IMPACT ON UNDERGROUND DEEP FOUNDATION EXCAVATION FROM ADJACENT CHANNELS DURING EARTHQUAKE

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One of the most important factors affecting the design of the structures is the impact of the earthquake loadings on the forces and the design displacements. Nevertheless, the influences of the near structures from the existing channels, that sometimes can cause great changes in forces and displacements, can never be neglected. Therefore, the induced displacement due to the adjacent channels of constructed buildings foundations has been investigated in this study. Having the results of the study, it can be evaluated, whether the amounts of variations in forces and displacements are in the allowable ranges, and what measures and precautions are needed to save the structures in case of having excess changes in these parameters. In this paper, the site characteristics of buildings foundations are first investigated. Then the excavation of the building is modeled, while the adjacent channels are taken into account. Finally, the impact of the excavation on the adjacent structures under earthquake loadings is studied and investigated. The accelerograph of El Centro earthquake has been used for seismic analyses and fifteen stories buildings have been modeled as well as the adjacent channels.

KEYWORDS: *Channels, excavation, Earthquake, foundation depth impact, distance between buildings impact.*

INTRODUCTION

The underlying soil layer highly affects the response of super structures, like buildings or bridges, exposed to seismic actions. So far, extensive studies concerning the impact of the earthquakes on underground and ground buildings have been carried out. These studies proved that underground structures are less vulnerable than the superstructures [1]. Although large number of buildings and underground spaces are without a seismic design, they have resisted against heavy earthquakes. For example, the Mexico-city underground building during 1985 earthquake [2] and the Los Angeles subway during earthquake escaped quietly undamaged while many surface buildings were largely damaged [3]. Consequently, the investigation of earthquake impact on the surface buildings is highly important. Particularly if a building crosses through the ground is planned in an area which greatly covered by residential and older ancient cultural buildings. For this reason a great attempt has been afforded to study and investigate the effect of different earthquakes on the adjacent buildings located on the path of the underground foundations buildings. The effect of the earthquake on super structures has been studied before construction of the underground foundations buildings and has been compared with those induced after excavation of the building. Regarding the

seism city of Egypt, based on the Egyptian code of practice for seismic resistant design of buildings [4], Egypt is recognized as a zone by relatively high risk in the seismic zone of Egypt, according to the results of the past studies in the region, in spite of medium earthquakes which have caused damages to the cities of Egypt.

During strong earthquakes foundation piles tend to modify soil deformations significantly, since they oppose the seismic motion of the subsoil. Further because of the interplay between soil and piles the motion at the base of the superstructure can significantly deviate from the free-field motion and the piles are subjected to additional bending, axial and shearing stresses. The bending moments, usually referred to as "kinematics" ones, may be very important even in the absence of the superstructure.

As a main approximation in the construction of the cone model, the soil is idealized as a linearly elastic medium. To incorporate soil nonlinearity into this model, the equivalent linear approach may be utilized. The equivalent linear approach is a well-known method for site-specific response analysis and the evaluation of earthquake effects on soil deposits. This approach is illustrated with reference to Figure 1, which considers degraded secant stiffness (an equivalent linear stiffness) and equivalent damping (indicating the hysteretic damping) as a representation of nonlinear stress-strain relationship of the soil at each specified shear strain level. To define degraded secant stiffness and its equivalent damping, modulus reduction curves and related damping ratio curves presented in the literature (e.g. Vucetic and Dobry 1991)[5] are used. As shown in Figure 1b, knowing shear strain level γ and initial shear modulus Gmax, the value of Gsec is simply determined. Similarly, equivalent damping ratio ξ is calculated by implementing the shear strain level into the damping ratio curves (Figure 1c). The assumed shear strain level can be estimated on the basis of the anticipated maximum ground acceleration (ATC 40)[6].
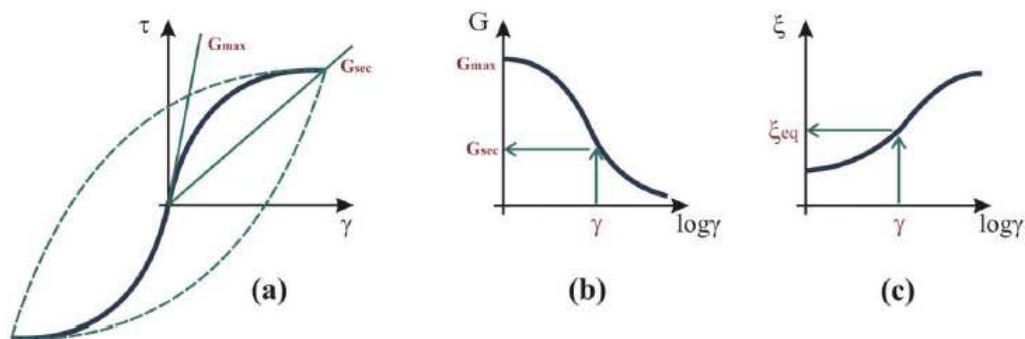

Figure (1): Equivalent linear idealization of soil stress-strain hysteretic loop

The equilibrium of slopes during seismic waves is significant effect on R.C. buildings built besides canals, especially when the depth of these channels are largest than foundation depth of building (Deep foundations (piles)), where the soil mass adjacent to the channel, which is the basis of the building, move more freely from the soil where there is no drilling channels did not. Effect of soil on structural elements of the building and its impact on the internal forces of the building under seismic forces large and especially in different layers of soil and seismic forces change directions (from left to right and vice versa).

It is worth to note that the displacement analysis is not capable of reproducing the deformation pattern of a slope / earth structure since actual deformations may be spread out over a zone, leading to bulging rather than sliding. Therefore, the computed permanent displacement should be always considering an index of seismic performance.

Despite of the simple analytical procedure required for applications that has better prediction capability with respect to the pseudo-static methods, displacement-based methods are not commonly used in engineering practice because they require to represent the seismic action by appropriate acceleration time histories and then requiring, as a consequence, a proper knowledge of site seismicity. This is why the pseudo-static methods are the most widespread in engineering practice for the analysis of slope stability under seismic conditions.

In the pseudo-static approach, the earth mass is assumed to behave as a rigid-plastic material and to be in a state of limit equilibrium under the action of inertia and static forces. The inadequacy of this approach in predicting the performance of a slope subjected to earthquake loading has been recognized from a long time. The pseudo-static inertia force is in fact considered constant while the earthquake loading is typically a transient action characterized by abrupt changes in modulus and sign. As a consequence, during the earthquake, the ratio of the resisting to the driving forces may drop below unity for a short period of time and in limited portions of the slope only and this may induce some movement without causing a complete collapse of the slope. The static equivalent force is proportional to the weight of the potential sliding mass through a seismic coefficient K of horizontal and vertical components K_h and K_v, respectively. The horizontal seismic coefficient is usually expressed as a fraction of the maximum site acceleration. Thus, despite some accurate assessments of seismic behaviours of superstructures and underground buildings individually, their seismic responses need to be re-evaluated together in which the interaction between underground buildings and adjacent structures plays an important role and may lead to different and new results. In the following section the method of this evaluation and the procedures of the analyses are presented and described in details.

The ability to predict with confidence excavation and tunnelling induced displacement is a crucial aspect of the design because ground movements transmit to adjacent structures as settlements, rotations and distortions of their foundations, which can, in turn, induce damage affecting visual appearance and aesthetics, serviceability or function, and, in the most severe cases, stability of the structures (Burland and Wroth, 1974; Burland et al. 1977; Boscardin and Cording, 1989) [7, 8, 9].

One of the main sources of seismic vulnerability in Italy is represented by the instability of slopes. Therefore, this is a subject of great significance, particularly in view of the growing attention that has been recently dedicated to the reduction of seismic hazard. The response of a slope under seismic loading is determined by the temporal and spatial distribution of the seismic forces in the soil mass, which in turn depend on the characteristics of the seismic input and on the mechanical properties of the soil. A number of different techniques exist to address this problem, each implying some level of approximation. Experience of using advanced numerical analysis is still somewhat limited, and it seems difficult to generalize the results of such complex analyses. An advisable approach would be that of carrying out the analysis of the same problem using a number of approaches characterized by different levels of complexity,

in order to assess the reliability and robustness of the different procedures. In the present research project, different research groups were given the task of pursuing the study of the seismic behavior of slopes using a number of different approaches, and investigating the possibility of using the results of the more advanced analysis as a guidance for a sound and reliable use of the simplest and most common analysis method, that still form the backbone of professional practice. Aversa et all. (2009).

MODEL DESCRIPTION

This study investigates the effect of seismic waves on the building which is constructed on banks of water channel and the effect of the shape of these channels.

The model is a building constructed on two layers of well defined soils, thickness of the top layer is 12.5m and consists of semi rigid clay (the properties as mentioned in table (1)), and the bottom layer from dense sand (the properties as mentioned in table (1)) its thickness is 87.5m. The building will be found in the middle of the soil portion which its dimension 400m long, and 100m thick and 20m wide.

The building consists of frame system (the properties of its elements as mention in table (2)). The foundation of the building was a pile foundation which its depth was 15m from badroom level (bedroom height from ground level is 4m). Piles penetrate the second soil layer by 5m (Dense sand layer). Table (1) shows the important values of the soil layers that are used in this research. Table (2) shows the characteristics of the buildings.

Table (1): The geotechnical characteristics of the soil layers.

Soil type	Soil layers Depth (m)	Unit Weight γ ,(t/m^3)	Poisson's Ratio (ν)	Elastic modulus E (kg/cm^2)
(1)	12.50	1.8	0.25	200
(2)	87.5	2.0	0.3	500

Table (2): The Buildings Characteristics.

| Type of the structure	The behavioral model	EA(kg/m)	EI(kg.m^2/m)	Unit weight of the length (kg/m/m)	Poisson's Ratio (ν)
Buildings	Elastic	1.18x109	2.329x108	1200	0.1

The building specifications are:
- Number of stories: 15 stories
- Column dimension: 70x70cm
- Beam dimension: 25x60cm
- Height of story: 3m
- Number of bays: 2
- Width of bays: 8m
- Column reinforcements: 16Ø16mm and stirrups 6Ø8/m`
- Beam reinforcements: upper reinforcement 2Ø12mm,

- lower reinforcement 4Ø16mm and stirrups 6Ø8/m`
- Concrete grade: C_{28}=250kg/cm^2
- Steel grade: st52.
- Live load : 200 kg/m^2

Figure (2) shows the used model. The tested building is 16m wide and its embedment depth from the ground surface is 4m. The horizontal distances between building and the adjacent channel is 50m. The building will be excavated by means of Boring Machine using the sheet-pile to protect the excavated trenches. The model of soils as shown in figure (2) are two layers of soil with a specified types, 400m long and 100m wide with 20m thick. The two layers were divided into small elements for each is 1mx1m, these divisions were within the divisions of the building. The dimensions of the first model channel (figure 2-i) were 50x50m and the distance between the upper edge of the channel and the tested building was 50m. The channel was embedded 12.5m in the first soil layer (the whole thickness of the soil (1)) and was embedded 37.5m in the second soil type (soil (2)). The bottom end of the soil (as a rigid rock base) was hinged support, and the sides of the soil profile were roller supports.

Figure (2-ii) shows the details of the second tested model. The channel adjacent to building was trapezoidal cross section with dimensions top 120m wide and bottom, 20m wide the height of the channel was 50m and the distance between the channel and building was50m. The sides slope of the trapezoidal channel cross section inclined by 45◦ with vertical. The materials that form the slopes were the same material of soil layers (1), and (2) with the same depths.

The smallest elements have been taken around the building and the channel, where there are areas of highly stress concentration, to increase the accuracy of the analysis. In the static analyses, the boundary conditions at the end of the model are hinged support and at the sides of the model are roller supports. The tested elements in the building were element (1) which is the frame element (column) connected beam of bedroom and ground floor the, element (2) frame element (column) connected pile cap and element (3), and element (3) frame element (column) connected bedroom beam and element (2). The tested points on the building were top point in building is top left corner point and bottom point was the left lower corner point adjacent building on the ground. (see figure 2).
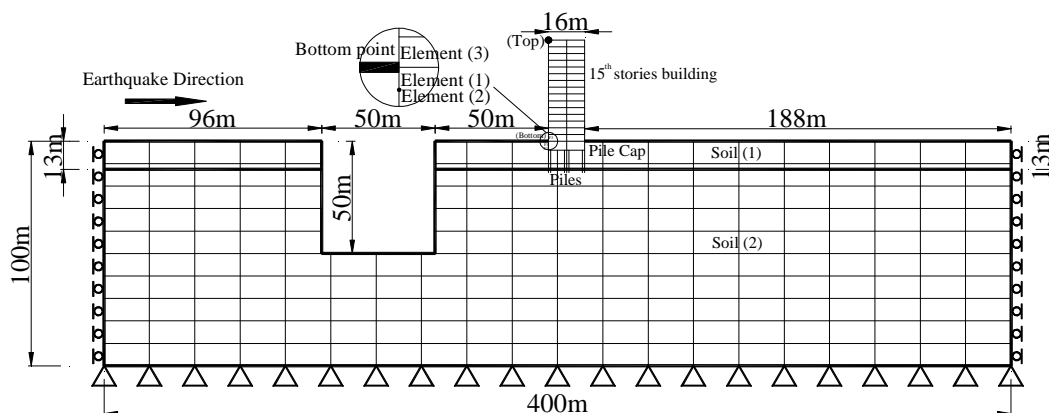
i) First model (the channel with rectangular cross-section) (Dim. In m)
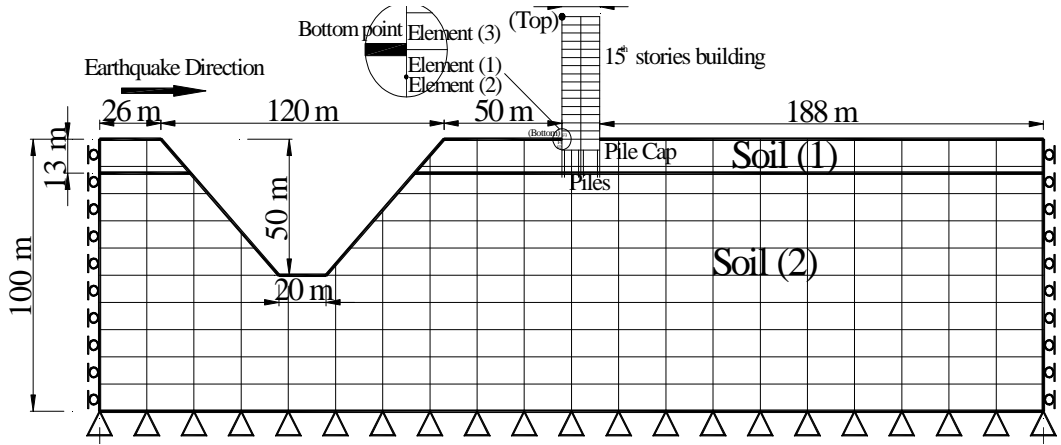
ii) Second model (the channel with trapezoidal cross-section) (Dim. In m)

Figure (2): Ground profile and the positions of the existing structures in the selected site

        Figure (3) shows the different studied cases. To show the effect of the seismic wave direction on the building existed near a channel with various cross section shape, many cases were studied.
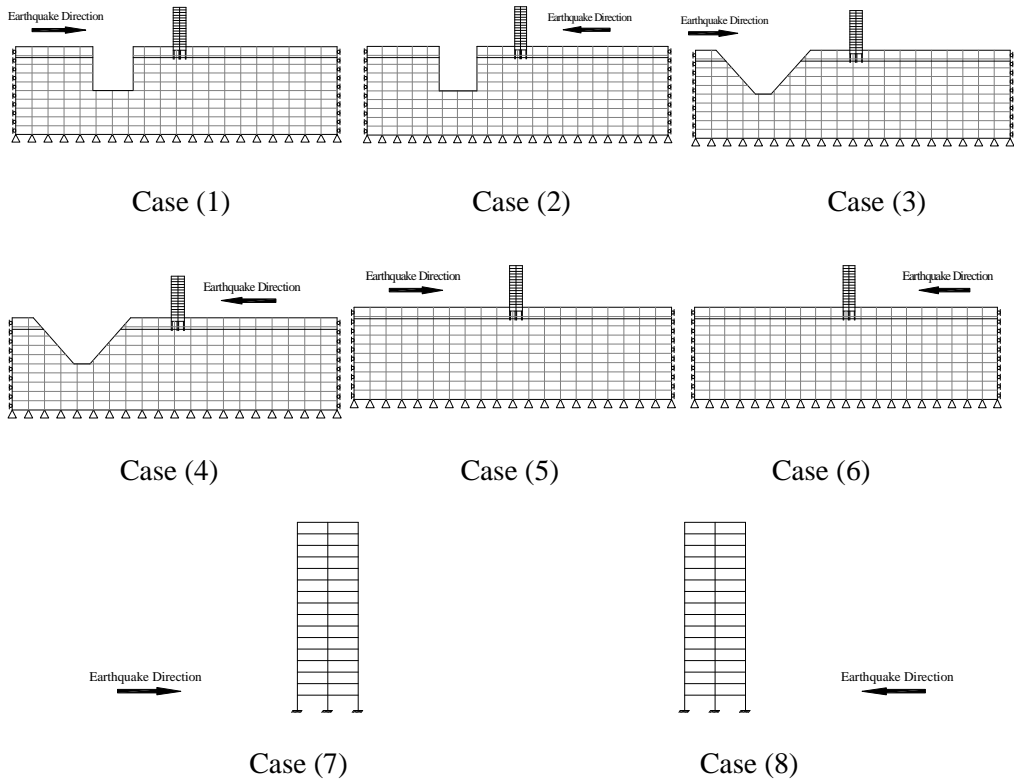

Figure (3): study cases

Table (3) shows the description of different studies cases.

Table (3): the description of different studies cases

Cases	Description	Earthquake direction
Case (1)	Rectangular cross section channel left building	Left to right
Case (2)	Rectangular cross section channel left building	Right to left
Case (3)	Trapezoidal cross section channel left building	Left to right
Case (4)	Trapezoidal cross section channel left building	Right to left
Case (5)	The building in the mid length of the soil without the existence of channels (reference case)	Left to right
Case (6)	The building in the mid length of the soil without the existence of channels (reference case)	Right to left
Case (7)	The building with fixed base	Left to right
Case (8)	The building with fixed base	Right to left

THE METHOD OF NUMERICAL MODELING

In this study a commercially available finite element package, SAP2000 V11 [11], which is capable of performing dynamic analysis of soil-structure interaction using the ground accelerographs, has been used. Since it is planned to investigate the impact of a channel constructions on the response of the adjacent building, two different cases have been taken into account: I) the first case, the seismic analysis of the building is performed before excavating channel, and II) the second case, the seismic analysis of the building after the construction of the channels. The Elcentro accelerograph was used to calculate the displacements of the buildings, base shear, and base moment at different distance and different foundation depth for first building. The fixed base model was taken in consideration to compare the results of different cases of the model.

SELECTION OF ADEQUATE ACCELEROGRAPHS

The recorded accelerograph El Centro (1940) earthquake shown in figure (4) is selected for seismic analysis of the model (the duration of this wave is 40sec.). According to the Egyptian code of practice for seismic resistant design of buildings (ECOL201), Egypt is classified as medium seismic risk area, and the design acceleration of the area is recommended to be 0.25g which is shown in figure (4). In this study the accelerographs have been used to perform the seismic analysis of the model, with varied accelerations of earthquake (0.25g, 0.5g, and 1g) to study the effect of excess earthquake forces in the studied cases.
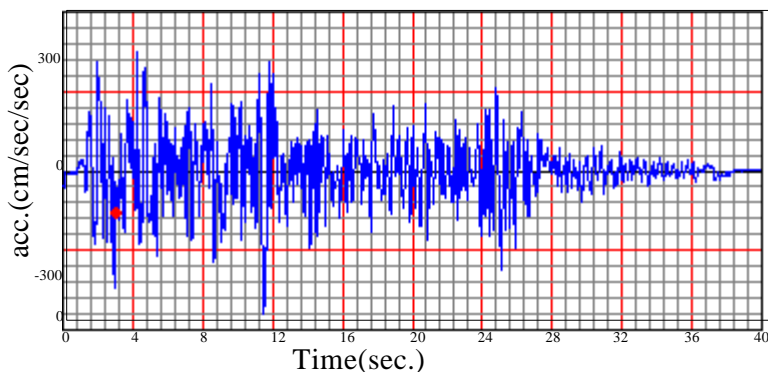
Figure (4): Elcentro accelerograph

RESULTS AND DISCUSSIONS

The dynamic analysis of model with and without the existence of an adjacent channel (reference case) using the accelerographs of the El Centro earthquakes was carried out. The building was considered to be 15 stories height. Based on the analysis results, the variations of the horizontal and vertical displacements of the buildings at points (1, 2) versus the time are shown in figure 5.
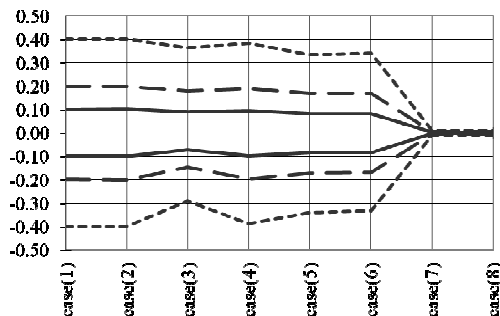
Figure (5-i) shows the lateral displacements at top point of the building at seismic acceleration 0.25g, 0.5g and 1g. The horizontal displacement in case (2) and case (4) equals half the displacement values in the cases 1, 3, 5 and 6 for all acceleration (0.25g, 0.5g and 1g). The building records the minimum values of displacement in the case 7 and 8 (the fixed base cases).

Figure (5-ii) shows the horizontal displacement for the adjacent point of building on ground level. The values of displacement are so close (cases 1, 2, 3, 4, 5 and 6), but the ratio between these values and the corresponding displacement in cases 7, and 8 equals nearly 10.

Figure (5-iii, iv) show the vertical displacements at top and ground point close to building at accelerations 0.25g, 0.5g and 1g. The vertical displacements in all cases are so close, but the ratio between these values and the corresponding displacement in cases 7, and 8 equal nearly 38.
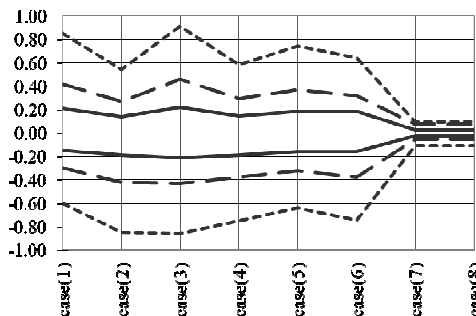
i) Horizontal displacement of top point of building ground point close

ii) Horizontal displacement at to building

iii) Vertical displacement of top point of building point close

iv) Vertical displacement at ground to building

———— 0.25g Max. ———— 0.25g Min. - - - - 0.5g Max. - - - - 0.5g Min.
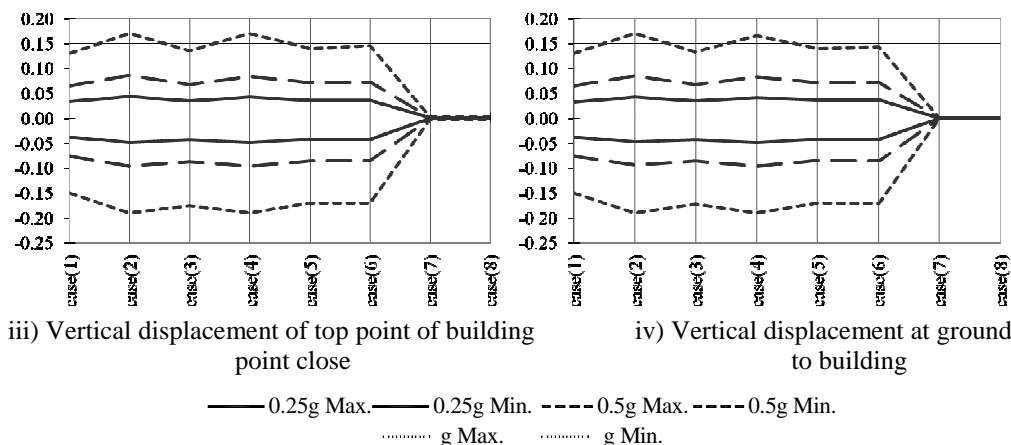
·········· g Max.   ·········· g Min.

Figure (5): Horizontal and Vertical displacements of the Model for Top and bottom points

Figures (6) i,ii, and iii show shear force in different cases for elements 1, 2, and 3 respectively (base element (1), column beam element (2) and ground surface element (3)), elements (1,2) are located under ground.

In figure (6-i) concerning shear force for element (1), it is clear that the maximum shear force appear in case (2), but the minimum value of shear force clear in cases (5, 6, 7, and 8). The values of shear forces in base element (1) gradually decreased from case (2, to 1, and 4, 3,5,6,7, to case 8). The maximum shear force in element (1) at case (2) (rectangle cross section channel) appear because of the direction of earthquake opposite the channel placement so, the building resist the sliding to channel by a high value of shear in this element. Cases (5, 6, 7 and 8) shear force nearly is equals for all acceleration values.

In figure (6-ii) base shear force for element (2), it is clear the maximum shear force appears in case (2), but the minimum value of shear force clears in cases (5, 6, 7, and 8). The values of shear forces in element (2) gradually decreased from case (1, to 2 and 3, 4,5,6,7, to case 8). The maximum shear force in element (2) at case (2) appear because of the direction of earthquake opposite the channel placement so, the building resist the sliding to channel by a high value of shear in this element. Cases (5, 6, 7 and 8) shear force nearly is equals for all acceleration values.

In figure (6-iii) shear force for element (3) (at ground surface); it is clear the maximum shear force appear in case (3), but the minimum value of shear force clear in cases (7 and 8) then case (2, 4, 1, 6 and 5). The maximum shear force in element (3) at case (3) appear because of the direction of earthquake in the channel placement so, the building resist the surface forces and the connected joint between the beam and the column (element (3)). Cases (7 and 8) shear forces nearly are equals for acceleration values.

i) Shear force element (1)

ii) Shear force element (2)

iii) Shear force element (3)

——— 0.25g Max. ——— 0.25g Min. ---- 0.5g Max. - - - - 0.5g Min.
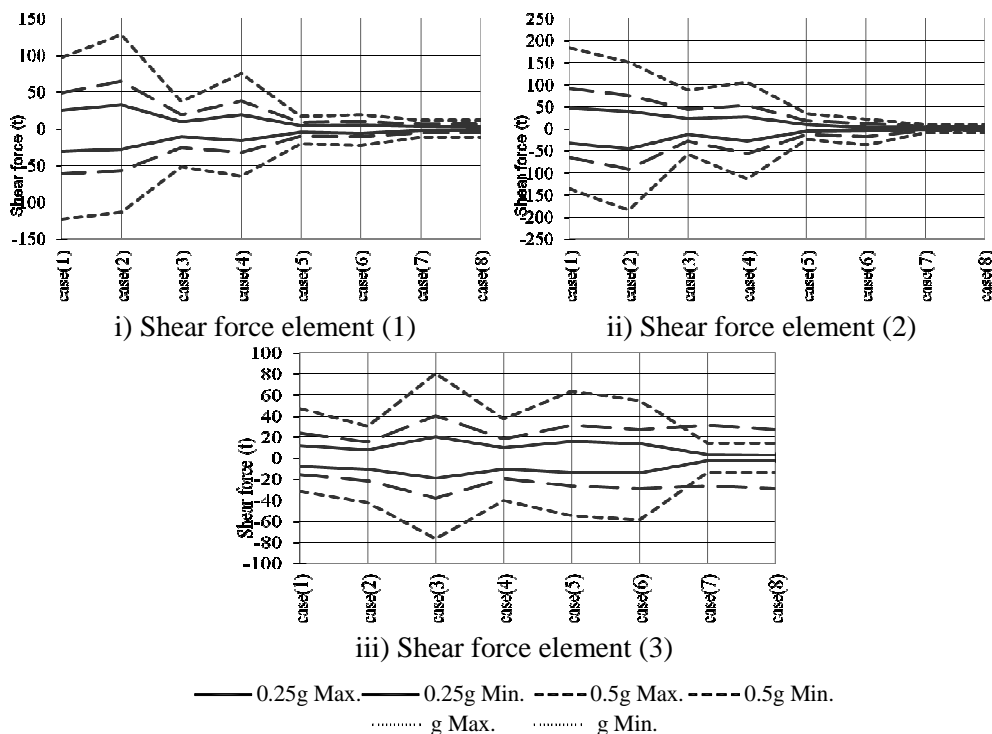·········· g Max.   ·········· g Min.

Figure (6): Shear force for elements (1, 2, and 3)

Figures (7) i,ii, and iii show moment for elements 1, 2, and 3 respectively. It is clear from figure (7-i) moment of element (1) having a maximum value in case (1) and gradually decreased in the other cases (2, 3, 4,5,6,7, and 8), the minimum values appear in the case (8). The minimum values of moment occur in the case (3) (the effect of soil takes in consideration) (the earthquake direction pass through the trapezoidal channel before the building) and the value of bending nearly close to the value of the case (7) (fixed base case). The bending moment in the high acceleration earthquake (1g) recoded a high moment values nearly 4 times the values of moments under 0.25g acceleration earthquake.

Figure (7-ii) shows base moment of element (2), the maximum moment value is at case (1) and gradually decreased in the other cases (2, 3, and 4); the minimum values appear in the case (5,6,,7,and 8) and the values are nearly closed. The minimum values of moment occur in the case (3) (the effect of soil takes in consideration) (the earthquake direction pass through the trapezoidal channel before the building). The bending moment in the high acceleration earthquake (1g) recoded a high moment values nearly 4 times the values of moments under 0.25g acceleration earthquake. The element (2) subject to a high values moments than element (1) (nearly, the values in element (2) equal 2.5 times its values in element (1)), because of it is connected with the base foundation of the building.

Figure (7-iii) shows moment of element (3), the maximum moment value is at case (3) for all values of acceleration (0.25g-0.5g-1g), the minimum values appear in the case (1, 2, 4, and 6 with taking the soil effect on consideration) and the values are nearly closed. The minimum values of moment in case (7 and 8) (fixed base case). The

bending moment in the high acceleration earthquake (1g) recoded a high moment values nearly 4 times the values of moments under 0.25g acceleration earthquake. The element (3) subject to a high values of moments than elements (1,2), because of it is connected with the beams at ground surface level.

i) Bending moment element (1)   ii) Bending moment element (2)

iii) Bending moment element (3)

——— 0.25g Max. ——— 0.25g Min. - - - - 0.5g Max. - - - - 0.5g Min.
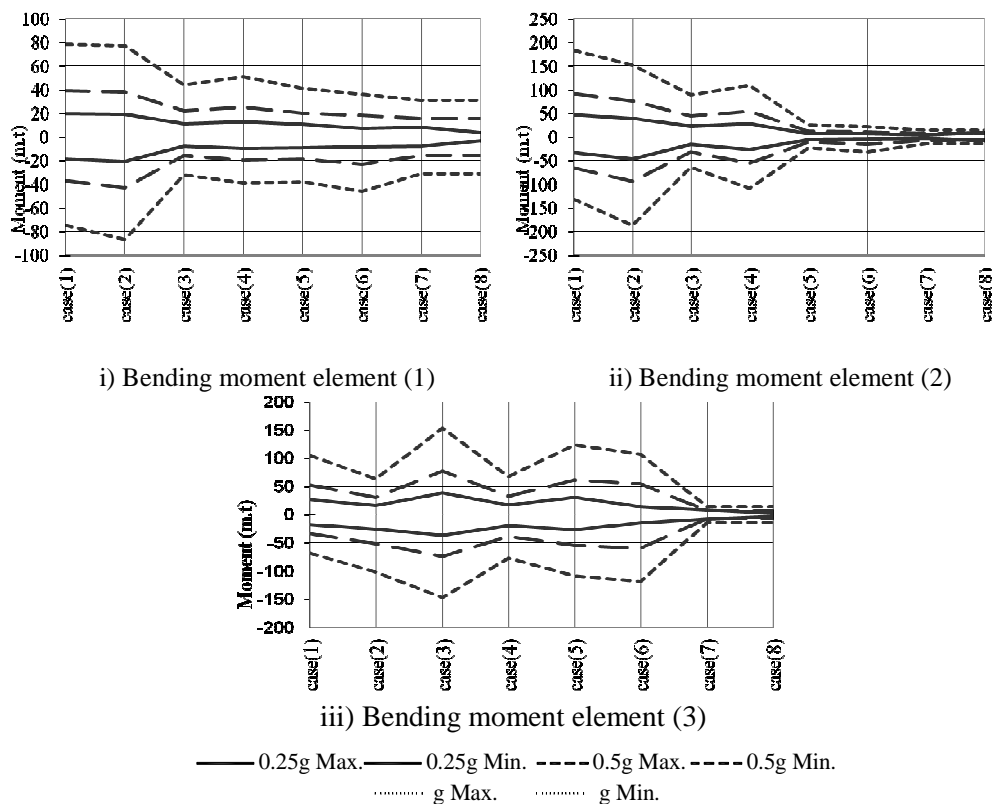
·········· g Max.   ·········· g Min.

Figure (7): Bending moment elements (1, 2, and 3)

Figure (8) shows the axial force for elements 1, 2, and 3 respectively. In figure (8-i) shows normal force in element (1), the maximum value of axial force appear in case (3) in all acceleration values, the minimum values occur in case (4) (the earthquake direction behind the building). Minimum values of axial force display in cases (7, 8) (fixed base cases) wherever the direction of earthquake. The values of axial force in earthquake acceleration 1g equal nearly 4 times the values in earthquake acceleration 0.25g. The values of axial force in cases (1, 2 , 4, 5 and 6) nearly equals a value equal 1.7 times the value in case (3).

Figure (8-ii) displays the axial force in element (2). The values of axial forces nearly are equal for all earthquake acceleration in cases (1, 2, 3, 4, 5 and 6). Axial force in cases (7,8) is equal and nearly equal to 4 times the values in cases (1,2,3, 4, 5 and 6).

Figure (8-iii) shows axial force in element (3), the maximum value of axial force appear in case (3) in all acceleration values, the minimum values occur in case (2) (the earthquake direction behind the building). Minimum values of axial force display in cases (7, 8) (fixed base cases) wherever the direction of earthquake. The values of axial force in earthquake acceleration 1g equal nearly 4 times the values in

earthquake acceleration 0.25g. The values of axial forces in cases (1, 2, 4, 5 and 6) are nearly equal to 6.7 times the value in case (3).
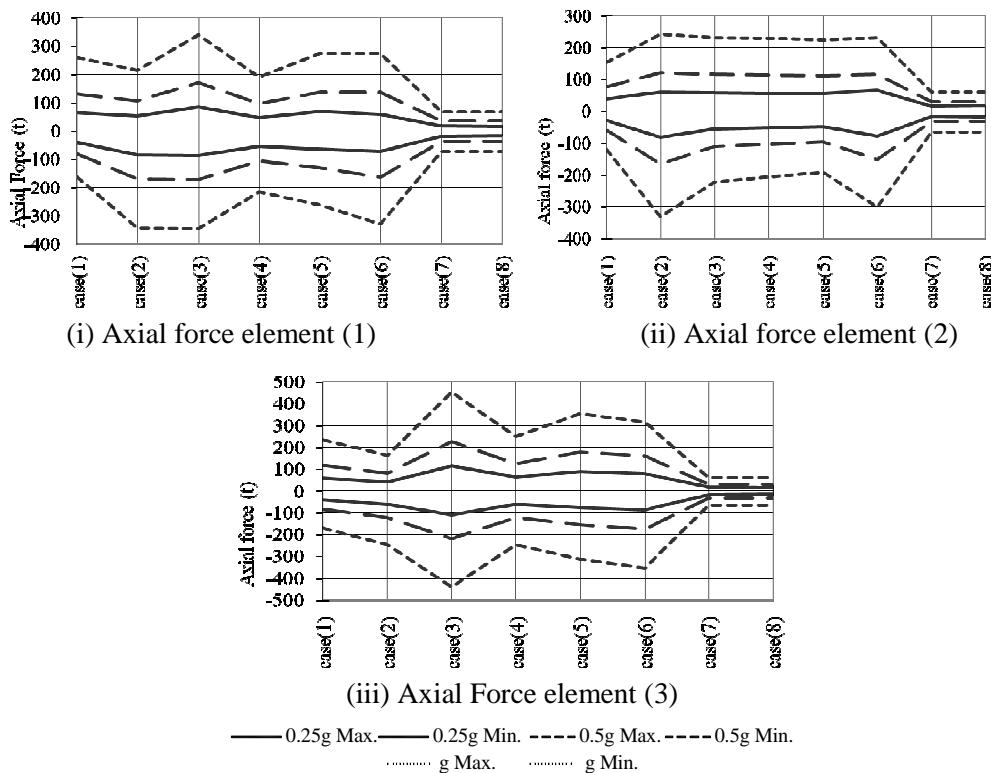

(i) Axial force element (1)   (ii) Axial force element (2)

(iii) Axial Force element (3)

——— 0.25g Max. ——— 0.25g Min. ---- 0.5g Max. ---- 0.5g Min.
············· g Max.   ············· g Min.

Figure (8): Axial Force for elements (1, 2, and 3)

CONCLUSIONS

The impact of the channels on the seismic responses of the adjacent high rise buildings has been studied and investigated. The SAP2000 V11 [11] finite element package capable of performing dynamic analysis has been used to model the site and existing buildings, soil and channels. The El Centro accelerograph is used to apply the seismic loadings to the model. Typical 15 stories building with deep foundation system (piles with depth of 15m under bedroom level which is higher than channel bed level) was considered in this study.

The effect of shape of channel (rectangle or trapezoidal), was also considered. The effect of soil-structure interaction on the predicted settlements and footing loads of two-dimensional multi-bay framed structures has been investigated.

The results of the analyzed examples showed that load redistribution significantly modifies the pattern of and mitigates differential settlements. Furthermore, the footing loads may increase or decrease due to the consideration of the effect of shape of channel (rectangular or trapezoidal). Structures and their supporting soils should, therefore, be considered as a one system, and taking their interaction into account is essential for reasonably obtaining accurate predictions of both soil

settlements and distribution of forces in the structural members. Even if neglecting the interaction effect do not result into harmful damages, it would however considerably reduce the margin of safety, or result in over-or underestimation of the real shear, axial force, and bending moments of the structural members.

According to the obtained results, the maximum variations of the horizontal displacement of the buildings after channels excavation during the above considered earthquakes increased by 18 to 24% which is considerable value, and for vertical displacement changes increased by 17 to 21% with respect to the model with and without the existence of an adjacent channel (reference case).

The variations of shear force rang from 7.5 to 1.3 times the shear in the alone model, axial force in the building elements increase by 10 to 20% of reference case, and the bending moment increased by 7.4 to 1.2 times of the bending moment in reference case.

Based on the present study, the horizontal and vertical displacements, shear force, axial force and bending moments induced in the adjacent buildings near excavate channels highly depend on the shape of the channels, earthquake direction and foundation type.

The three dimensional building and soil model study will give a realistic seismic behavior of the building response near existing channels under earthquake load.

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تآثر المبانى ذات الاساسات العميقة المنشاة بجوار قنوات تحت التاثير الزلزالى

لدراسة التاثير الزلزالى الحادث للمبانى المنشاة على ضفاف مجارى مائية تم عمل نموذج ثنائى الابعاد لدراسة هذا التاثير. ابعاد النموذج (يمثل الارض) 300م طول × ارتفاع 100م و بسمك 20م. ينقسم النموذج الى طبقتين ،الطبقة العلوية بسمك 12م (وخواصها تشبة خواص التربة الطينية الطميية) وتحتها الطبقة السفلية بسمك 88م (وخواصها تشبة التربة الرملية) (كما هو الحال فى طبقات التربة بالقرب من مجرى نهرالنيل مثلا).

ان اتزان الميول اثناء الموجات الزلزالية له تاثير كبير على القوى الناشئة على المنشات المقامة بجورا هذه الميول. القنوات المائية و المقام بجوارها منشآت خرسانية مسلحة و خصوصا عندما يكون عمق هذه القنوات اكبر من منسوب تاسيس هذه المنشآت (اساسات عميقة (خوازيق))، حيث ان كتلة التربة المجاورة للقناة و التى يوجد بها اساس المبنى تتحرك بحرية اكبر من التربة التى لا يوجد بها حفر للقنوات. تاثير التربة على العناصر الانشائية للمبنى و من تاثيرها على القوى الداخلية للمبنى تحت القوى الزلزالية كبير و خصوصا فى الطبقات المختلفة للتربة و تغيير اتجاهات القوى الزلزالية (من الشمال الى اليمين و العكس).

المبنى المنشاء على هذا النموذج هو منشا اطارى بارتفاع 15 دور. الاساسات عبارة عن اساسات عميقة (خوازيق بطول 15 من منسوب ارضية البدروم تخترق الطبقة الاولى من التربة بعمق 12 م (طبقة الاحتكاك للخازوق) والطبقة الثانية بعمق 3م (طبقة الارتكاز للخازوق). المسافة بين المبنة و حافة القناة 50م.

تمت الدراسة على نموذجين الاول بقناة بقطاع على شكل مربع بابعاد طول 50م و عمق 50م والنموذج الثانى بقطاع على شكل شبه منحرف (القاعدة العليا 120م و السفلى 20م).

تم اسنخدام عدد ثلاث عجلات مختلفة للزلزال (1g – 0.5g - 0.25g) فى اتجاه (X) بحيث يكون اتجاة العجلة الزلزالية مرة من اليمين الى الشمال و مرة اخرى من الشمال الى اليمين. و كانت الحلات المستخدمة كما هو بالجدول التالى:

اتجاه العجلة الزلزالية	وصف الحالة	الحالة
من الشمال الى اليمين	المبنى على شمال قناة مربعة القطاع	حالة (1)
من اليمين للشمال	المبنى على شمال قناة مربعة القطاع	حالة (2)
من الشمال الى اليمين	المبنى على شمال قناة شبة منحرف القطاع	حالة (3)
من اليمين للشمال	المبنى على شمال قناة شبة منحرف القطاع	حالة (4)
من الشمال الى اليمين	المبنى وسط التربة وحيدا	حالة (5)
من اليمين للشمال	المبنى وسط التربة وحيدا	حالة (5)
من الشمال الى اليمين	المبنى مثبت القاعدة	حالة (6)

حالة (7)	المبنى مثبت القاعدة	من اليمين للشمال

العنصر (1) هو جزء من العمود المواجة للقناه والمتصل بكمرة سقف الدور الارضى فى منسوب الارض والعنصر (2) هو جزء من العمود المواجة للقناه والمتصل باساسات المبنى والعنصر (3) العمود المواجة للقناه والمتصل بين كمرة سقف الدور الارضى و الدور الاول علوى.

تم استخدام نموذج سطح الارض بدون قنوات و النموذج ذو القاعدة المثبة كحالات مرجعية للمقارنة للنتائج. ولحساب تاثير القنوات و شكل قطاعاتها على المبانى المنشاة بجوارها تم تسجيل نتائج الازاحات الافقية والراسية فى اتجاه (X,Z) لقمة المبنى ولنقطة على سطح الارض ملاصقة للمبنى وقوى القص والعزوم والقوى المحورية الناتجة من تاثير الزلزال على الاعمدة السفلية للمبنى (العمود المتصل بالقاعدة والمتصل بكمرة سقف البدروم).

ومن خلال هذه الدراسة يتضح ان القوى الزلزالية تتاثر بوجود مجرى مائى (حفر عميق يصل الى منسوب اسفل تاسيس المبنى) بالقرب من المبانى العالية الارتفاع و خاصة الخازوقية التاسيس على طبقات من التربة الضعيفة حيث وجد ان القص على الاعمدة يزيد عن الحالة العامة (المبنى بدون قنوات على التربة) عند تاثيرالزلزال من اليمين الى الشمال فى حالة القناة المستطيلة للعنصر (1) ومن الشمال الى اليمين فى حالة القناة المستطيلة و شبه المنحرف للعنصرين (2) و(3) على التوالى. اما بالنسبة للقوى المحورية فان الزيادة عن الحالة الحاكمة تكون فى حالة الزلزال المؤثر من الشمال الى اليمين للقناه شبة المنحرف للعنصرين 1، 2 اما قوى العزوم فانها تزيد للعنصرين 1،2 فى حالة الزلزال المؤثر من الشمال الى اليمين للقناه المستطيلة و القناه شبة المنحرف للعنصر 3 بنفس الاتجاه.

هذه الزيادات فى القوى المختلفة تكون نتيجة وجود هذه القنوات ذات القطاعات المختلفة و القطاع الاكثر تاثيرا فى زيادة القوى بالمبنى كان القطاع المستطيل (الراسى الجوانب). و لزيادة دقة النتائج و جعلها اكثر واقعية يجب اجراء هذة الافتراضات على نموذج ثلاثى الابعاد لكلا من التربة و المنشاء الخرسانى لزيادة وضوح النتائج و جعلها اكثر تطبيقا.