



Numerical Analysis of Improving the Structural Resistance during Earthquake Using Skirted Foundation

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Abstract: Structural skirts were used to implement in the marine structures and wind turbines to reduce settlement and increase the bearing capacity. Consequently, the installation of the skirts on the buildings undertake to seismic load showed that the efficiency of the skirts were improved the seismic response of foundation under displacement, acceleration, excess pore water pressure and shear strain. In addition to, improve the structure response to earthquakes. Earthquake is the most reason of structure hazards, Therefore, extensive investigation to safeguard buildings and foundation from disintegrate has been done using different techniques. The main notions of this paper are investigating the influence of skirted techniques for the foundation to enhance the durability and the serviceability of superstructure. The influence of the raising the sub-grade stiffness by skirts system on the foundation and structure steadiness through a seismic force are studied. Numerical finite element model for the analysis is investigated to simulate the earthquake effect and the skirt existence. A reinforced concrete building consists of 4 stories its foundation is a raft simulated by 2D model in case of using skirts and without using skirts. In the present study, a 2D plain strain PLAXIS program, (dynamic version) is set. The models for the problem under investigation are run at variety of skirt embedment lengths beneath the raft base. Nodal displacement and element strains are studied for the foundation in case of skirt system and with no skirting and different points along the building are also monitored. Another model for simulating the direct effect of the earthquake on the structure is presented using SAP 2000 to study the damage effect and how the skirted system reduce the possibility of the structure failure. The paper outcomes stated a noticeable efficacy in the structural stability of the building because of the confinement influence and increasing sub-grade stiffness. The usage skirts techniques can adjust and reduce the under-laying behavior. Accordingly, the mounting of the base stiffness can vary and reduce the horizontal deformation of the structure besides decreasing the induced staining action on the building elements. This mechanism of the skirting is considered to be an effective technique to amplify the stability of the inertia, enhance the movement resistance stiffness of the structure through the seismic wave, and decrease the building acceleration. [W. R. Azzam¹ and M. N. El Siragy. **Numerical Analysis of Improving the Structural Resistance During Earthquake Using Skirted Foundation.** *J Am Sci* 2020;16(1):64-74]. ISSN 1545-1003 (print); ISSN 2375-7264 (online). <http://www.jofamericanscience.org>. 7. doi:[10.7537/marsjas160120.07](https://doi.org/10.7537/marsjas160120.07).

Key Word: Structural skirts, lateral confinement, displacement, acceleration, excess pore water pressure and shear strain.

1. Introduction

Seismic forces earthborn deformations through soil that transfer to the footings of the structures which could lead to a huge harmful effects on the structures. The total building distortion mostly depends on the repeated forces which come from the huge earthquake forces and the liquefiable soil stratum characteristics as well as the footing type. Repeated and everlasting structure deformations were influenced by the interface between soil and the structure response. The interface of the structure deformation with the repeated pressure of the water in the soil voids which make the soil softer then a drop in the pressure. This is in difference with evaluating liquefaction-induced settlement in the free-field, for

which several widely accepted procedures have been proposed e.g., (M. Hatanaka et al. 1987), (Azzam and Nazier 2012), and (Lombardi and Bhattacharya 2014). The soil improvement ways to be safe for liquefaction is focusing on increasing the soil solidity and to reach the maximum soil compaction which will not lead to the increase on the water pressure. According to the previous definition of densification, the both side surrounding system of the soil beneath the footing is accomplished by a structural skirts which attached to the footings corners. This technique is useful for enhancing the properties of soil during seismic forces and the borne liquefaction as reported by (Azzam, 2011), (Azzam and Nazier, 2012), (Gazetas 2013), and (Maiti and Ajayswarup 2018).

The skirted foundation is defined as a steel sheet plates. It is the same idea of sheet pile, but it constructed along the building beneath the raft around the building specifically. The main point is to do a lateral confinement with a vertical reinforcement. The skirted foundation basically used in the marine structures and wind turbines since the 1970s. The first countries in the globe using the skirts foundation was in the NorthSea. It used it to increase the bearing capacity, increase the effective foundation depth and decrease the settlement. As a development to their work a lot of facilities were used skirts in the sea bridges with long span. The installation of skirted foundation in the seismic conditions may achieve good results during the earthquakes. It's expected to reduce the settlement, acceleration, excess pore water pressure, velocity and straining action. In addition to, the decreasing in the excess pore water pressure will affect clearly on the liquefaction mitigation during the earthquakes.

Previous knowledge explained that in the first stages of constructions, setting up regulations against earthquakes is the critical protection against the earthquake hazard. Lots of researchers investigated the liquefaction behavior and its influence the building as stated after (Seed & Idrees, 1971), (Yasuda, 1997) and (Chu et al 2004). Processes of liquefaction reduction are generally centered on raising the liquefaction soil resistance by enhancing the soil properties for foundation protection against failure. Liquefaction reduction could be made by some techniques of soil enhancement such as dynamic compaction, vibro stone columns and wick drains

(Dise et al 1994) and (Luehring et al 2001). As well as enhancing the liquefaction strength by means of varial ways is studied and discussed by (McManus et al 2005), (Naein and Moaye 2006), and (Krishna and Madhav (2009). The using of deep foundation aspect is considered to be an effective way to mitigate the liquefaction (Martini and Madabhushi 2005).

The present paper focused at studying the influence of raising the sub-grade stiffens by skirted system against deformation properties of the structure. Besides, to illustrate that, the used system of the skirted foundation is supposed to be a modern approach of the structure resistance against Liquefaction.

This research illustrate the following, to evade the dimensions difference influence and the difficulty of the quaking table, a bursting size experiments are applied to reproduce the real structure footings performance that subjected to an earthquake using finite element method by Plaxis dynamic version 2002.

1. Numerical modeling and parameters selection.

(The 6 node) element method with plane strain model is used. The details of the used parameters are summarized in Table 1.

Fig 1 shows the geometry of finite element model. The selected monitored point a long structure and footings are included to recognize the behavior of the foundation and structure during seismic loads. The places of the measuring picked at the highest point of the structure and another at the footing inside the detained sub-grade.

Table 1: The properties of the model under investigation

Subsoil is a sand layer of 20 m thickness	$\gamma = 16 \text{ kN/m}^3$, $\nu = 0.27$, $E = 35000 \text{ kPa}$, $\beta = 0.01$
ground water table at 2 m below the ground surface	Undrained model
The structure is 5 floors	6 m wide
The building and foundation are simulated as plate properties (Elastic Simulation)	
The floor and wall plate properties	$EA = 5 \times 10^6 \text{ kN/m}$, $EI = 9000 \text{ kN/m}^2/\text{m}$ with weight of 10 kN/m/m and Poisson's ratio $\nu = 0.1$
The building foundation is a reinforced concrete raft	0.5 m thickness
plate properties	$EA = 100 \text{ kN/m}$ and $EI = 22.000 \text{ kN/m}^2/\text{m}$
beam elements and elastic material are used to simulate the skirting system	
Skirts are steel sheets made	0.4 cm thickness and varied in depth (L)
(L) expressed as a term of (B) = L/B	L/B ratio in values of (0.5, 1, 1.5 and 2)
skirts are axial bending stiffness	$EA = 64000 \text{ kN/m}$ & $EI = 8.7 \text{ kN/m/m}$.
(Ux = 0.01m and Uy = 0) for the earthquake	

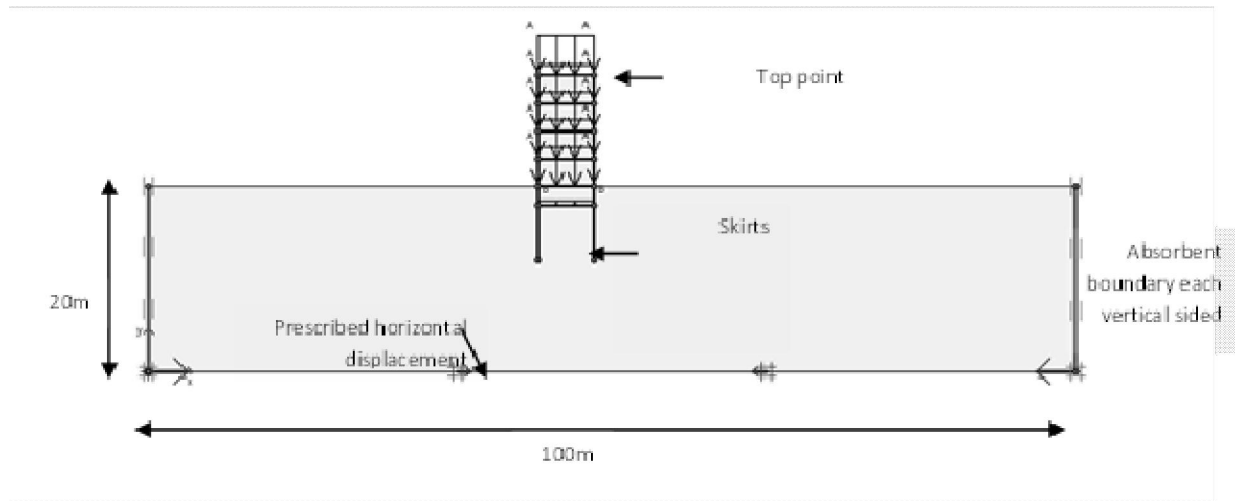


Fig. 1: The element of the adopted finite element model.

1.1 Model Verification

This part describes an example that has been used to verify the dynamic response of a footing in PLAXIS Using PLAXIS 2D -Dynamic Module - Version 2007. In this example the plane strain is adopted with 6 node element. Soil is considered to be sand with 40 m thickness. It supposed to be Mohr-coulomb, the soil material is considered to be undrained. The soil characteristics are as follow sand ($\gamma = 18 \text{ kN/m}^3$, $\nu = 0.27$, $E = 50000 \text{ kPa}$, the Raleigh damping is assumed at perpendicular edge with (α and $\beta = 0.01$). The adopted building consists of basement and five stories with 10.0 m wide. The building and

foundation are simulated as beam elements of elastic material. The properties of the beam are ($EA = 1.540E+07 \text{ kN/m}$, $EI = 6.288E+05 \text{ kNm}^2/\text{m}$, $d = 0.7 \text{ m}$ and own weight = 17 kN/m/m). The properties of the column are ($EA = 6.600E+06 \text{ kN/m}$, $EI = 4.950E+04 \text{ kNm}^2/\text{m}$, $d = 0.3 \text{ m}$ and own weight = 7.5 kN/m/m). The properties of the foundation are ($EA = 1.320E+07 \text{ kN/m}$, $EI = 3.960E+05 \text{ kNm}^2/\text{m}$, $d = 0.6 \text{ m}$ and own weight = 15 kN/m/m). The seismic forces is simulated using a stipulated horizontal dislocation used in manual default. The geometry of finite element model adopted for the analysis is shown in Fig.2.

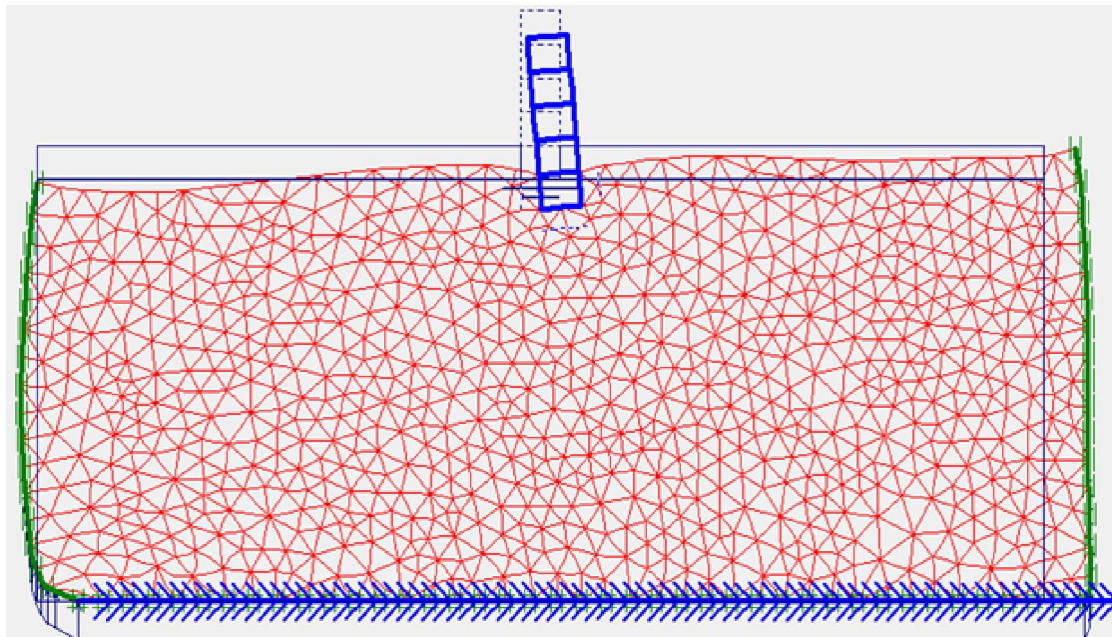


Fig. 2: The element of the adopted finite element model. In Plaxisdynamic 2002, deformed mesh

2 Analysis procedures

The computation process has two stages. The normal plastic calculations are the first one where the structure is created. The dynamic analysis is the second stage where the seismic force is added to the model. The acceleration of the input earthquake is

chosen considers Loma Prieta earthquake 1989. The acceleration time history applied as the typical input of Plaxis with the maximum horizontal acceleration of $0.3g = 2.94 \text{ m/s}^2$ as shown in Fig 3. (USGS). The results indicated that total stress at foundation level equal to 180.0 kN/m^2 , as shown in Fig 4.

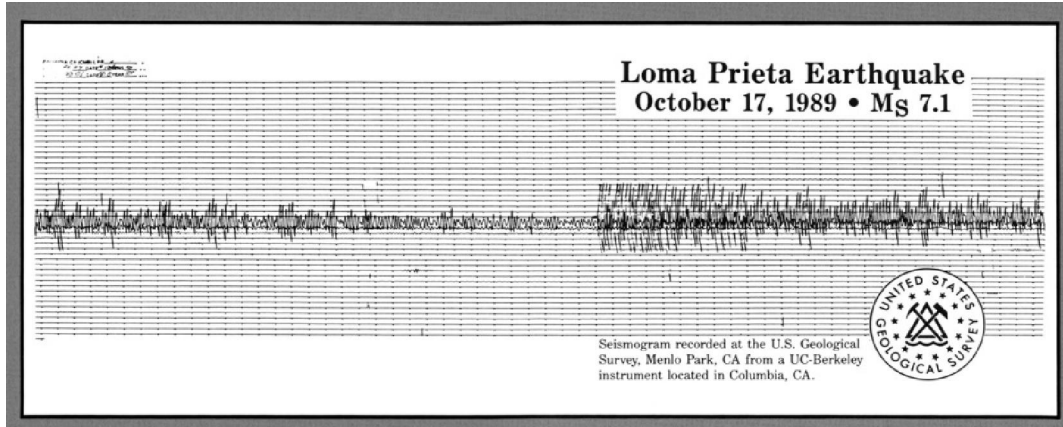


Fig.3: Seismogram acceleration for Loma Prieta earthquake 1989 as recorded in USGS

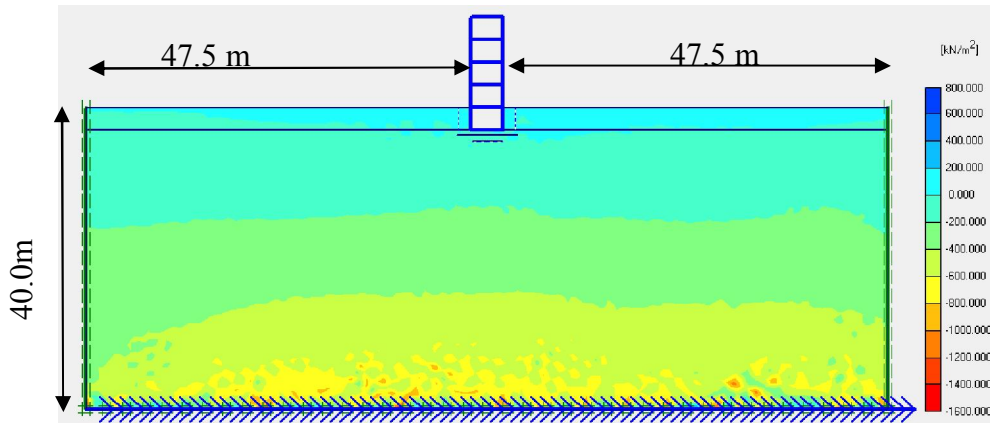


Fig.4: shading of stress obtained in Plaxis – stress at the foundation level= 180 kN/m^2

To verify the dynamic response of a footing in PLAXIS This example has been resolved manual using Equivalent Static Load (Simplified Modal Response Spectrum) method.

$$F_b = S_d(T_1) * \lambda \frac{W}{g} \text{ (Eq.1)}$$

F_b = Ultimate base shear force

$S_d(T_1)$ = The opposite values for T_1 on the response spectrum curve

λ = Correction factor

W = Total weight of the structure above foundation level

g = Gravitational acceleration

$$T_1 = C_t H^{\frac{3}{4}} \text{ (Eq.2)}$$

T_1 = Periodic time of different mode shapes

C_t = Factor depend on structural system and material

H = Height of the building from foundation level

$$\therefore T_1 = 0.075 * 15^{\frac{3}{4}} = 0.571$$

And according to the soil type used (Type B, dense sand)

S = Soil factor = 1.35

T_B = Limit constant factor for elastic response spectrum = 0.05

T_C = Limit constant factor for elastic response spectrum = 0.25

$T_D = 1.2$

γ_1 = Importance factor for ordinary buildings = 1.0

η = Damping factor corrected for horizontal response spectrum, Reinforced Concrete=1.0

R = Response modification factor, system resistance for lateral load = 5.0

$T_1 \leq 4T_c$ And $T_1 \leq 2.0$, two conditions have been achieved.

$$\therefore, T_c \leq T_1 \leq T_D$$

$$\text{Thus, } S_d(T_1) = a_g \gamma_1 S_R^{2.5} \left[\frac{T_c}{T_1} \right] \eta \quad (\text{Eq.3})$$

$$S_d = 0.3 g * 1 * 1.35 \frac{2.5}{5} \left[\frac{0.25}{0.57} \right] * 1.0$$

$$\therefore, F_b = 0.08 W$$

$$W_{\text{slab}} = 6.0 \text{ kN for one story}$$

$$W_{\text{column}} = 54.0 \text{ kN for one story}$$

$$W_{\text{Beam}} = 43.75 \text{ kN for one story}$$

$$\text{So } W_{\text{Total}} = 518.75 \text{ kN}$$

$$\therefore F_b = 40.14 \text{ kN}$$

The earthquake force which affected the building is distributed on the number of stories in elevation with different values depending on the level of each floor. After calculating the value of affecting force on each floor this value is distributed on each floor separately on the members which will resist it in plan.

- Distribution of lateral force (F_b) in elevation

$$F_i = (F_b) W_i H_i / \sum W_i H_i \quad (\text{Eq.4})$$

F_i = the lateral force affecting on the floor number i

W_i = the weight of each floor

$$\sum W_i H_i = 463.5 \text{ t.m}$$

\therefore The force on each floor is as following and shown in Fig.5

$$F_1 = 2.76 \text{ kN}$$

$$F_2 = 5.5 \text{ kN}$$

$$F_3 = 8.2 \text{ kN}$$

$$F_4 = 11 \text{ kN}$$

$$F_5 = 13.8 \text{ kN}$$

After calculating the lateral force affecting at each floor the over turning moment is calculated from this equation:

$$\text{Over turning moment} = \sum F_i H_i = 450.4 \text{ kN.m} \quad (\text{Eq.5})$$

Then the stress at foundation level is calculated from equation 6

$$\bar{\sigma} = N/A \pm (M/I) * y \quad (\text{Eq.6})$$

When:

N = Weight of the building including foundation

A = Area of the footing

$$I = bh^3/12 = 5.3333333 \text{ m}^4$$

$$A = 4 \times 1 = 4.0 \text{ m}^2$$

$$W_{\text{Reinforced concrete raft}} = 160.8 \text{ kN}$$

$$\therefore W_{\text{Total}} = 690.67 \text{ kN}$$

$$\text{Max} = 340 \text{ kN/m}^2 \text{ and } \text{Min} = 1.25 \text{ kN/m}^2$$

$$\text{Average} = 170 \text{ kN/m}^2$$

1.1.2 Results and Validation

By comparison between the average stress for the numerical models as stated before and calculated values of the average stress of the same models using response spectra technique as specified in Egyptian Code of Loads (2012), it has been found that good agreement is accomplished among the two approach. Consequently, the PLAXIS dynamic version 7.2

(FEM) is capable of simulating the behavior of the problem under investigation. It also can be used to verify the problem of scale effect or prototype. Therefore, in this paper a series of large-scale models are run under different dimensionless parameters to determine and analyze the foundation and building response during the earthquake.

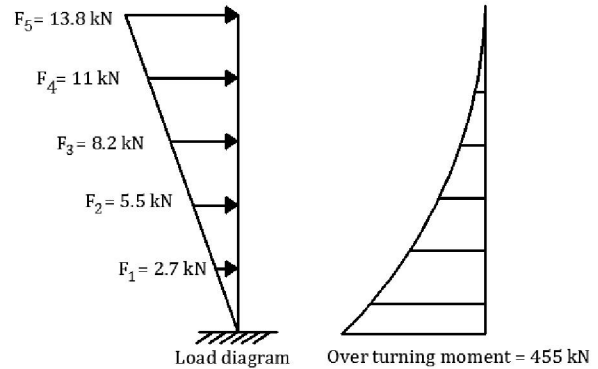


Fig.5: Load diagram and overturning moment on the building

3. Results and analysis

3.1 The influence of skirting system on the performance of footing sub-grade

The skirting system around the footing is an effective way to enhance the sub-grade stiffness during the seismic forces. The skirting system is able to considerably manage the horizontal soil displacement beneath the footing and amplify the stability of soil. It has a significant influence on mitigation the liquefaction and adjusts the water pressure in the void ratio and protects the footing from failure as stated after (Azzam, 2011). In this paper, it is noticed that, for the case of none skirting, a seismic force will reason movement in the soil for both directions. The soil is very rigid which make it does not go after the deformation outlines, its motion will be influenced by kinematic interface, though with no weight if the footings and building on ground, under the surface. Whereas the skirting system can raise both the sub-grade stiffness and the efficacy of the footing depth therefore, the footings and the soil performed in the same harmony.

The flexural stiffness of the confinement system averts the sub-grade flowing the vertical direction for the none skirted displacement. The skirted sub-grad among the skirted foundations is carried out as a stiff block that manages the horizontal displacement of the sub-grade soil particles. Overall, the axial stiffness of the footings stopping instantly the beneath layer of soil from deforming disjointedly and performed as vertical obstacle against the shear stress from the seismic loads. Accordingly to that, the footing sub-

grade performance are modified, Fig. 6 illustrates the efficacy of skirting system in reducing the sub-grade movement reasoning an ideal compaction during the loading phases and noticeably reducing the borne shear strains connected within the skirted soil. The following graph shows the major direction and position at which strains happens.

It can be seen that the confinement system easily could be adjusted and decay the distribution of the seismic strains to the surrounding soil. This is necessary for the effectiveness of the confinement system against shear stress. The strains are largely existed external the skirted area. This performance is

backed to that the skirting system and the sub-grade confinement as if embedment footings, stiff unit match up to the condition of the building without skirting. In addition to, those boundaries in strains are referred to the kinematic interface reducing the total overturning load magnitude on the footing.

Fig. 7 illustrates that the gradual shear strains that are founded in the sinisterly side in the open system also beneath the confinement area, the skirting system has a high efficacy in decaying the stress directly to the surrounded field through the seismic path. Opposing for the right hand side area the contours concourse is observed.

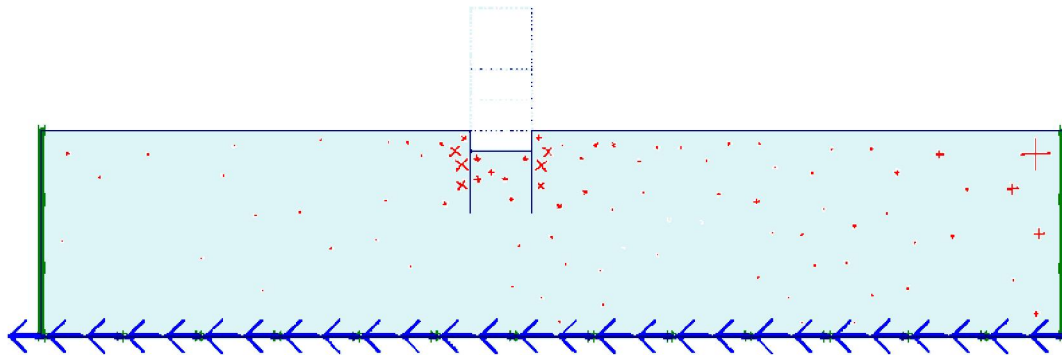


Fig. 6: Principal direction of total strains for building foundation with skirts (L/B=2)

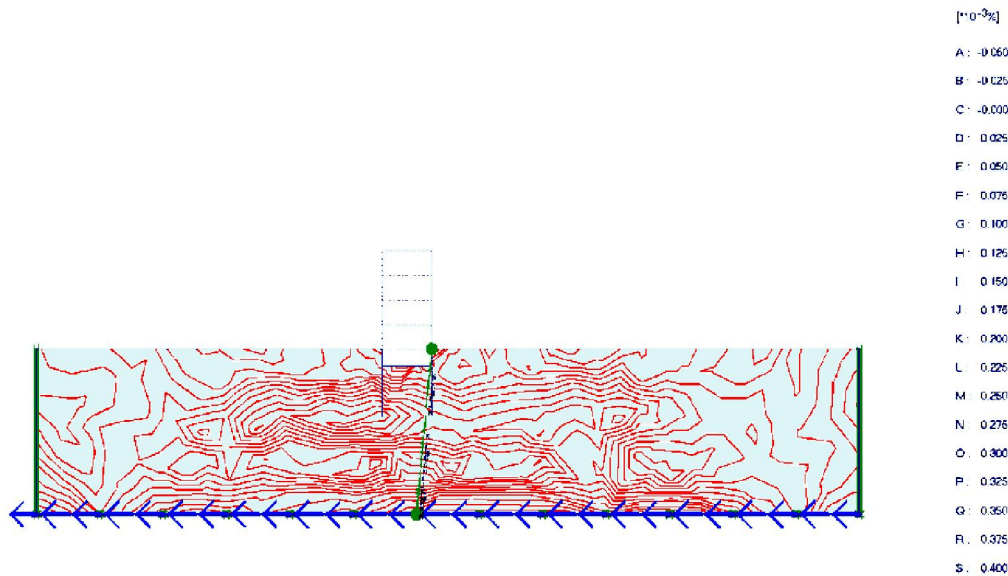


Fig. 7: Contours of Incremental shear strains for building foundation with skirts (L/B=2)

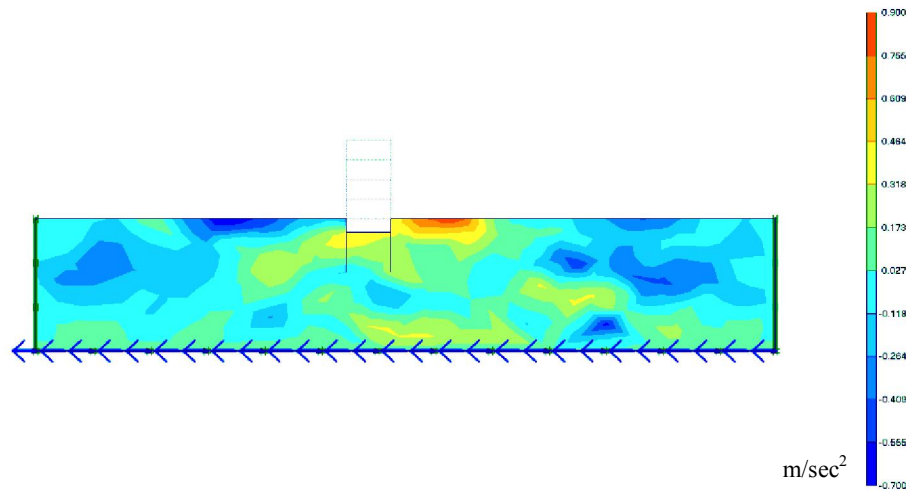


Fig. 8: Shading of extreme horizontal acceleration for building foundation with skirts ($L/B=2$)

In addition, Fig. 9 validated the significant of the skirting system in reducing the footing sub-grade acceleration due to the influence of the confined system. The relevant figure obviously shown the maximum horizontal acceleration area that influenced by skirting existence, it can be seen that the footing and the confinement sub-grade acceleration is amazingly decreased contrasted to the first condition of not using skirting. The maximum acceleration records are in the exterior of the confinement area as well as beneath the confinement building block. It illustrated that the skirting enlarges the inertial

interface. Thus, the deformation performance is customized. On the other hand, The skirting deepness is a very significant factor in the adjustment of footing performance, see Fig. (10-a) to (10-d) that shows the dissimilarity of the skirting embedment lengths (L/B) through the determined values of; maximum shear strains (ϵ_{xy}), maximum horizontal acceleration (a_{max}), maximum horizontal velocity, (V) and the borne extreme horizontal force at the footing, (F_x). Generally the increasing in the skirting embedment length gives an enough resisting depth which makes sub-grade denser and raising the sub-grade stiffness.

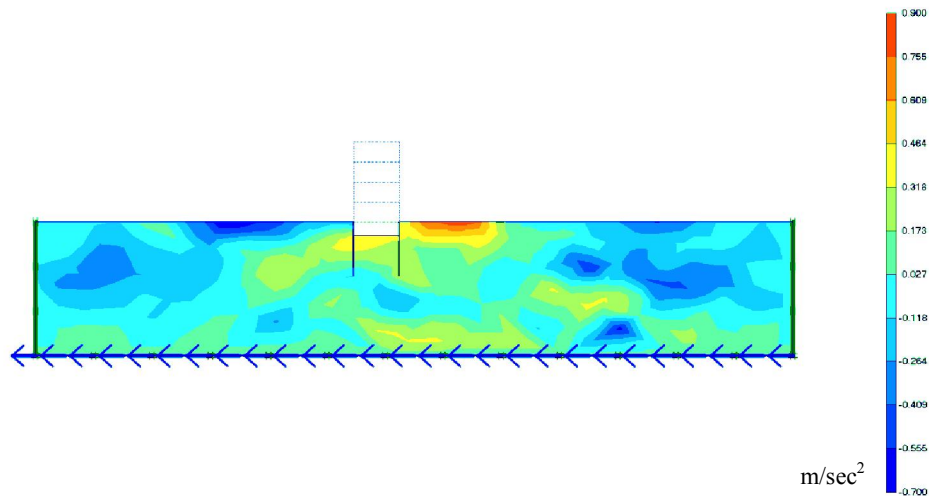


Fig. 9: Shading of extreme horizontal acceleration for building foundation with skirts ($L/B=2$)

Accordingly, for the confinement area and at the footing level, the borne share strains, greatest

horizontal acceleration and the sub-grade velocity are considerably reduced by the raising of skirting

embedment length. On the other hand, mounting the skirting embedment length appreciably raise the horizontal footing capability which shown in the borne pedestal footing force as shown in Fig 10d.

3.2 Influence of the skirting system on the structure performance

The main aim of this section of the research is to investigate the influence of the skirting existence with footing on the structure behavior to illustrate the advantages of raising the sub-grade stiffness of the footing. Furthermore investigate and discuss the pattern of the confinement block and the sub-grade density increase against the seismic forces. The recorded values of the horizontal deformation for the building () for the point on the top of the building,

the related model is carried out for variety skirting embedment lengths after that contrasted to the horizontal deformation () for the case of not using skirting and represented as relation $R = (/)$.

Fig. 11 illustrates the value of R with the term of (L/B). It is noticed that the skirting existence could considerably decrease the structure deformation by increasing the skirt embedment length, the dropping in lateral movement is attained up to 49.05% at (L/B=2) contrasted to the original records without using the skirts. That performance is referred to using the skirting which gives an efficient footing fixation and increasing the confinement area by raising skirting embedment length, leading to an increase of the building inertia.

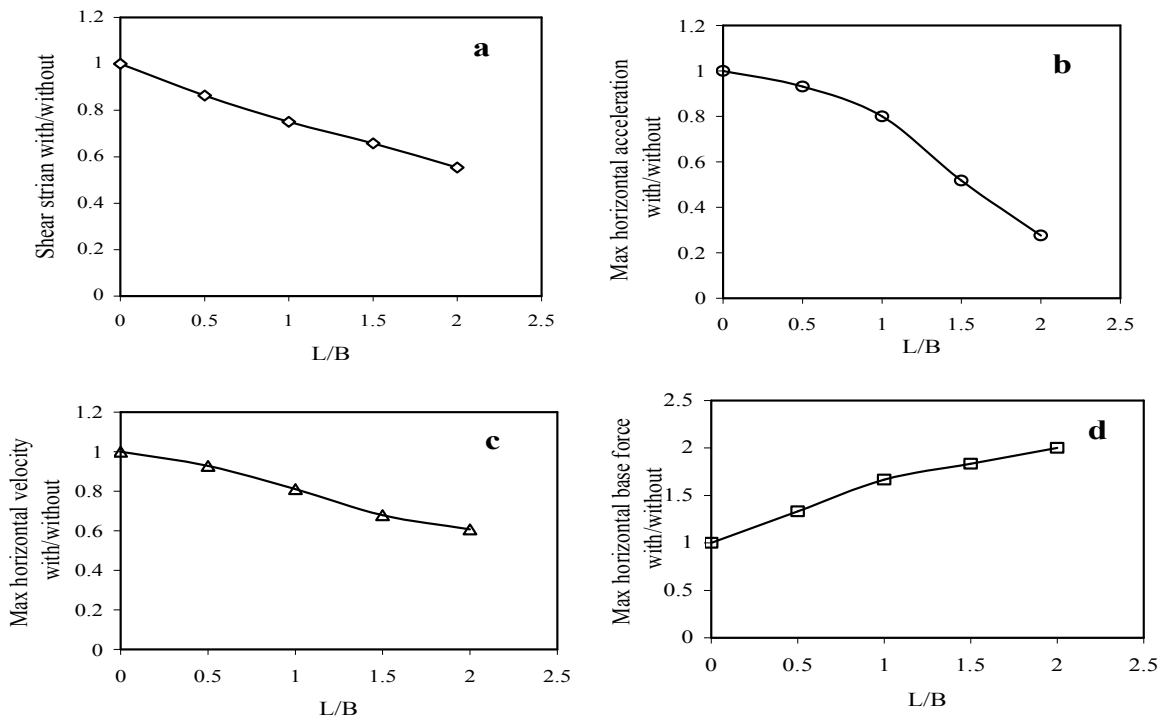


Fig. 10: Variation of skirts depth ratio with: a- maximum shear strains, b- maximum horizontal acceleration, c- maximum horizontal velocity and d- maximum horizontal base force.

Furthermore, the utmost horizontal acceleration of the building in the top point (a_{max}) and the skirting embedment length relation is recorded and matched up to the horizontal acceleration ($a_{max,o}$) which calculated in the first condition without using the skirting system in the term of $R_a = (a_{max}/ a_{maxo})$ see Fig.7. Obviously, the highest horizontal acceleration for the structure is reduced by increasing the skirting embedment length. It can be seen that the skirting system can considerably decrease the highest horizontal acceleration for the sub-structure by increasing skirting embedment length, the decrease in the lateral horizontal acceleration is attained up to

59.3% at (L/B =2) contrasted to the original records in first condition. That results referred to that the skirting system significantly increase the interface between the soil and the structure and create a major fixation as it previously illustrated. At this point, the skirting system raised the footing thickness. The footing and the confinement soil among skirts are performed as one unit that augment the stability of the structure and absorb the soil irritation. This can be defined as a constraint attached with the building footing. That connection put off the acceleration intensification happening. The following graph proves that using skirting system reduces the structure horizontal

acceleration. It is referred to the skirting existence can afford an effectual raise in building stiffness. Where the highest borne moment loading at the top position on the structure (M) is calculated at diverse skirting embedment lengths and matched up to the bending moment in the condition of not using skirting (M_o). The disparity in the ratio $R_M = (M/M_o)$ is seen in Fig. 8; it can be seen that the using of that skirting system reasons a decrease reduction in the straining action represented in the moment by increasing the skirting embedment length. This showing that the skirting system can considerably amplify the structure stiffness as a consequence; the horizontal deformation as well as acceleration of the building. in addition to

finding that the skirting system can appreciably decreases the straining actions of the structure by increasing the embedment length of the skirt, the decrease is up to 65.65% at $(L/B = 2)$ contrasted to the original record of the first condition. It is illustrated that the skirting that attached to the footing corner is effective and economically for the concrete section design and is considered to be an effective method to raise the structure constancy during the seismic loading. Table 2 shows the way of improvement in maximum lateral deformation of the top of the building, lateral acceleration and greatest bending moment as a result of using skirts.

Table 2: Improvement percentage owing to the existence of the skirting in the form of reduction factor R

Ratio of (L/B)	Reduction of Maximum lateral deformation R_d with skirt/without skirt %	Reduction of Maximum lateral acceleration R_a with skirt/without skirt %	Reduction of Maximum lateral bending moment, R_M with skirt/without skirt %
0	100	100	100
0.5	91.5	92.3	94.5
1	75.5	76.3	81.1
1.5	62.3	72.8	75.7
2	49.05	59.3	65.65

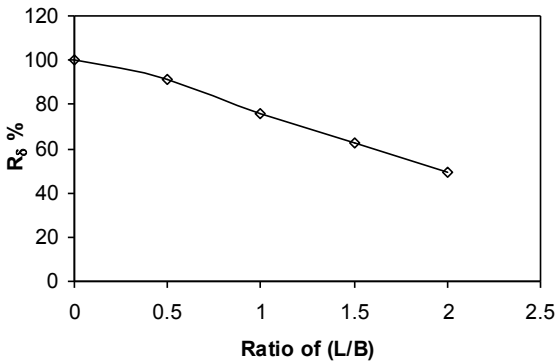


Fig. 11: Variation of (R_d) % with skirts depth.

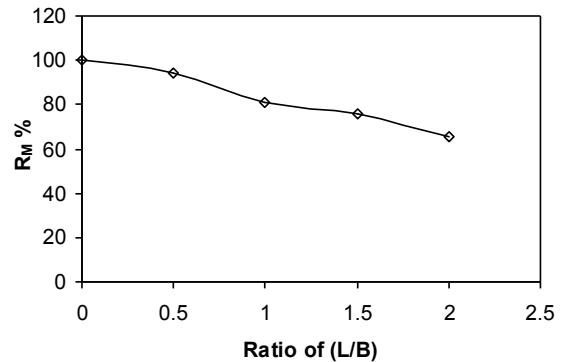


Fig. 13: Variation of (R_M) % with skirts depth.

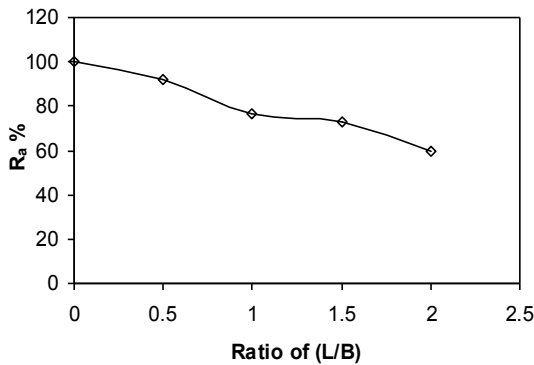


Fig. 12: Variation of (R_a) % with skirts depth.

4. Soil Structure Interactions

4.1. The influence of the skirt existence against earthquake on the adjacent building

The effect of the direct damage of seismic waves on the structures is difficult to be shown by Plaxis model therefore another model using SAP 2000 is proposed to study the direct effect of the earthquake waves on the building. The acceleration versus time history of the recorded earthquake is used as an input in another module using SAP2000 V.14 to simulate the structure that is affected by such dynamic effect.

In order to study the effect of pile driving on adjacent structures, the numerical program SAP2000 V.14 was used to simulate the structure by modeling a skeleton structure consists of beams, columns, slabs and springs that represents the soil sub-grade reactions

as shown in Figure 14. The horizontal acceleration of the recorded earthquake is used in the SAP model to study the effect of driving induced waves which affect not only on the soil underneath the structure but also directly to the structure

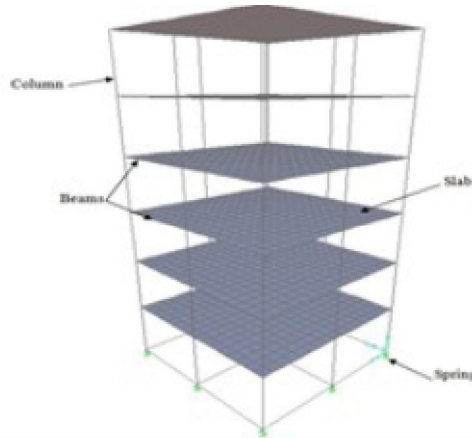


Fig. 14: 3D skeleton of the 5 floor building

The SAP model simulates a residential building (skeleton) consists of six floors and supported by

isolated footings. The building had footprint of 10m x 10m. The slabs were 0.12 m in thickness. The external columns had 0.3m x 0.6m in cross section. The internal column had 0.3m x 0.9m in cross section. The beams had dimensions of 0.25m x 0.50 m in cross-section. The footings are rectangular in shape. The external footings were 2.5 m in width and 3.5m in length, while the internal footing was 3m in width and 4m in length. A live load of 2kN/m² was considered.

It can be seen that the existence of the skirted confinement on the building reduces the direct damage of earthquake on the building as shown in Fig.15 the straining actions are reduced by almost 40% from the influence of the earthquake force on the building compared by the case of without skirted foundation. The mechanism of the skirting in reducing the seismic waves is by preventing the wave propagation to reach the foundations of the buildings. It can be an ideal solution for using the skirting system for the protection of the sensitive structures against the earthquake loads to insure the safety of the buildings.

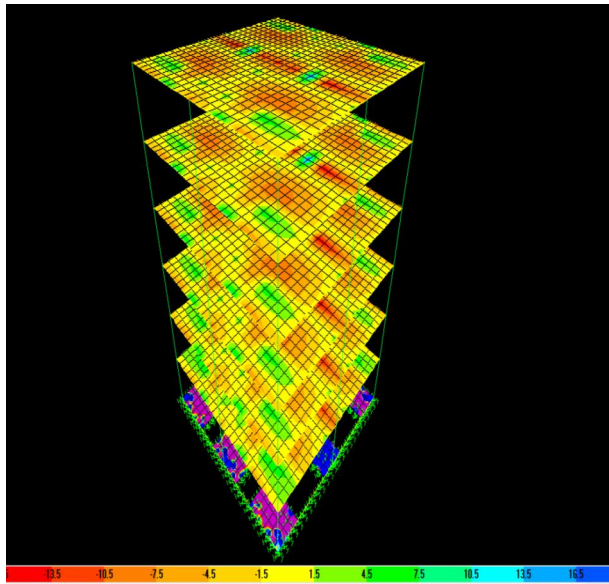


Fig 15: The influence of the earthquake on the building with the skirted foundation.

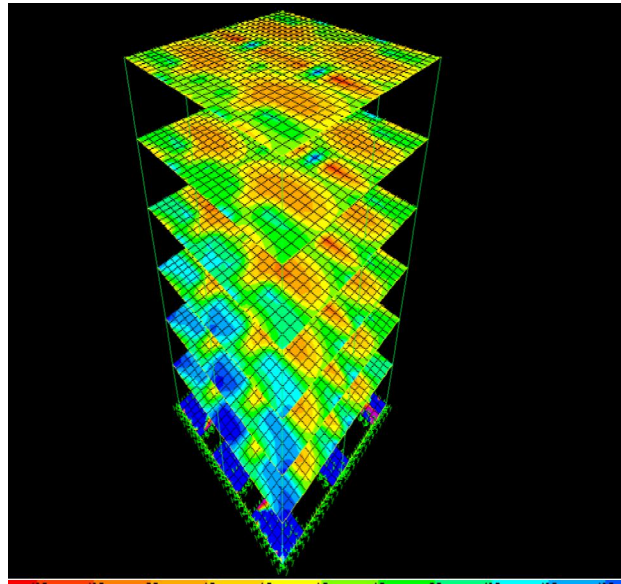


Fig 16: The influence of the earthquake on the building

Conclusions

Founded on the FE analysis for the skirted footing under earthquake load, this conclusions can be extracted:

1. The finite element analysis of the problem under investigation is helped in better understanding the deformation behavior, failure pattern and induced building deformation under the effect of earthquake.

2. The foundation and soil between skirts behaves as a coherent mass and a progressive densification is achieved therefore, the soil shear strains associated with earthquake loading is took place under and outside this treated densified zone.

3. The skirts can improve the kinematic interaction that decrease the net overturning moment applied in foundation. Hence, the existence of such skirts prevented the system to rock as well as

translated, even though the foundation stability is increased

4. The extreme acceleration values were found outside the confined zone and under the confined block therefore it provided a fixed base structure and increases the inertial interaction.

5. The installation of the skirts along each side of the foundation has a good effect in increasing the kinematic stiffness of supporting sub-grade due to densification effect and decreasing the liquefaction potential within the confined block.

6. The skirts have a considerable effect in decreasing both the building lateral deformation and acceleration in addition to increase the building stiffness. Therefore it considered as an economic in superstructures design.

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