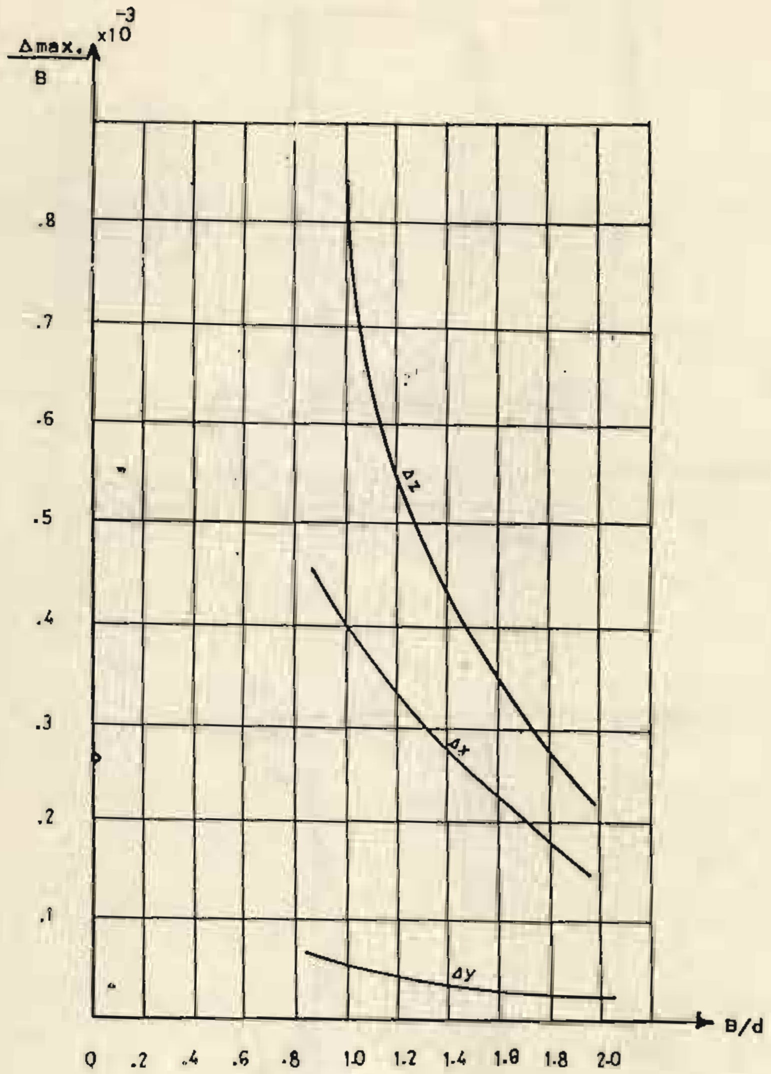


Figure (9) Maximum displacements for eccentric load in two directions.

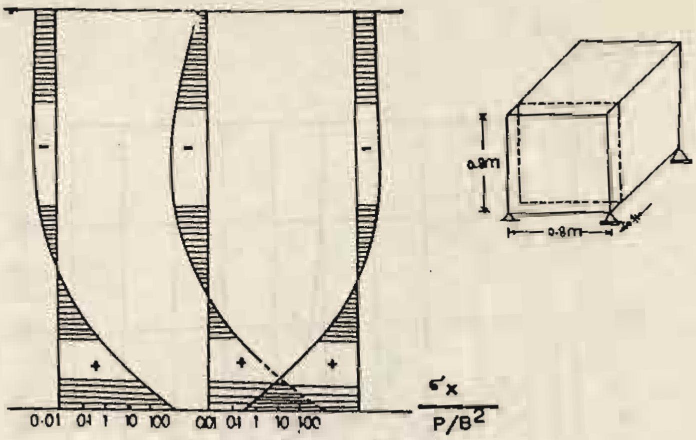


Figure (5.16-a) Distribution of normal stress (σ'_x) on face plane for case of symmetric loading.

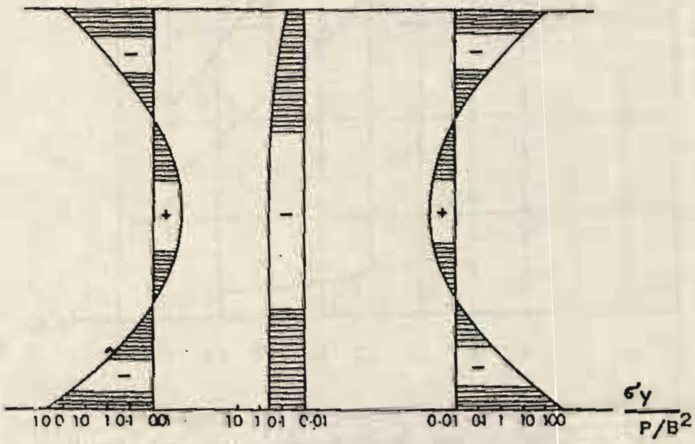


Figure (10) Distribution of normal stress (σ'_y) on face plane for case symmetric loading.

SCALE OF PILE CAP 1:100

SCALE OF DISPLACEMENTS 20:1

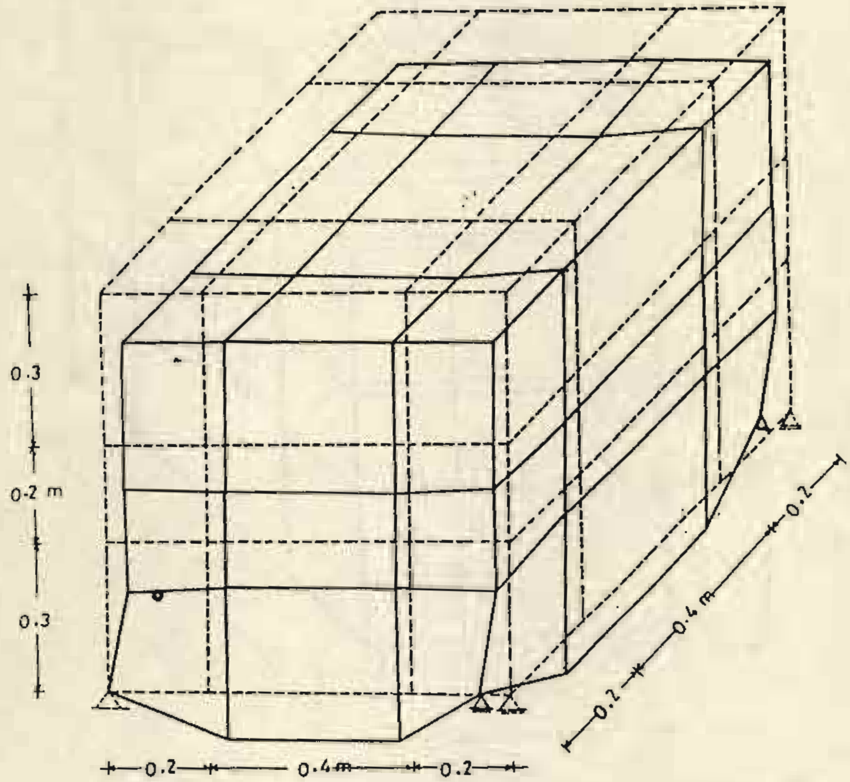


Figure (11) Distortion shape of pile cap for axial symmetric loading.

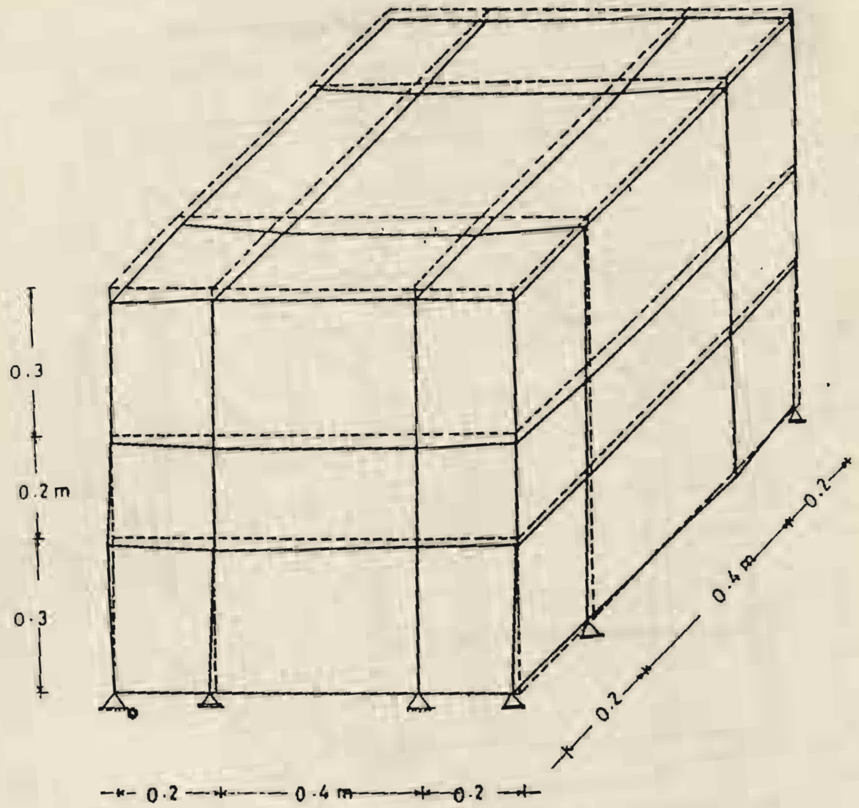


Figure (' 12.) Distortion shape of pile cap for axial symmetric loading with consider supporting piles have big diameters.