Journal of Environmental Science and Technology

ISSN 1994-7887

Journal of Environmental Science and Technology 2 (1): 40-47, 2009
ISSN 1994-7887

Soil Behavior Prediction under Footings Regard to the Elasto-Plastic Models (Shahkarami Model)

J. Khazaie, S.A. Amirshahkarami and M. Goodarzy
Department of Civil Engineering, Amirkabir University of Technology,
(Tehran Polytechnic)-424, Hafez Avenue, Tehran, Iran

Abstract: Experiences and studies were shown that the modeling of geotechnical material behavior was very difficult by using of mathematical equations. For this reason, the calibration of models and establishment of parameters may be available for some stress-path. Presently all stress-paths are not analyzable by any of behavior models. Therefore in engineering designs, we must be studied a large domain as a model. The stress-path and calibration must be coordination. Models and parameters for small footings had a shearing behavior and for large footing had an isotope compression. In the shearing behavior by increasing the load and deformation after yielding the behavior of soil would be softening but the behavior of soil under the large footing would be hardening. Therefore the behavior of soil under the footing was related to the dimension of footing. In this study, we will consider the different types of analytical models for large and small footing on the hard earth. In this investigation are used the finite element methods by ANSYS software for analyzing.

Key words: Stress path, size effect, soil behavior, soil stiffness matrix, soil-structure interaction, modeling

INTRODUCTION

World of new engineering (software analyze of material and engineering creations in using of new engineering) is provided for analyzing and designing of a phenomena. We must do modeling and simulation in mould of mathematical equation for considering these phenomena.

Here, we must solve, stability, compatibility and behavior equations. In the past times analyses were concentrated on the stability analysis and were used stability equations and compatibility equations. In the past times for considering and analysis of foundation were used usually limit equation analyze and fracture mechanism analysis. Stability equations in this manner are collected on the base of parameter C and ϕ and most experimental-analytical equation such as Terzaghi relation has been used. In these relations just soil material are important but according to the special stress level and stress path we can determine different values for ϕ and C in the laboratory. On the other hand in the earth-structures interaction behavior we have most uncertainty that for consider the behavior of soil under the large foundation. We need to investigation about effect of foundation size on the behavior of earth (Owen and Hinton, 1980; Zienkiewicz and Taylor, 2000; Khazaie and Amirshahkarami, 2007; Amirshahkarami, 1978-2007).

THEORIES AND COMPUTATIONAL MODELS

Geotechnical materials, that they usually are called friction materials have different types. They are started from sand or gravel to materials such as glass, ceramic, wood and other materials which they

Corresponding Author: Jahangir Khazaie, Department of Civil Engineering, Amirkabir University of Technology, (Tehran Polytechnic)-424, Hafez Avenue, Tehran, Iran
Tel: 00982144004856 Fax: 00982144077829

have interlocking in their micro structure. Internal friction angle can change some property of material. On the other hand for every ϕ the deformation mechanism and material behavior can changes in the both of the measuring an qualitative and may be by rotation and change of stress the behavior of material change, this subject in the behavior of earth that located under the large and small footing is important by three shape:

- Stress level
- Rotation of principle stress path
- Domain of distribution stress

In a part of the domain that located under the footing, the vertical stress will be larger than the horizontal stress and in the other parts the horizontal stress will be larger than the vertical stress, Then rotation of principle stress are occurred in the ground under the footing. On the other hand soil behavior changes by stress level. In three axial test, for less σ_3 we have brittle behavior and by increase it the material behavior become soften and for large σ_3 we have ductile behavior for material, So by change of σ_3 mechanical behavior of material will change because the behavior of material is friction (Fig. 1). In direct shear test also have a similar outcome, when σ_n is small, material shown the brittle behavior and soil behavior similar to over consolidated soils and we have dilation phenomena. But for large σ_n the behavior of material become ductile and soil behavior similar to normal consolidated soils and strength of material increase, therefore material behavior or stiffness matrix of material increase, also by increase of stress volume that they have down direction, volume of ductile material will be increase.

In the part of earth that located under the footing σ_1 (main stress) will be vertical and in the other parts it will be horizontal and in this parts the earth have a shear fracture and in the parts that maximum main stress vertical (σ_1), soil is bearing. So in the parts that we have a horizontal (σ_1) the back part of this zone is passive which will be susceptible to breakage, but in the parts the σ_1 is vertical, zone is active and bearing, so if footing have a large zone of the vertical σ_1, this footing have a large bearing. In the small footing this zone is small and this zone will be progress by increase of footing dimension (Owen and Hinton, 1980; Zienkiewicz and Taylor, 2000; Khazaie and Amirshahkarami, 2007).

In the large footing due to the increasing the confined zone that located under the foundation and decreasing deviatoric stress in this zone bearing on the footing can increase. Also this agent cause the

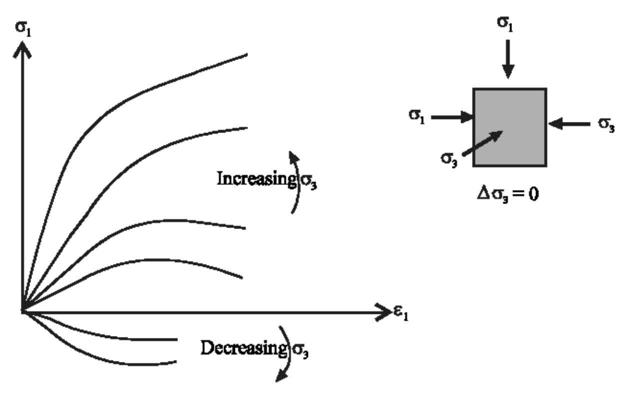


Fig. 1: The different behaviors of the material in three axial conditions

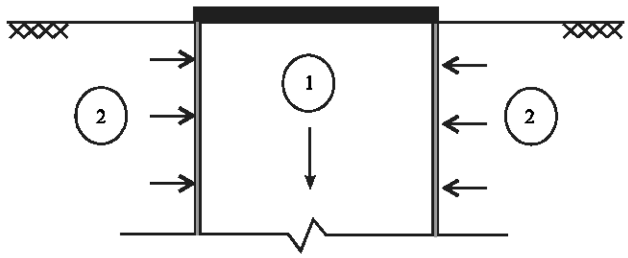


Fig. 2: Schematic of the reaction of the ground under large footing

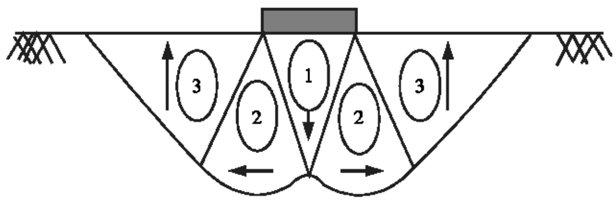


Fig. 3: Schematic of the region of the ground under small footing

increase of reaction earth in the middle of footing compared to the edges. In region 1 the reaction of soil is less than the region 2, then by drawing the soil reaction curve and determining the inclination point we could separate two regions (Fig. 2). Therefore when the earth is put under the vertical pressure the confined pressure will increase and it can effects to the region 1. Due to this pressure, region 1 want to move toward the edges or move up, according to the boundary conditions, none of these moves are possible for these regions then this will react as confined pressure (Fig. 3). The confined pressure that acts from region 1 to region 2 will cause reduction of deviatoric stress and breakage from shear state in the region 2. In the small footing region 1 under pressure of region 2 move up and shear fracturing will occur.

SUGGESTED MODEL

In recent research for prediction of soil behavior has been used (Shahkarami, 1998) model. This model has suggested for σ_d-σ_m space and this model consists of three parts F_1, F_2, F_3 (Fig. 4).

σ_m explain the medium stress in the material and σ_d explain the deviatoric stress in the material. They are calculated by:

$$\sigma_m = \frac{\sigma_1 + \sigma_2 + \sigma_3}{3}$$

$$\sigma_d = \frac{\sigma_1 - \sigma_3}{2}$$

Intersections of the loading path to the F_1 envelope cause the expansion of the plastic surface and the expansion of the elastic region in the material cause that materials becomes density, where as intersection with the F_2 and F_3 envelopes causes in the shrinkage of the plastic surface and expand material and the elastic area will becomes smaller (Fig. 5).

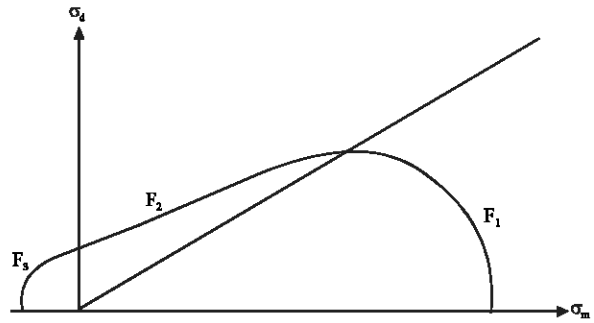


Fig. 4: The Shahkarami model in the $\sigma_d - \sigma_m$ expression

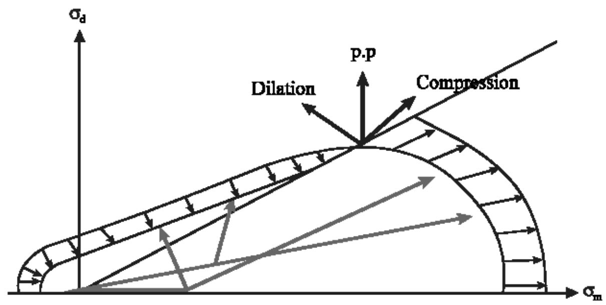


Fig. 5: Stress path in behavior Shahkarami model

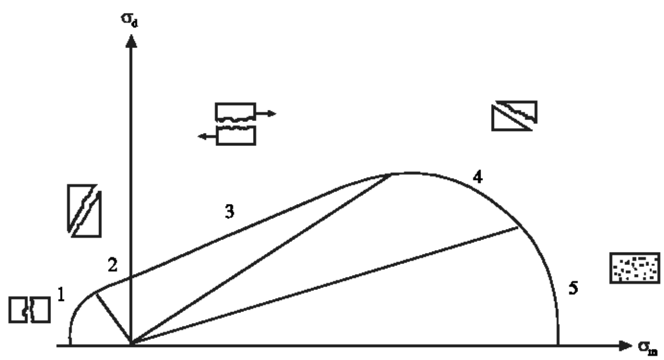


Fig. 6: Yielding surface in behavior Shahkarami model

In this model, envelope area is divided to the five zones: In the first zone behavior of material is tensile. In the second zone there is the combination of tensile and shear stresses. In the third zone the stresses are shear stress, in forth zone we observe the combination of shear and compression stress and ultimately if the stress path of the material across the fifth zone the material are under the compression stresses (Fig. 6).

Intersection of loading path with 4 and 5 envelopes will cause plastic surface and elastic domain of material increase and material compact. But intersection with 1, 2 and 3 envelopes will cause shrinkage of elastic zone and elastic domain of material would be smaller and material would be expansion (Amirshahkarami, 1978-2007).

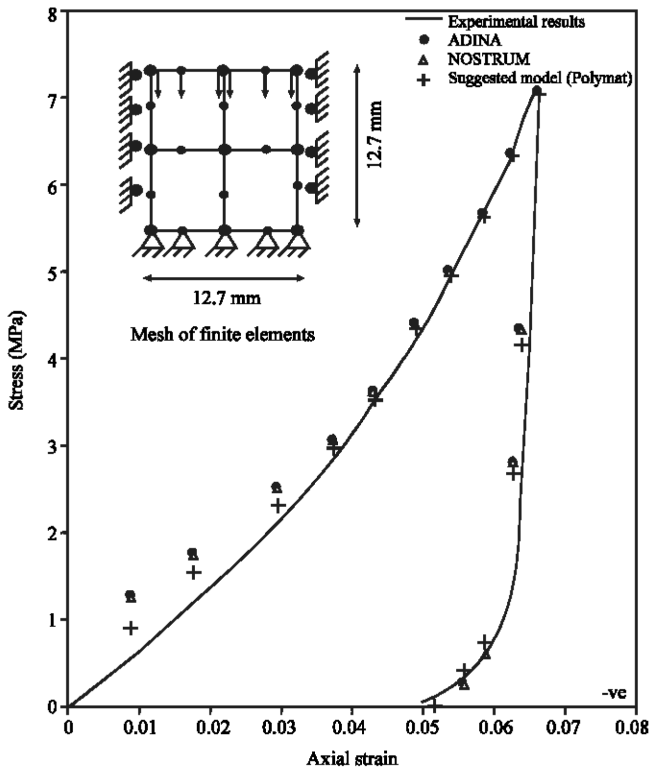


Fig. 7: Correlation and verify of this model suggestion

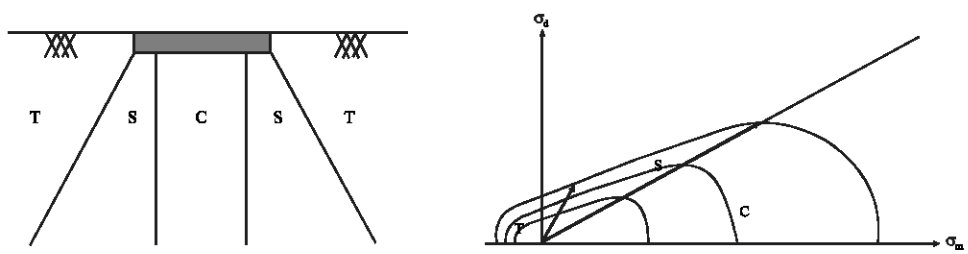


Fig. 8: Soil behavior prediction under footing in Shahkarami model

For correlation and verify of this model we use the POLYMAT software and the results of this comparing are shown in the Fig. 7.

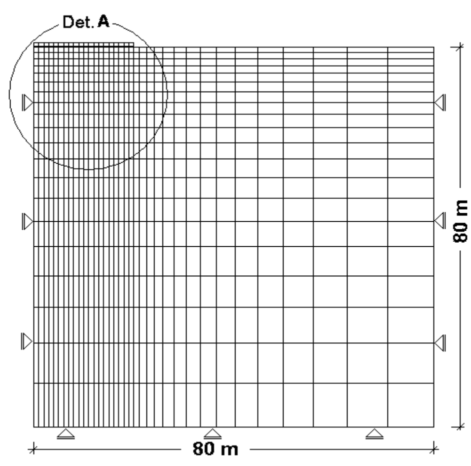
According to this model in the earth that located under the foundation three kind of behavior are observable and dividable that they are shown in Fig. 8 (Khazaie and Amirshahkarami, 2007):

In the C zone behavior of soil is mainly compressive, in the S zone behavior of soil would be shear compressive and in the T zone behavior of soil would be shear-tensile.

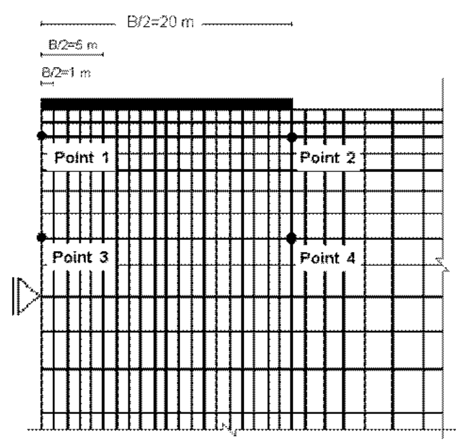
In the large footing the failure envelope is located in the C zone and will be bigger then volume of C zone is large, for this reason bearing capacity of foundation increase. But under a small footing the C zone is very small and the main volume under the footing would be in S or T zone and it will show shear and tensile behavior and it could imagine that the soil behavior is softening and bearing of small footing will be decreasing gradually. On a large footing the behavior of main portion of the soil under the footing surface is hardening. This subject is observable in the different in situ tests such as Plate Loading Test it means that behavior and property of soil changes when the dimension of footing change.

EVALUATION ANALYSES

In this study, the ANSYS software has been used for modeling and analyzes. The geometrical idealistically would be done for the large enough soils with regards to interaction composite model of structure as a permanent domain in this study. Constant meshing has been considered in this analytical model which is free from the foundations dimensions. The constant study media including the footing and part of the soil located under and around the footing which has been effective in bearing and deformation (settlement) and is sufficiently large (about 4B at sides and beneath the large footing) has been taken in to account two-dimensional, such that the boundaries of the study media are sufficiently far away from where the footing is located and the effect of stress as well as the deformations at those points are insignificant and negligible (Katsutoshi *et al*., 1998, 2000). The edges of domain are far enough from the location of foundation in which the deformation effects are negligible and two dimension numerical analyses has been done with regard to large deformation. Studies on permanent and designated points which are constant in stress path and soil behavior changed have been done in pointed point. The concrete footing and the soil with plane 82 elements have been modeled (ANSYS Manual, 1995). This element is in the form of eight-node and two dimensional having three transitional degrees of freedom in each node and is able to take account of elasto-plastic behavior and large deformations in the plane strain state. The 2 dimensional model of foundation are done by ANSYS software are shown in Fig. 9 (Owen and Hinton, 1980; Zienkiewicz and Taylor, 2000; Taylor, 2000; Khazaie and Amirshahkarami, 2007; ANSYS Manual, 1995). The results of analysis in the Fig. 10 and 11 show that dimension of foundation can effects on the behavior of soil that located beneath the foundation.



(a)



(b)

Fig. 9: Domain of study meshing in ANSYS model (a) Total of domain and (b) Point of study in ANSYS model

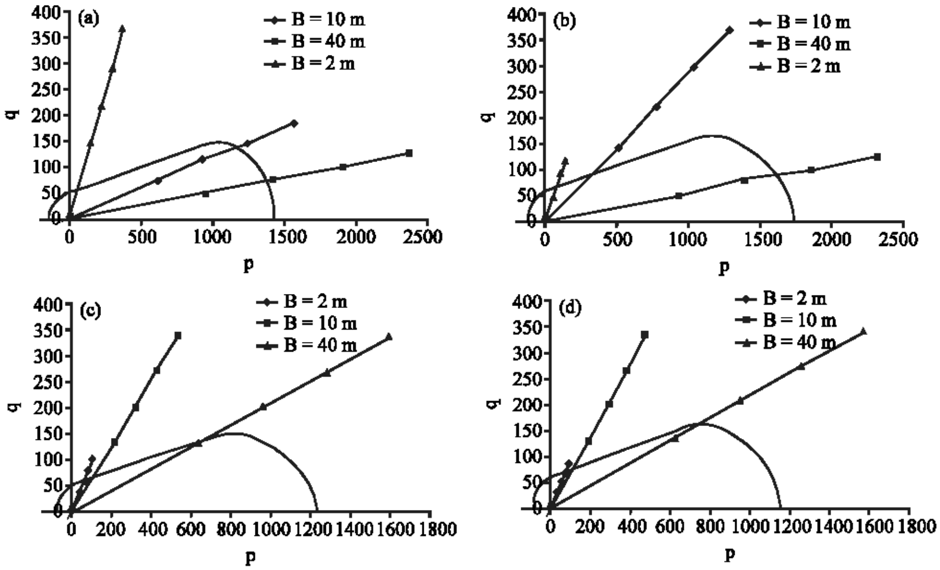


Fig. 10: Stress path of domain under small and large footing in ANSYS model (a) Stress path in point 1, (b) Stress path in point 2, (c) Stress path in point 3 and (d) Stress path in point 4

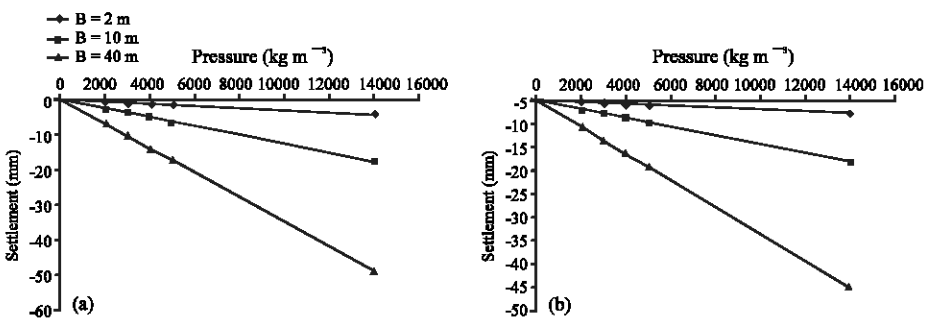


Fig. 11: Soil behavior (stiffness matrix) of domain under small and large footing in ANSYS model (a) in point 1 and (b) in point 2

CONCLUSION

By regarding the stress path of the points under the small and large foundations are realized that the behavior of the soil on total area that located under the small foundations is shear behavior. But in middle point of the soil under the large foundations the behavior is compressive and in the edges of the foundation the behavior of shear will change gradually. By considering the behavior curves of the soils under the large and small foundations we come to the conclusion that the behavior of the soil separated from the loading intensity by changing the dimensions would be changed this phenomena was not consider in theoretical foundations. And this subject is equal with this proposed theory and suggested model. Also by considering the change of property and distinction between soil behavior when it's placed under small and large foundations, prediction of suitable tests in investigation of earth and finally selecting the best improvement method for earth underneath the foundation with consideration of foundation dimensions is a very important subject. On the other hand, the settlement control problem with attention to increase of stress in depth, in large foundations, is more important than small foundations. It's obvious that the 3-D modeling can get more accurate results. But the real modeling in lab is proposed for the other investigators.

REFERENCES

ANSYS, 1995. Structural nonlinearities manual. Swanson Analysis System. Houston, PA.

Amirshahkarami, S.A., 1978-2007. Soil-structure interaction note. Lecture in Department of Civil Engineering, Tehran Polytechnic University.

Katsutoshi, U., M. Kinya and M. Yoshito, 1998. Prediction of ultimate bearing capacity of surface footings with regard to size effect. Soils Foundations Japanese Geotech. Soc., 38: 165-178.

Katsutoshi, U., M. Kinya, K. Osamu and N. Migitoshi, 2001. Reappraisal of size effect of bearing capacity from plastic solution. J. Geotech. Geoenviron. Eng., 127: 275-281.

Khazaie, J. and S.A. Amirshahkarami, 2007. Mat foundations size effect in soil density behavior regard to the elasto-plastic models (*Shahkarami model*). Proceeding of 3rd Iranian Rock Mechanics Conference, Oct. 16-18, Amirkabir University of Technology, Tehran, Iran, pp: 21-26.

Owen, D.R.J. and E. Hinton, 1980. Finite Elements in Plasticity: Theory and Practice. 1st Edn., Pineridge Press Ltd., Swansea.

Terzaghi, K., 1943. Theoretical Soil Mechanics. 1st Edn., Wiley, New York.

Zienkiewicz, O.C. and R.L. Taylor, 2000. The Finite Element Method. 5th Edn. Butterworth-Heinemann, Oxford, UK., ISBN-10: 0340759844.