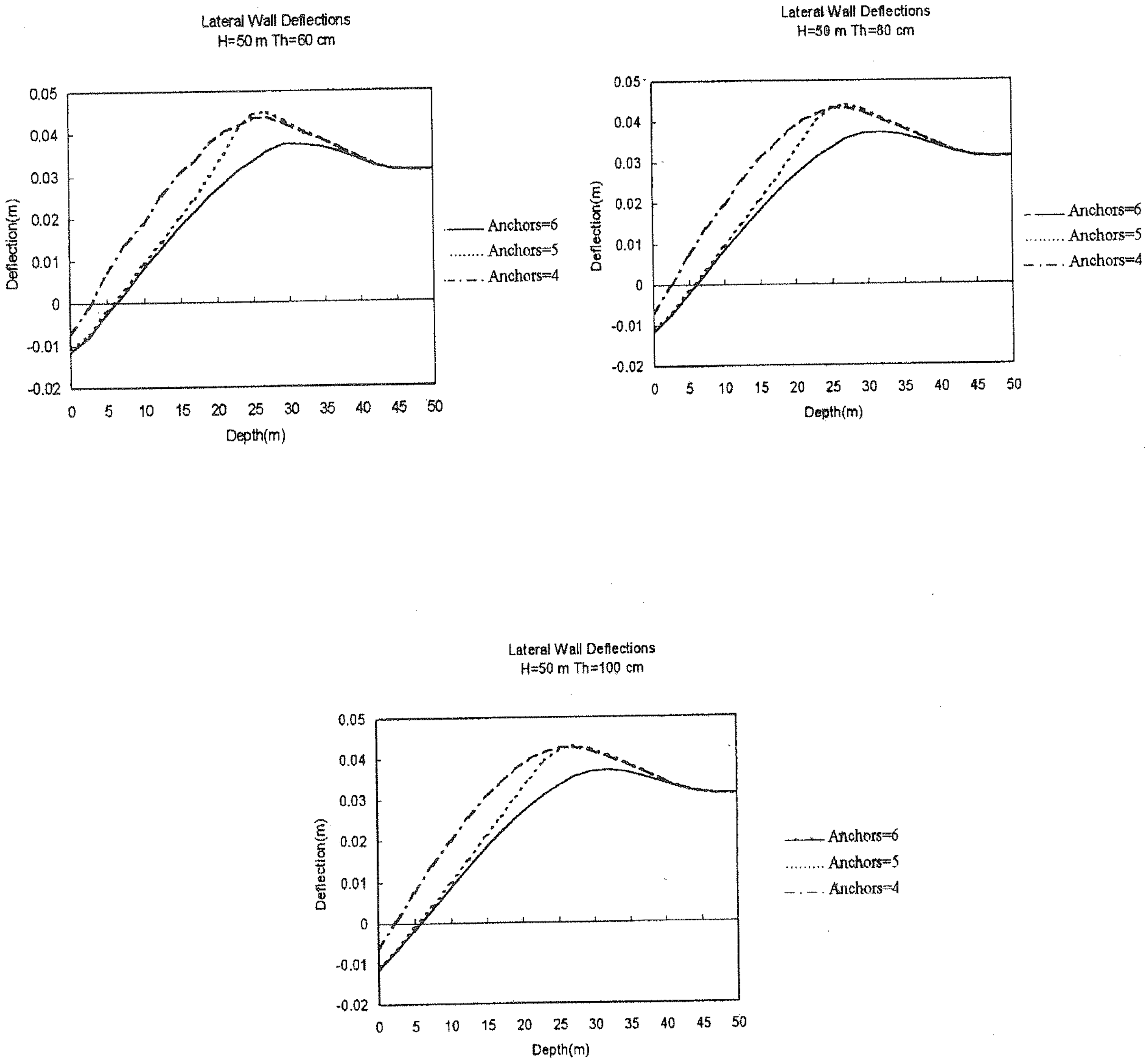

Figure (6) Effect of wall thickness and number of anchors on wall deformation.

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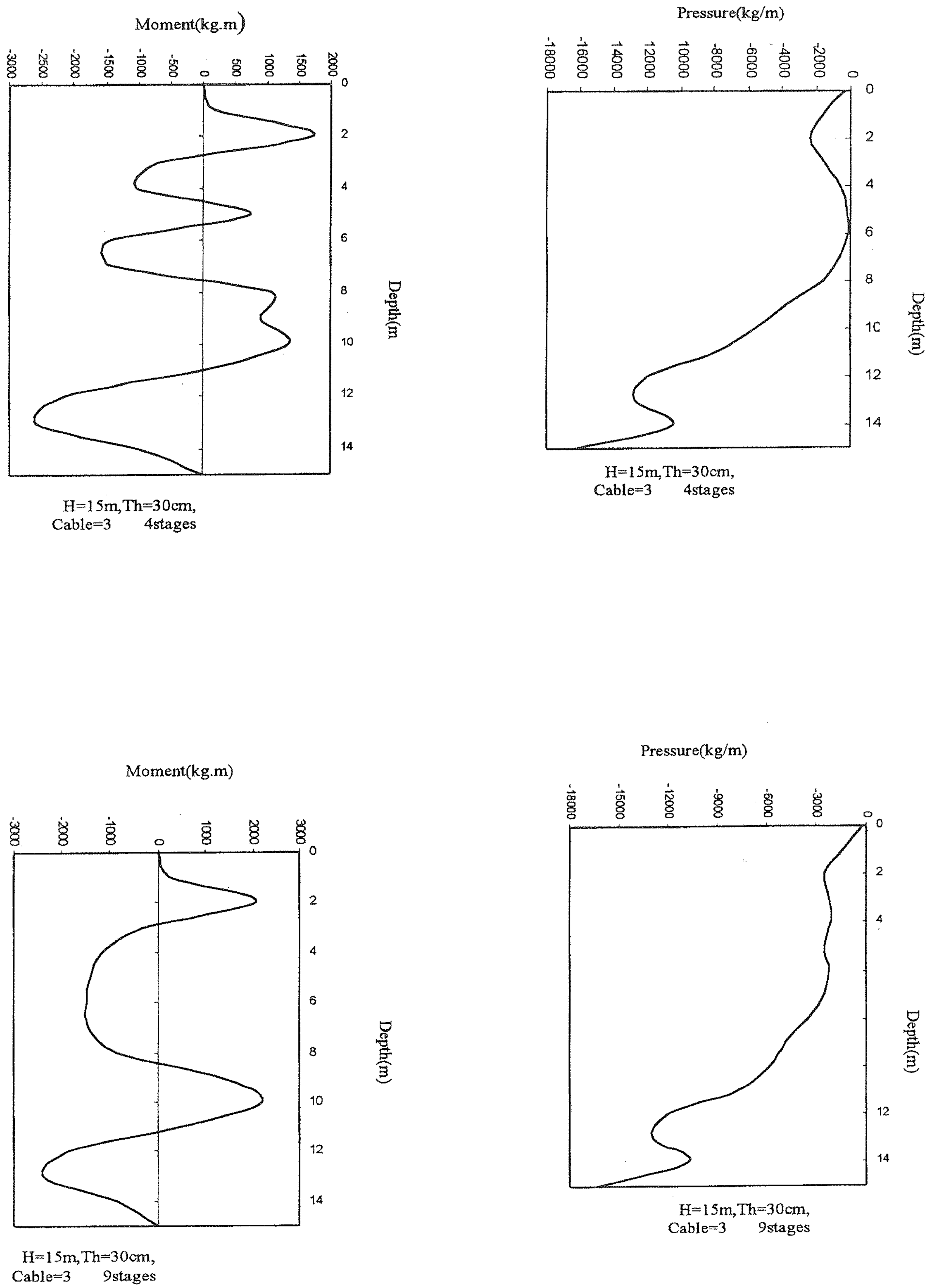

Figure (8) Effect of number of excavation layers on lateral pressure and bending moment.

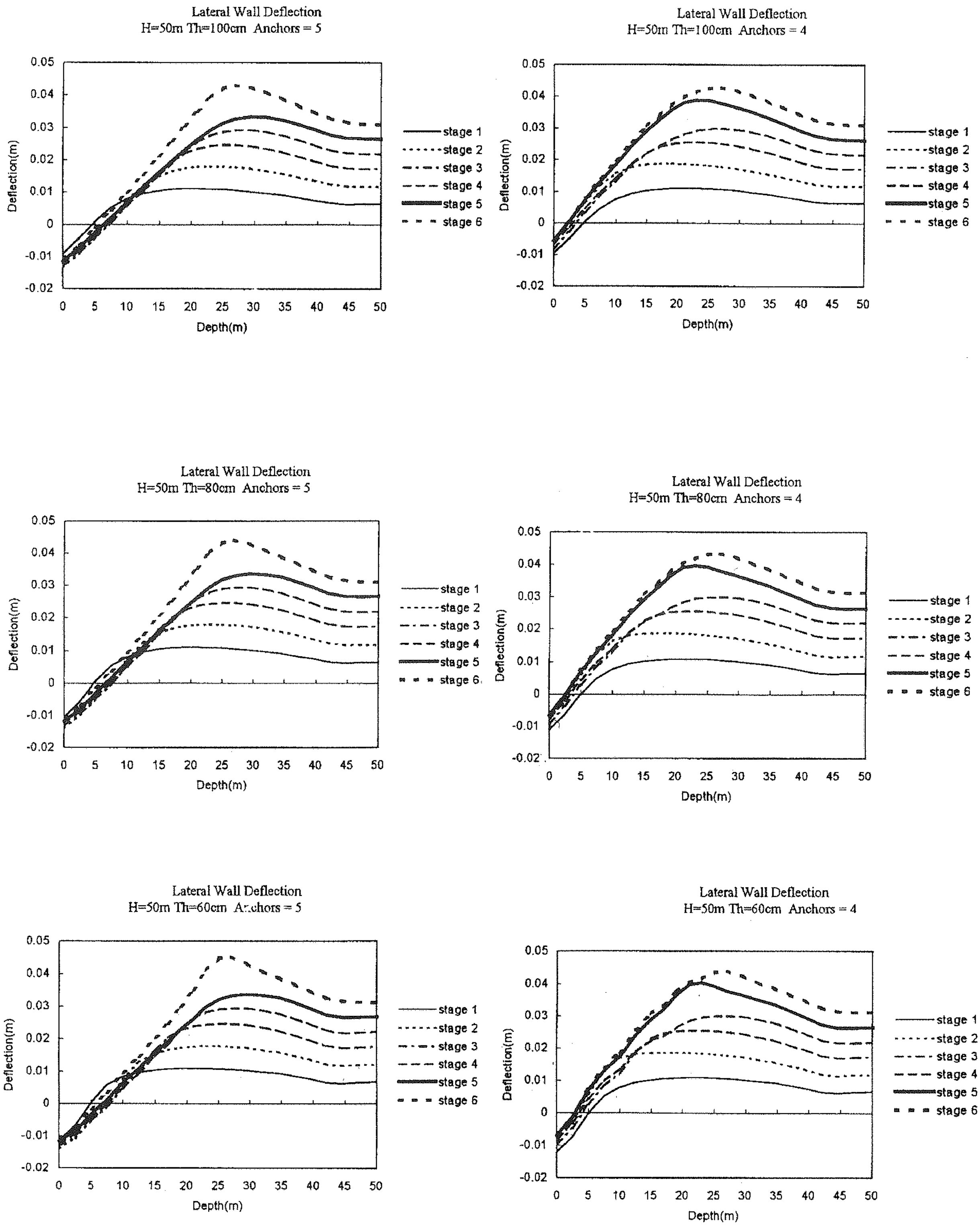

Figure (7) Effect of the thickness or number of anchors on wall deformation.

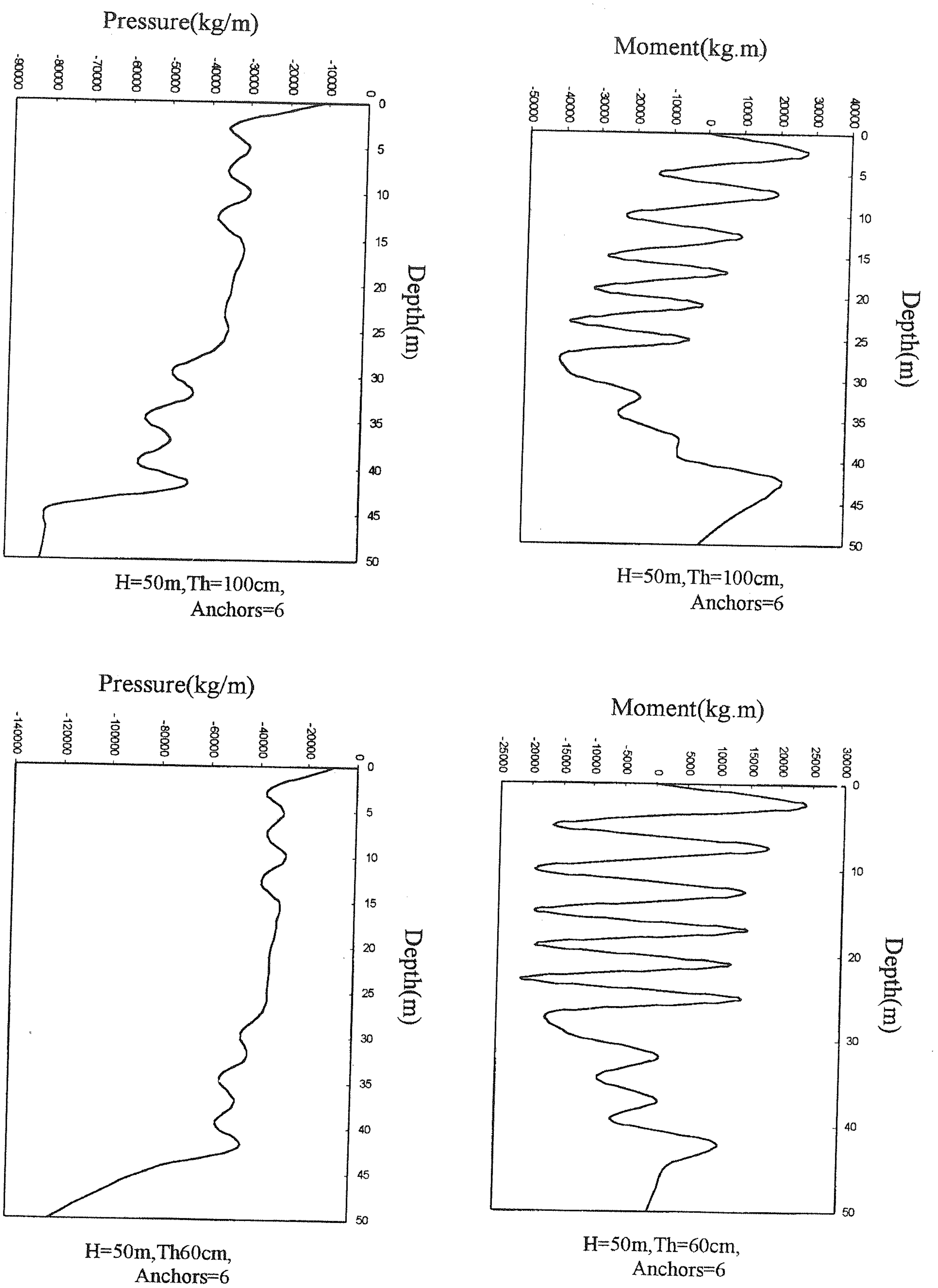

Figure (5) Effect of wall thichness on lateral stress and bending moment.

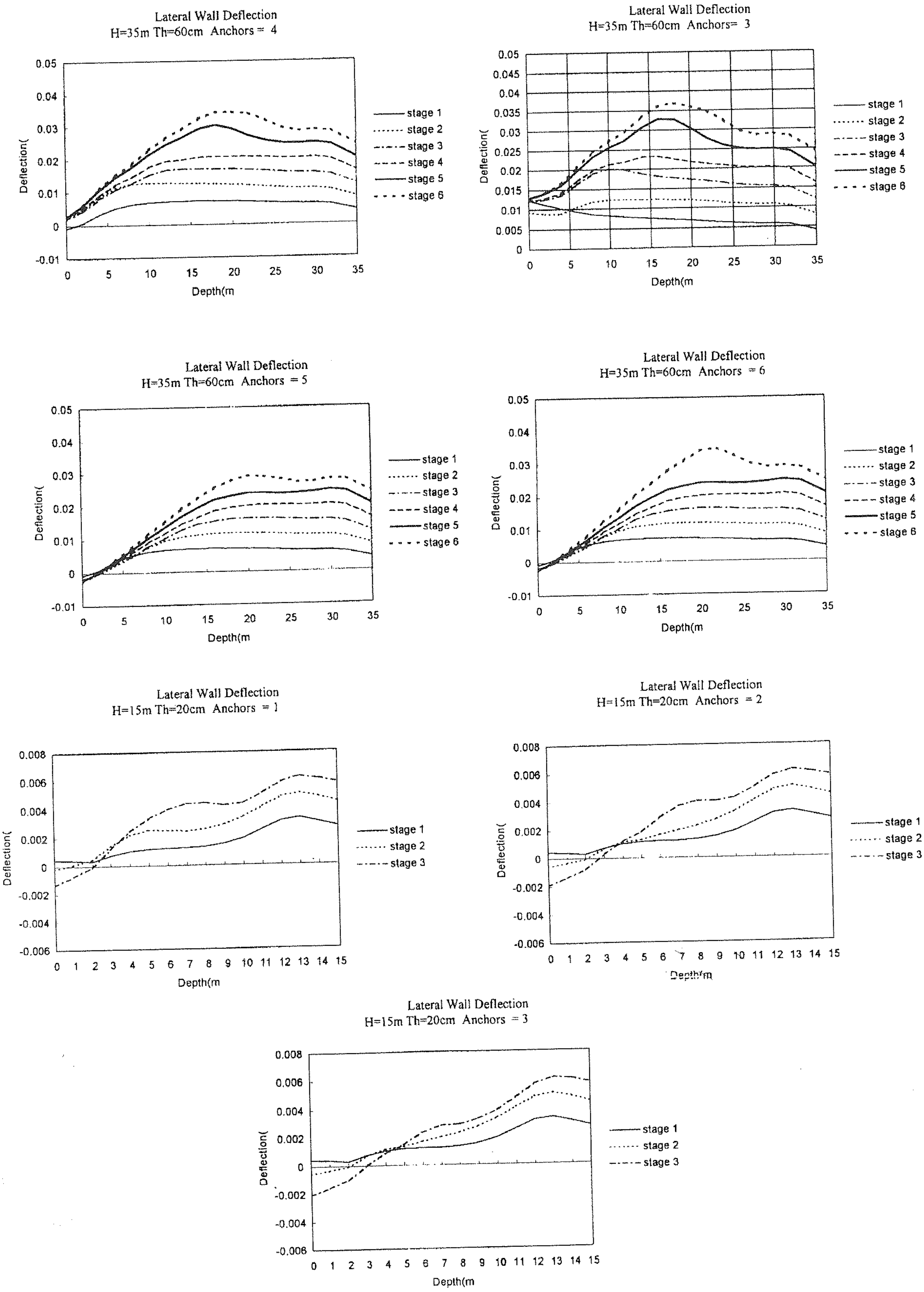

Figure (4) Effect of number of anchors on lateral wall deformation.

deformation and its bending moment decreases, and is more uniform in the wall height, when the number of rows of anchors increases.

Also the wall deformation and lateral pressure increases, as the number of excavation layers increases.

The amount of anchor force increases, as the excavation layers decrease. It may be concluded that for obtaining an optimum condition, the number of excavation layer, with attention to the augmentation of anchor forces, should be decreased.

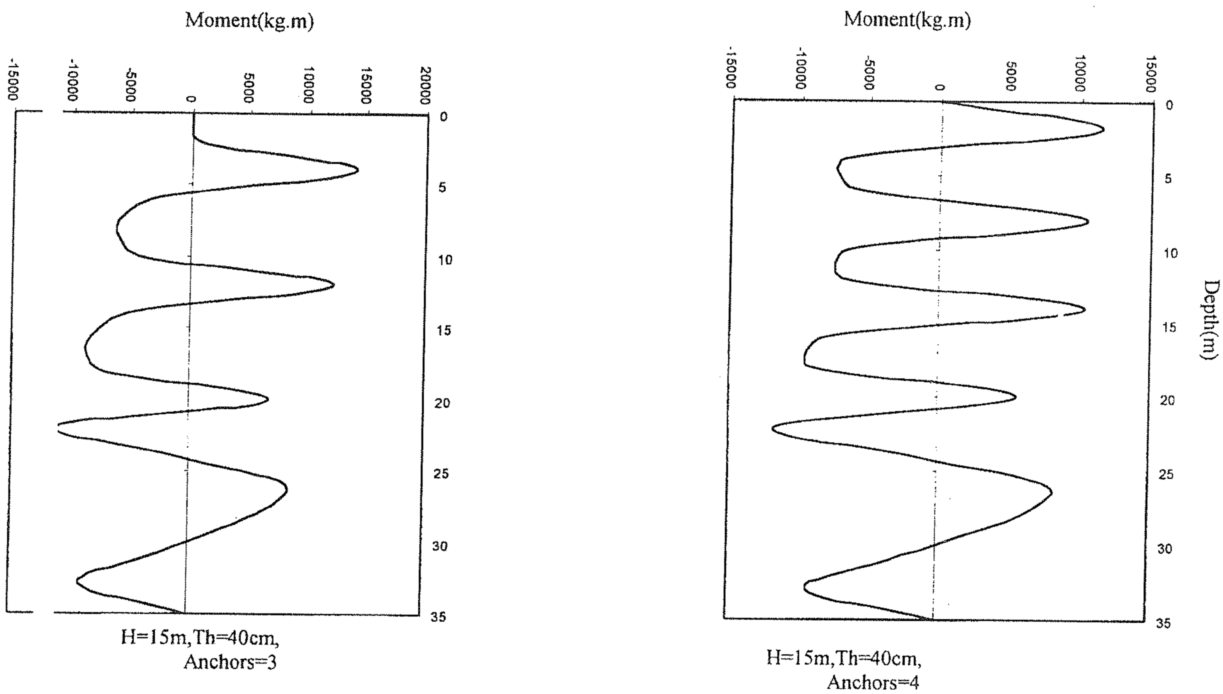

Figure (2) effect of number of anchors on bending mement.

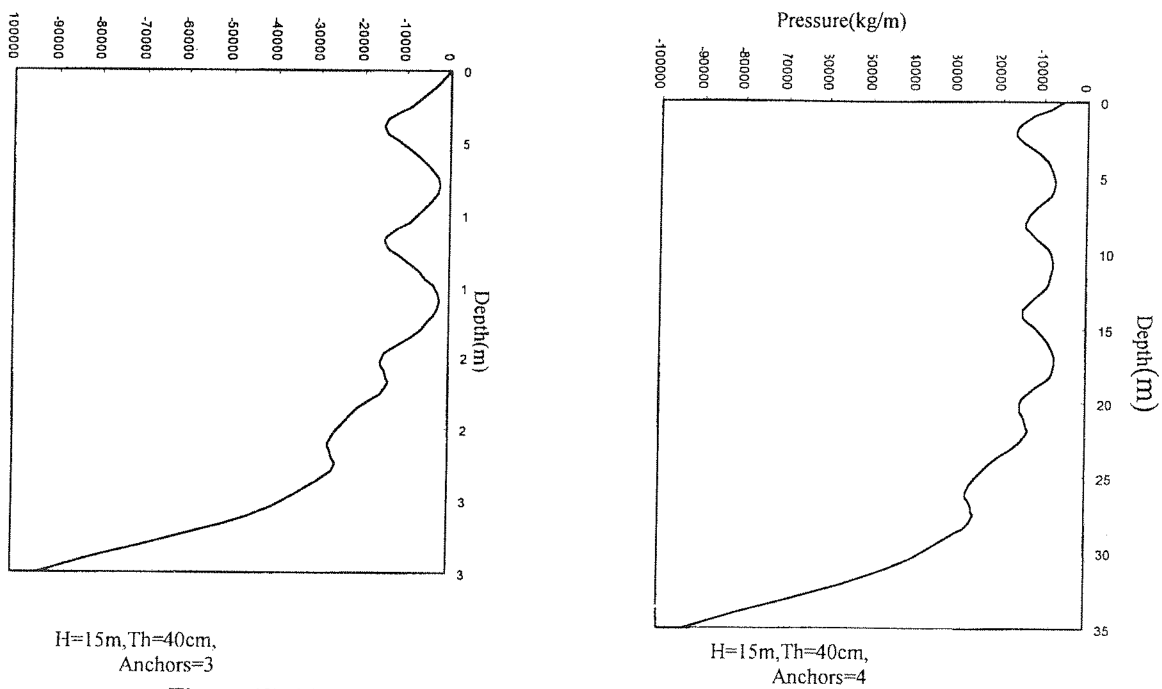

Figure (3) Effect o.` number of anchors on lateral; stress distribution.

For example, by reducing the wall thickness from 1 meter to 0.8 meter, the area under the bending moment curve reduces by 33 percent. This percentage becomes smaller for the change in wall thickness from 0,8 meter to 0.6 meter. These variations are larger for walls with smaller heights and thicknesses due to reduction of its rigidity.

3-5-Effect of Thickness on Wall Deformation

In most of the models, reducing the wall thickness, results in a reduction of deformation in the upper part of the wall. Also, considering the impact of the prestress force, the height of the negative deformation area increases. However, from a certain point on the wall, deformation increases with a drop in the thickness, the phenomenon being more pronounced for low numbers of anchors. As an example, for the 50 meters wall, changing the thickness from 1 meter to 0.8 meter results in a 3 percent jump in the maximum deformation (Fig. 6 & 7).

3-6-Effects of Varying Anchor Force

Deformation in the wall as a result of lateral loads, assuming a constant end block, would lead to maximum 10 percent increase in the anchor forces. This increase is larger in lower anchors. Reducing the wall thickness would result in a limited drop in the anchor forces.

3-7-Effects of Changing Number of Excavation Layers

An analysis was performed to determine the effects of varying the number of excavation steps for different models, coupled with changing the thickness of the layers. The analysis focused on the resulting change to the lateral forces, bending moments and anchors forces in different situations.

Specifically, excavation steps were varied for a wall of 15 meter height as follows:

- In 9 steps in the form of nine 1m-thick layers
- In 4 steps in the form of one 3m-thick layer and three 2m-thick layers
- In 3 steps in the form of three 3m-thick layers
- In 1 step in the form of one 9m-thick layer

The analysis was performed for each case,the results of which are shown in figure 8. The results indicate.

a- The deformation increases with an increase in the excavation steps, and the minimum deformation corresponds to the case where the excavation is done in one 9m layer. The reason is the quick loading of the wall and simultaneously exerting the three-anchor prestress force which forces the wall more towards the soil and thus does not allow any deformation.

b- Reduction in the number of excavation layers observed to result in slight increase of the lateral stress behind the wall. Also, a look at the area under the bending moment curve reveals that the area drops as a result of increasing the number of excavation layers.

c- When the excavation is done is one step, the value of forces produced in the anchors show a steep increase. For instance, the force increases multifold in the lowest anchor.

4-Conclusions

In this investigation, various models for cut off walls having 10 to 50 meters height were analyzed using finite element method. The wall deformation and its internal forces and lateral stresses were calculated and compared with respect to the number of excavation layers and number of row of anchors.

In general, the magnitude of wall

layers for each case is studied.

For the first step in the analysis, the complete mesh is analyzed aiming to determine the initial stresses in the soil without any excavation. The calculated values are used as the initial stresses through out the analysis, and further analysis carried out after each excavation step and modelling of the anchors. The procedure is continued for the whole depth of the excavation.

3-Results and Discussions

The effect of various parameters on deformation and stress distribution through the wall are studied separately as follows.

a. Effect of the number of anchors

b. Effect of the wall thickness

c. Effect of the wall height

After analysis of each case, deformation graphs, lateral stress distribution behind the wall, shear forces and bending moments in the wall and also tensile forces in the anchors were plotted. Figures 2, 3 and 4 show typical results.

The following conclusions are remarkable:

3-1-Effect of Number of Anchors

In general, increasing the number of row of anchors would result in decreasing the bending moments, whose variation becomes more uniform with height.

As an example, for a 50m wall with 6 row of anchors, the bending moments do not exceed 40 ton-meters, while with reducing the number of rows to 4, the moment will be doubled.

In this case, by changing the thickness of the excavation layer and increasing the anchor spacing, the maximum amount of bending moments would reach 55 ton-meters.

For this wall, changing the number of row of anchors from 6 to 5, will result in a 22 percent increse in the maximum value of the positive moment in the lower parts of the excavation area. The maximum positive moment occurs deep down the excavation zone,or at the location of the first anchor.

3-2- Effect of number of anchors on lateral stress distribution behind wall

By increasing the number of the row of anchors, the lateral stress distribution becomes more uniform. The uniformity is more pronounced in the case of lower thickness and higher number of rows. In general, results indicate the accurate negative deformation in the upper parts of the wall (Fig. 3).

3-3-Effect of Number of Anchors on Wall Deformation

The deformation graphs (figure 4&5), show that as the number of row of anchors becomes higher, their distribution in heights becomes more uniform and the wall deformation becomes smaller. By reducing the number of anchors, the negative deformation in the upper part of the wall is reduced. For example in the case of a 50m wall, by reducing the number of row of anchors from 6 to 4, height of area of negative deformation drops from 6 meters, an over 50 percent reduction. Without using the anchors, there will be a noticeable increase in the deformation at the location, and increasing the number of anchors would push down the point of maximum deformation.

3-4-Effect of Thickness in Bending Moment

In most of the cases, reducing the wall thickness results in a reduction in the bending moments. However, the points of maximum positive and negative moments do not move farther (Fig5).

$$\frac{1}{6}\left[(\sigma_{11}-\sigma_{22})^2+(\sigma_{22}-\sigma_{33})^2+(\sigma_{33}-\sigma_{11})^2+6\sigma_{12}^2+6\sigma_{23}^2+6\sigma_{31}^2\right]-K^2=0$$

In this criterion, the yield stress of the material is related to the pure shear stress condition [5]. In order to select the model parameters, a soil sample from north of Tehran was tested. The test results are shown in table 1.

The analysis of the wall was performed with plane strain assumption and considering the wall's thin thickness compared with its length and height.

To take into account the friction between the soil and wall models, a slipping compression element is used which connects any points of the soil surrounding the wall to a point on the wall's surface. The coefficient of friction is assumed to be 0.43.

The soil is modelled as plane strain four node elements with perfect elasto-plastic behavior, and for the concrete, a beam type element with linear behavior is used. The anchors are modelled as linear elements with tensile strength only.

The length of the anchors through some preliminary calculations, and assuming their extension outside the soil's active zone, is taken to be 11.4-25 meters. The anchors primary tensile stress is 70 percent of its rupture stress.

The height of the wall in different models is taken to be 10-50 meters and its thickness from 0.4 to 1 meter. For each height, through preliminary analysis, an area for a finite elements mesh is determined. For example, for a wall with 50m-height, the area is 86m x 80m, and for a wall with 15m height, the mesh area is 60m x 50m (Fig. 1). A rolling support is assumed at the vertical side of the mesh while the bottom side is taken to be against a hinge support. As for the row of anchors, their number is varied between one and six for each wall height, and the deformation of the wall relative to the thickness of the excavation

Table (1) Characteristics of Materials.

surrounding soil	$\gamma = 20KN/m^3$	$E_c = 80MPa$	$\nu = 0.3$
concrete wall		$E_c = 20000MPa$	$\nu = 0.15$
anchor tandons	$f_{prg} = 18800MPa$	$E_s = 189000MPa$	

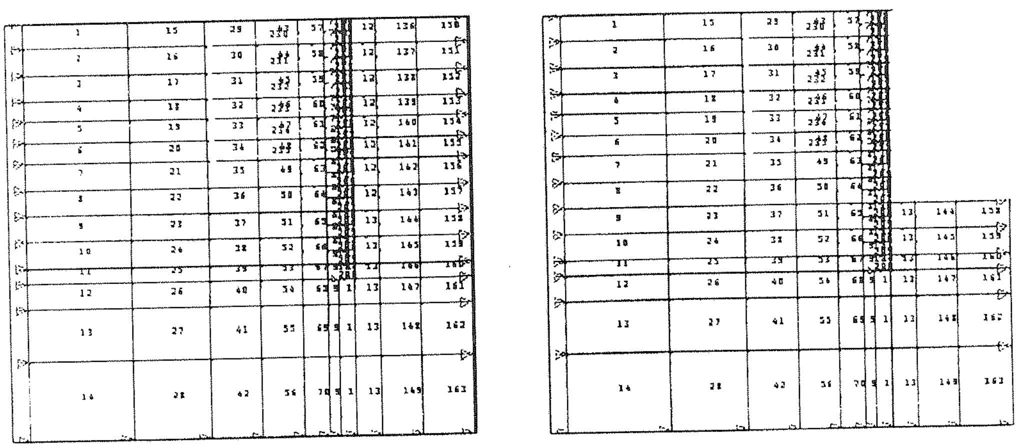

Figure (1) F.E mesh for a wall with 50m height.

Investigation of Excavation Layers Thickness and Anchor System on Stress Distribution in Cut-off Walls

Ali Reza Rahaii
Associate Professor
Civil Engineering Department,
Amirkabir University of Technology

Abstract

Regarding the vast application of cut-off walls in different structures, their behavior under different executive conditions have been investigated by numerical methods. Using finite element method with nonlinear models, the effects of excavation layers thickness, installation of anchors on deformation, lateral stress and internal forces of the walls are studied.

1-Introduction

Concrete cut-off walls are commonly used in civil engineering projects as retaining walls, or bearing walls. These walls, usually up to 50 m height, are constructed in steps of: excavation, placement of steel reinforcement bars or tendon, and adding concrete or instead, placement of pre-fabricated pieces. Following the construction of the wall, excavation is done in several steps, where generally after each step, a row of anchors is implemented [6].

To optimize the wall thickness, it is necessary to analyze exactly the distribution of internal forces through the wall under various conditions. The analysis is carried out with the assumption that the flexibility of the wall, and the thickness of the layers well as the number of row of anchors have major effects on the internal stresses [2].

In 1979 Kantakous analyzed different models of cut-off walls, and also studied the effect of adjacent structures on the wall behavior assuming linear property for the materials.

In 1981 Kasterpolus made an experimental model and studied the soil-wall interaction, and examined its effect on the distribution of internal forces [1].

In 1990 Litel and MacFarlin studied the effect of anchors on the wall deformation.

In this paper, the effects of number of excavation layers and the position of anchors, on the stress, deformation and behavior of cut-off walls are studied with taking into account nonlinear behavior for the materials.

2-Method of Analysis and Proposed Models

In a cut-off wall system, proper models should be selected for the behavior of concrete wall, the surrounding soil and the anchors. Considering the flexibility of the wall and the soil deformation, the Von-Mises elasto-plastic model with four parameters of E, v, E_c, and σ_y is employed. In Von-Mises criterion, the plastic behavior of the material begins when the deviatoric energy reaches a critical value. This energy for the unit volume of the material is presented in the from of: $W_d = \frac{1+v}{E} J_2$

Considering the dependance of deviatoric energy on the non variable deviatoric stress tensor, Von-Mises of octahedral shear stress criterion is written in the from of: $J_2 - K^2 = 0$

Using the general condition for the stresses, the above relation can be written as follows: