Earthquake Response of Building Analysis Considering the Type of Soil and Including the Effect Of SSI

1. Abstract

The reflection between both interaction and structures, such as base foundation and soil under the base foundation for studies analyses and design of the composition change the actual behavior of the structure than earn from the reflection of the structure only. It is a significant proposal in this study called soil-structure interaction, and the structure designer for earthquake engineering meanwhile it is carefully associated with the safety assessment of many crucial superstructure engineering projects, from all customary design practices is assumed the structures have been fixed base, however in the real design built on bendable area, the soil is capable and bends under foundation base of affecting constitution for motion, individual during sensational quake moving. In this investigation and paper design building of the structure and the assets of twelve-story floors is modeled to four different types of soil structure, such as fixed base structure, very dense soil, medium soil, and weak soil, for dense soil shear wave velocity is equal to $(500\, m/sec)$, for medium soil shear wave velocity is equal to $(250\, m/sec)$, for the weak soil, shear wave velocity is equal to $(120\, m/sec)$. A common method used for modeling SSI is the Finite element Method for the simulation of structural behavior, for the structural analysis put on strong earthquake records, and for linear structural analysis by the software program SAP2000. The primary goal of this research study has been to consider the effect, structure behavior, and influence of both interaction and structural behavior and the type of soil that is constructed. The Phenomenon of design includes SSI and is compared with straight design by determining: 1. Displacement 2. Drift between each floor 3. Max. Shear force 4. Max. bending moment 5. Max. torsion and spectral velocity SSI models

Keywords: SSI, earthquake, Finite element method, shear wave velocity

2. Introduction

Soil–structure interaction (SSI) is an in disciplinary field of effort which duplicities at the connection of soil and structural technicalities, dynamics of soil and structure, engineering of earthquake, geophysics and geomechanics, the science of materials, computational and numerical methods, and diverse other technical restraints. The approaches, in which the response of the soil structure effects of indication behavior of structure and response of the structural effects of the indication of the soil structure is denoted to SSI. Many several periods of the Soil-structure Interaction was fundamentally based on the supposition equivalent linear elastic and linear soil performance [1] [2]. SSI effect on the structural response by seismic was broadly considered more than the last five periods. In recent years some few exclusions, like research studies estimate the effect of SSI on structural behavior see, for example, [3][4][5]. Research on dynamic soil-structure interaction in earthquake engineering shows that this interaction generally increases the flexibility of a structure and its effective damping due to the energy loss throughout the soil, [1]. Studies on dynamic soil-structure interaction in the engineering of earthquakes display that the flexibility of a structure commonly increases due to this interaction and the energy will be lost, making it effective damping. SSI was usually considered to be constructive to the seismic response of a structured behavior.

The reaction of any structure during earthquake shaking depends on the combination cycle between structure and foundation, the first structure, second foundation, third soil below and soil around all contact faces of the foundation, on another hand, Soil structure interaction analysis is calculated all cycle combination reactions to special earthquakes. Some of the researcher used the statement Soil-Structure Interaction (S.S.I) and Soil Foundation Structure Interaction (S.F.S.I). During shaking by the earthquake, the response of somewhat structure is certain of a combination cycle between the foundation base and structure shape. Meanwhile, SSI analysis determines all cycle combination reactions to the exceptional earthquake, there have been some researchers that worked before and used the statement of SSI and Soil foundation structure interaction (SFSI) [6] [7].

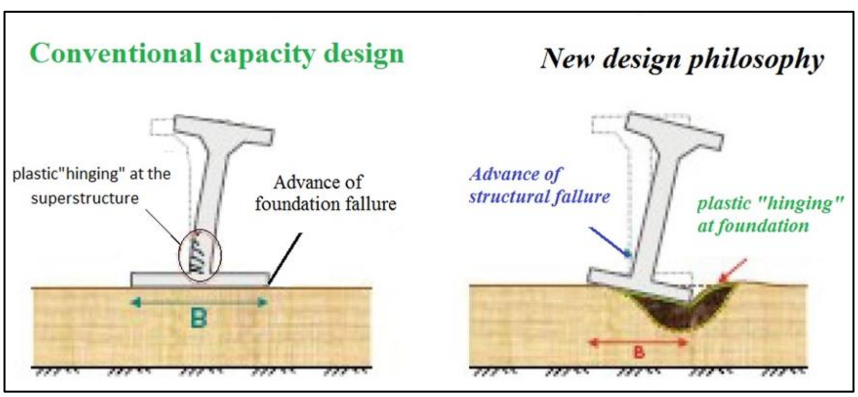


Figure 1: The conventional design which fixes base theory and new design philosophy include SSI

The effect of interaction is strong in certain properties of structural dynamic, properties of base foundation geometric, and properties of supporting medium and 5-free field earthquake characteristic [8]. Different foundation quake is related to free field ground quakes. The response of the soil bearing is a response to the structure and the response of the structural properties of soil reply, denoting SSI [9]. There is a small quantity of investigates observing the SSI effect on the seismic show of super-tall buildings [18] the Shanghai Tower was taken as the research aim and object and the effect of the SSI on the dynamic properties and seismic displacement reactions. Many researchers investigate seismic analysis of soil-structure interaction for different types of structures such as bridges, minarets, etc [19] [20] [21]. In past years, numerous investigators have conducted research on the properties of SSI on the dynamic seismic response of the structure [22][23][24] and noted that SSI may be very significant for medium- and long-age structures when the principal site ages are large. The rate of shear force increases more pronounced on the mid story as compared with the ones remaining story. This may lead at the explanation of heavy damage on the midrise buildings under the resonance at some seismic including SSI [25]. Dynamic (SSI) is also significant in designing big superstructure developments for the structural author and insurance companies, trying to present the theory of performance. Based design in the engineering community requires a more refined model to maintain engineering requirements parameters [26].

The main objective of this study is to examine the inspiration, effect, and behavior for interaction between structure and soil that construct on it during earthquake mode, and covenant for new spectacles of design and compare with straight design (fixed base design) by determine (i) displacement,(ii) drift between story floor, (iii) Max. Shear force, (iv) Max. Bending moment, (v) Max. Torsion and spectral velocity for fixed base design method and soil-structure-interaction for the different type of soil structure, (very dense soil, medium dense soil, and loose soil). In this paper, it uses finite element method software program called SAP2000 it a common software used worldwide that used to structure analysis.

3. Overview of Soil-Structure Interaction

All combined response of the structure behavior are assessed by earthquake soil-structure interaction (SSI), the foundation and geologic zone below and boundary of the base foundation to designate free field ground effort. The structure vibration or wave speared is not made an influence for free field state and that one of base foundation around. The theoretic concept has been neglect of the effects of SSI, then the structure unbending base substance was resting with the stony area or very rigid soil, thus SSI for identified the dissimilarity in the middle of the real response of the structure behavior and response of the fixed base structure behavior [7]. The effect of Soil-Structure Interaction for the proposal of the structure behavior and engineering analysis be subject to this three key parameter be located below: [10]

1. Base foundation Rigid and damping of structure, and inertia interaction develop vibration of structure then gives increase to base shear, torsion and moment of inertia. Due to these forces and loads on the contact are of soil and base foundation make lateral displacement and rotation of base Happening.
2. The dissimilarity between base foundation input and free field ground movements, it is deferential happen between free field movement and base foundation indication by reason of Interaction of kinematic and relation between deflection and rotation, foundation and free field.
3. Foundation bends. Deflection, loads and displacements are applied by both structure and the soil, the elements of the foundation have to design to which kind of zone in earthquake and demand, and it is significant, good for flexibility and weak foundation structures for instance raft foundation and piles.

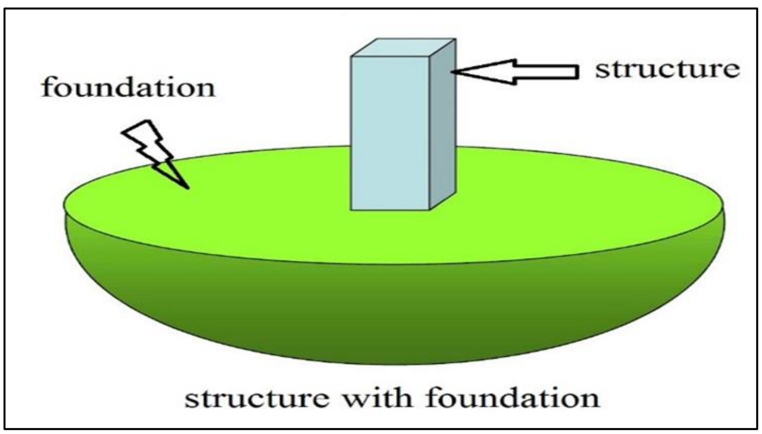


Figure 2: (a) foundation with the structure

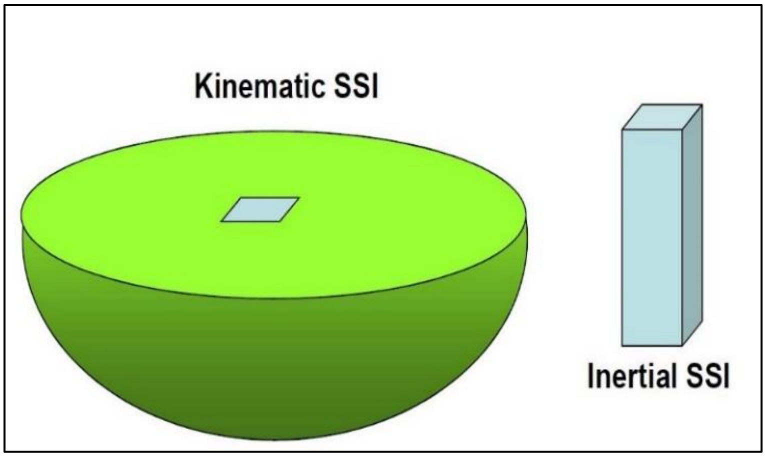


Figure 2: (b) illustrative kinematic and inertia soil structure interaction [9]

4. Kinematic Interaction

Kinematic interaction outcome from the stiffness of the foundation combination up or below the soil, which reason movement at the foundation to separate from free field movement. Base slab averaging one reason of these separate, the stiffness and strength of the combination foundation reason to change magnitude and response of earthquake within structure wrapper are averaged within the foundation footmark.

The stiffness of the base foundation from up and below the soil in the structure is the kinematic interaction, which causes undertaking at the foundation to be discrete from free field movements. And it has one cause is called base slab, The magnitude and reaction response of earthquakes change by the stiffness and strength of the combination base foundation intention within the structure wrapper are averaged within the foundation footmark, and the second cause is discrete Second reason of discrete is denoted effect in any foundation structure level movement is decreased as a result of seismic Reduction with depth under the ground level [11].

5. Inertial Interaction

Inertial interaction effects are generally obvious for the essential methods response of the flexible base system, furthermore, responses related to higher modal frequencies are relatively small [12][13]. The lateral response is reduced by the kinematic interaction in generally, and the similar response will increase nor reduce due to inertial interaction. The inertial interaction related via displacement, rotation and deflection on the foundation of the structural behavior.

6. Methods for analysis Soil structure interaction (SSI)

There are currently two major methods for analyzing seismic soil-structure interaction and determining the effect and structural behavior of soil-structure interaction, these methods are the direct method and substructure approaches method [14].

6.1 Direct analysis

The soil and structure with the foundation are included within the one integrated model completely analyze together. As showed in Figure 3 and 4 usually soil characterized as a continuum together with base foundation and structural elements, for instance, finite element, transmitting boundaries at the limits of the soil mesh, and interface elements at the edges of the foundation. Transferring limits at the boundaries of the soil finite element and interface elements at the foundation edges.

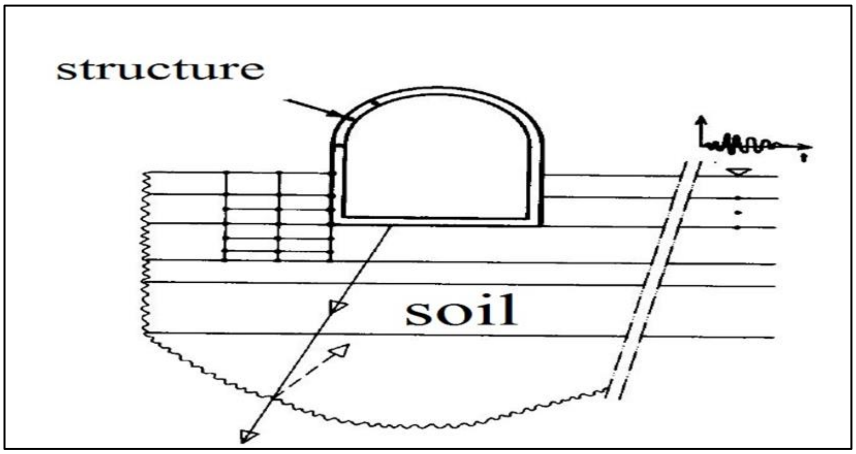


Figure 3: Fundamental objective of SSI analysis [15]

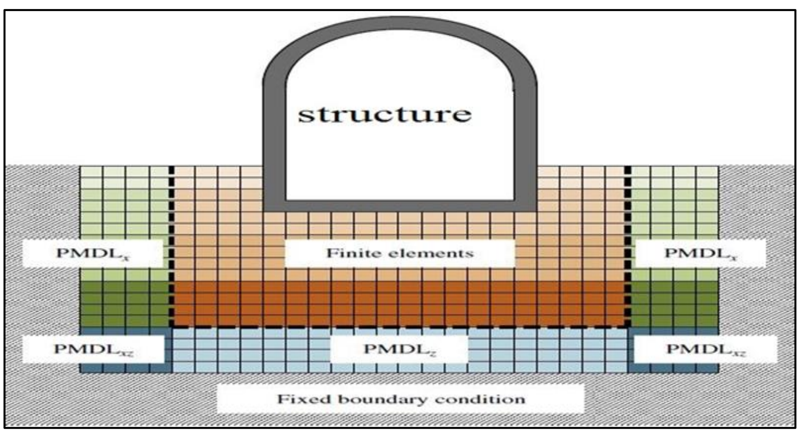


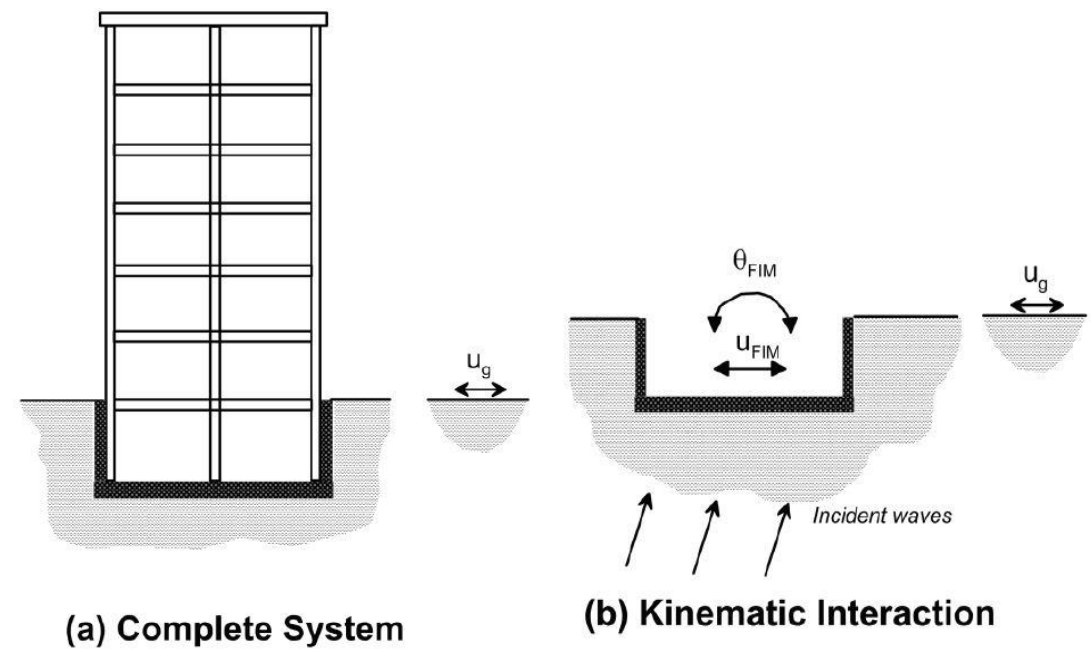
Figure 4: Direct Analysis (finite elements) soil-structure-interaction [16]

6.2 Substructure Approach

Substructure approach, The SSI problem is split into several parts, which are combined to formulate the complete solution. The reflection of Soil-structure interaction that effects on substructure approach related to:

1. Same properties of soil material and evaluation of free field ground action.
2. Evaluation of transfer function for the change of free field action within details.
3. Joining springs and dashpots to display inflexibility and damping at the ground base foundation interface.
4. Response analysis of the combined structure spring and dashpot method with foundation input movement applied.

The substructure approaches require a hypothesis of a linear ground and property and behavior of structure, also in practical this supplies frequently only rely on an equivalent linear sense such as shown in figure 5. [17]



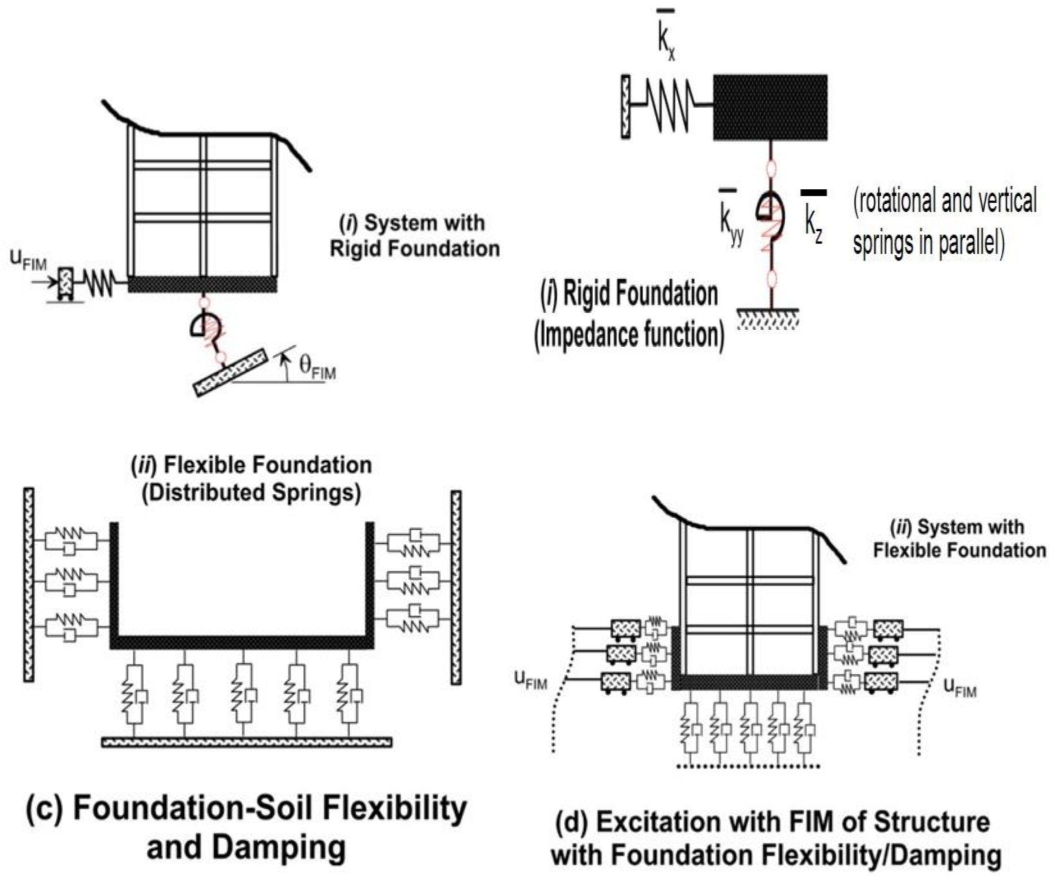


Figure 5: Representation diagram of a substructure approach to the analysis of soil structure interaction using either: 1- Rigid foundation; or 2-Flexible foundation assumptions. [17]

7. Different types of soil that studied and investigated in this research.

the time-averaged V_S30 is calculated as 30 m divided by the sum of the travel times for shear waves to travel through each layer. The travel time for each layer is calculated as the layer thickness (d) divided by V_S. [27], showed in Eq.1

$$VS30 = 30 / \Sigma (d/VS) \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(Eq.1)}$$

Where (d = depth of soil layer, Vs=shear wave velocity)

The shear modulus was calculated by using the equations of (Eq.2)

$$G_{max} = \rho (V_s)^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(Eq.2)}$$

Where (ρ=density, Vs=shear wave velocity)

And the elasticity modulus was calculated by using the equations of (Eq.3)

$$E_{max} = 2(1+\nu)G_{max} \quad \text{………………………………...……….} \quad \text{(Eq.3)}$$

Where (ν= Poison ratio)

7.1 Structure and dimension description of reinforcement concrete building.

The reinforcement concrete structure building contains mat foundation, the structure was designed by the Eurocode standard (EN 1992-1-1 PER EN 10025-2). The compressive strength for this design is equal to 30 MPa, and the tensile strength of steel is equal to 420 MPa. The dimensions and material used for in design of the structure shown in table 1 below

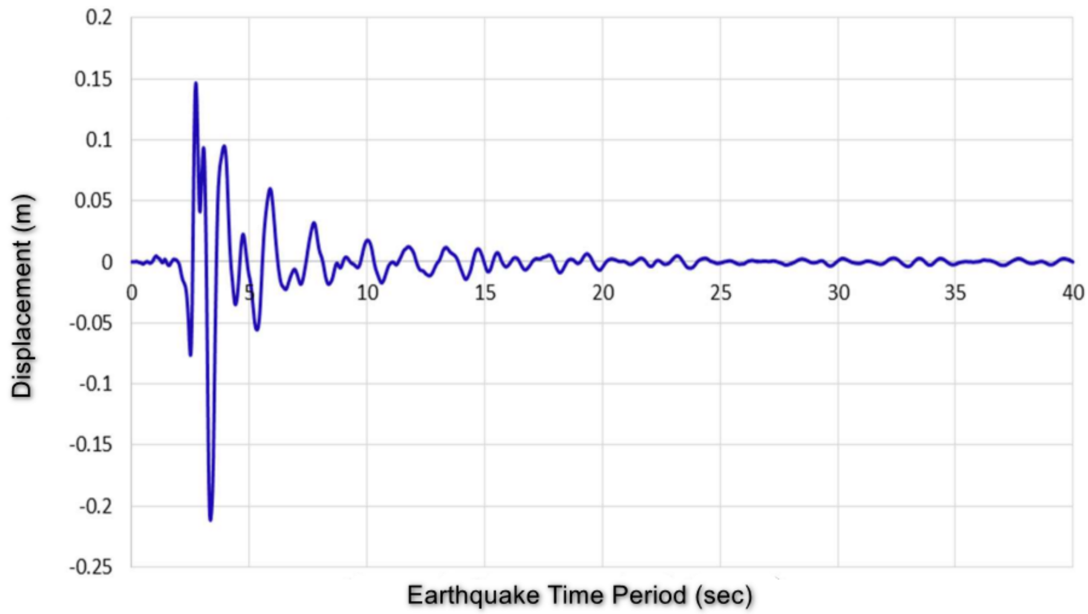
Table 1: the property of the material used to design allows the structure

Type of soil	Shear wave velocity (m/sec)	Poisson ratio ν	Density (KN/m^3)	Modulus of elasticity	Shear modulus
Very dense soil	500	0.3	18	1192600	458692
Medium dense soil	250	0.35	16.5	283800	105111
Loose soil	120	0.4	15	61600	22000

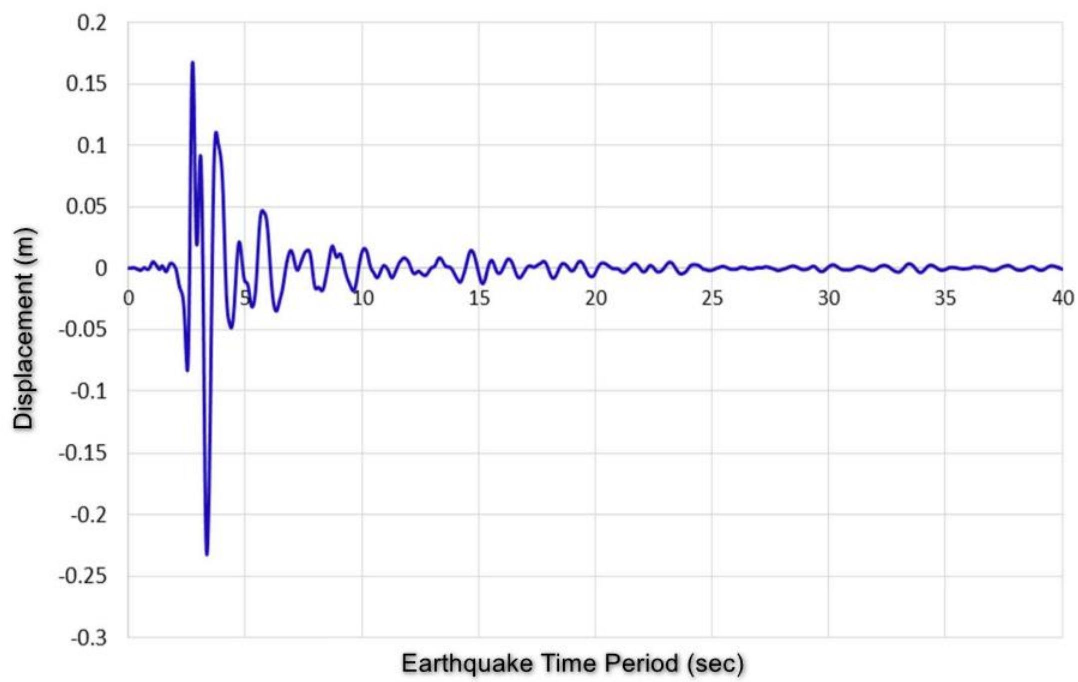
8. Result and Discussion

8.1 Displacement

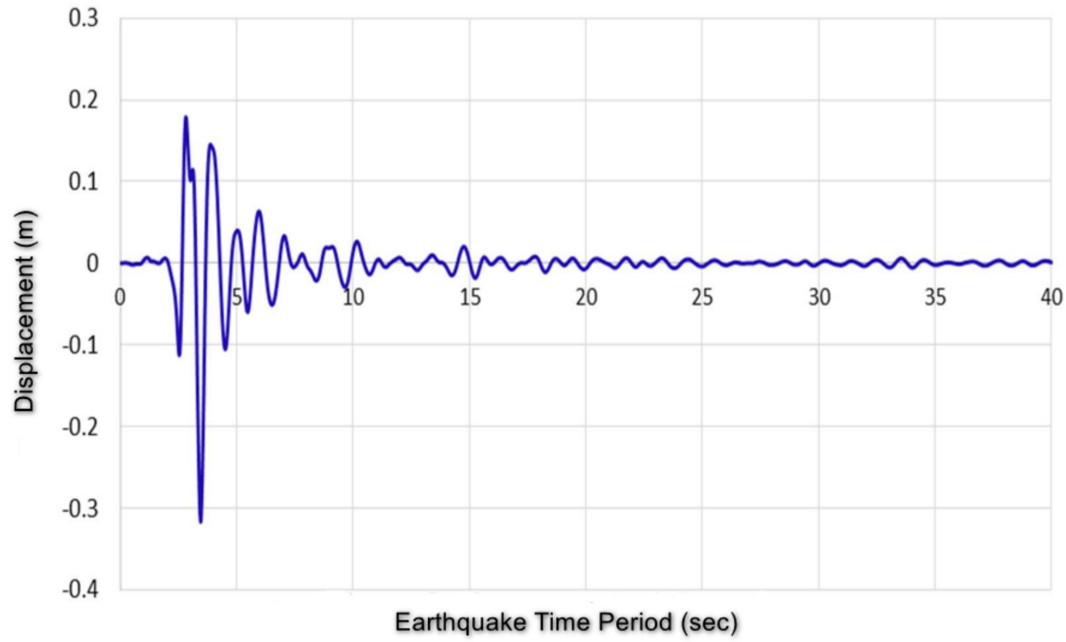
The displacement mention to the distance of the building change from an original point due to the seismic waves. This study investigated changes in the type of soil on this structure built, for the increase and decrease of the displacement of the structure, the strength and stiffness of this structure have big instructions. One of the most significant of design is Maximum story displacement and which type of soil structure can be the role it should be considered important, in this research models are considered and analysis from different types of soil foundations in the figure 7 show the maximum displacement of at last floor of building during earthquake period and from figure 6 explain the displacement of the top floor and variations with earthquake magnitude acceleration. and period



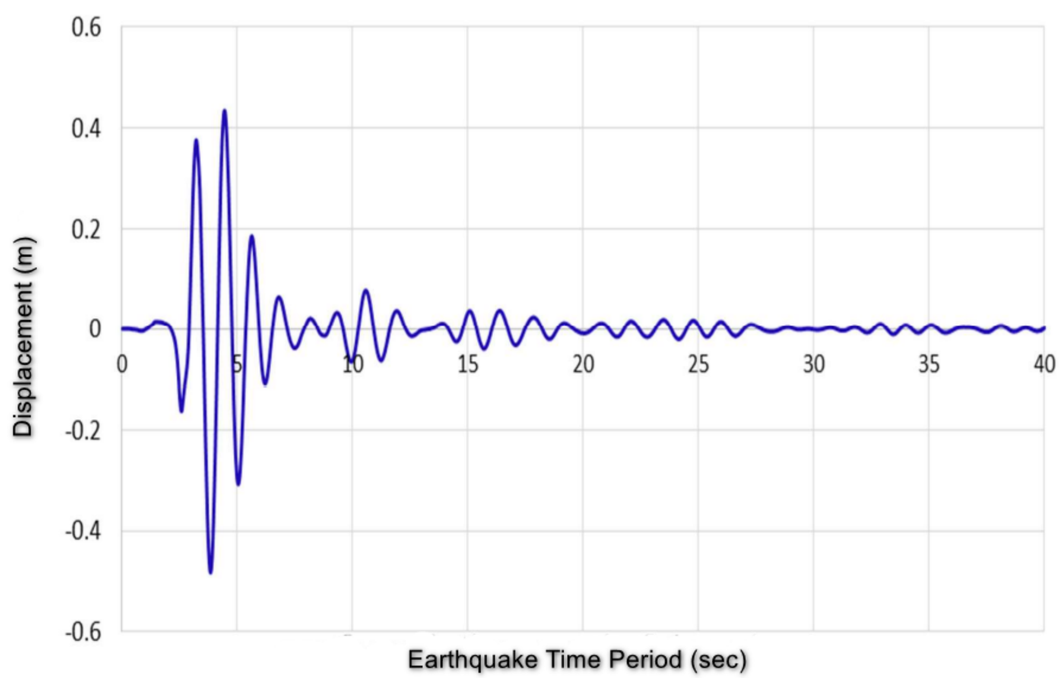
(a) The Displacement of the last floor through the earthquake exciting period for the fixed bass model



(b) The Displacement of the last floor through the earthquake exciting period for a very dense soil model



(c) The Displacement of the last floor through the earthquake exciting period for medium-dense soil model



(d) The Displacement of the last floor through the earthquake exciting period for loose soil model

Figure 6: explain the displacement of the top floor and variations with earthquake magnitude acceleration. and period (a) for fixed base model, (b) very dense soil, (c) medium stiffness, (d), Weak and loose soil

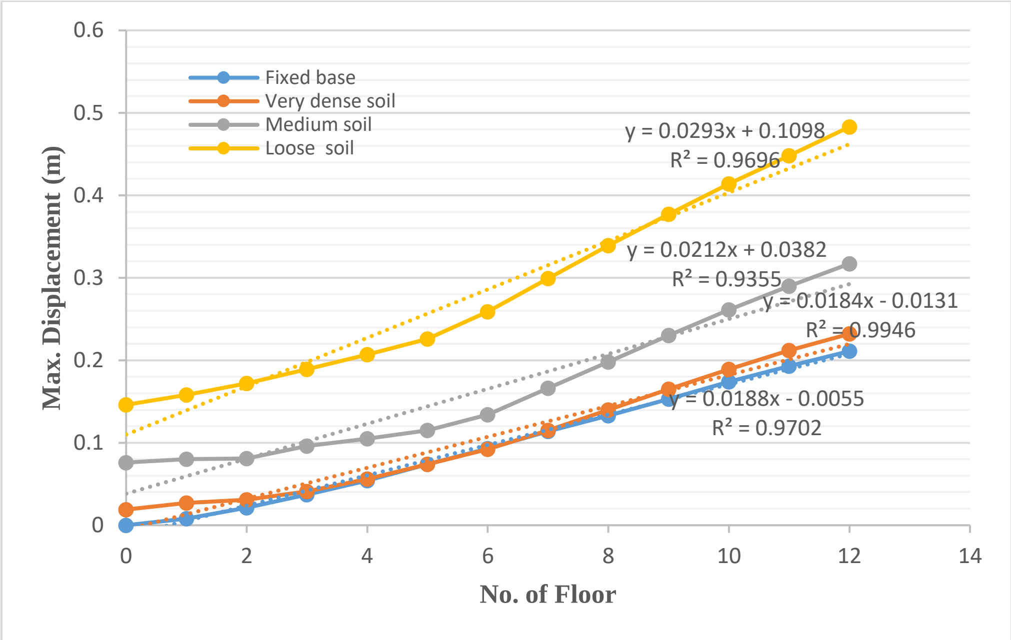


Figure 7: Maximum displacement for each floor in the x-direction

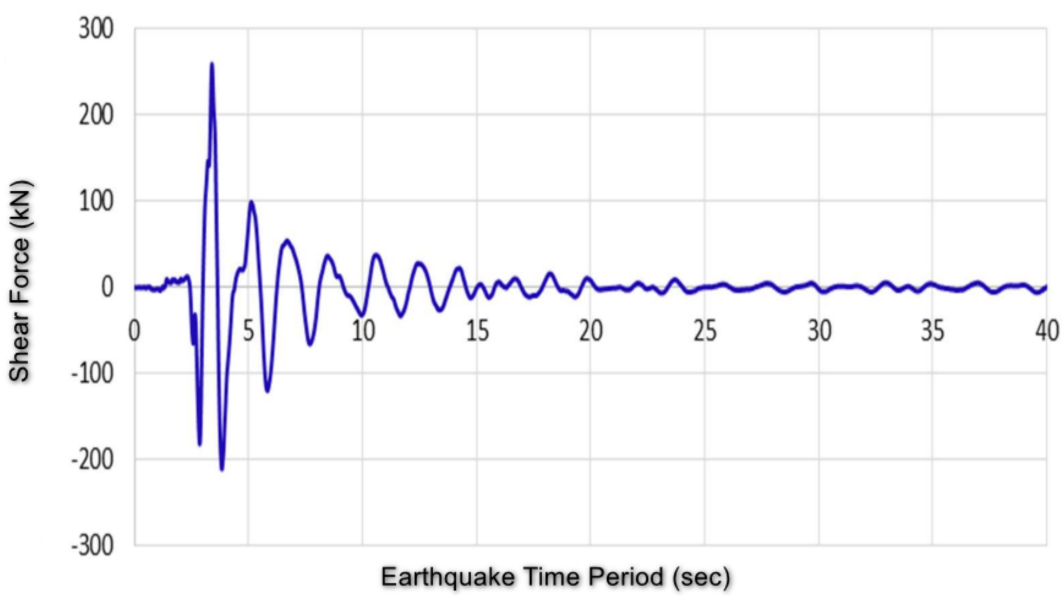
The displacement for building for separate floors summarized max. Displacement
In earthquake exciting from each floor, explained in figure 7.

In the result of how the displacement going to be changed by changing the type of soil, with decreasing stiffness and dens of soil the displacement will increase and between two models such as fixed base and dense soil or rocky soil have not big rule for change result due to can neglect, and for the medium soil extend displacement compare very dense soil and fixed base attributable to SSI reflect, it going to extend in (11cm) more than fixed base, mean that 52% increase more than fixed base and the (9 cm) more than very dense soil (39% increase more than very dense soil), in the weak soil type displacement increase over and above fixed base type of structure, extend of 27% over and above fixed base type, 128% over and above the fixed base, increasing 25 cm over and above very dense type of soil structure 108% increase over and above very dense type of soil, and increasing 16 cm over and above medium stiffness type of soil that 50% of it increase over and above stiffness soil. In this study showed that if any designer built a structure on weak and loose type of soil structure would be big wearing about displacement due to earthquake movement, meanwhile, any structure designer should consider SSI if constructing any building on weak or loose type of soil structure, special approach super high rise building structures, dam and nuclear project.

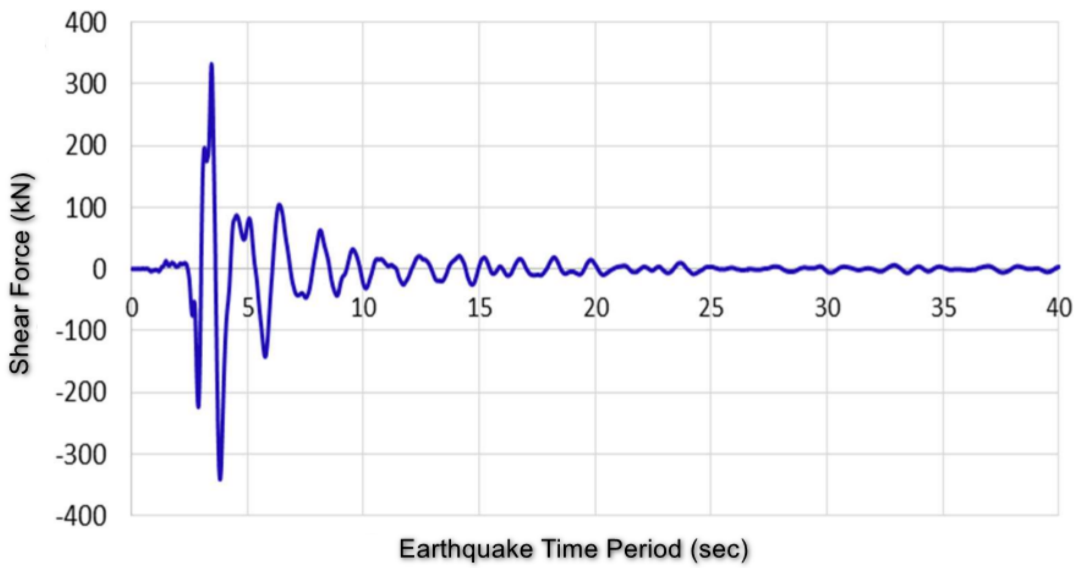
8.2 Shear force for base column includes the effect of SSI

On the shear force in a base column that shows from the front of the building with a cross-section (40×80) and the base of the frame building is equal to 3.2 m, during applying earthquake mode all the results will be recorded for each model, and show maximum shear force for each model showing result from figure 8 and 9 below.

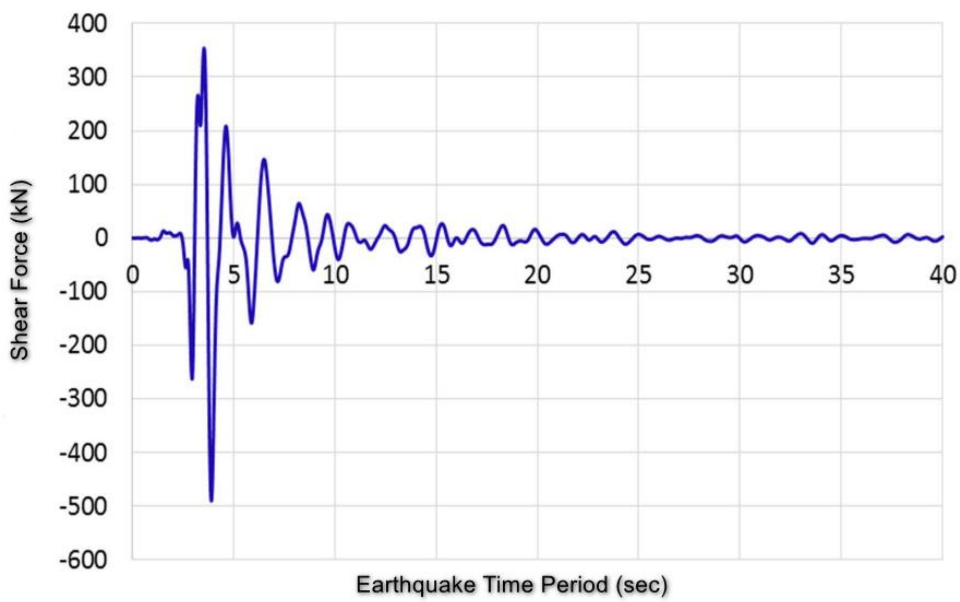
Vibration between the fixed base model and former model increase very dense soil by 31% over and above fixed base and medium soil is increased by 43% over and above fixed base and loose soil is increase by 186% over and above the fixed base model. And the quantity of the shear force is overexcited changing by the influence of SSI by using an analysis method that called the direct method. It should be very carefully using soil-structure interaction in analysis and future perspective.



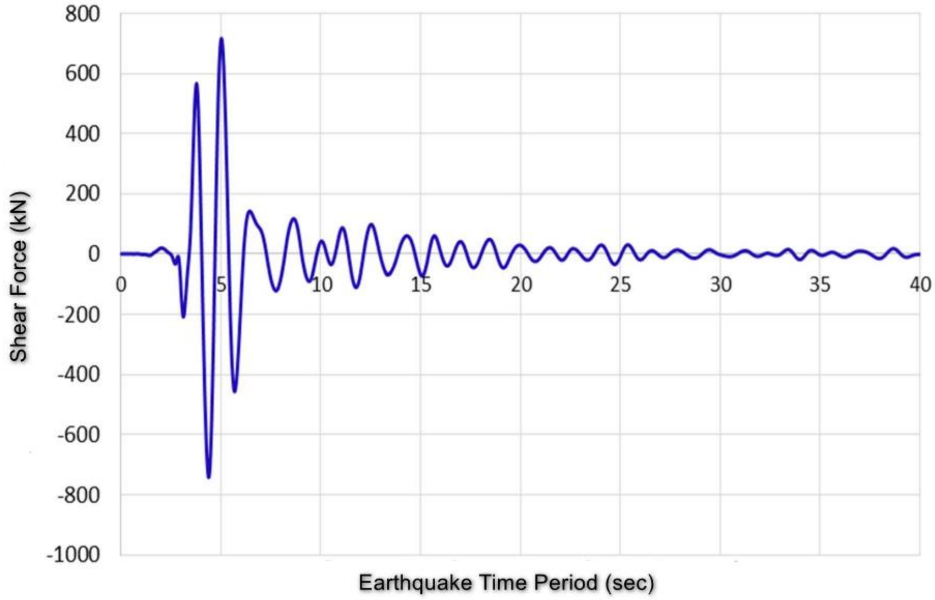
(a) Shear force for the base structural column through earthquake action on the exciting period for the fixed bass model.



(b) Shear force for the base structural column through earthquake action on the exciting period for the very dense soil.



(c) Shear force for the base structural column through earthquake action on the exciting period for the medium-dense soil.



(d) Shear force for the base structural column through earthquake action on the exciting period for the loose soil.

Figure 8: (a, b, c, d) Explain the shear force for the base column during the earthquake mode period in each model

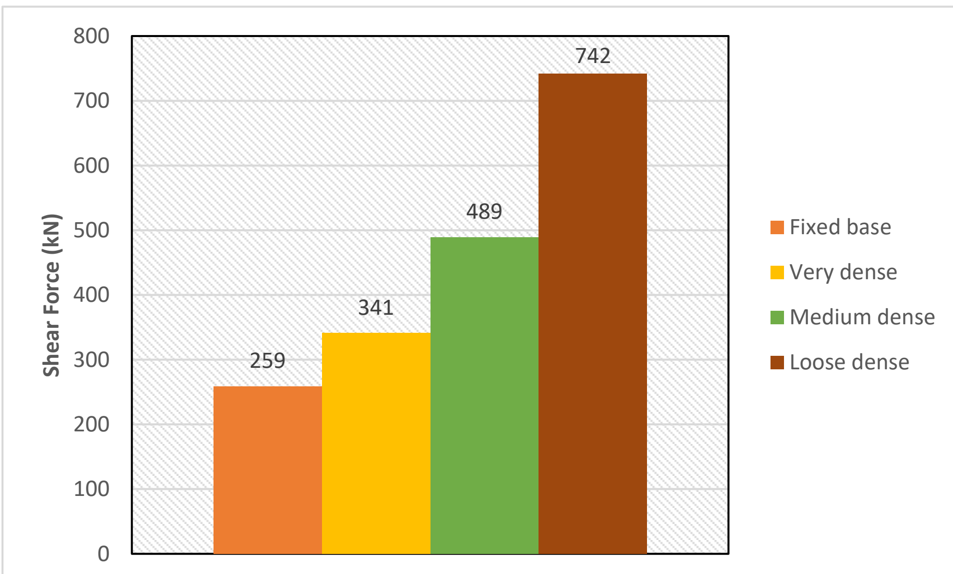
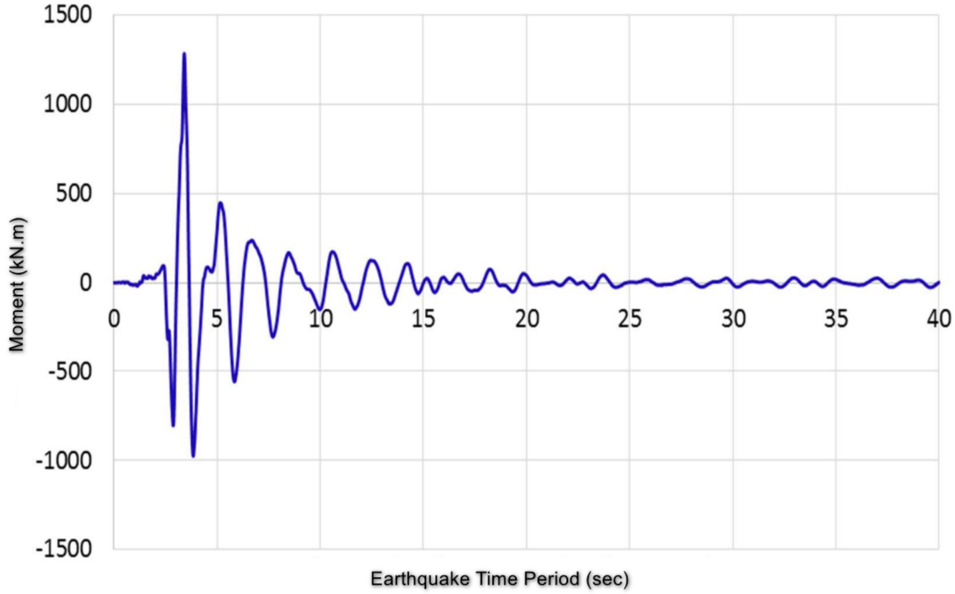


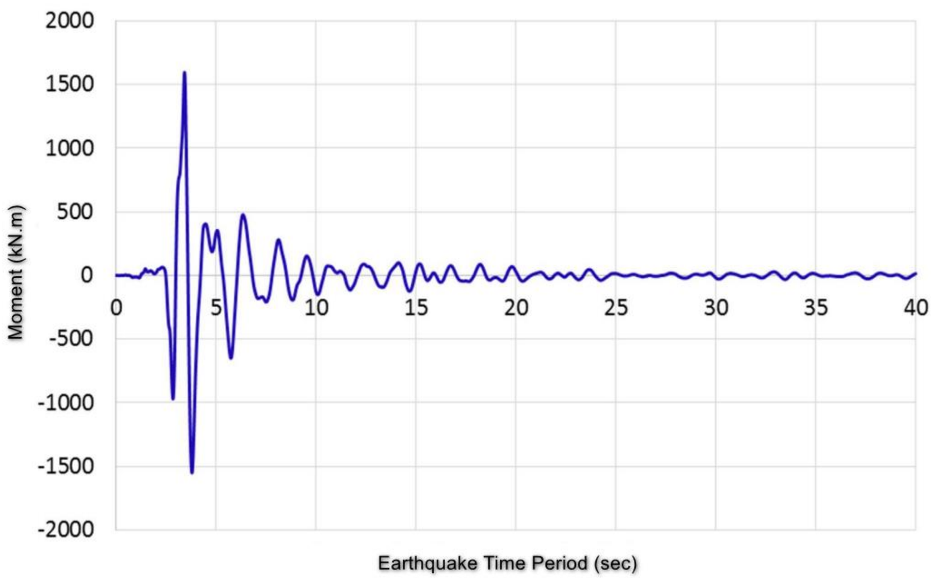
Figure 9: Comparison of maximum shear force for a base column in each model during an earthquake

8.3 Bending moment

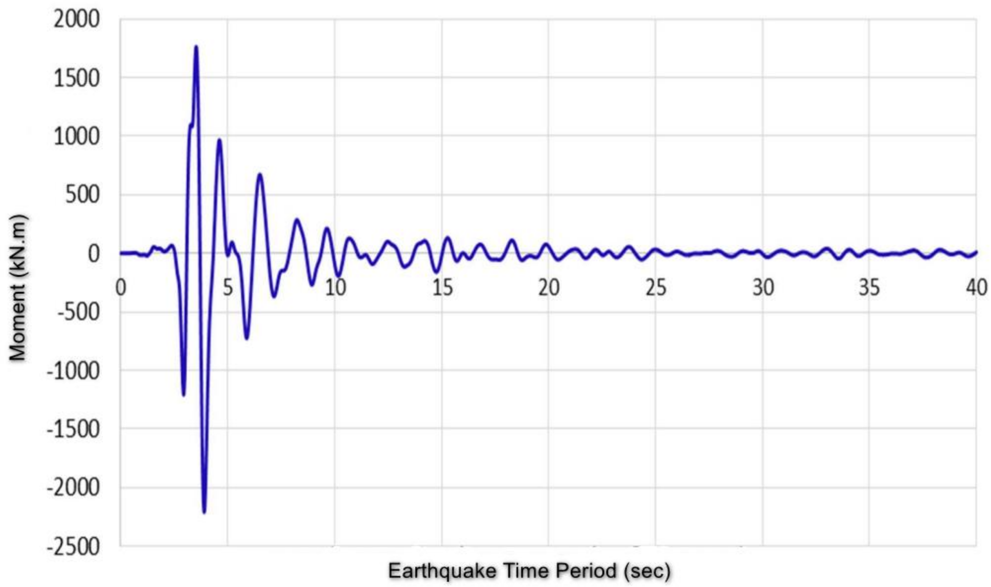
During earthquake mode for the main floor of the structural beam for each model, the result was recorded and summarized, three types of soil results are shown in Figure 10 and 11 below.



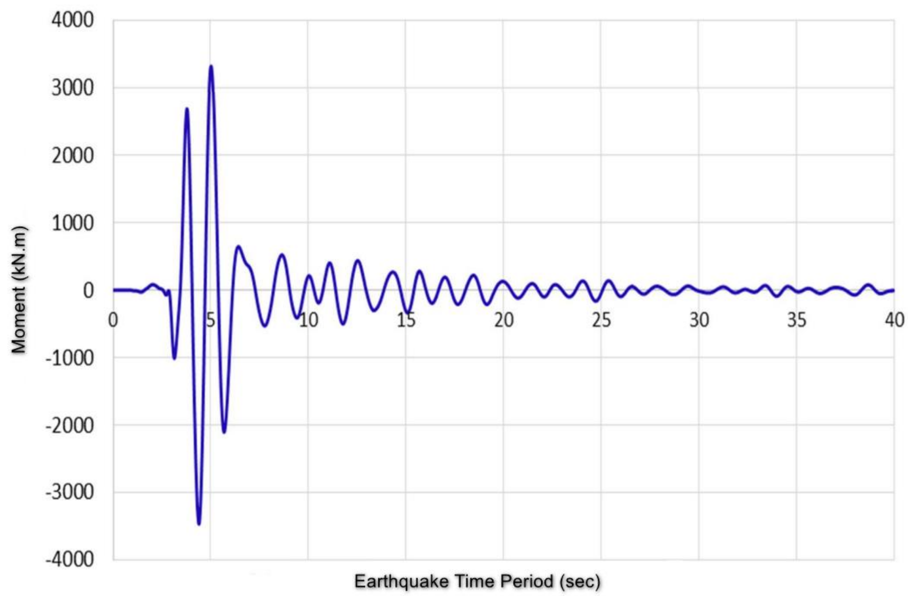
(a) Moment for the structure base column through earthquake action on the exciting period for fixed base model



(b) Moment for the structure base column through earthquake action on the exciting period for the very dense soil.



(c) Moment for the structure base column through earthquake action on the exciting period for the medium-dense soil.



(d) Moment for the structure base column through earthquake action on the exciting period for the loose soil.

Figure 10: explain the change of moment principles for ground floor beam during earthquake mode for all model

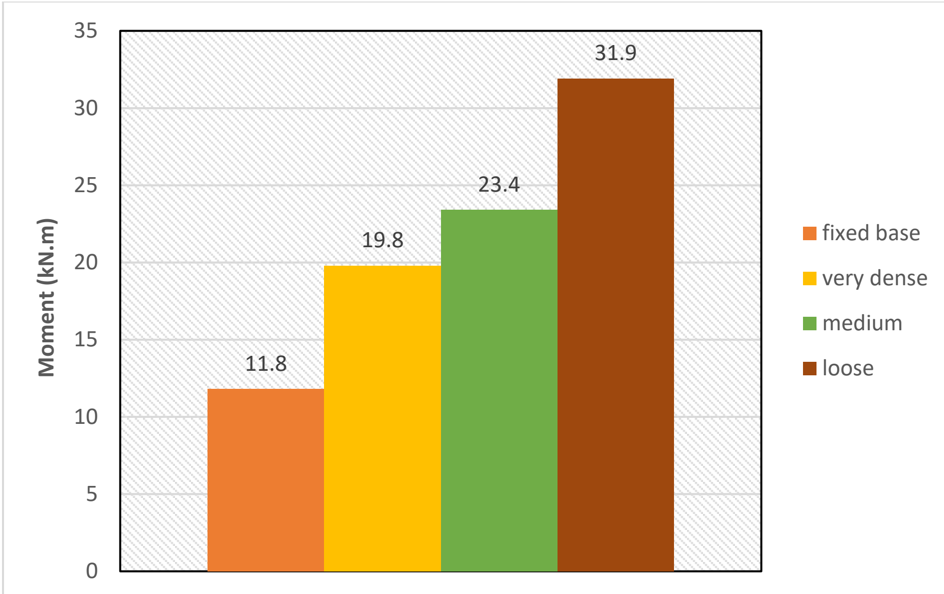


Figure 11. Comparison between maximum moments for the beam in each model

8.4 Spectral velocity

Another character describes the performance of the structure during earthquake mode. The spectral velocity is explained for all models in the type of soil, the spectral velocity could be increased when the SSI is considered for analysis furthermore the spectral velocity could be increased when the soil went weaker in figures 12, and 13 below show

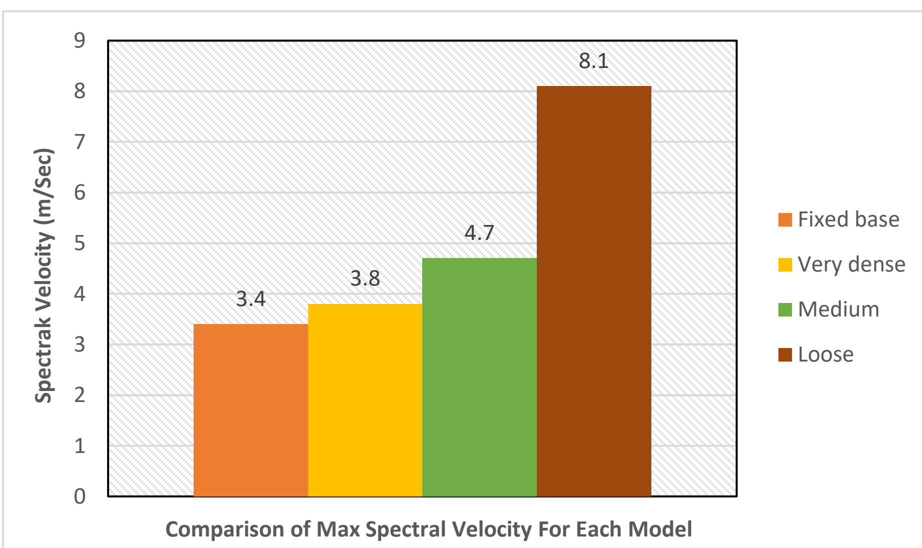


Figure 12: Comparison of maximum spectral velocity for each model

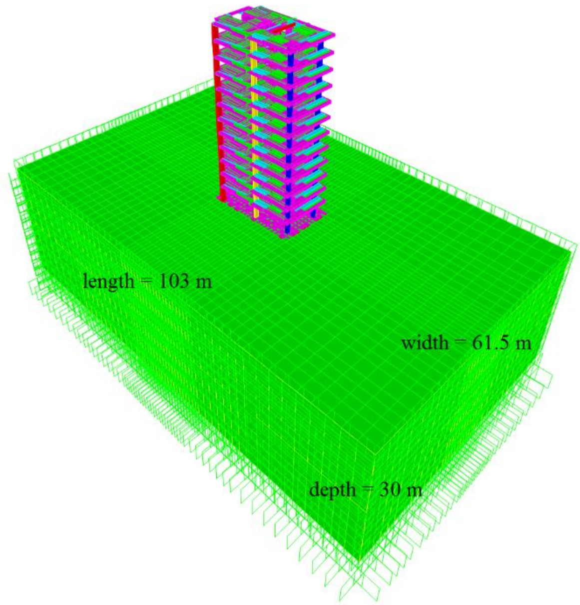


Figure 13: 3D View of building with soil-structure-interaction was modeled in SAP2000. For three types of soil

9. CONCLUSION

A big number of article and large books had been writing for soil Structure interaction analytic and design, filed and structure response during earthquake exciting. The main of this research have been specified to the full three-dimension linear dynamic of the twelve real story building structure with the fixed base model and consist of effect and performance of SSI due to using numerical engineering SAP2000 for three types of soil.

- Looking for the pick point of the structural failure that shows from the previous figure such as maximum Displacement, drift, shear force, moment, torsion, spectral velocity were very significant deviation during earthquake mode while SSI contains for structural analysis, and the magnitude has been an increase in all of the parameters before SSI have used compare with characteristic design fixed base, the increased value of all them when soil intended for weaker.
- Experimental soil has good engineering property and high value of shear wave velocity safer for structure behavior. The soil intended to weak behavior when the shear wave velocity is a smaller amount than (Vs< 180 m/sec). And the designer should be careful about the specification of this type of soil and this type of situation need a special structural design.

- SSI have to think through in design and analysis while super-structure and strategic project built for instance high rise building structure, dam, nuclear power.
- To perfectly assessment the effect of SSI is essential for known all properties of soil surface up to layer of rock like shear wave velocity, modulus of elasticity, density and Poisson ratio by way of all property of structure like cross-section of beam, column and slab with specification for reinforcement of concrete and reinforcement steel bar with know very well use numerical application.
- The software engineering Finite element program Used for simulating and analysis structure behavior is called SAP2000 numerical engineering program.
- Experimental indirect method analysis for SSI the values are overexcited increase more than typical design (fixed base), it's the reason that very infrequently recycled in practice. In typical design development of structure is generally neglect the SSI influence and assuming all structure fixed base foundation.

10. References

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