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A simulation on soil structure interaction with ABAQUS; effect on the behavior of a concrete building of soil layers and earthquake properties

ABAQUS ile zemin-yapı etkileşiminine bir simülasyon: deprem ve zemin tabaka özelliklerinin betonarme bina davranışına etkisi

Yazar(lar) (Author(s)): İnan KESKİN[1], Mohammed Yadgar AHMED[2]

ORCID[1]: 0000-0002-8011-3296

ORCID[2]: 0000-0003-2977-4352

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A Simulation on Soil Structure Interaction with ABAQUS; Effect on The Behavior of A Concrete Building of Soil Layers And Earthquake Properties

Highlights

- *Soil structure interaction is modeled with Abaqus.*
- *Soil structure interaction under earthquake effect has been discussed.*
- *The behavior of the building built on the ground with different characteristics during an earthquake has been modeled.*

Graphical Abstract

In the analysis, stratified soil is simulated with 4 different models (soft-hard, hard-soft). Through these analyses, influence of different soil layer (soft and hard), buildings displacement, in addition to the frequency content of the earthquake have been investigated.

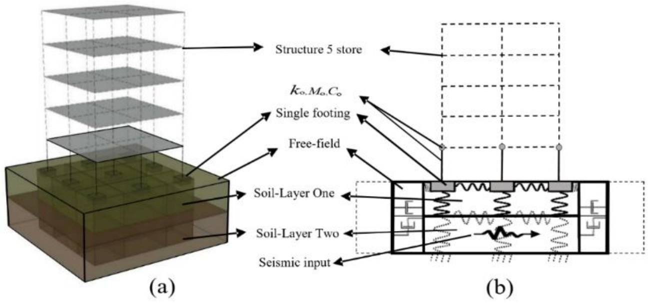

Figure 1. Supported by foundations considering dynamic soil-foundation-structure interaction with building in seismic motion (a) 3D model clarifies (b) Model 2D supported by foundations considering dynamic soil-foundation-structure interaction with building.

Aim

In this article, it is aimed to examine the effects of soil properties and earthquakes on a structure built on a multi-layered foundation using Abaqus/CAE.

Design & Methodology

The research model was created and analyzed in Abaqus/CAE

Originality

Structure-soil interaction with Abaqus/CAE was discussed

Findings

The fndings clearly show that the seismic properties together with the soil properties have a great influence on the structure.)

Conclusion

Finite element software, especially Abaqus software, has been evaluated as a usable tool in structure-soil interaction analysis.

Declaration of Ethical Standards

Bu makalenin yazar(lar)ı çalışmalarında kullandıkları materyal ve yöntemlerin etik kurul izni ve/veya yasal-özel bir izin gerektirmediğini beyan ederler. / The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

A Simulation on Soil Structure Interaction With ABAQUS; Effect on The Behavior of A Concrete Building of Soil Layers And Earthquake Properties

Araştırma Makalesi / Research Article

Mohammed Yadgar AHMED[1] and İnan KESKİN[1]
[1]Karabük University, Faculty of Engineering Department of Civil Engineering 78050, Karabük Türkiye
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ABSTRACT

In this article, the effect of soil properties and earthquakes on a structure built in a multi-layer foundation soil is studied using Abaqus/CAE. Single foundations are one of the most common types of foundations traditionally required to support buildings in earthquake-prone regions. Most researchers work on the dynamic interaction between the foundation and the soil, which can affect the response of the building during earthquakes due to the type of earthquake and the properties of the soil layer. In this paper, four different earthquakes were applied to a reinforced concrete building constructed in two-layer soils with very different soil properties, and a discussion on soil-structure interaction was opened using Abaqus software. In the analysis, a layered soil is simulated with 4 different models (soft-hard, hard-soft). Through these analyses, the influence of the different soil layers (soft and hard), the building displacement and the frequency content of the earthquake were studied. According to the result of the analysis, it is important to consider the earthquake characteristics, the soil properties, and the type of foundation in the dynamic soil-structure interaction.

Keywords: Abaqus/CAE, soil-structure interaction, finite element model, foundation, soil.

Abaqus İle Zemin-Yapi Etkileşimi Üzerine Bir Simülasyon: Deprem ve Zemin Tabaka Özelliklerinin Betonarme Bina Davranışına Etkisi

ÖZ

Bu makalede, Abaqus/CAE kullanılarak çok tabakalı bir temel zemin üzerine inşa edilmiş yapıya zemin özelliklerinin ve depremlerin etkisi incelenmiştir. Tekil temeller, depreme eğilimli bölgelerdeki binaları desteklemek için geleneksel olarak gerekli olan en yaygın temel türlerinden biridir. Çoğu araştırmacı, deprem türü ve zemin tabakasının özelliklerinden dolayı deprem sırasında binanın tepkisini etkileyebilen temel ve zemin arasındaki dinamik etkileşim üzerinde çalışmaktadır. Bu çalışmada, çok farklı zemin özelliklerine sahip iki tabakalı zeminlerde inşa edilen betonarme bir binaya dört farklı deprem uygulanmış ve Abaqus yazılımı kullanılarak zemin-yapı etkileşimi üzerine tartışma yapılmıştır. Analizde 4 farklı model (yumuşak-sert, sert-yumuşak) ile katmanlı bir zemin simüle edilmiştir. Analizlerde farklı zemin katmanlarının (yumuşak ve sert) etkisi, binanın yer değiştirmesi ve depremin frekans içeriği incelenmiştir. Elde edilen sonuçlar, dinamik zemin-yapı etkileşiminde deprem özellikleri, zemin özellikleri ve temel tipinin birlikte dikkate alınmasının oldukça önemli olduğunu göstermiştir.

Anahtar Kelimeler: Abaqus/CAE, zemin-yapı etkileşimi, sonlu elemanlar modeli, temel, zemin.

1. INTRODUCTION

Soil-structure interaction is usually neglected in seismic design of structures. Soil conditions have much to do with damage to structures during earthquakes [1]. Therefore, it is extremely important to discuss these conditions in detail for engineering solution. The combined effect of earthquake and site conditions can cause great damage [2–5]. Many recent earthquakes and especially the 1985 Mexico City earthquake, clearly demonstrate the importance of soil properties in the earthquake response of structures. The soil-structure interaction is influenced by the soil type and properties of the soil and the type and properties of the building materials, as well as by, the frequency of the earthquake. The analysis of soil structure interaction in earthquakes is generally by two methods [6]. The first is a full interaction analysis, in which the variation of motions in the structure and in the adjacent soil is considered, and the second is an internal analysis, in which the motions in the adjacent soil are assumed to be the same at all points along the foundation depth. Different aspects of seismic soil-structure interaction analysis have been studied by different researchers in the literature [7,8]. The extent of strengthening depends on several factors, such as the nature and properties of the soil, the content of seismic motions, and the characteristics of the structure. Individual combinations of soil properties, building shapes, and seismic motion excitations, which mainly result in low effective damping, amplify rock

*Sorumlu Yazar (Corresponding Author)
e-posta : inankeskin@karabuk.edu.tr

motion very strongly [9]. Abaqus/CAE can simulate multi-layered complications with a direct analysis method that requires a high computational effort [9–11] Use of Abaqus/CAE for revising soil-structure interaction problems. The numerical modeling procedure used for the simulation of structural elements and soil models, as well as for the contact surfaces and boundary conditions, is explained below [12].

The combined effect of earthquakes and local ground conditions is often referred to as the site effect. The field effect is fully understood when the structure and the earthquake are evaluated together. Nowadays, computer simulations are used to predict the response of structures subjected to earthquake excitation. And Abaqus/CAE occupies an important place among the programs used for this purpose. It is known that the dynamic interaction between the soil, the foundation and the structure can affect the seismic behavior of the building during earthquakes. Modeling the dimensions of this interaction with finite element software, which has been widely used recently, will provide important benefits in terms of earthquake engineering. Consumption practice Abaqus/CAE software for finite element analysis on the proximity realization on behalf of numerical analysis consumption three seismic motion case communication with the system divided into two sectors, implemented, which have been developed for three-dimensional seismic motion analysis in Abaqus [13]. The devices include the assembly of innovative elements used for implementation. The free-field edge procedure in Abaqus/CAE and a free-field mesh maker that resolves viscous edge an essential requirement for the free-field edge procedure for domain reduction.

In this study, the effects of earthquake properties together with the engineering properties of soil layers on a building constructed on a stratified foundation soil were comparatively investigated with Abaqus/CAE [14]. In this study, the factors that will all have an impact on a foundation embedded in soil and, consequently, on the building are investigated. In addition, all aspects of soil-structure interaction under seismic conditions are discussed in this study. In this study, the behavior of structural elements with the change in the interaction between the soil and the foundation elements was revealed, and the information that can be used in the structural, economic, and conservative design of the foundation was numerically evaluated. The results of the study show that the seismic behavior depends on the soil properties, the type of seismic force and the interaction time and is not stable in all cases. Therefore, it was concluded that the size of the foundation, the characteristics of the seismic action, and the interaction between the soil, foundation, and structure affect the dynamic properties and seismic response of the building. Therefore, the designer should carefully consider these parameters to ensure safety and cost.

2. FINITE ELEMENT MODEL

In this system, there are individual foundations on two-layer soil with different properties (Figure 1a). Springs are used to represent stiffness and damping at the soil-foundation interface, and then the analysis is performed for the entire system (Figure 1b). Model parameters and soil properties in Abaqus/CAE used in the analyzes are presented in Table 1 and Table 2. This study was simulated by considering different earthquake characteristics and soil models. The first model, named case one, consists of two layers; the first layer of the soil is soft, and the second layer is hard. The other model, named case two, also has two layers, but here the first layer is hard and the second is soft. The dimensions of the soil layer and the properties are shown in Table 1 and 2. The nonlinearity of soil plays an important role in the dynamic response of soil-structure arrangements in seismic designs. The equivalent linear method has been used by researchers for many years to calculate ground wave propagation and response spectra in areas with seismic excitations. In this study, the equivalent-linear method is [15] was adopted and used in the analyses. The model is used to perform a linear analysis with some assumed initial values for the attenuation ratio and shear modulus in the different areas.

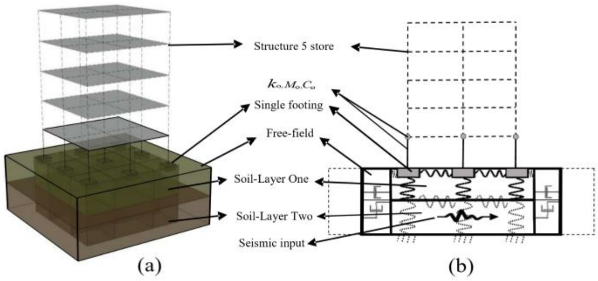

Figure 1. Supported by foundations considering dynamic soil-foundation-structure interaction with building in seismic motion (a) 3D model clarifies (b) Model 2D supported by foundations considering dynamic soil-foundation-structure interaction with building.

Table 1. The dimension of soil (SI)

Dimension	Length (m)	Width (m)	Depth (m)
Soil layer (one, two)	14	14	4
Free-field	20	20	8

The structures (beams and columns) were simulated with wire deformable, the floor slabs with shell deformable and the foundation with the stiffness structure of the model. The dimensions of the beams, columns, slabs and foundations are shown in (Tables 3) respectively, the structural elements were modeled with elastic-plastic properties and yield stress of concrete (σ_y) was assumed to be equal to the compressive strength of concrete (f'_c) (Figure 2) illustrates the elastic-perfectly plastic behavior

Table 2. The property of soil (SI)

		Elastic		Mohr-Coulomb plasticity			
Parameter of soil	Density	Young's modulus	Possion's ratio	Friction angle	Dilation angle	Cohesion yield stress	Abs plastic strain
Layer One	1595	4.5E+7	0.42	34	17	4.5E+4	0.0
Layer Two	1575	2.4E+7	0.43	30	15	3E+4	0.0

of the structural elements used in this study [16]. For the structural concrete used in this design and analysis, the specified compressive strength (f'_c), similar values for concrete reinforcement were presented in (Tables 3). For, interaction structure concrete related element used general contact (Standard/Initial) global property assignment used tangential behavior and normal behavior and friction coefficient (0.2). Pressure-termination selected hard contacts, constraint tie master column to slave surface foundation, master beam and slab to slave column were non-adjust slave surface initial position for the concert property (Table 4).

Table 3. The dimension of concrete (SI)

Concrete element	Length (m)	Width (m)	Depth (m)
Slabs	6	6	0.2
Columns	4	0.4	0.4
Beams	6	0.4	0.4
Single footing	1.5	1.5	0.75

Table 4. Property of concrete (SI)

Concrete	Young's modulus	Passion's radio
Plastic	3E+10	0.2
Concrete	Yield stress	Plastic strain
Elastic	2.5E+7	0.0
Density	2.4E+3	

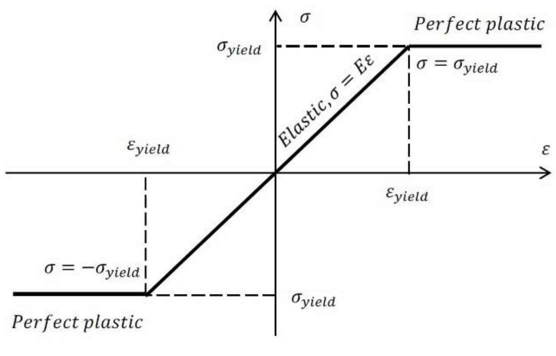

Figure 2. Illustrates the elastic-perfectly plastic behavior of the structural elements

3. EARTHQUAKES USING IN ANALYSIS

The seismic response of a soil-structure system during an earthquake is influenced by many factors such as soil type and parameters of the soil, height of the structure, and the material properties, but also by the frequency content of the earthquake and soil-structure interaction [17]. To account for the multi-layered effect of soil and soil parameters, analyzes were performed considering four different earthquakes. On the other hand, the influence of the frequency content of the earthquake on the seismic response of the soil-structure system was investigated considering the aforementioned actual ground motion records [9]. The analysis is performed for a five-story the building to investigate the effects of the building and the soil-structure interaction on acceleration response to the various seismic motions. Table 5 shows that the properties of four different earthquake case on multilayer soil for 5 story building. The effect of soil-structure interaction (kinematic) on foundation input motion is assessed by comparing the free-field motion and the foundation input motion [18] Input earthquake information including the Düzce 1999, Kobe 1995, Parkfield 1966, and Mammoth Lakes 1980 earthquakes referring to Table 5 and Figures 3, Figure 1b shows the model components and the numerical mesh for the building supported by the single foundations [19]. The analyzes were performed with meshes that had the same properties for all model dimensions, regardless of the finite element mesh variables, and to make the results comparable for foundations of different sizes.

Table 5. Earthquakes used in the analysis and their basic properties

Earthquake	Country	Year	PGA (g)	Mw (R)
Duzce	Turkey	1999	0.348	7.2
Kobe	Japan	1995	0.833	6.8
Parkfield	California	1966	0.367	6.0
Mammoth lakes	USA	1980	0.416	6.1

4. METHODOLOGY AND ANALYSIS METHOD

There is continuous research on the impact of this interaction on the foundation under the dynamics of structure-soil interaction shows that the embedment of the foundation in the system with the natural frequency increase but increases with the internal friction in the soil. The soil-foundation structure interaction has two main effects on the structural response: the first is the soil-structure system with an increasing number of degrees of freedom and thus the changed dynamic properties, and the second is the essential part of the vibration energy of the soil-structure system, which emits waves from the vibrating foundation-structure system to the ground. is the system in which it is distributable by backpropagation. Bielak [20] according to whole equations including structure when the seismic motion act on structure position foundation there is a difference about the following point by comparison with fixed type at the foundation soil behavior and surface layer have an effect spring and damping for a frequency depend on function the result is denoted by equation 1 and 2 [13,21].

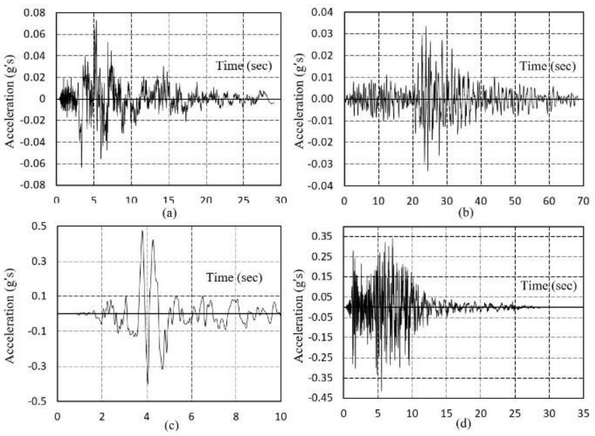

Figure 3. Complete earthquake records: (a) Duzce (Turkey) 1999; (b) Kobe (Japan) 1995; (c) Parkfield 1966; and (d) 1968 Mammoth Lakes 1980.

$$U = \frac{m_o + \frac{8Pa^2H}{\pi}\sum_{n=1,3,....}^{\infty}\frac{1}{n^2}\Omega_n}{R_o - m\omega^2 + \frac{8pa^2H}{\pi}\omega^2 q \sum_{n=1,3,....}^{\infty}\xi_n^2\frac{\Omega_n}{n^4}} uq\omega^2 \text{ .....1}$$

$$U = \frac{m_o + D}{R_o - m_o\omega^2 + S} uq\omega^2 \text{ ....2}$$

$$f = \frac{m_o H_s + \frac{16a^2PH^2}{\pi^2}\sum_{n=1,3,...}^{\infty}\frac{(-1)^{\frac{n-1}{z}}}{n^3}\Omega_n}{R_R - I_o\omega^2 + \frac{32a^2PH^3}{\pi^3}\omega^2 q \sum_{n=1,3,....}^{\infty}\xi_n^2\frac{\Omega}{n^4}} uq\omega^2 \text{ .....3}$$

$$\Omega_n = \frac{k_1(\gamma_{Ln}) + k_1(\gamma_{Tn})A_n}{k_1(\gamma_{Ln}) + \gamma_{Ln}K_o - k_1(\gamma_{Tn})A_n},$$

$$A_n = \sqrt{n^2 - \left(\frac{\omega}{\omega q}\right)^2 + l2hg\frac{\omega}{\omega g}n^2} \text{ ....4}$$

Where; $\omega_{g = C_T\frac{\pi}{2H}}$ is pseudo damping constant on a surface elastic layer (K_w) is 2nd kind modified Bessel function (C_T) is transverse velocity (C_w) longitudinal velocity. (D) and (G) in the equation (1), (2) mean soil pressure and real part of (S) and (F) mean spring effect, imaginably part of this mean damping effect. Whole equation including structure (s), (y) define Laplace's parameter and absolute displacements respectively, whole equations are gained like an equation (3)

$$S^2[M]\{Y\} + S\,[C]\{Y\} + [K]\{Y\} = -[M_\circ]\{\ddot{U}_g\} \text{ ....5}$$

where {Y} c {y} ,{U} c {u} use matrix to find (M), (K), (C), (Y), ($M_\circ$) in the matrix $[M_\circ]$ meaning external force [K] meaning stiffness (S), (F) are added and (s) change the position i_w (i = $\sqrt{-1}$), the displacement transfer function is defined as

$$\frac{D_{j=}\,Y_j(i_w)}{\ddot{U}_g(i_w)} \text{ for j=1,2,3....., n, and } \Psi\,\frac{i_w}{\ddot{u}_g}\,(i_w)$$

These transfer functions represent the amplitude and phase of the steady-state response of the building soil system subjected to a harmonic ground motion of unit amplitude. $Y_g(i_w)/\ddot{U}(i_w)\,\frac{Y_\circ}{\ddot{U}_g}, \frac{\Psi}{\ddot{U}_g}$, represent the transfer function of (j) the story, swaying, rolling motion respectively [22].

Time series responses are obtained as Fourier inverse transforms [16]. Soil structure interaction dependent discrete model recommended by considerable half-space of unbounded soil, gradually formation of the gap induces more deform, the discrete structure consists of a mass attached to rigid structure support with spring and with a damper ($M_\circ, K, C_\circ$) Figure1. There are some coefficients independent frequency [23]. The discrete structure is semi-empirical, Dynamic soil-structure interaction dependent substructure method. Several approaches have when special free field ground motion based on the foundation rigid dynamic response of elastic half-space. They are required in cases where a fixed base is not representative of real conditions (e.g. when the lower boundary is placed within a uniform half-space) [24]. The foundation is placed on the surface of a uniform half-space. The method is well suited for problems that are characterized by a single seismic source on the surface of, or embedded within, a homogenous medium. This includes SSI problems with a single surface structure on a half-space. However, the method is not exact for surface waves or for body waves arriving at multiple angles [18,24,25]. There are two methods of assessing the above effects, direct and indirect. Both are included in the same model and analyzed as a complete system. The soil and structure are represented as a continuum. The Direct analyses render all of the SSI effects, however, in practice, this approach is generally avoided because of high computational time especially when the geometry of the system is complex or irregular [26]. Substructure approach, this method is quite convenient and a step-by-step procedure. In the first step, the motions of the soil in the free field are determined, and in the next step, the transfer functions are calculated to convert the motions of the free field into the motions of the foundation. The analyzes performed in this study were conducted using Abaqus. The process was repeated to ensure that there were no errors and that the result was indeed closed. In the Abaqus simulation, the model consists of whole layers of the structure (one and two) and the free field that has the characteristics of the soil, because there are two soil layers that are analyzed in two cases, in the first case is the soft soil above, but in the second case is the hard soil above that the foundation in its and all four earthquakes are analyzed that each time a case is analyzed. The influence of soil-structure interaction dynamics between the direct method and the substructure method. The substructure method is another suitable method because the free field was chosen to facilitate the model and informal understanding. It is another standard used under layer two for facilitating the simulation until the single foundation nature has become visible after the analysis and interval of foundation movement of reality after loading on it and after earthquake. The coefficient of friction is the contact between soil and single foundation was taken as (0.2). The free-field elements have three functions [25]. First, the static and dynamic behavior is simulated, second, the elastic stresses in free space are converted into surface tractions applied to the adjacent face of the main model, and third, an absorbing limit is provided for outgoing seismic waves in the main model (Figure 4). The free-field element is associated with three system matrices the stiffness matrix (K), the damping matrix (C) and the mass matrix (M) [13].

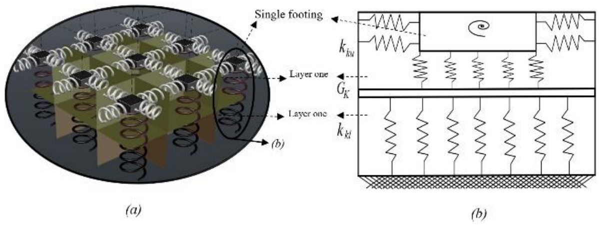

Figure 4. General boundary conditions resting (a) Kerr's model 3D (b) Kerr's model 3D (or modified Pasternak).

The respective mathematical equations as derived by [27] are given by.

$$p = k_p w_0 - G_p \nabla^2 w_0 \quad \ldots.6$$

Where k_p= spring coefficient per unit area G_p coefficient of the shear element in Pasternak's model with the dimension of force per unit length; and ∇= Laplacian operator [27] for one layer soil but for two-layer soil equation….5

$$p - \frac{G_K}{(k_{k_u} + k_{k_l})} \nabla^2 p = \frac{k_{k_u} k_{k_l}}{(k_{k_u} + k_{k_l})} w_0 - \frac{G_k k_{k_u}}{(k_{k_u} + k_{k_l})} \nabla^2 w_0 \quad \ldots..7$$

Where, k_{k_u} and k_{k_l} = stiffness per unit area of the upper and lower spring beds, respectively; and G_K = coefficient of the shear element [27].

Numerical computations are carried out in two steps: (I) Static computation to initialize the stresses and the internal variables of both the soils and the superstructures constitutive models; (II) Dynamic perturbation analysis around the stress state and the internal material memory obtained in the static computation [17]. The finite element meshes used for modeling different in structure for column and beam (wire) is B31 (Beam in space, linear). for slab (shell) is S4R (Conventional stress/displacement shell (S), 4-node linear brick, reduced integration) for a single foundation is C3D8R (Continuum stress/displacement (c), three-dimensional, 8-node linear brick, reduced integration, hourglass control elements). Shown in Figure 5 (a, c) in the soil for layer one and layer to together is C3D4 (Continuum stress/displacement (c), Three-dimensional, reduced integration) and free filed is C3D10. (The three-dimensional, 10-node linear one-way infinite brick). The analyze of the seismic wave's movement in the soil and effectively on the structure has been beholden in Abaqus in boundary condition and loads in the structure and the soil. Gravity loading was calculated by the type of body force and the boundary condition set in the bottom of the second layer and the free field. Attention to vertical then the interaction between the layers, soil, single-foot, and the building structure, with mesh. The dynamic soil-structure interaction impossible to exercise any effect in the free field zone, but it has a continuous boundary until the analyses are simpler.

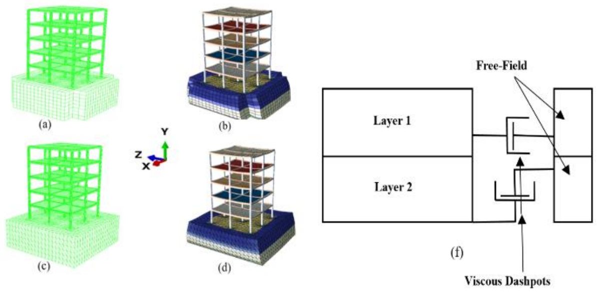

Figure 5. (a, b) illustrate the method for take free-filed (c, d) illustrate choose method in study this paper its (f) 2D.

The system used two types of boundary conditions for displacement rotation in the initial step-free x-axis and fixed all-direction for acceleration in dynamic steps (1 kN) spoke for the x-axis and take amplitude according to the (4) double model, used gravity load for the system. Infinite boundary conditions were assigned to the numerical model to simulate free field boundaries. For different free field, two of them will be selected almost behavior effect seismic motion in structure-soil interaction in a realistic model according to Darbre and Wolf [28].

5. RESULTS AND DISCUSSION

The model was analyzed for different earthquakes depending on whether the soft ground is on top and the hard ground is on the bottom, or whether the hard ground is on top and the soft ground is on the bottom, and the results are shown in Figure 6, Figure 7, Figure 8, and Figure 9. From these figures, it is clear that earthquake features are very effective in evaluating soil-structure interaction based on the first (a) and second cases. Considering the differences in Düzce 1999, Kobe 1995, Parkfield 1966, and Mammoth Lakes 1980 earthquakes, it is easy to conclude that the analyzes emphasize the earthquake effects. Depending on the earthquake acceleration, different displacements of the structural elements are observed for two different models for each earthquake (Figure 10). In the Düzce earthquake, whit the soft ground is on top, the largest displacement in the slab occurred at 4.2 second. However, when building a foundation on hard soil, larger displacement in the columns occurred at the same time. Moreover, the deformation of the plate in the model with the hard ground at the top is quite small. In the other 3 earthquakes, similar deformations of the structural elements occurred in both models. As can be seen from the corresponding figures, the displacements in the model with the soft ground at the top start before. When comparing the stress states obtained from the analyzes (Von Mises), it was found that the stresses (pa) to which the foundation, column, beam, and slabs were subjected during earthquakes changed significantly as a function of time (sec) (Figure 10). Each earthquake created different stresses on the building elements at different times, depending on the soil layer properties (Figure 11). The Parkfield earthquake and the Mammoth lakes earthquake caused enormous stresses in the structural elements in both models. As can be understood from the results obtained, it is important to consider earthquake properties, soil properties and foundation type in dynamic soil-structure interaction.

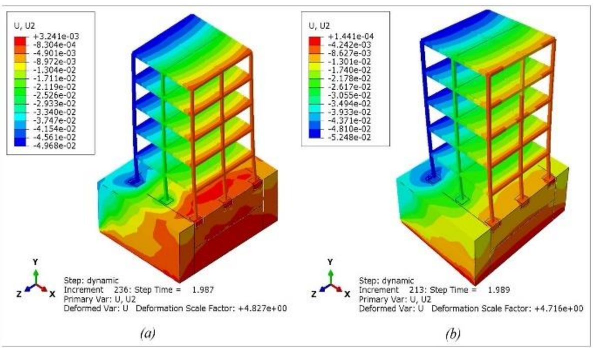

Figure 6. Influence of 1999 Düzce earthquake (a) simulation displacement (Y-axes) in case One displacement in 1.98 Time (b) Simulation displacement (Y-axes) in case Two in 1.98 Time.

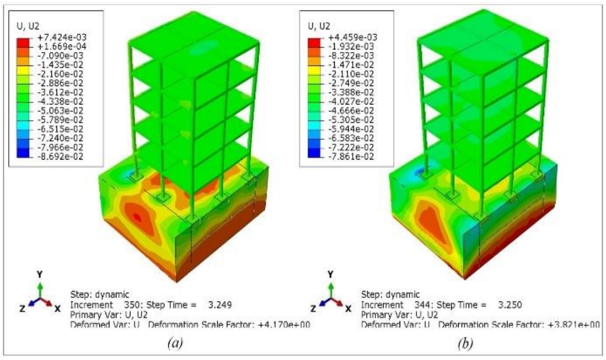

Figure 7. Influence of 1995 Kobe earthquake (a) simulation displacement (Y-axes) in case One displacement in 3.24 Time (b) Simulation displacement (Y-axes) in case Two in 3.25 Time.

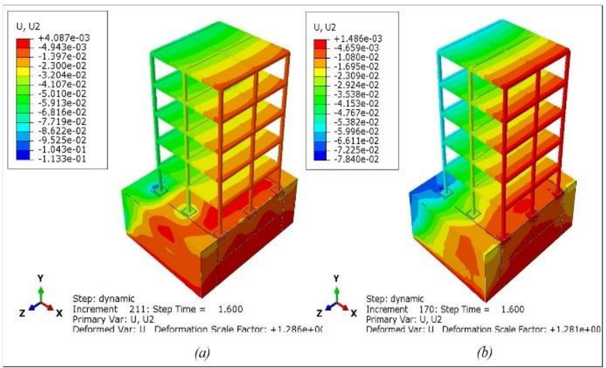

Figure 8. Influence of 1966 Parkfield earthquake (a) simulation displacement (Y-axes) in case One displacement in 1.60 Time (b) Simulation displacement (Y-axes) in case Two in 1.60 Time.

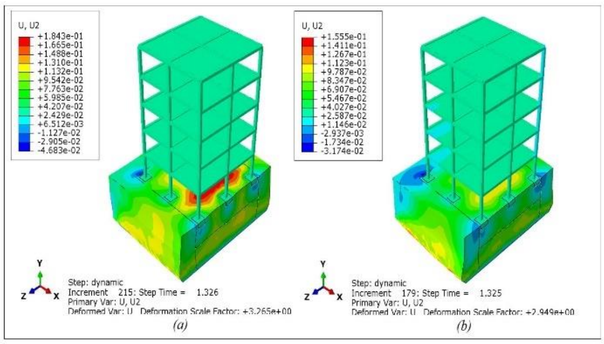

Figure 9. Influence of 1980 Mammoth lakes earthquake (a) simulation displacement (Y-axes) in case one displacement in 1.32 Time (b) Simulation displacement (Y-axes) in case two in 1.32 Time.

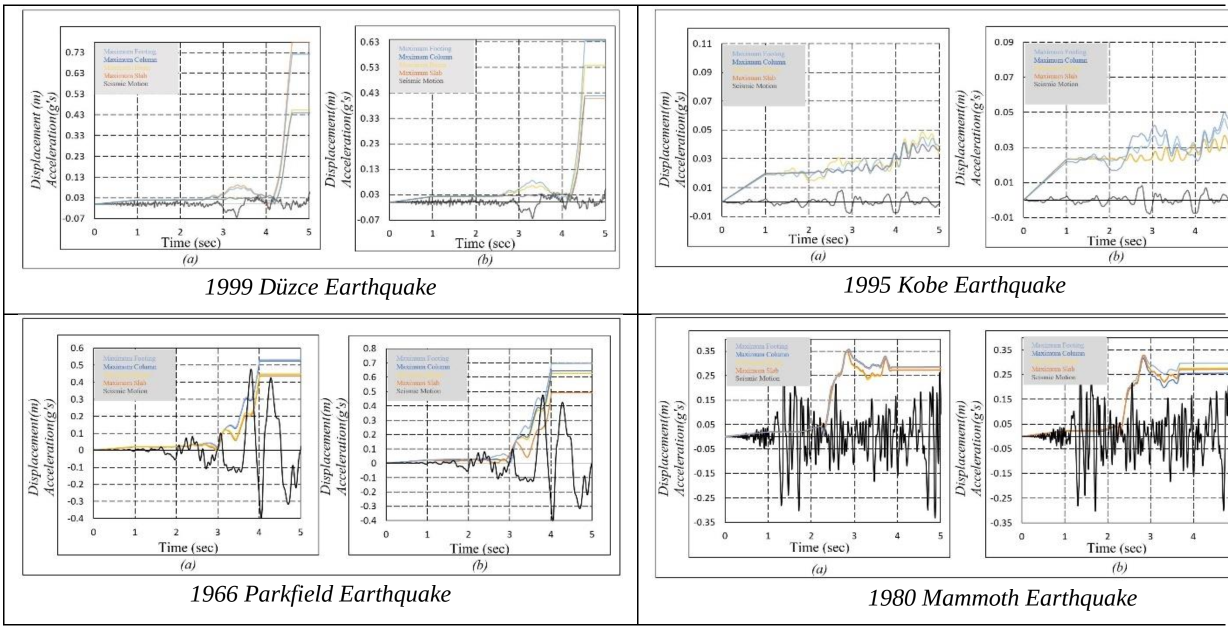

Figure 10. Response of part of structure with crave between Displacement and Acceleration according to the time and under earthquake: (a) maximum displacement element structure place case One; (b) maximum displacement element structure place case.

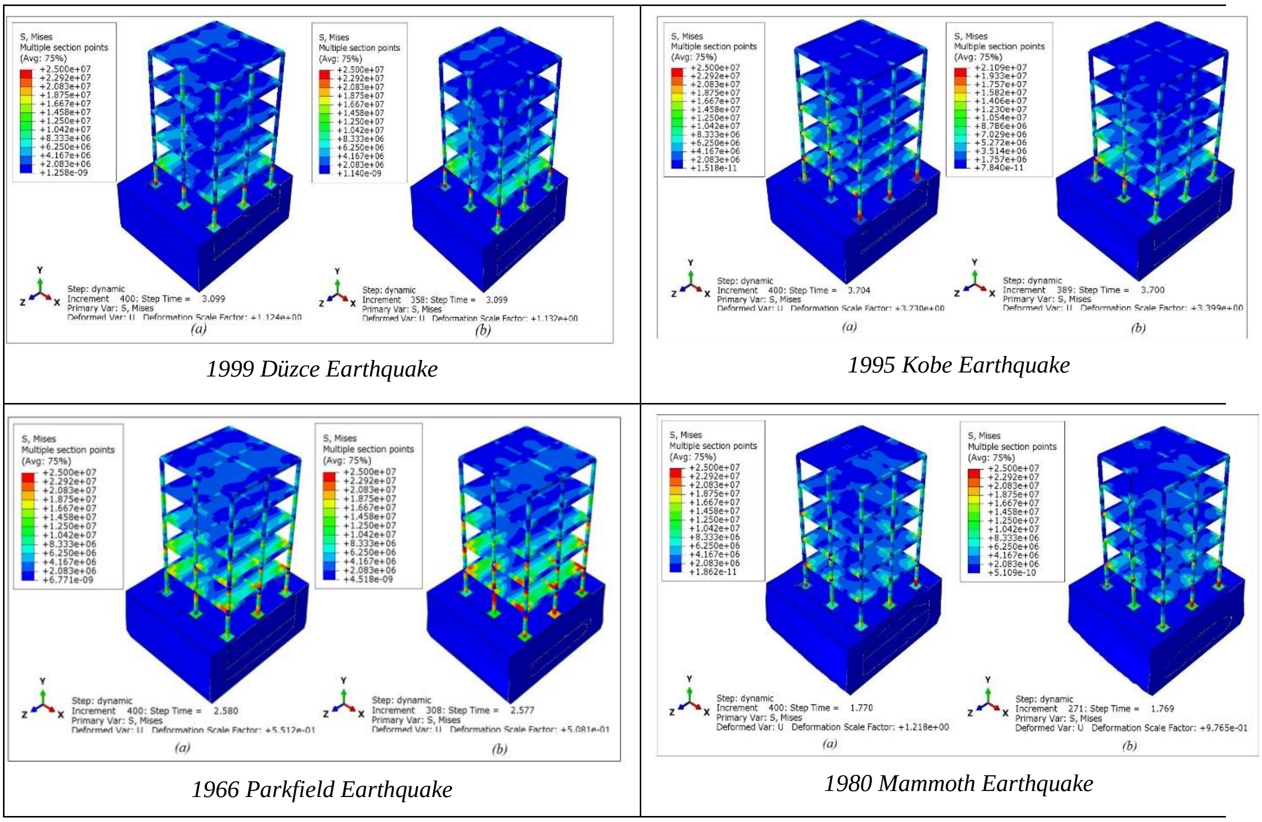

Figure 11. Influence of 1999 Düzce earthquake (a) simulation Stress (S, Mises) in case One stress in 3.09 Time (b) Simulation stress (S, Mises) in case Two in 3.09 time.

6. CONCLUSION

In this study, a soil-structure interaction model is analyzed in Abaqus finite elements. In the analysis, a reinforced concrete structure is modeled on foundation soil with different properties, considering the effects of the foundation soil and the earthquake situation. The results clearly show that the seismic properties together with the soil properties have a great influence on the structure. Although the obtained results are predictable in terms of geotechnical engineering, it is very important to prove that the finite element software, which has been frequently used in geotechnical studies recently, clearly shows this effect, in terms of the reliability of the data of similar studies. In addition, it has been evaluated that the performance of the software will give reliable results in terms of solving such engineering problems.

DECLARATION OF ETHICAL STANDARDS)

The authors of this article declares that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

AUTHORS' CONTRIBUTIONS

Mohammed Yadgar AHMED: Carried out the simulations designed within the scope of working with Abaqus. Helped write the first draft

İnan KESKİN: Discussed the results of the simulations and analyzed all results. Wrote the manuscript and directed the study.

CONFLICT OF INTEREST

There is no conflict of interest in this study

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