

Effect of stiffness of building adjacent to excavation on deformation of the excavation wall

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Abstract:

In contemporary urban environments, the scarcity of space and the prevalence of apartment living necessitate extensive excavation to secure adequate space and appropriate infrastructure for most construction projects. The influence of the structural rigidity of adjacent buildings on controlling ground displacement induced by excavation is critically important yet underexplored. This study investigates the effect of the rigidity of neighboring buildings' structural elements on excavation by analyzing nearly all relevant components. The results show that the structural rigidity of adjacent buildings significantly impacts the horizontal deformations of the excavation wall and the positions of maximum horizontal deformation in both the excavation wall and the ground beneath the structures. As the building's rigidity increases, the maximum horizontal deformations of the wall occur at greater depths within the excavation. Additionally, increased rigidity causes the location of maximum horizontal deformations of the ground beneath the structure, near the excavation, to shift towards the center of the building. Furthermore, as the building length increases, the depth at which maximum horizontal deformation occurs also increases. However, the location of deformation beneath the adjacent building is independent of the building's width and does not change with variations in the building's length.

1. Introduction

Today, due to the shortage of space and the expansion of apartment living in urban areas, excavation is inevitable to access sufficient space and suitable infrastructure in most projects. Incorrect design and failure to observe safety principles in protecting the excavation can lead to irreparable damages. Additionally, one of the important issues in excavation in urban environments is its impact on neighboring buildings, which can sometimes lead to irreparable human and financial damages. In this regard, the impact of the neighboring building's structural rigidity on controlling the ground displacement caused by excavation is also of special importance, which has been less studied. In most of the analyses conducted, it is observed that limited

settlement components shows much higher settlement than reality. Also, two-dimensional modeling in finite element software is less accurate and detailed than three-dimensional models and can provide misleading results. Safe excavation design, on the one hand, and the economic viability of structural guard designs, on the other hand, have led to further studies on the effects of distance and neighboring structure rigidity on excavation design and comparison of numerical results with actual settlement rates on-site. Excavation with different depths for the construction of tall buildings and important structures is inevitable. This issue is of great importance in urban areas, especially in their centers, considering the presence of buildings and facilities around the excavation site.

Despite the extraordinary facilities and capabilities provided by finite element software in analyzing excavations, without knowledge of the effective factors and characteristics of the excavation system's behavior, the use of finite element software can provide misleading and inappropriate results. One of these factors is the modeling of the neighboring structure's excavation, which depends on the neighboring

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structure's weight, geometry, and rigidity. Many studies have been conducted by researchers in this field, both experimentally and numerically.

Seok, J.W et al. (2001) [1] studied the settlement of the neighboring building due to braced excavation by creating a test model. They concluded that if the neighboring building is at a depth from the ground surface, the amount of ground movement depends on the depth. When the depth of the buried structure is high, the ground settlement under the structure will decrease, so if this depth is about more than half of the excavation height, this settlement will be negligible. Finno et al. (2002) [2] studied the effect of excavation on neighboring structures in the reconstruction of underpasses in the state of Chicago. The effect of the neighboring structure's weight on classical and finite element calculations has been introduced as a completely clear phenomenon in engineering literature, and with the addition of weight, the amount of displacement increases, and the stability reliability coefficient decreases. The geometry of the structure in terms of dimensions in the plan and its distance from the excavation wall can play an important role in the amount of environmental displacement. Numerous studies have been conducted on the effect of structures on excavations. However, the rigidity of the structure has not been considered in these studies. Despite the importance of the existing inconsistencies in the situation, the rigidity, and the different weights of the structures around the excavation, specific research in this area has not been conducted.

Boscardin (1989) [3] investigated the response of the structure to tunneling by modeling the structure as a deep beam. Based on the deformation characteristics of the deep beam, such as horizontal strain and slope changes along the beam, he presented qualitative criteria for estimating the damage to the structure caused by tunneling. Zapata-Medina (2007) [4] studied the semi-empirical method for designing excavation structures based on controlling displacement. Razeghi et al. (2011) [5] stated that the overall stability and the amount of deformation of the excavation walls, including lateral deformations and settlement rates, as well as the stability of existing structures adjacent to the excavation, depend on how the forces of these members are calculated. Zolghadr et al. (2011) [6], in examining the stability of excavation retaining walls, concluded that the predicted deformation shapes by numerical models show values greater than reality. Therefore, they provided solutions to improve the modeling process and bring the results closer to reality based on recursive analysis. Sabzi et al. (2013) [7] used the method of inclined struts to reduce deformation and prevent damage to adjacent structures, and by using numerical modeling, they studied the effective factors in this method and recommended suitable constraints for the main parameters for the safe implementation of this

method. Elshafie, M. (2008) [8] conducted a series of centrifuge experiments on structures exposed to ground displacement caused by excavation. The structure consists of two types of foundations: radial and individual footings. The modeled structures were made of micro-concrete with variable hardness, weight, and surface roughness. Their findings showed that horizontal displacements are affected by smooth interfaces and rough interfaces control the horizontal movements of the structure. Surface roughness affects the contact surface between the structure and soil significantly. Increasing roughness increases the structural axial stiffness. The interaction between soil and structure is particularly evident for structures with low flexural stiffness. Rigid structures tend to tilt regardless of interface roughness. In examining the effects of excavation construction on nearby buildings, various approaches have been utilized to simplify the structures, including the overload method [9], the equivalent elastic beam method [10], and the building structural method [11, 12]. Of these, the building structural method is particularly effective in accounting for the impact of structural stiffness on the outcomes [13]. The relationships among the building's upper structure, pile foundation, and surrounding soil layers are notably intricate, surpassing the complexity of shallow foundations. Currently, research on this topic has not been conducted in-depth [14, 15,]. Ding et al. (2019)[16] delved into factors like building floor numbers, foundation types, and tunnel-building positioning effects on neighboring structures during tunnel excavation. Their findings emphasize the notable influence of building foundation type on structural deformation characteristics. Mirmoradi et al. (2021) [17] evaluated the numerical effect of piles on the behavior of reinforced soil walls. The results indicate the importance of the combined effect of piles and other factors on the performance of reinforced soil walls. The results of this analysis show that (1) the probable failure surface in the soil behind the excavation is almost independent of the location of the building relative to the excavation, and (2) the position of the building concerning the probable failure surface is critical to the resulting horizontal displacement and rotation of the building. Lemmen et al. (2017) [18] evaluated the effect of foundation stiffness on the behavior of surface strip footings on sandy soil. Laboratory tests were performed using a centrifuge device with an acceleration of 30 times the earth's gravity on 7 piles with different depths and stiffness. It was found that when a pile is classified as a hard pile, the stress distribution under the pile is almost uniform. However, as the relative stiffness decreases, the stress distribution under the pile in the corners is a percentage of the maximum stress under the column located above the pile. This indicates that the constant stress under the edge of the pile can be expressed as a function of the relative stiffness of the pile (Uribe-Henao et al.,2023) [19]. Madah et al.

(2020) [20] conducted a comprehensive numerical study on the interaction between structures and excavations. In this study, the results of a comprehensive numerical study of the strain on the interaction between a 6.32-meter excavation and a 12-story building were presented. To calculate the settlement, rotation, and lateral displacement of the building edge, three-dimensional PLAXIS software was used. The parametric analysis results show that (1) the probable failure surface in the soil behind the excavation is almost independent of the location of the building relative to the excavation, and (2) the position of the building concerning the probable failure surface is critical to the resulting

horizontal displacement and rotation of the building. Tavakoli et al. (2019) [21] investigated the effects of excavation-induced displacement on adjacent structures in urban areas by performing 2D numerical modeling. The effect of the stiffness of the adjacent structure on the ground movement caused by excavation was considered. The results show that the stiffness of the adjacent structure has a significant effect on controlling the ground displacement due to excavation. The stiffness of the adjacent structure causes the maximum horizontal displacement to occur in the lower areas of the excavation wall, whereas without considering the stiffness, the maximum horizontal displacement occurs near the ground surface.

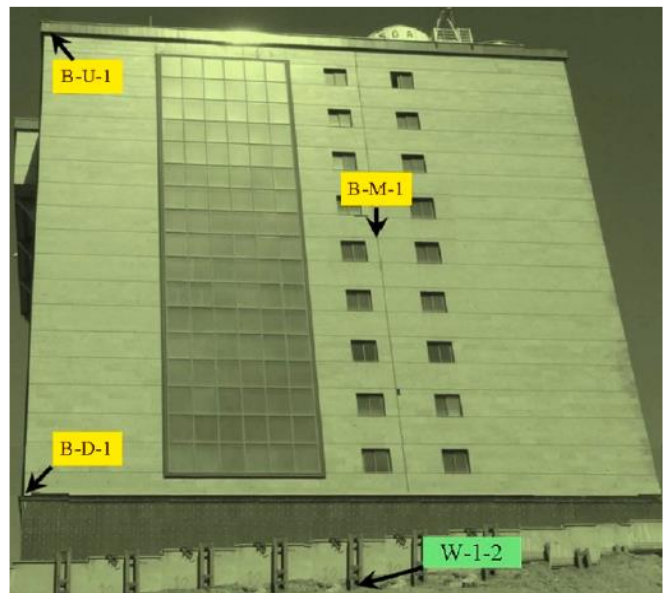
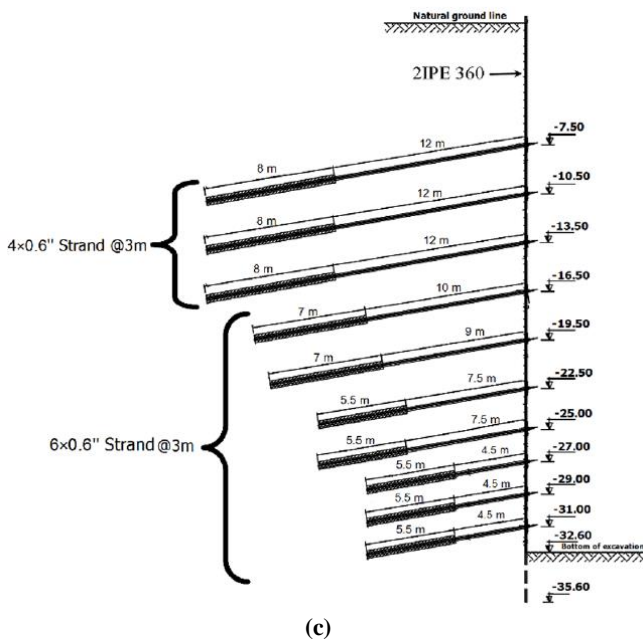
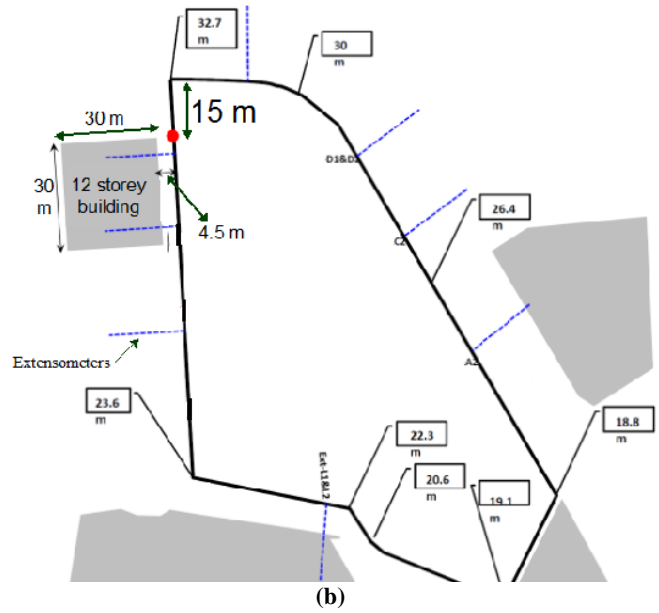


Fig. 1: Case study: (a) building and excavation wall; (b) excavation plan; (c) specifications of the SOE; (d) target points on the excavation crest and adjacent building

Based on the research results in the field of the effect of adjacent structures on excavation deformations, it can be stated that a 3D numerical analysis can well apply the geometry effect, and the effect of the dimensions and stiffness of the adjacent structure has been less studied and is usually applied as an equivalent dead load in a flexible surface in classical and finite element calculations (Russo et al., 2024) [22]. It seems that the stiffness of the adjacent structure plays a significant role in controlling the displacement in the excavation wall and ground surface, and on the other hand, excavation causes changes in the internal forces of the structure members, which is addressed in this study.

2. Characteristics of the case study

The validation of the numerical modeling was carried out using a case study of a 31.2 m deep urban excavation next to a 12-story concrete building on the western side of the excavation (Figure 1(a)). The building, as depicted in Figure 1(b), has dimensions of 30 m in length (B) and width (L), an embedment depth of 4.5 m, situated 15 m away from the excavation corner, and 4.5 m from the excavation edge. It features a 1.5 m thick mat foundation, frames with 6 m spans, and a floor height of 3 m. The building's retaining walls and floor slabs are 20 cm thick, while the columns and beams measure 70×70 cm and 30×50 cm, respectively.

The project site consisted of a thick, uniform layer of relatively dense cementitious granular soil, with the groundwater level below the excavation's bottom level. Pre-stressed anchors and reinforced shotcrete were utilized as the support of the excavation (SOE) system for the entire project, except around the building where a combination of steel piles, anchors, and shotcrete was used due to the building's weight and restrictions on allowable induced displacements. The characteristics of the piles and anchors in a cross-section of the SOE are shown in Figure 1(c). The piles (2IPE360) were spaced 3 m apart horizontally and embedded to ensure soil fixity below the excavation's bottom level. Following each excavation step, a 10-cm thick layer of reinforced shotcrete was added. Each strand (15.24 mm diameter) was subjected to a tensile force of 150 kN, resulting in pre-stress forces of 600 kN and 900 kN for the 4-strand and 6-strand anchors, respectively. A surveying network and various types of instrumentation were used for excavation monitoring, although unreliable results were obtained due to poor instrument quality and/or incorrect installation. Consequently, the numerical model results were solely compared with surveying data from four target points on both the building and excavation crest.

3. Numerical modeling

The numerical analysis of the building-excavation interaction was conducted using the finite element method implemented in Midas GTS. To ensure accuracy, two models were employed: a wide slice model consisting of two consecutive piles of SOE, and a fully 3D model as depicted in Figure 2. Before proceeding with the parametric studies, the modelling procedure was thoroughly evaluated by examining a case study presented in Section 2. Once the models from the case study were validated, the parametric studies were performed by modifying the variables.

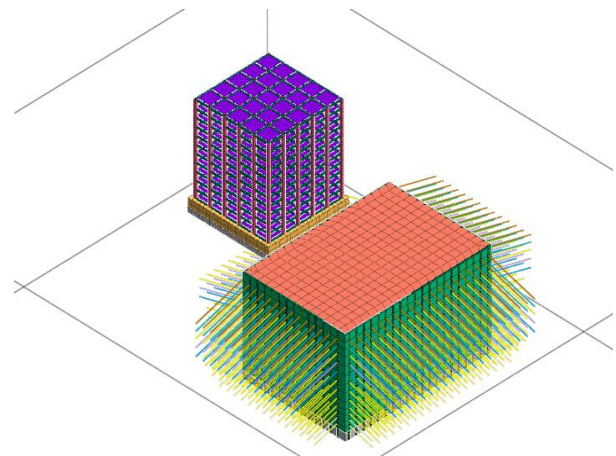


Fig. 2: An overview of the case study modeling in Midas software

3.1 Soil constitutive model

As mentioned earlier, the project site consisted of a relatively compact homogeneous layer of soil-cement granules, and the groundwater level was lower than the excavation level. The soil constitutive model used for defining the soil behaviour was the Hardening Soil model available in the Midas GTS software. The Hardening Soil (HS) model differentiates between the loading modulus (E_{50} or E_i) and the unloading/reloading modulus (E_{ur}), making it highly suitable for deep excavation analysis. This model is based on the Mohr-Coulomb strength criterion and incorporates two yield surfaces. The yield surfaces include the "yield cap surface," which has an associated flow rule that accounts for volumetric plastic strains, and the "shearing yield surface," which is used to compute distortional plastic strains. The flow rule is non-associated, with the plastic potential function defined to ensure a hyperbolic response. Table 1 presents the model parameters and their selected values for the numerical modeling of the case study, as well as for the forthcoming parametric study. The parameter values of the HS model are obtained from the results of laboratory tests.

Table 1: Soil properties and parameters of the HS model used in numerical analyses

Parameter	Case study	Parametric study
E_{50}^{ref} (MPa)	60	60
E_{oed}^{ref} (MPa)	60	60
E_{ur}^{ref} (MPa)	300	300
Power (m)	0.6	0.5
c'_{ref} (kPa)	50	25
φ' (°)	39	36
ψ (°)	5	0
ν_{ur}	0.2	0.2
P_{ref} (kPa)	100	100
K_0^{nc}	0.37	0.37
γ (kN/m ³)	20	20

“ref” denotes reference pressure at which model parameters should be determined

Pre-stressed anchors and shotcrete reinforcement were utilized as a retaining structure system for the entire project, except around the building where the weight of the structure and constraints on acceptable displacements require the use of a combined system (steel anchor with tie rods and shotcrete reinforcement). Figure 1(c) illustrates the specifications of the steel anchor and tie rods at the cross-section level of the wall. The horizontal distance of the steel anchor and pile (2IPE360) was 3 meters, and their buried depth was 3 meters to ensure stability in the soil below the excavation level.

The Midas software provides a tool called Anchor Wizard to directly model the tie rod. In this section, the software takes the length of the embedded section, the free length, the execution angle counterclockwise relative to the horizontal axis, and the pre-tension force directly from the user to model the tie rods. A tensile force of 150 kN was applied to each strand (with a diameter of 24/15 millimeters), resulting in pre-tension forces of 600 and 900 kN for the 4-strand and 6-strand tie rods, respectively.

A layer of shotcrete was applied around the excavation area. To facilitate modeling, after each excavation stage, a 10-centimeter layer of shotcrete was added. Two-dimensional shell elements were used to model the shotcrete in the Midas software. It should be noted that a layer of shotcrete was also modeled using two-dimensional shell elements around the building foundation and the first floor, which is buried in the soil.

3.2 Equivalent Load and Structural Modeling

A uniform load of 12 kN/m² was used as the dead load for each floor of the building for structural modeling purposes. One-dimensional elements were used to model the beams

and columns. It is worth mentioning again that the dimensions of the beams and columns were considered 50×30 and 70×70, respectively. The length of each span (distance between two adjacent columns) was 6 meters, and the height of each floor was 3 meters, following the actual project specifications (Fig 2). The specifications of the concrete used in the structural modeling are provided in Table 2.

Table 2: Concrete properties and parameters

Parameter	Value
Weight per unit volume	25 kN/m ³
Modulus of elasticity	20 GPa
Poisson's ratio	0.2

4. Verification of model

The actual project site measurements have been taken at four specified points shown in Fig 1(d), which are, the top of the building (B-U-1), the middle of the building (B-M-1), the bottom of the building (B-D-1), and the excavation crown (W-I-2). Figure 3 represents the output values of the points specified in the modeling performed by Midas software and the actual data collected from the site. As observed, the software output results have a very good match with the data collected from the project site. For example, for the top point of the building, the actual data collected from the site was approximately 43 millimeters, the output data from PLAXIS software (presented by Madah et al. (2021) [23]) was around 35 millimeters, and the output data from Midas software used in this research was 42.5 millimeters, indicating the high accuracy of the analyzed model in this article. Therefore, the accuracy of the performed modeling can ultimately be confirmed.

The slight difference observed between numerical calculations and measurements in Fig. 3d can be attributed to the interaction between the soil and the steel profile, as the actual measurements were taken on the vertical steel profile at this point. Although the steel profile is modeled in the numerical calculations, the positioning and implementation details significantly impact the interaction between the soil and the steel structure.

5. Parametric analysis

In this section, the analyzed models are examined and compared. It should be noted that throughout this section, the default model refers to the model mentioned in the previous section, which was modeled based on the real conditions of the project site, and the verification was performed according to that model.

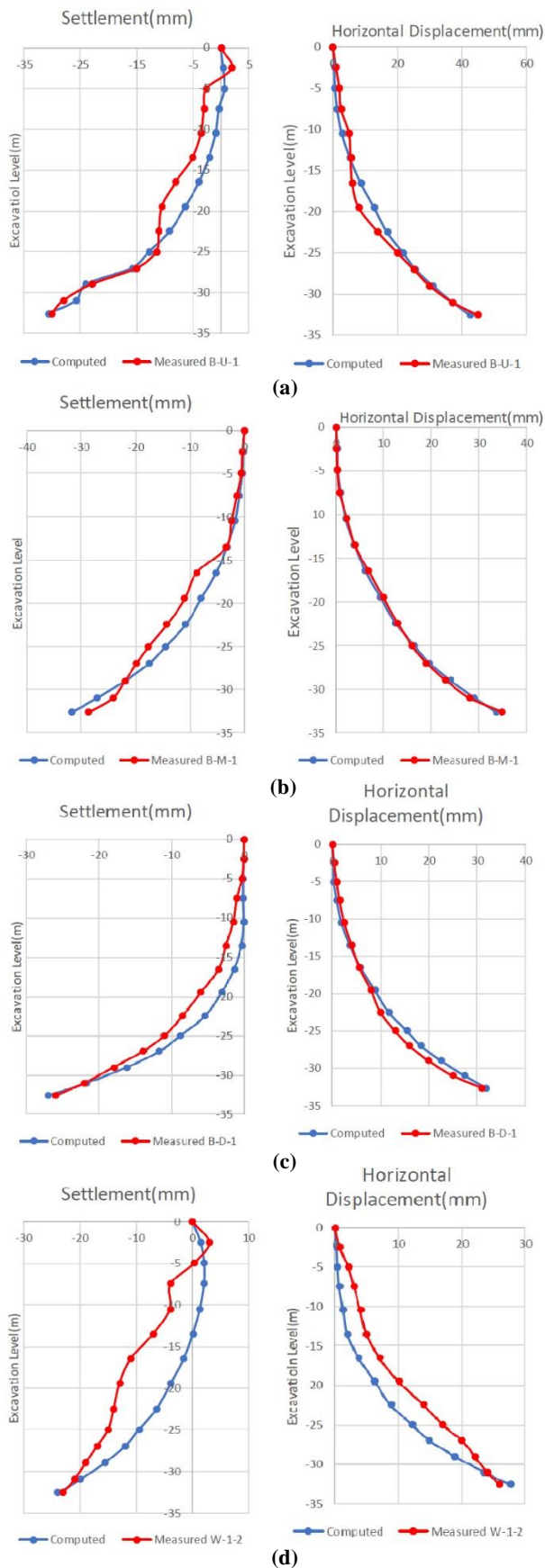


Fig. 3: Comparison of measured and computed displacements for target points: (a) B-U-1 (top of building); (b) B-M-1 (middle height of building); (c) B-D-1 (base of building); (d) W-1-2 (crest of excavation).

5.1 Effects of foundation and neighboring structure

To further investigate the effects of modeling the neighboring structure on excavation, this section compares two models: one without modeling the neighboring structure and directly applying the load on the adjacent soil, and the other only modeling the foundation and applying the load on it. The aim is to examine and compare the deformations of the excavation walls and compare them with each other. The investigation indicates a significant impact of modeling the foundation and neighboring structures on the deformations of the excavation walls. The software output results show that in cases where the neighboring structure is not modeled and an equivalent load is directly applied to the soil, the calculated horizontal deformations are much greater than when the adjacent structure is modeled. In the case of this research, the output results in the scenario where the neighboring structure is not modeled are approximately 1.87 times the initial state. Additionally, the settlement values indicate 1.59 times the initial state.

Madah et al. (2020) [23] stated that the location of the maximum ground settlement is likely to be geometrically related to the location of the excavation disturbance. In other words, for $e + B / 2 < 20$ meters (B is the length of the structure adjacent to the excavation, and e is the distance of the structure from the excavation wall), the structure is mainly located inside the excavation disturbance (where rotations are aligned with the ground surface characteristics in a clockwise direction). Since in the investigated excavation of this research, $e+B/2$ is greater than 20 meters, the structure tends to move outside the excavation disturbance, which is accompanied by smaller settlements and rotations in the clockwise direction. Therefore, the hypothetical rotation of the structure may be relative to its position concerning the excavation disturbance. Figure 4 illustrates a magnified image of the deformation amplification in the rotation of the structure towards the excavation. Another model, in which only the adjacent structure foundation is modeled, had more strain variation results compared to the initial model, but compared to the other model, the results were reduced in a way that in the model where the adjacent structure foundation is modelled, the maximum horizontal deformation of the excavation wall was 4.1 in the initial state and this ratio was 1.27 for settlement. As a result, it can be stated that modeling the foundation and adjacent structure of the excavation is of great importance and plays a major role in the deformation of excavation walls.

Maleki et al. (2010) [24] examined the effect of excavation interaction and adjacent structure in analyzing excavations in urban environments. They considered the adjacent structure with a reinforced concrete moment frame system, whose stiffness is taken into account in the analysis at different stages of excavation. The interaction of excavation

and adjacent structure plays a significant role in the numerical analysis of anchored excavations.

This study also examined the effect of adjacent building stiffness. It was observed that in the model where the adjacent building is modeled, the location of the maximum horizontal deformation of the excavation wall occurs at deeper depths, but in the case where the adjacent building is not modeled and its equivalent weight is directly applied to the soil, the maximum horizontal deformation is inclined towards the top of the excavation. In the case where only the foundation is modeled, the location of the maximum horizontal deformation is a numerical value between the other two cases. Figure 5 shows the location of these deformations and Figure 6 shows the location of the maximum deformations in each model. Furthermore, the studies show that in the case where the adjacent building is modeled, its stiffness and the rotation that occurs due to excavation cause the maximum horizontal deformation of the foundation to occur on a side of the building that is far from the excavation edge, but in the case where the equivalent weight of the building is applied to the soil, the maximum horizontal deformation occurs towards the side of the building that is adjacent to the excavation. Figures 7a and 7b respectively show a representation of the distribution of these deformations in the model without the adjacent building and in the model with the adjacent building through color contours. By analyzing the maximum settlement beneath the adjacent building, it was determined that, when the adjacent building is not modeled (i.e., no stiffness is applied), the location of maximum settlement shifts towards the transverse direction of the building, adjacent to the edge of the excavation. Conversely, when the foundation and the building are modeled, the maximum settlement shifts towards the center of the building.

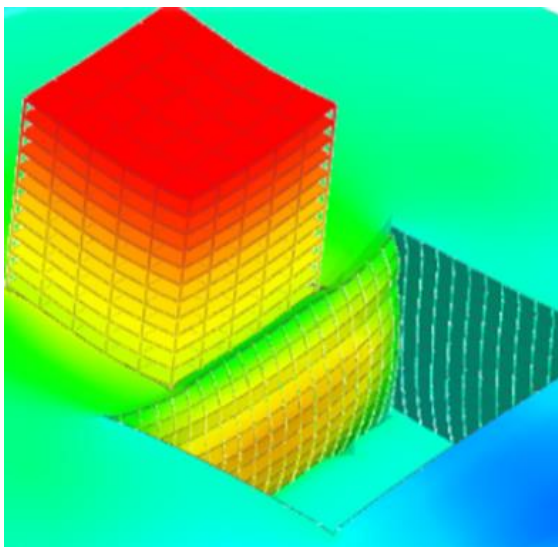


Fig. 4: Exaggerated image of tendency of building to turn towards excavation

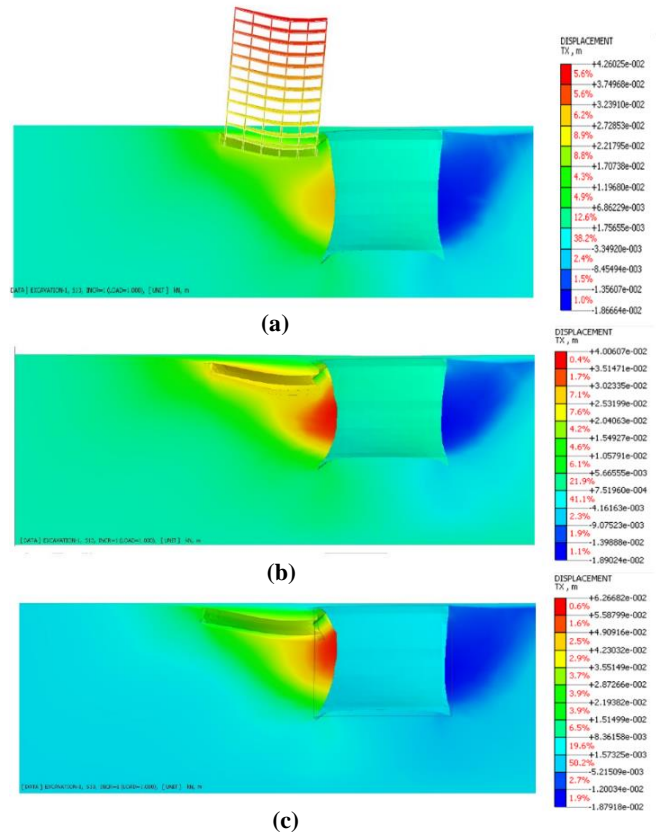


Fig.5: Horizontal deformation of a) default, b) with foundation (WF), and c) without foundation (WoF) models.

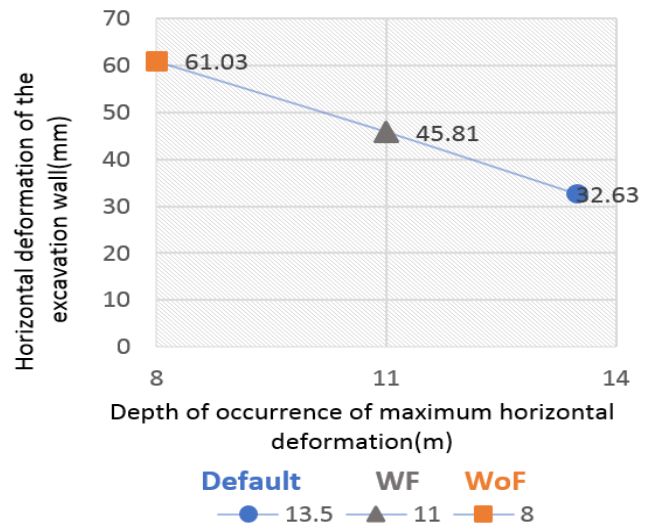


Fig. 6: Maximum horizontal deformation of default, with foundation (WF) and without foundation (WoF) models.

This observation can be summarized as follows: as the stiffness of the adjacent building increases, the location of maximum settlement beneath the building shifts towards its center. Based on calculations of the maximum settlements occurring in the ground under the structure, values of 38 cm, 52 cm, and 68 cm were obtained for the model with the building, the model with the foundation, and the model

without the foundation, respectively. This demonstrates the impact of the foundation and structure stiffness on the extent of settlement.

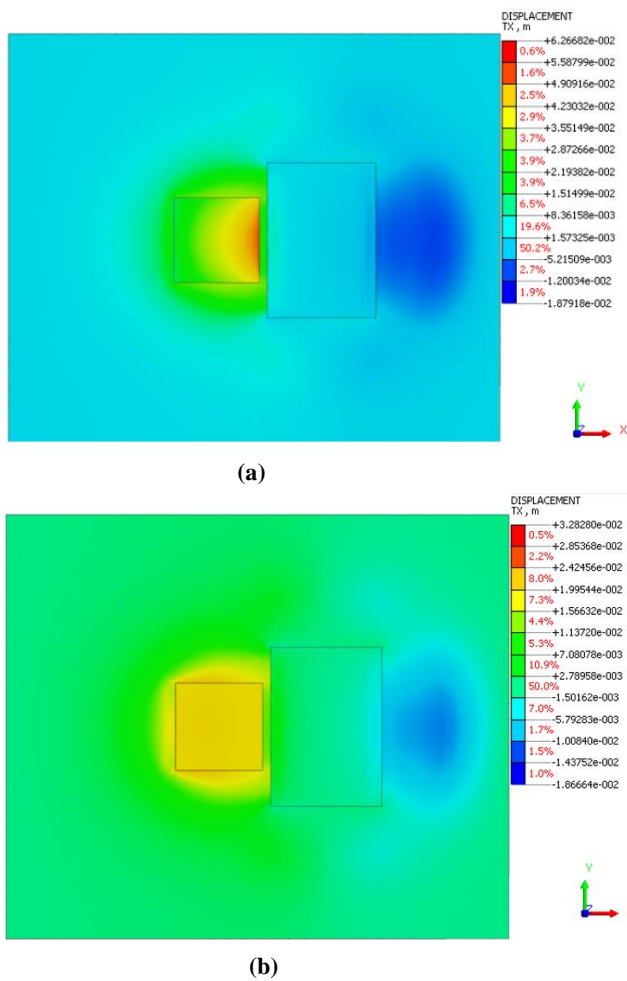


Fig. 7: Colored contour plan of horizontal deformation of ground beneath building adjacent to excavation; a) modeling without building and b) modeling with building

5.2 Effect of different types of adjacent structure foundations

In this section, the effects of different types of adjacent structure foundations on the deformation of the excavation were examined and analyzed by modeling them as mat, strip, and isolated foundations. To maximize scalability, the thickness of the strip and isolated foundations was considered to be 1.5 meters, similar to the mat foundation in real conditions.

The weight of all foundations was assumed to be equal by varying the specific weight of the consumed concrete. Based on the results obtained from modelling, it was determined that the deformation of the excavation wall is dependent on the type of adjacent structure foundation, where the maximum deformations occurred in the isolated foundation and the minimum in the mat foundation. Furthermore, in this section, the effect of foundation type on the location of

maximum horizontal deformation of the excavation wall was examined. As expected, the greatest depth was associated with the mat foundation, and the smallest depth was associated with the isolated foundation. The depths of the occurrence of maximum horizontal deformation in the mat, strip, and isolated foundations were 13.5, 10, and 5 meters, respectively, as shown in Figure 8.

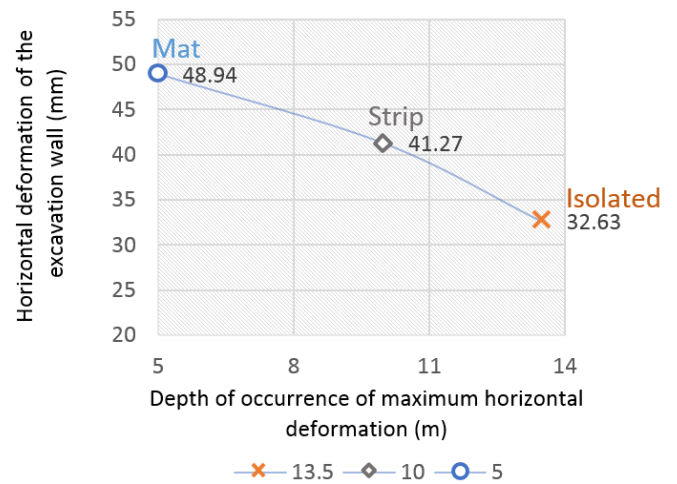


Fig. 8: Horizontal deformation of mat, strip, and isolated foundations of building adjacent to excavation.

5.3 Effect of structure length on adjacent excavation

To investigate the effect of structure length, the geometry of the structure was considered. In this section, by varying the length of the structure (L), the effects of structure geometry and consequently the stiffness of the adjacent structure on the deformation of the excavation wall were examined. Four models with different numbers of spans were studied. In each model, the number of spans was considered as follows: 1 span, 3 spans, 7 spans, and 9 spans, each with a length of 6 meters. Finally, the deformations of the excavation wall were compared with the initial model, which included 5 spans of 6 meters. Figure 9 shows an illustration of the modelling performed in this section. To neutralize the effect of changes in the weight of the structure on the deformations of the excavation wall, the weight of all models was assumed to be equal by increasing or decreasing the weight of the concrete used in the modelling. Based on the results obtained from modelling, the geometry of the adjacent structure, especially the length along the excavation wall, plays a significant role in the deformations of the excavation wall. As the length of the structure (L) decreases, the horizontal deformations and settlements of the excavation wall increase, and vice versa. For example, the horizontal deformation in the model with one span compared to the model with nine spans indicates a 2.5-fold difference, and the maximum settlement shows a 1.5-fold difference.

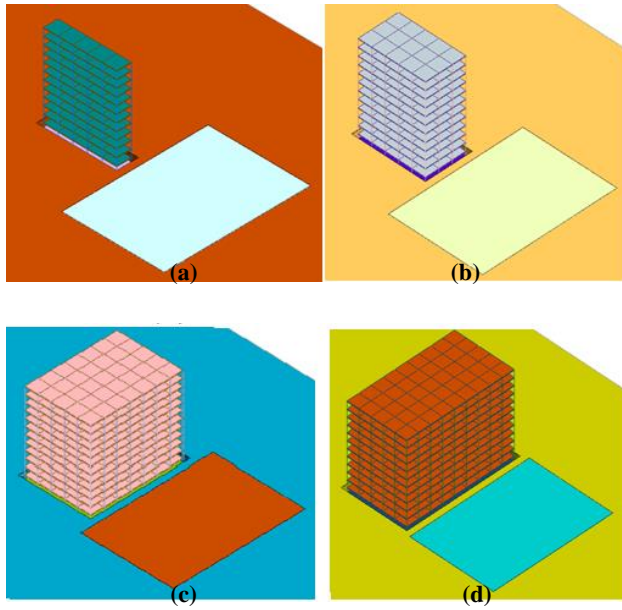


Fig. 9: Modeling building adjacent to the excavation with (a) 1span, (b) 2 spans, (c) 7spans and (d) 9 spans.

Additionally, in this section, the effects of the number of spans of the adjacent structure, or in other words, the length of the structure (L) adjacent to the excavation, on the location of maximum horizontal deformation of the excavation wall were examined. The results indicate that the length of the structure and consequently the length of the load applied to the excavation affect the location of maximum horizontal deformation, where an increase in the length of the structure leads to a greater depth of occurrence of maximum horizontal deformation. Figure 10 illustrates the depth of occurrence of maximum horizontal deformation relative to the number of spans of the structure. No significant variations were observed regarding the maximum horizontal deformations and settlement of the ground beneath the foundation relative to the distance of the adjacent structure to the excavation, Therefore, it can be concluded that the location of deformation occurrences in the ground beneath the structure is independent of the width of the adjacent structure to the excavation.

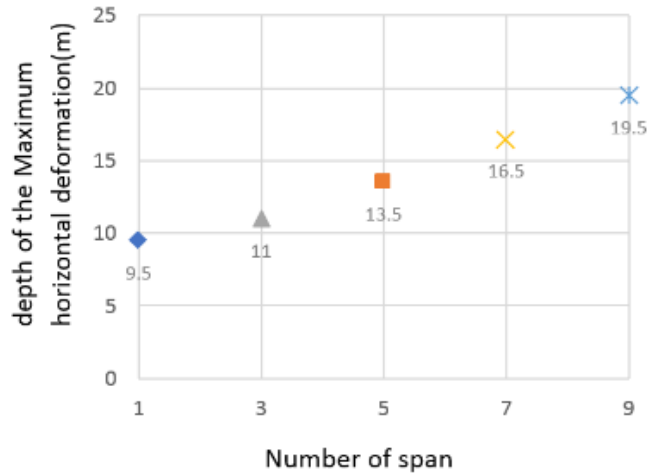


Fig. 10: Depth of occurrence of maximum horizontal deformation relative to number of spans of adjacent structure

5.4 Effect of beam and column stiffness in adjacent buildings

In the final section of this study, the effect of beam and column stiffness due to their dimensional changes was examined. Nine models with different dimensions of beams and columns were analyzed and studied. Consistent with previous procedures, the weight of all models was equalized by disregarding the effect of weight. Table 3 presents the dimensions of the beams and columns used, along with the specific weight of the concrete used in them. The mentioned dimensions for the beams and columns are in centimeters. Figures 11 and 12 show the maximum horizontal deformation and maximum settlement of the wall of the excavation, respectively, in models with structures of different beam and column dimensions. Changes in the dimensions of the adjacent building's beams and columns, and consequently changes in the structure's stiffness, also affect the deformation of the excavation walls. The software output data shows that as the stiffness of the adjacent building increases due to the increase in the dimensions of the beams and columns, the horizontal deformations and settlement of the excavation walls decrease, and vice versa, with a decrease in the stiffness of the adjacent structure, the deformations increase.

Table 3: Properties of adjacent building models

Model name	200×400	320×160	240×120	160×80	120×60	80×40	60×30	50×25	40×20
Beam (cm)	200×200	160×160	120×120	80×80	60×60	40×40	30×30	25×25	20×20
Column (cm)	400×400	320×320	240×240	160×160	120×120	80×80	60×60	50×50	40×40
Weight per unit volume of concrete (kN/m ³)	1	1.56	2.77	6.25	11.11	25	44.44	64	100
Total weight (kN)	38016								

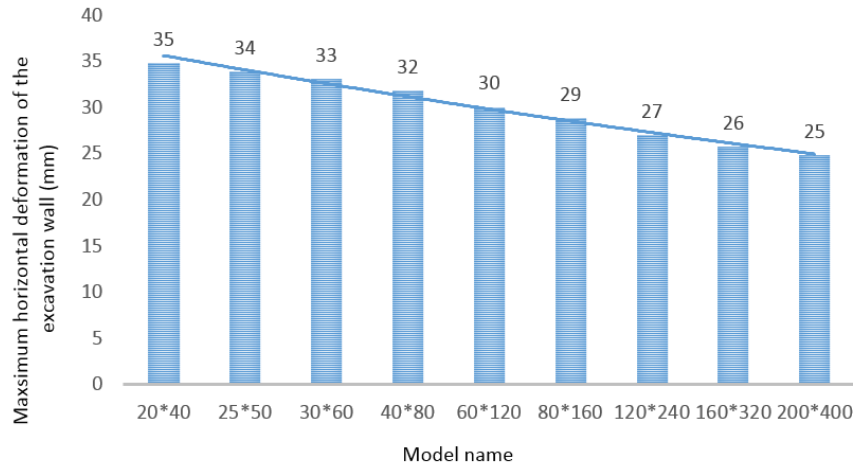


Fig. 11: Maximum horizontal deformation of excavation wall in models with different beam and column dimensions of adjacent building

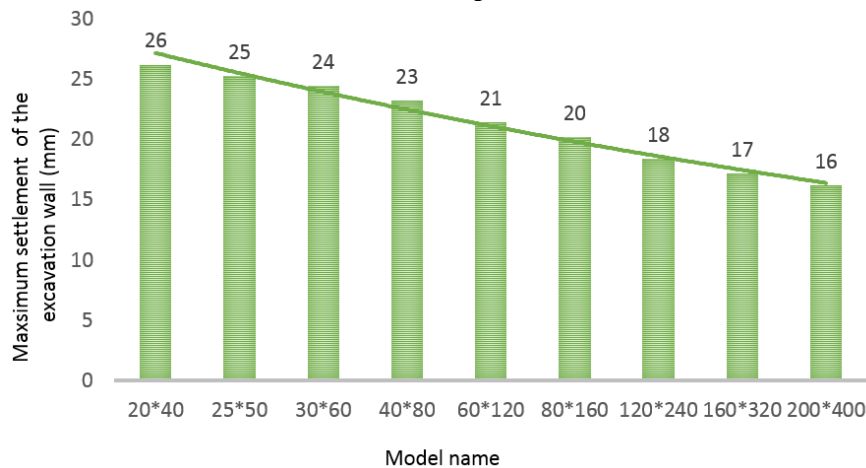


Fig. 12: Maximum settlement of excavation wall in models with different beam and column dimensions of adjacent building

6. Conclusions

In this study, the parametric analysis of the effect of different elements of the adjacent building on the maximum horizontal deformation and settlement of the excavation walls and the ground beneath the structure was investigated. The summary of the results obtained from these numerical modelling is presented below.

- 1) The results show that modelling the adjacent building and considering its stiffness causes the maximum horizontal displacements of the excavation wall to occur in the lower regions of the wall, whereas, in the absence of considering the stiffness, the maximum horizontal displacements occur near the ground surface.
- 2) The effect of the adjacent building's stiffness through its modelling in the software causes the maximum horizontal deformation of the foundation soil to occur on a side of the building that is far from the excavation edge, but without

considering the effect of the adjacent structure's stiffness (without modelling the structure), the maximum horizontal deformations tend to occur towards the side of the building adjacent to the excavation.

- 3) The shorter the building length (L), the greater the horizontal deformation and settlement of the excavation walls, and vice versa, as the building length increases, the deformation values decrease. For example, the horizontal deformation in the model with one span is 2.05 times higher than the model with nine spans, and the maximum settlement changes 1.5 times.

- 4) The building length and consequently the length of the imposed load on the excavation affect the location of the maximum horizontal deformation of the excavation wall, such that with an increase in the building length, the depth of the location of the maximum horizontal deformation increases.

- 5) The location of the deformation of the ground beneath the adjacent building is independent of the building's width and

does not change with an increase or decrease in the building length.

6) By ignoring the weight parameter and only considering the structure's stiffness, increasing the stiffness of the adjacent structure's beams and columns leads to a decrease in the deformation and settlement of the excavation walls.

7) In general, the stiffness of the adjacent structure affects both the deformation and settlement values of the excavation walls and the location of the maximum horizontal deformation of the excavation wall. With an increase in the adjacent structure's stiffness, the location of the maximum horizontal deformation occurs at deeper depths of the excavation.

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