Effect of unbraced excavation in clayey soil on adjacent buildings

Effet de unbraced fouilles dans des sols argileux sur les bâtiments adjacents

E. H. Ramadan, M. H. Hussein, A. A. Senoon
Civil Engineering Dept.,Assiut University , Egypt
A. A. Mohamed
Civil Engineering Dept., Quena, Al-Azhar University, Egypt

ABSTRACT
Excavations inevitably result in deformations of the adjacent ground and settlement of adjacent buildings. This problem was investigated numerically in the present research using finite element method. The two dimensional plane strain program PLAXIS was used in this study. Two parameters were considered, the first is the foundation depth and the second is the distance of building from the excavation. Nodal displacements and elements straining actions were obtained from the finite element model results and were analyzed.

RÉSUMÉ
Fouilles inévitablement à des déformations du sol adjacent et le règlement des bâtiments adjacents. Ce problème a été étudié numériquement dans la présente recherche en utilisant la méthode des éléments finis. Les deux dimensions souche PLAXIS programme a été utilisé dans cette étude. Deux paramètres ont été considérés, le premier est la fondation la profondeur et la seconde est la distance du bâtiment de l'excavation. Nodal déplacements tendre actions et des éléments ont été obtenus à partir de l'élément fini et les résultats des modèles ont été analysés.

Keywords: excavation, relative distance, relative depth, stresses, lateral deformation, settlement.

1 INTRODUCTION

Unbraced excavation in clayey soil to shallow depths nearby existing buildings is a common practice in Egypt which leads to many structural problems in these buildings. The design of these excavations should include an estimation of the ground movement as well as stability check of the adjacent buildings. Since ground settlement occurs as a consequence of the lateral movement of ground, it is expected that a relatively heavy structure will undergo additional settlement due to its loads and due to the decrease in the stiffness of the foundation soil. The reduction of soil stiffness is a result of the lateral movement of the excavation sides. Consequently the building as a rigid body and its individual members will undergo translation and rotation. This will result tensile strains and bending strains in the building members. Boscardin and Cording [1989] and Boone [1996] have recognized that excavation-related limiting criteria is a function of building type and its orientation with respect to the excavation, type of support system, excavation techniques, and soil conditions. Seok et. al. [2001] observed that braced excavations inevitably result in deformation of the adjacent ground and settlement of adjacent buildings behind the wall. Building settlement is believed to exceed the amount of associated ground settlement because of the additional settlement under building weight which is due to decreas stiffness of the foundation soil. Son et.al. [2005] observed that the bearing walls oriented in a direction perpendicular to an excavation wall tend to become distorted with shear strain and lateral strain at the foundation level. When ground movement initially impinges on the front of the building, it is primarily subjected to shear distortion and lateral strain at the base.

The main objectives of the present research are:

a. Establishing an analytical model to represent realistic behavior of the excavation and the adjacent building.
b. Study the effect of the building foundation depth and the distance between the building and excavation on the behavior of both excavation and building.

2 NUMERICAL MODELING AND PARAMETERS

2.1 *Finite element model*

Mohr - Coulomb model in 2D plane strain PLAXIS program was used for problem idealization, to make realistic predictions of the stability and deformations of excavation and adjacent building.The finite element model for excavation, adjacent area and adjacent building is shown in Figure 1. Where the width of excavation is 4.0 m, the depth H = 4.0 m, and the building is at distance (x) from the excavation. The finite element mesh is generated automatically by the program as a very fine mesh.

2.2 *Soil and building models*

Soil is assumed to be a deposit of silty clay and is modeled by 15 node triangular element in the analysis as an elastic perfectly plastic Mohr - Coulomb model. The soil parameters are presented in Table 1.

The studied structure was considered as a reinforced concrete building consists of five typical floors each 3.00 m height. The slab floors were 0.20 m thickness flat slab, fixed supported on columns of two type cross section, external columns 30 × 50 cm and internal columns 30 × 60 cm, which also fixed with raft foundation 0.5 m thickness. Each column row was converted to an equivalent wall, with the same length of the building. The wall thickness, teq , was calculated so that the moment of inertia about y-axis is the same for both columns row and equivalent wall, as shown in Figure 2. Equivalent walls, slabs and raft foundation were idealized with five nodes isoparametric beam element in the analysis. Interface element was used to represent the contact between beam elements and soil.

doi:10.3233/978-1-60750-031-5-1774

2.3 Analysis Procedure

The elastic perfectly plastic finite element analysis involves number of iterations. Excavation and adjacent building were analyzed. The parameters taken into consideration are distance of building (x) and the depth of foundation (Df). Table 2. presents all cases, which were computed by PLAXIS program. This table contains five groups which will be discussed in the following items.

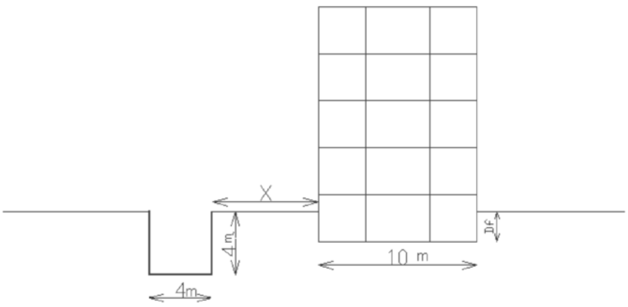

Figure 1. Model of excavation, adjacent area and building

Table 1. soil parameters of silty clay

Parameter	Notation	Value	Unit
Dry unit weight	γd	15	kN/m3
Wet unit weight	γwet	18	kN/m3
Young's modulus	E	30000	kN/m2
Poisson's ratio	υ	0.33	-
Cohesion	c	40	kN/m2
Friction angle	φ	8	degree
Dilatancy angle	ψ	0	degree
Interface reduction factor	R	1	-

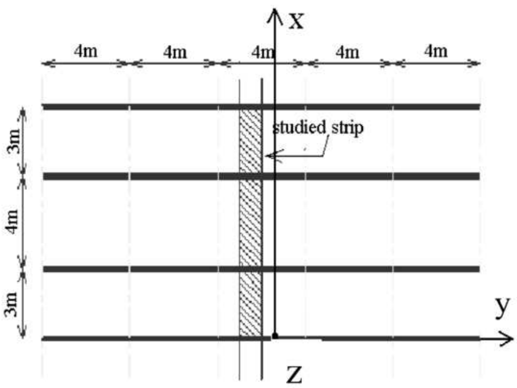

Figure 2. Plan of equivalent walls system

Table 2. Cases of study computed by PLAXIS program

Case No.	Rx = X / H	Rd = Df / H
1-4	0.5	0,
5-8	1	0.25,
9-12	1.5	0.5,
13-16	2	0.75
17-20	2.5	

3 RESULTS ANALYSIS AND DISCUSSION

3.1 *Effect of Excavation on building*

3.1.1 *Effect of Excavation on raft foundation*

The foundation depth was found to be the significant factor before excavation process. The distribution of settlement and internal forces of the raft foundation are symmetrical and the maximum values occurred when Rd = 0. They decrease with the increase of foundation depth. For instance the settlement corresponding to Rd = 0 is 2.5 times more than that at Rd = 0.75, Figure 3.

The effect of foundation depth after the completion of excavation process was analyzed. Figure 4. shows the distribution of settlement along the raft width for different values of Rd at Rx = 0.5. It is clear that the maximum settlement was achieved when the building foundation is at the ground surface, Rd = 0. The percentage increase of settlement after excavation was ranging from 55% to 180%.

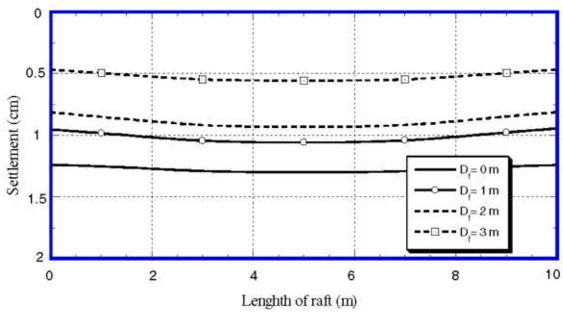

Figure 3. Effect of foundation depth on raft settlement before excavation

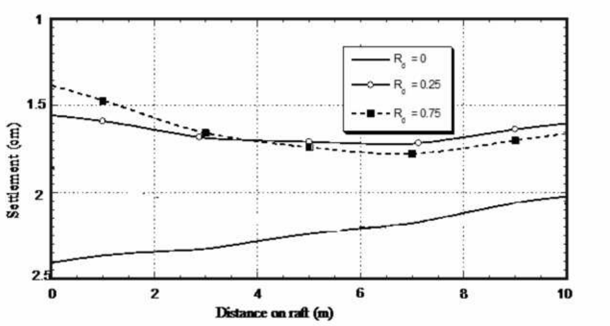

Figure 4. Variation of raft settlement for different values of Rd, (Rx = 0.5)

3.1.2 *Effect of Excavation on floor slabs and walls*

The vertical displacement of the upper roof slab before excavation was uniform of average value 1.3 cm. After excavation this distribution is non-uniform of maximum value 2.4 cm at the edge near to the excavation and of minimum value 2.1 cm at the far end of slab, Figure 5.

The equivalent building wall near to the excavation has almost zero average lateral displacement before excavation. This displacement was 0.84 cm at wall top and 0.38 cm at its bottom after excavation, Figure 6. The same trends were noticed for the other roof slabs and walls of building. Consequently the shearing forces and bending moments decreased in values but with inverse signs with the increase of displacement.

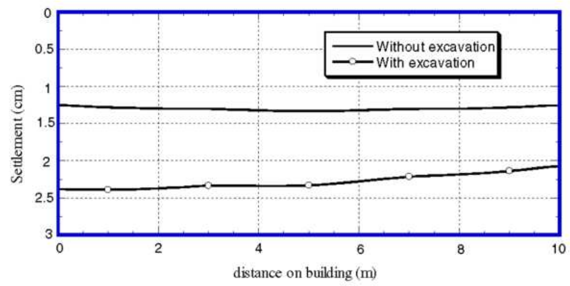

Figure 5. Settlement versus distance of upper slab before and after excavation at Rx = 0.5 and Rd = 0.

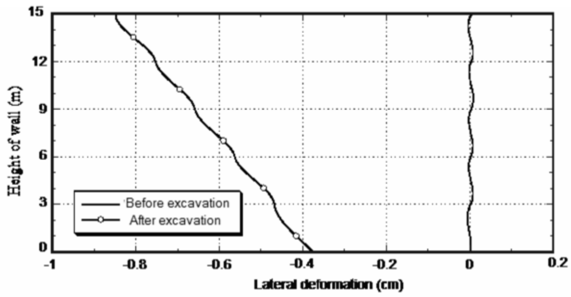

Figure 6. Lateral displacement of equivalent wall before and after excavation at Rx = 0.5 and Rd = 0.

3.2 *Deformations and stresses in soil due to Excavation*

The analysis of results concludes that the vertical and horizontal displacements before excavation are symmetrical with respect to building axis. After excavation they have irregular distributions. The maximum horizontal displacement of soil was -0.0052 m before excavation and increased to about 2.9 times after excavation, Figure 7. At the same condition the maximum vertical displacement beneath building before excavation process was -0.013 m at Rd = 0, while after excavation increased to 1.85 times at Rd = 0 and Rx = 0.5, Figure 8. This figure shows that the vertical downward displacement concentrates under the building while upward displacement, i.e. heave, is observed at excavation bed.

Figure 9. shows the effect of the relative distance of building, Rx, on the lateral displacement of excavation side near to building. The maximum lateral deformation was reached when Rx = 0.5 and Rd = 0. This displacement decreases as Rx increases. If Rx is more than 1.5 no considerable decrease of displacement is noticed for different foundation depths.

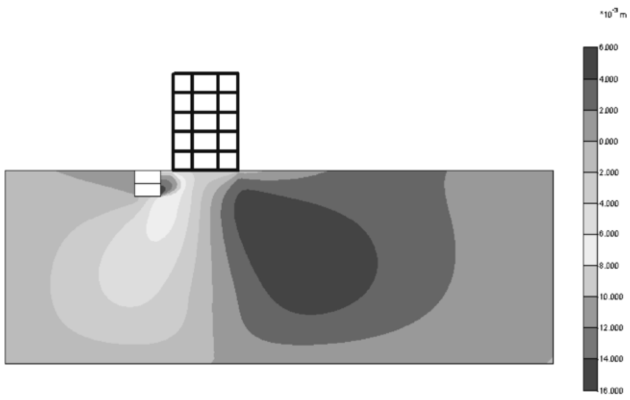

Figure 7. Horizontal displacement after excavation at Rx = 0.5 and Rd = 0.

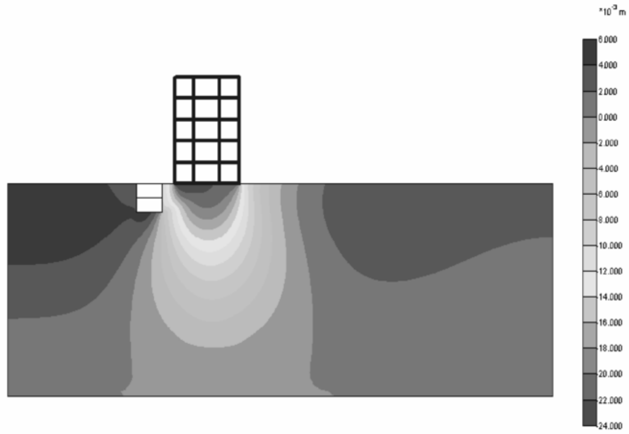

Figure 8. Vertical displacement after excavation at Rx = 0.5 and Rd = 0.

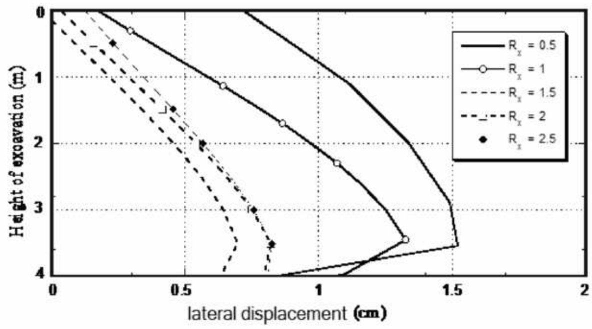

Figure 9. Lateral displacement of excavation side for different values of Rx and Rd = 0

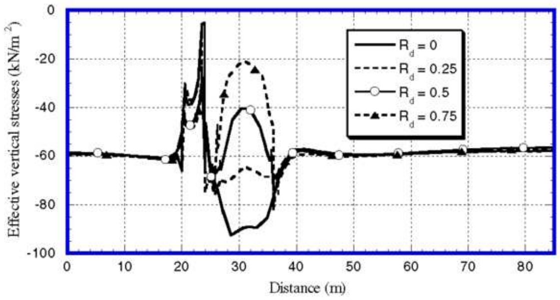

Figure 10. Effective vertical stresses at level (-4.00) for different value of Rd, Rx = 0.5

The effective vertical stress distribution at level (-4.00) below ground surface is shown in Figure 10. for Rx = 0.5 and different foundation depths. In this case and other Rx values the effective vertical stress under the building decreases by increasing the relative foundation depth, Rd, and the relative distance, Rx.

3.3 *Conclusions*

a. The settlement and internal forces in building elements and foundation before excavation have maximum values when the building is founded at ground surface. They decrease with the increase of foundation depth.

b. The settlement under the building is non uniform after excavation process. The maximum settlement and internal forces in building elements occur when the relative distance of building from excavation equals to half excavation height. When this relative distance is more than 1.5 the distribution of settlement is almost uniform.

c. The distributions of vertical and horizontal displacements and effective stress in soil before the excavation are symmetrical. After the excavation process, they have irregular distributions. These displacements are concentrated under the building at the near side to the excavation.

d. The effective vertical stress after excavation has maximum value under the building. This stress decreases by increasing the relative foundation depth and the relative distance of building from excavation.

e. Finite element modeling in Plaxis program is used successfully to represent the realistic behavior of building nearby an excavation.

REFERENCES

Boone, S. J. 1996, Ground movement related building damage, Journal of Geotechnical Engineering, Vol. 122, No. 11, pp. 886 – 896.

Boscardin, M. D. and Cording, E. J. 1989, Building response to excavation induced settlement, Journal of Geotechnical Engineering, Vol. 115, No. 1, pp. 1 – 20.

PLAXIS Version 7.2,1998, Material models Manual- Finite Element Code for Soil and Rock Analysis, Balkema Publishers.

Seok, J. W., Kim, O. Y., Chung, C. K. and Kim, M. M. 2001, Evaluation of ground and building settlement near braced excavation sites by model testing, Canadian Geotechnical Journal. Vol. 38.

Son, M. and Cording, E. J. 2005, Estimation of building damage due to excavation-induced ground movements, Journal of Geotechnical and Geoenvironmenta l Engineering, ASCE, February, pp. 162 – 177.