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Effect of Existing Building Walls on the Geotechnical Behavior of Foundation under Earthquake Loading

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***Abstract* — Structure's systems are subjected to additional loads due to earthquakes that may be produces progressive failures. The building illustrates dissimilar categories of failure mechanism for the minor to major earthquake conditions. These structures categorized to the most susceptible type of building has experienced serious hazard or even full failure for the period of seismic activities, therefore their investigation is a complex thing to do. Consequently, this research aims at studying the behaviour of large-scale model of structures constructed with and without brick walls under seismic conditions. The effect of building walls on the performance of the structure during earthquake loading is investigated numerically using PLAXIS 3D software. An eight story building with basement designed on a mat foundation is simulated as three-dimensional model in case of brick walls existing and without brick walls case. The effect of existence such wall building on the stability of foundation soil system is discussed in the form of lateral, horizontal deformation, and foundation acceleration. The studied showed that the reduction of extreme horizontal displacement and bending moment for building foundation with brick walls reached to 43%, and 68% respectively compared to the building without walls. The consideration of wall as filling for super structure significantly reduce the foundation acceleration by as much as 72% of its initial value, which lead to considerable effect of increasing the foundation stability.**

***Index Terms*— Brick building wall, Earthquakes, PLAXIS 3d, Foundation, Sand.**

I. Introduction

Brick structures globally shows significant hazard and usually fail in latest powerful seismic activity experiences. It is famous with their brittle material properties, that is generally because of the following reasons 1) it has a very low tensile strength, 2) large weight and 3) weak connection between structural elements, is the main limitation for their structural accomplishment in residential structures. Bricks widely used in every part of the residential buildings processes due to being economic materials, effective in sound and heat isolation, can be found easily, and reachable to all sites and skilled labor. In general, brick properties are considered to be non-elastic, non-homogeneous and anisotropic material composed of two dissimilar materials, bricks and cement. The tension strength is low for this composite material because of the fragile bond between both of them. To make the significance of the properties of the materials and structural characteristics specific clear for brick structures which affect the behavior of brick buildings to seismic forces, the noticed performance of the brick structures, in addition to any damage that take place in structure for the period of the earthquakes, should be investigated in detail [1], [2]. Majority of the information required for the structural validation and design easily can be attained from the ground acceleration records [3], [4]. The analysis of seismic behavior of brick structures shows the magnitudes of the effective peak ground accelerations are in correspondence with the earthborn earthquake vibration and detected damage to the structure [5], [6]. The accessibility of brick simulation for the seismic analysis of brick building will correspond to a significant step to a suitable evaluation of new and existing brick structure. The effect of shear wall in concrete structures were investigated to resist the lateral loaded in a wide range thought different models adopted in finite element analysis as presented by [7]-[9]

It can be seen that the effect of wall on the structure stability has been considered in the analysis of reinforced concrete structure world-wide, [7]. But this technology cannot be thoroughly investigated to show their effects on the geotechnical behavior of foundation also there are a lack of knowledge about the subject. Therefore, the main target of this research is to study the geotechnical behavior of structures subjected to earthquake loading with and without in filled of walls building between columns. The effects of such building walls on the foundation deformation and stress distribution are investigate under earthquake loads. The main benefit of the studied paper is to present a new novel technique to increase the stability of foundation soil system during earthquake, that may be relief the stress and control the system deformation.

II. Numerical Modeling and Selection of Parameters

PLAXIS 3D software is used in this research, for the mesh generation, the global coarseness is set to 'medium'. The soil under investigation formation is deposit of sand stratum of fourty meters depth. The sand layer simulated by Mohr-coulomb in dynamic analysis stage. The material properties of the sand layer are listed in Table I. The Rayleigh damping is considered at vertical boundaries with α, β=0.23 and 8×10^{-3}, respectively for Rayleigh waves resistance. While the plastic material properties for soil are illustrated by using material damping factors, that is described in PLAXIS model by Rayleigh coefficient (α and β), while the damping

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expression is believed which is proportional to the mass and stiffness of the system of the Rayleigh damping such that: C=α M + βM, where C is the damping coefficient, M is mass, K is the stiffness and. (α and β) Rayleigh coefficient. The Rayleigh damping is assumed to be object-dependent in material data set to be the plastic properties of soil throughout the dynamic investigation stage in PLAXIS model. The structure under investigation is consisted of basement and 8 stories with total height 24 meters; it has two bays with total width 10 meters. The structure and foundation elements are modeled as plate properties, the upper part of the building such as beam modeled as elastic material. The floor and wall plate material properties are listed in Table II. The foundation is selected as a reinforced concrete raft, and simulated as an elastic plate element, and the mate thickness is 1.20 m depth its plate properties are as shown in Table II. The seismic activity is simulated by imposing a prescribed horizontal displacement at the side surface of the boundary in contrast to standard unit length (Ux = 1m, Uy = 0 and Uz = 0) as used in manual default given by the PLAXIS manual. The geometry of finite element model under investigation for the analysis is illustrated in Fig. 1. The chosen monitored points along the structure and the underground raft was used to classify the performance of both foundation and structure throughout the earthquake. The points are selected to be on the top of the structure and at foundation base level.

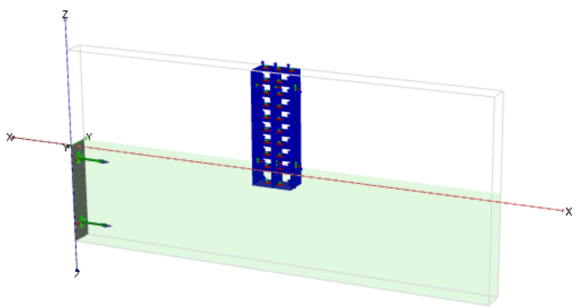

Fig. 1. Geometry model for investigated building foundation model with standard earthquake boundary conditions.

TABLE I: PROPERTIES OF SANDY SOIL USED IN THE STUDY

Parameter	Medium sand
Material type	Un- drained
Material model	Mohr coulomb
Soil weight	17
Permeability	0.01 m/s
Modulus of elasticity	35000
Poisson's ratio	0.25
Angle of friction (φ)	35
Dilatancy angle(Ψ)	5
Material type	Un- drained

TABLE II: MATERIAL PROPERTIES OF BUILDING AND FOUNDATION

Parameter	Name	Building walls	column	Raft foundation	unit
Thickness	d	0.12	-	1.2	m
Unit weight	γ	33.33	-	33.33	kN/m^3
Material behavior	-	Linear isotropic	Elastic	Linear isotropic	-
Young modulus	E	1.5×10^4	-	3×10^7	kN/m^2
Poison's ratio	υ	0	-	0	-
Rayleigh damping	α , β	0.2320, 8×10^{-3}	-	0.2320, 8×10^{-3}	-
Normal stiffness	EA	-	2.5×10^6	-	kN

III. STUDY PROCEDURES

A series of dynamic numerical models were run for the problem under consideration using different models of structures with and without brick walls. The numerical process has four phases. First one is the initial conditions phase, the second phase is a simulation of building construction, the third is a loading, free vibration analysis and the fourth is a dynamic analysis stage where the earthquake force is modeled. At this stage the displacement is set to be zero also the time interval is taken 10 sec, the ground acceleration of the earthquake is taken based on the defaulting acceleration input file in PLAXIS (225 smc) (SMC, Strong Motion CD-ROM). The acceleration time history used as a default in program with maximum horizontal acceleration of (a_{max}= 2.3 m/sec^{2}at time of 2.53. The water pressure must be activated regard as the pore water pressure before the mesh being generated.

IV. RESULTS AND ANALYSIS

A. Effect of the Presence of Brick Walls on the Performance of Foundation Sub Grade

The brick walls existence is an appropriate technique to amplify the stiffness during seismic loading. It can considerably reduce and manage the lateral deformation of the soil and structure above. In this research, it is discovered that, in the free field, an earthquake will make the soil have a displacement in both directions horizontally and vertically. On other hand where the foundation and building located on the ground surface, or embedded in the soil, the existence of brick walls can increase the sub-grade stiffness due to increasing the building mass and prevents the sub-grade soil from flowing in horizontal component of free field displacement. Fig. 2 illustrates and confirms the effectiveness of brick walls in decreasing total displacement of the soil during earthquake. The reduction of max horizontal displacement was reached to 45.5%. Also, Fig. 3 and 4 illustrate the shading of lateral displacement for building with and without brick walls.

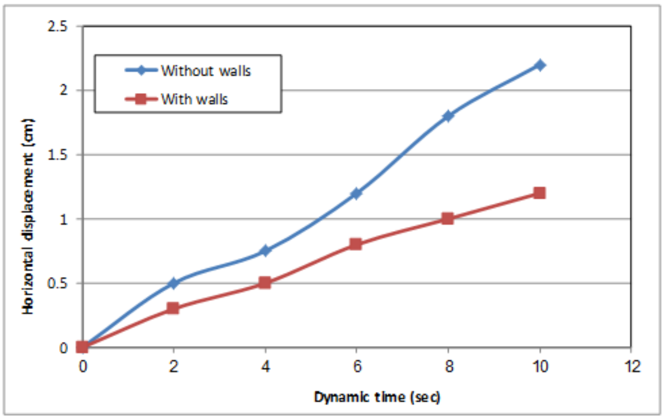

Fig. 2. Reduction of horizontal displacement of foundation sub-grade with and without the existence of walls.

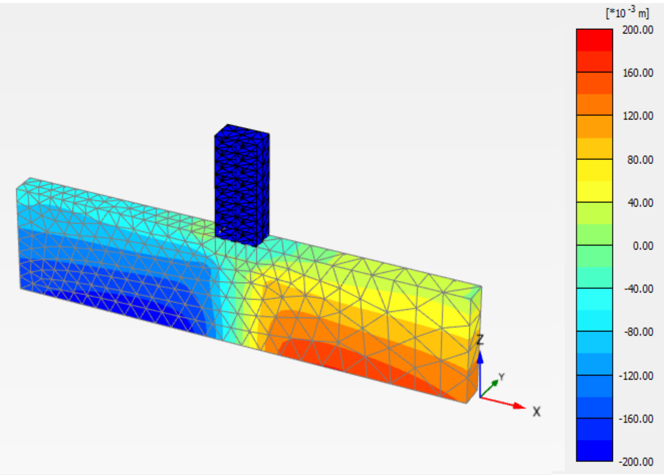

Fig. 3. shading of horizontal displacement in case of building without brick walls.

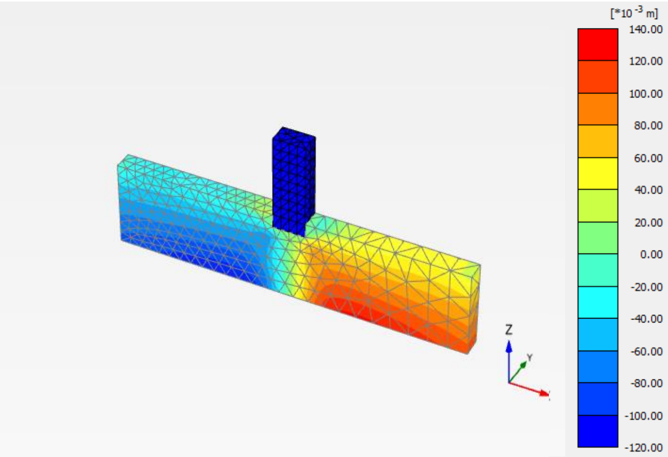

Fig. 4. shading of horizontal displacement in case of building with brick walls.

Also, the existence of building brick walls has a vital responsibility in adjustment of building behavior as clearly shown in Fig. 5 and 6 which present the horizontal displacement behavior of building and foundation with and without walls during earthquake loading. It has been found that using these walls enlarged the sub-grade stiffness. accordingly, at the foundation level the maximum horizontal displacement was significantly decreased by 43.2% compared to case of without walls. Also, at the top point of the building there was a reduction in horizontal displacement reached to 40% as presented in Fig. 6. In addition, the existence of brick walls reduces the foundation acceleration by 72% of its initial value this led to considerable effect of increasing the foundation stability as illustrated in Fig. 7. Also, the building acceleration decreased. The relative among the utmost horizontal acceleration of the structure at the peak point (a_{max}) and the dynamic time was recorded and then compared with the lateral acceleration (a_{max},o) for the case without brick walls in the form of ratio Ra = (a_{max}/ a_{maxo}) as shown in Fig 8. It is found that, the greatest horizontal acceleration of the structure is reduced by 65%.

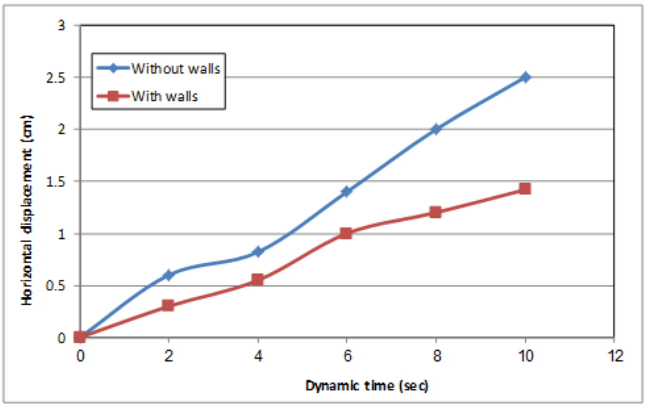

Fig. 5. Reduction of horizontal displacement at foundation level with and without the existence of walls.

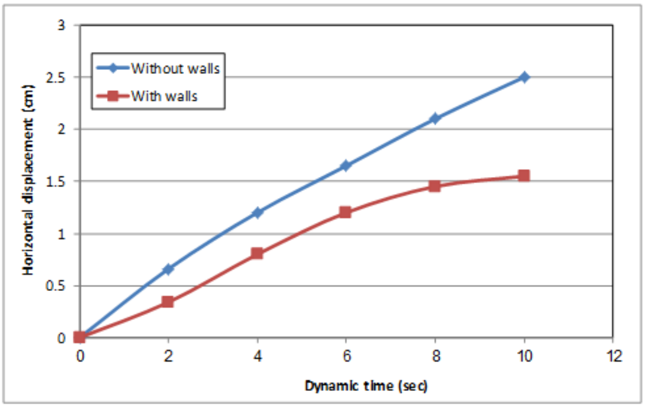

Fig. 6. Reduction of horizontal displacement at the top point of building with and without the existence of walls.

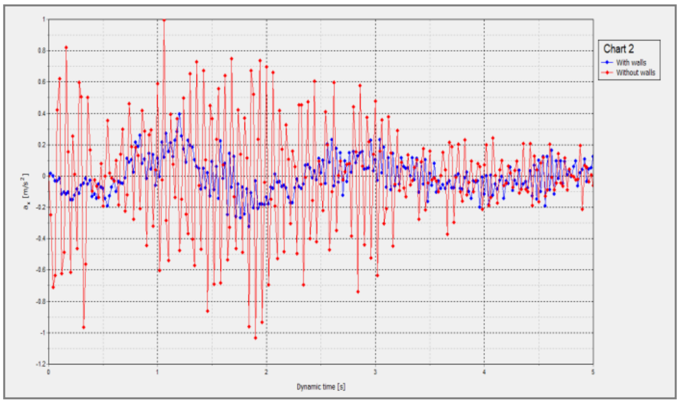

Fig. 7. Reduction of horizontal acceleration at foundation level with and without the existence of walls.

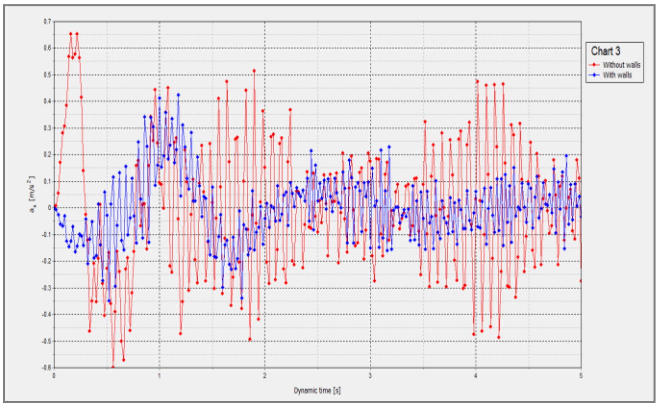

Fig. 8. Reduction of horizontal acceleration at the top point of building with and without the existence of walls.

B. Effect of Increase Wall Stiffness on the Foundation and Building Response

The effect of adopting different wall material or stiffness can also be investigated. It is founded that increasing the wall stiffness improve the displacement behavior of both the foundation and building above in addition improving the soil behavior too. Fig. 9 and 10 show the variation of the value of horizontal displacement at the foundation level with the variation of wall stiffness in dimensionless ratio (I/Io) where Io is the initial wall stiffness, and I is the increased wall stiffness with different material. It has been found that the existence of brick walls be capable of considerably decrease the horizontal displacement of structure and foundation with the enlarge of wall stiffness; this may be because the wall act as a strut helps in increasing the building strength during earthquake loading. The reduction was reached to 43.2% and 45% for foundation and building respectively at I/Io =3. Moreover, increasing the wall stiffness decrease the soil displacement during earthquake loading, the reduction reached to about 45% as shown in Fig. 11.

In addition, increasing the wall stiffness ratio I/Io decreased the induced bending moment on building and foundation. Fig. 12 and 13 show the variation of the value of maximum induced bending moment, max horizontal acceleration for the top point on the structure and at foundation level with the variation of wall the wall stiffness ratio I/Io then compared with values of without walls building case. It has been found that there is a great reduction in the maximum induced bending moment with the raise of wall stiffness, the decrease was achieved to 68% and 60% for foundation and building respectively at I/Io =3. Moreover, the decrease of lateral acceleration was accomplished to 70%at L/B =3 as illustrated in Fig 13. These improvements were backed to dynamic interlock induced between the structural elements of the building due to the existence of the walls which resulted in increasing the building strength to earthquake loading.

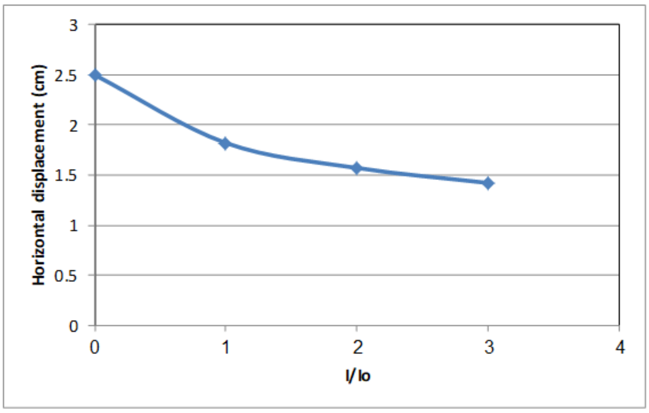

Fig. 9. Reduction of horizontal displacement at foundation level with increasing brick walls stiffness.

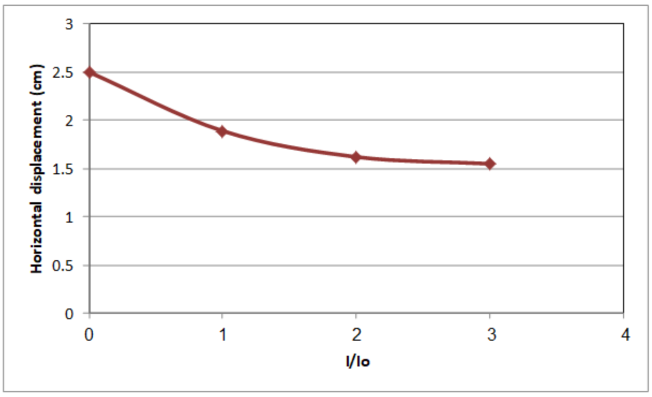

Fig. 10. Reduction of horizontal displacement at the top point of building with increasing brick walls stiffness.

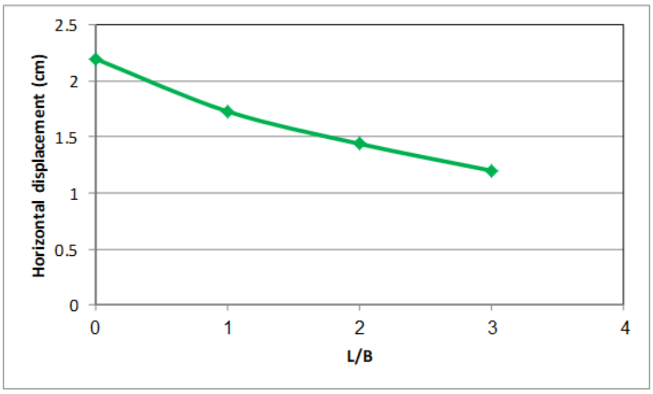

Fig.11. Reduction of horizontal displacement for foundation subgrade with increasing brick walls length.

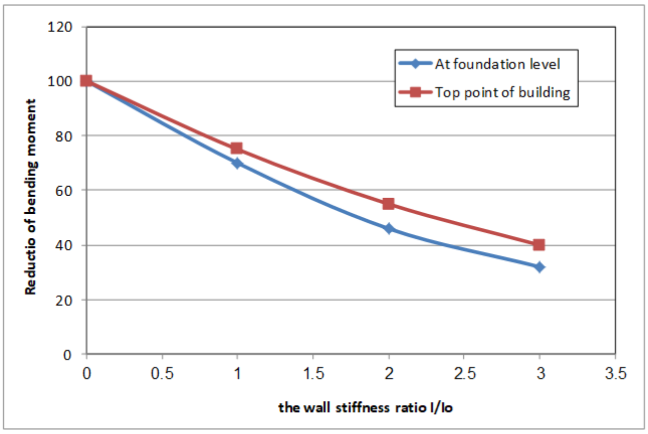

Fig. 12. Reduction of induced bending moment for foundation and structure with increasing brick walls length.

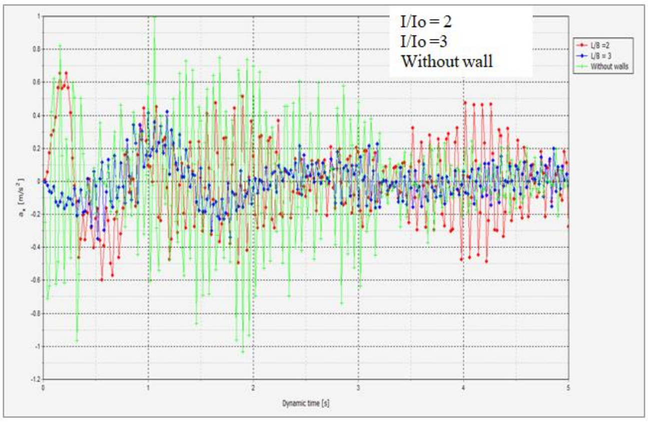

Fig. 13. Reduction of horizontal acceleration at foundation level with increasing brick walls stiffness.

V. Conclusion

According to the finite element investigation for foundation soil system during the earthquake, the benefits of using brick walls buildings were demonstrated in this paper through reducing the footing structure displacement and increase the structure stability on the existence of such wall.

The next conclusions can be illustrated as follow:

1) The finite element investigation of the model is helped for enhancing understanding the theory of the deformation mechanism, failure pattern and the output structure deformation during the earthquake.

2) The reduction of extreme horizontal displacement and bending moment for building foundation with brick walls reached to 43%, and 68% respectively compared to the building without walls.

3) The existence of building walls reduces the foundation acceleration by 72% of its initial value this led to considerable effect of increasing the foundation stability.

4) There is considerable reduction in the lateral deformation, acceleration and bending moment of the superstructure, these reductions were 40%, 65% and 60% respectively in addition to increase the building strength during earthquake loading due to inclusion of the brick walls.

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