Earthquake Analysis of 12 Storey Building Considering Built on Three Type of Soil Include Effect of Soil Structure Interaction

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Bakhtyar Saleh AHMMAD

ABSTRACT

EARTHQUAKE ANALYSIS OF 12 STOREY BUILDING CONSIDERING BUILT ON THREE TYPE OF SOIL INCLUDE EFFECT OF SOIL STRUCTURE INTERACTION

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The consideration interaction between structure, foundation and soil under the foundation for analysis and design of the structure change the actual behavior of the structure than earn from the consideration of the structure only. Soil-structure-interaction has been a major topics in researchers of structural and earthquake designer engineering since it is closely related to the safety evaluation of many important super structure engineering projects, In the typical and traditional design practice all will assume that structures are fixed base but in real built on flexible area, soil under foundation is flex and capable to cause structure for motion, special during earthquake exciting. In the presented study the property of (12) real storey building are modelled under four type of different soil, first fix base model, Second very dense soil that shear wave velocity are equal (500 m/sec). Third medium soil stiffness that shear wave velocity are equal (Vs = 250 m/sec), fourth weak soil that shear wave velocity are equal (120 m/sec). Finite Element Method is used to model soil-structure-interaction, apply strong earthquake record for the structure and analysis linear dynamic of structures by numerical software engineering program SAP 2000 Version number 19. The main objective of this research are to investigate the influence , effect and behavior for interaction between structure and soil that build on it during earthquake exciting, and deal for new phenomena of design include soil-structure-interaction and compare with conventional design (fix bass design) by (i)determine displacement, (ii) drift between storey floor , (iii) maximum shear force, (iv) maximum bending moment, (v) maximum torsion and spectral velocity for fix base design theory and soil-structure-interaction consideration for different type of soil.

Keywords: Soil structure interaction; earthquake; shear wave velocity; finite element method; SAP2000

ÖZET

ÜÇ BİÇ TEK ZEHİRDE ZAMAN ALANINDA DİKKAT EDİLECEK 12 MATERYALI BİNALARIN DEPREM ANALİZİ ZEMİN YAPISININ ETKİLEŞİMİ ETKİSİNE DAHİLDİR

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Eylül 2017
59 sayfa

Yapı arasındaki dikkat etkileşimi, Temel ve zemin altında analiz ve yapının tasarımı için yapının gerçek davranışlarını değiştirmek sadece yapı dikkate alınarak kazanmak. Toprak-yapı-etkileşim, birçok önemli süper yapı mühendislik projesinin güvenlik değerlendirmesi ile yakından ilişkili olduğu için, yapısal ve deprem tasarımcısı araştırmacıları araştırmacıları için önemli bir konudur. Tipik ve geleneksel tasarım uygulamalarının tümü, yapıların sabit baz olduğunu varsayacaktır ancak temelde esnek alan üzerinde inşa edilmiş olup temelin altındaki zemin esnektir ve hareket için yapıya neden olabilir, bu da deprem heyecan vericidir. Sunulan çalışmada, (12) gerçek katlı binanın mülkiyeti dört farklı toprak çeşidi altında modellenmiştir; Ilk düzeltme temel modeli, Kesme dalgası hızının eşit ikinci yoğun denge (500 m / sn), Kayma dalga hızının eşit olduğu üçüncü orta dereceli zemin sertliği (Vs = 250 m / sn), kayma dalga hızının eşit olduğu dördüncü zayıf toprak (120 m / sn). Sonlu Elemanlar Yöntemi, zemin-yapı-etkileşimini modellemek için kullanılır, Yapılar için kuvvetli deprem kayıtları uygulayabilir ve sayısal yazılım mühendisliği programı SAP 2000 Sürüm numarası 19 ile yapıların doğrusal dinamiğini analiz edebilir. Bu araştırmanın temel amacı, deprem esnasında oluşan strüktür ile zemin arasındaki etkileşim etkisini, etkisini ve davranışını araştırmaktır. Ve tasarımın yeni olguları için anlaşma, toprağın-yapı-etkileşimini ve geleneksel tasarımla (sabit bas tasarımı) karşılaştırmasını içerir; (i)determine displacement, (ii) kat kat arasında sürüklenme, (iii) maksimum makaslama kuvveti, (iv) maksimum eğilme momenti, (v) sabit taban tasarımı teorisi için maksimum torsiyon ve spektral hız ve farklı zemin tipleri için zemin-yapı-etkileşim hesabı.

Anahtar kelimeler: Zemin yapısı etkileşimi; deprem; Kesme dalga hızı; Sonlu elemanlar yöntemi; SAP2000

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LIST OF SYMBOLS/ABBREVIATIONS

S.S.I.	Soil structure interaction
S.F.S.I	Soil foundation structure interaction
Vs	Shear wave velocity
Tn	Fundamental period of the fixed-base structure.
H	Structure's effective height
R_{eq}	Equivalent radius of the foundation.
FIM	Foundation input motion
r	Plate radius
G	Shear modulus
ν	Poisson's ratio
ρ	Mass density
σ	Wave parameter

CHAPTER 1
INTRODUCTION

1.1 Introduction

The reaction of any structure during earthquake shaking depends on combination cycle between structure and foundation, first structure, second foundation, third soil below and soil around all contact face of the foundation, In another hand, Soil structure interaction analyze is calculate all cycle combination reaction to special earthquake. Some of researcher used the statement Soil Structure Interaction (S.S.I) and Soil Foundation Structure Interaction (S.F.S.I). In this literature, the foundation take into account of the structure, (foundation is a part of structure) and the statement S.S.I. it was adopted**.** [1]

Moreover; type (analysis and design) of earthquake does not participate flexibility and elasticity of soil and foundation, the structure design separate and assume it's completely fix on foundation, also foundation design separate consider provide fix area to structure, finally all performance parameter just upon the structure, this type of design is ordinary and typical, in reality the seismic parameter and earthquake performances of structure except including the flexibility and elasticity of the soil and foundation, may be huge individual from those of the real structure, at final may be drive to an unsafe design. (Mylonaky and Gazeta, 2000). [2]

The estimate, value and magnitude of earthquake at the site that cause vibrate structure is the most important side of seismic design or reconstruction for project. Because of the large number of assumes required, researcher in many time not agree about the magnitude and value of earthquake assume at the site except the structure include. Accurate about input seismic is shortage, anyway, it's not reason that not necessary to make approximately dynamic analyze for the structure, foundation interaction and soil under and around all structure faces. (Edward L. Wilson 2002).[3]

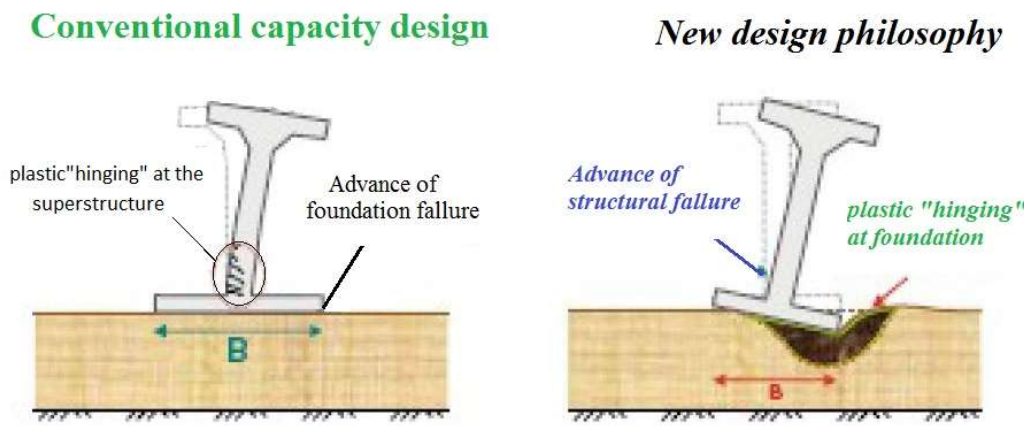


Figure 1.1 Example of pier design, illustrated conventional design (fix base theory) and new design philosophy include soil structure interaction (Katherine Carys Jones 2013)

The reaction of soil influence the reacting of structure and the reaction of the structure affects the reaction of soil; referring to soil structure interaction. (Kramer, 1999). On another hand; Structures rest on a compliant soil experience a different foundation movement associated to the free field ground movement, a significant part of their vibrational energy may be dissipated by hysteria action in the soil and by radiate of waves into the supporting soil layer. Interaction effects are strongly dependent on the (i) dynamic properties of structure, (ii) geometrical properties of foundation, (iii) properties of supporting medium and (iv), the characteristics of the free field earthquake. (Veletsos and Nair (1975). [4]

1.2 Overview of S.S.I

earthquake S.S.I analyze estimated the all integrated reaction of the structure, the foundation and geologic zone below or boundary of the foundation to indicate free field ground movement. The free field state is movement that not influence by structure vibration or wave speared around and itself of foundation. The influences of S.S.I are neglect due to theoretical theory that construction stiff foundation resting by rocky zone or very stiff soil, therefore explain S.S.I for known the difference between the real reaction of the structure and reaction of the fix base. [1]

In many structural codes and researcher such ass (FEMA-P-750), (NEHRP), (FEMA-2009) and (Whitman-1975). S.S.I. influences were divided for three main part; (i) Influence of Inertial interaction. (ii) Influence of kinematic interaction. (iii) Influence of soil and foundation flexibility. Kinematic and inertial interaction state were defined by (Whitman-1975) and (Kausel-2010). Influence of S.S.I for engineering analysis and design depend on this three key parameter were explain below: (FEMA440-2005).

First: - Foundation rigidity and damping, Inertia interaction improve vibrating structure gives increase to base shear, moment, and torsion. Deflections, lateral displacements, and rotations happing due to those forces for the contact area of soil and foundation. Due to flexibility and elasticity of soil and foundation only deflection, displacement and rotation occur, it will be important participate to all collective structural flexibility and improve the structure period. Therefore increase energy loses by scattering and separate occur due to displacement. Significant Influence of inertia interaction return to structure damping and hysteria soil damping since influence on foundation of structure.

Second: - difference between free field ground movement and foundation input movement. Deferential occur between free field movement and foundation input motion due to (i) kinematic interaction; rigidity of foundation elements location at or under the ground surface reason to foundation movement to deviate from free field movement because of base-slab-averaging, wave separate and influence of embedment in the loss of structure and foundation inertia; (ii) relative between deflection and rotations, foundation and the free field, working in partnership with structure and foundation inertia.

Third: - Foundation Distortions. Force, displacements and deflection applied by the structure and the soil therefore; generated Flexural, axial, and shear damages of structural foundation elements occur, foundation element must be designed to which type of earthquake zone and demand, it's important and significant, special for flexible and weak foundations such as raft foundation and piles.

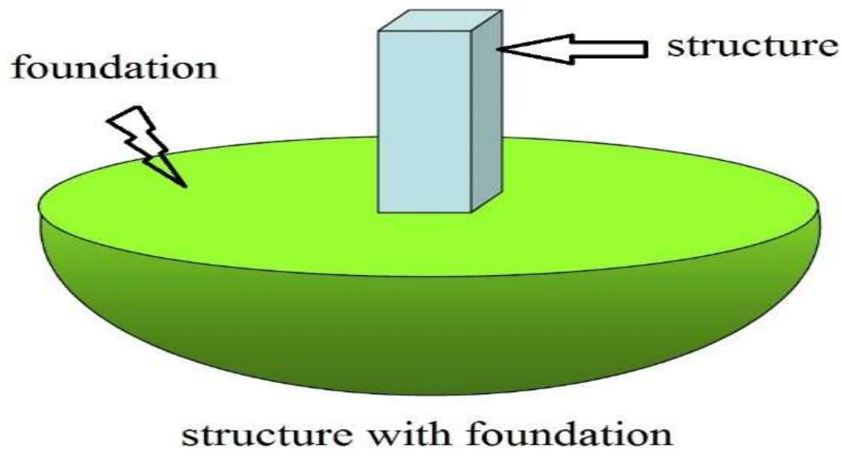


Figure 1.2 (a) foundation with structure

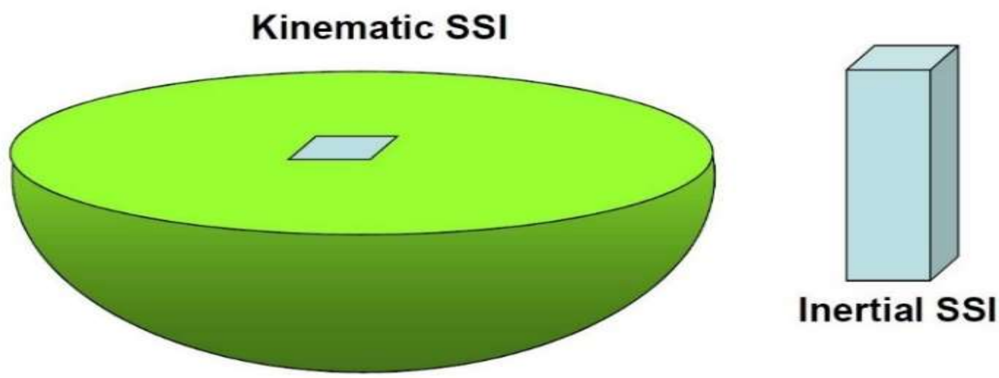


Figure 1.2 (b) illustrative kinematic and inertia soil structure interaction (Steve Kramer; 1999)

1.3 Kinematic Interaction

Kinematic interaction outcome from the stiffness of foundation combination up or below soil, which reason movement at 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 envelope are averaged within the foundation footmark. Second reason of separate is embedment influence in any structural foundation level movement is decrease as a result of seismic reduction with depth under the ground level [2]. Moreover, during a seismic excitation, movement in soil at any given instant is generally change from point to point. This spatially variable nature of seismic waves can be expressed by two major idea: First, incident waves originating from different sources reach the foundation at different instants and strike with different angles; this is called wave passage effect. Second, wave characteristics change both in magnitude and phase while waves are propagating through different paths and different soil layers or when they are reflected and scattered around the foundation; this is called ground motion incoherence (Veletsos, 1993). Upon the introduction of relatively stiff surface or embedded foundation elements, spatially variable free field motions reduce in the form of an averaging and/or scattering effects, which are characteristic as base slab averaging and embedment effects, respectively. On another hand, rotational motions are introduced in addition to decrease in translational movements, these influence are return to as kinematic interaction and are very sensitive to wave property, (FEMA440, 2005). Their significance on the response is maximum for short period structures subjected to high frequency wave content. (Kim and Stewart, 2003).

1.4 Inertial Interaction

Inertial interaction associated with displacements, rotations, and deflection on the foundation plane of a structure, resulting from inertia-driven forces such as base shear and moment. The inertial soil structure interaction influence on inertial shifts and rotations can be a major source of flexibility and energy distribution in the soil structure interaction. [1]

Inertial interaction influences are generally pronounced for the fundamental modes reaction of flexible base system, moreover, responses associated with higher modal frequencies are relatively small (Jennings and Bielak (1973); (Bielak, 1976 and Veletsos, 1977; Veletsos, 1993). The kinematic interaction generally reduces the lateral reaction, the inertial interaction can reduce or increase the similar reaction.

1.5 Aim and Scope

The main objective of this research to investigate the influence , effect and behavior for interaction between structure and soil that build on it during earthquake exciting, and deal for new phenomena of design and compare with conventional design (fix bass design) by determine (i) displacement ,(ii) drift between storey floor, (iii) Max. Shear force, (iv) Max. Bending moment, (v) Max. Torsion and spectral velocity for fix base design theory and soil-structure-interaction for deferent type of soil, (very dense soil, medium dense soil and loose soil). In this study we use engineering software SAP2000 (structural analysis program, its full complete software for analysis structure and design) and real residential 12 storey building reinforcement concrete with strong ground motion record.

1.6 Outline of the Thesis

Chapter 1; Introduction: presented general define of soil-structure-interaction with aim and scope of this study.

Chapter 2; Literature review: presenting Previous research and investigate based on the scope of this research have been reviewed, Parameters of S.S.I, Methods used to analysis S.S.I and Historical Key Factors in Soil-Structure Interaction.

Chapter 3; Case study: This chapter provided an explanation of the analytical modeling of the real 12 storey reinforced concrete frame residential building system. Furthermore, the methodology for the analysis and design of the structures was summarized.

Chapter 4; Results and discussion: Results obtained from the linear dynamic analysis for the 12 storey building with different three type of soil and fix base. Discussion on the results of the analysis was described in this chapter.

Chapter 5; Conclusions: The conclusions are built on the results or these comparative investigations which were provided in this section.

CHAPTER 2
LITRETURE REVIEW

2.1 Parameters of Soil-Structure-Interaction

Over many researches there are a clearly indicate the parameters and characteristic influence on soil-structure-interaction effects. Among these parameters only two of the key parameter mention in this study.

First; Wave parameter (Veletsos, Nair (1975): Wave parameter, (σ), refer to the relative the structure and stiffness of the foundation medium. (Kim and Stewart, 2003) have concluded that the influence of inertial interaction is significant related with wave parameter: "Inertial interaction on foundation translations increases with decreasing σ". Case studies performed by (Stewart et al. 1999) have shown that inertial interaction is not important for $\sigma > 10$.

$$\sigma = \frac{V_s T_s}{H} \quad \text{(Eq. 2.1)}$$

Where,

Vs = Average shear-wave velocity in the soil medium under the foundation.

Tn = Fundamental period of the fixed-base structure.

H = Structure's effective height ($H \approx 0.7H_{tot}$, if it is a multistory structure).

Second; Aspect Ratio (Veletsos, Nair (1975): Aspect ratio is a geometric definition based on the relationship of the effective structural height to the equivalent foundation radius. Inertial interaction based on rocking of structure is expected to be more significant with the rise aspect ratio and reduce wave parameter.

$$\text{Aspect Ratio} = \frac{H}{R_{eq}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \text{(Eq. 2.2)}$$

Where; H = height of structure

R_{eq} = Equivalent radius of the foundation.

2.2 Method for analysis soil structure interaction

Methods that can be used to calculate above influence and behavior S.S.I can be classified as direct method and substructure approaches method. First direct analyze, the soil and structure with foundation are included within the one integrated model completely analyze together. Second; substructure approach, The S.S.I problem is split into several parts, which are combined to formulate the complete solution. [1].

2.2.1 Direct Analysis.

As showed in (Figure 2.1) typically soil represented as a continuum together with foundation and structural elements such as 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.

The estimation of the site reaction with the wave propagation analysis by the soil is important for this approach. Such analyzes are most frequently carried out using an equivalent linear representation of soil properties in the finite element, individual finite or numerical formulations of boundary element (Wolf-1985 and Lysmer et al-1999), Direct analyzes can be performed by all S.S.I. influence define before,. But the integration of the kinematic interaction is challenging because it requires the specification of three-dimensionally variable input motions. Because direct solution of the S.S.I. The problem is difficult from accounting point of viewpoint of view, especially when the system is geometrically difficult or contains significant nonlinearities in the ground or in structural materials contains.

Three dimensional finite element method description of the all property for soil characteristic, the foundation and the superstructure property at the same time (Fig. 2.2). This method is often return to as direct method of analysis. The solution is achieved in two stage. First stage is the modification of stipulated free field ground movement for the driving base excitation that is referred to as the site reaction analysis. The second stage is the modification of the model with the transmitting boundaries (also referred to as silent boundaries) which are used to eliminate reflection of outgoing waves travelling from near-field to far-field soil domain (Mengi, 2002).

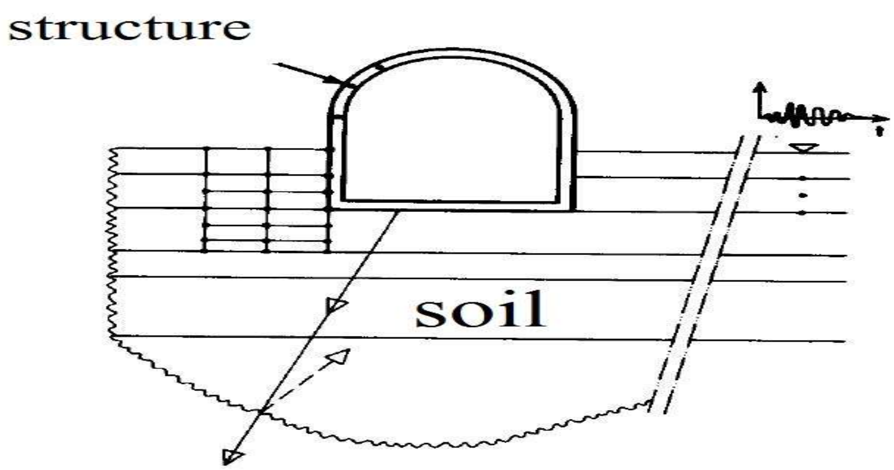


Figure 2.1 (a) fundamental object of analysis soil-structure-interaction john (wolf, 1985)

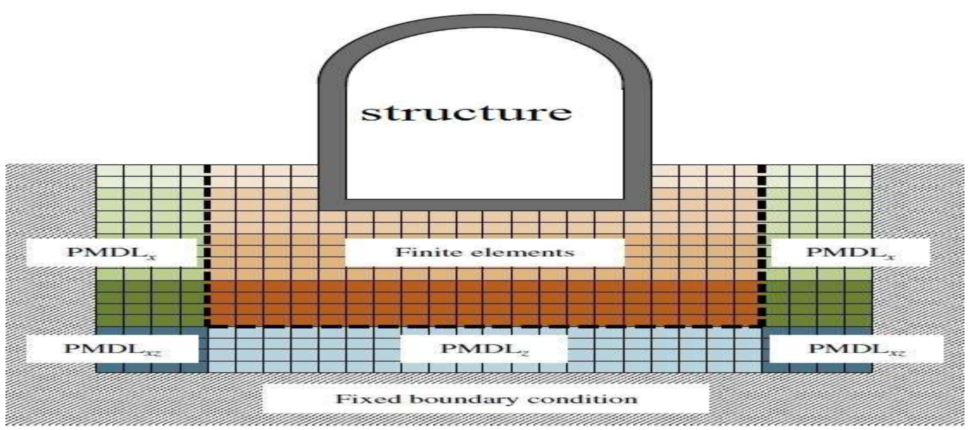


Figure 2.2 (b) Direct Analysis (finite elements) soil-structure-interaction (Lee, et al. 2014).

2.2.2 Substructure Approach

Correct consideration of S.S.I. influence in a substructure approach depends on; (1) estimate of free-field ground movements and similar soil material properties. (2) Estimation of transfer functions for the conversion of free field movements into fundamentals. (3) Combining springs and dashpots to show rigidity and damping at the ground foundation interface. (4) Reaction analysis of the integrated structure spring and dashpot system with foundation input movement applied. The overlay inherent in a substructure approach requires an assumption of a linear ground and property and behavior of structure, also in practical this requirements are frequently only depend on an equivalent linear sense such as showed in (Fig. 2-3). The theory of substructure approach procedures are define as; first: - Property of a foundation input movement (F.I.M.) which is the movement of the base plate which takes into system of foundation rigidity and geometry Due to inertia is treated separately, the (F.I.M.) applies to the theoretical condition of base plate and structure without mass (Fig. 2-3b). This movement generally different from free field movement, includes both translational and rotational components and is the earthquake requirement of foundation and structural system. The changing between the free-field and foundation input movement is described by a transfer function representing the relation of the Foundation free-field movement in the frequency domain. Since inertial influences are neglected. The transfer function represents only the influence of the kinematic interaction,

First: - basic step in defining the F.I.M. is to estimate the free-field reaction of the site which is the spatial and temporal changing of ground movement in the absence of the structure and foundation. This function requires that the earthquake input movement in the free field is either at a certain point such as (ground surface and rock projection) in the form of incident waves, such as (sloping shear waves), which propagate from a reference depth. After determination of the free-field movement, wave propagation analyzes are performed to evaluate the foundation input movement along the intended ground-foundation interface, as shown in (Figure 2-3d), Soil characteristics of Equivalent Linear such as (modulus of shear and damping of material), as part of this analysis.

Second: - The rigidity and damping property of the (S.S.I.) are participate by relatively simple impedance function models, a series of distributed springs and shock absorbers. Impedance functions represent the frequency-dependent rigidity and shock absorbers property of S.S.I., the use of impedance function models for stiff foundations is represented in (Fig. 2-3c, i). Typical type of distributed springs and dashpots acting around the foundation is represent in (Fig. 2-3c, ii). At final case of distributed springs and dashpot is necessary when foundation elements are not rigid or when internal demands (moments, shears, and deformations) are the results of the analysis.

Third: - The structure is modeled over the foundation and the system is excited by the foundation by moving the ends of the springs and shock absorbers (dashpots) with the swings and translational components of the (F.I.M). Note that (F.I.M) varies with depth; in the case of the distributed spring and dashpot model, differential ground shifts should be applied over the depth of the embedding.

This method of spatially variable displacements performs a rotational component to the (F.I.M.), which is why a rotational component will not appear specific in (Figure 2-3d-ii).

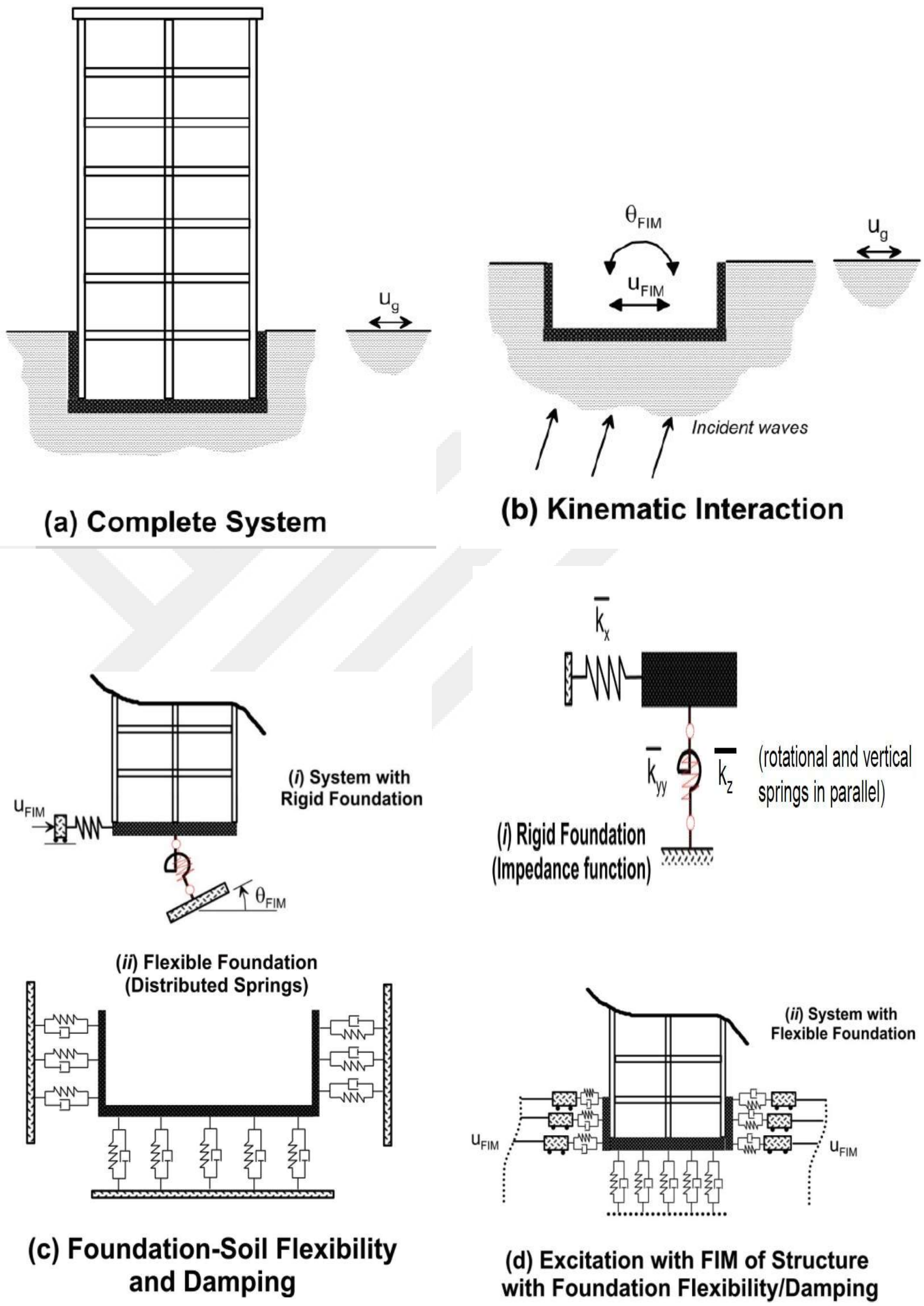


Figure 2.3 Schematic illustration of a substructure approach to analysis of soil structure interaction using either: (i) rigid foundation; or (ii) flexible foundation assumptions. (NIST GCR 12-917-21)

2.2.3 Determine soil spring stiffness

From theory in Fundamentals of Earthquake Engineering, by (Newmark et al., 1971). For the calculation of the ground spring stiffness and damping for all axes (x-y-z) and rotation about all axes depending on the plate radius of the foundation, modulus of shear and Poisson ratio of soil. [3].

Table 1.1 equation to calculate of soil spring stiffness and damping with soil mass

DIRECTION	STIFFNESS	DAMPING	MASS
Vertical	$K = \frac{4Gr}{1-\nu}$	$1.79\sqrt{K\rho r^3}$	$1.50\rho r^3$
Horizontal	$18.2Gr\frac{(1-\nu^2)}{(2-\nu)^2}$	$1.08\sqrt{K\rho r^3}$	$0.28\rho r^3$
Rotation	$2.7Gr^3$	$0.47\sqrt{K\rho r^3}$	$0.49\rho r^5$
Torsion	$5.3Gr^3$	$1.11\sqrt{K\rho r^5}$	$0.70\rho r^5$

Where; r =plate radius; G =shear modulus; ν =Poisson's ratio; ρ=mass density

2.3 Soil Structure Interaction key factor

Engineers of earthquake long time ago had recognized that soil and structural properties are significant roles in determining the level of S.S.I. And consequently degree of damage it may be to occur in a system during an earthquake exciting. Such as factor from points 1 to 4. [5].

1. Consider a parameter that participate in the system, includes speed, with often shear waves travel at a site for the subsurface component of (S.S.I), building property and dimension of integrate structure of the system.

2. Ratio of height structure to foundation dimension of foundation.

3. The natural frequency of the structure to the underground column and the ground movement

4. Relative stiffness of the superstructure to the subsurface.

2.4 General literature review on soil structure interaction

Earthquake S.S.I influence the performance level of superstructures built in weak soil, by increase displacement between floors which may increase performance level of the superstructure from safety to near damage or full destroy. The displacement of structures on the floating pile foundations were strengthened in comparison to the fix base theory, (34% established on the laboratory measurements and 27% established on the 3D numerical predictions). **(**Aslan et al. 2013).

The rate of shear force increase more pronounced on mid storey as compared with the ones remaining storey. This may lead at the explanation of heavy damage on the midrise buildings under the resonance at some seismic include S.S.I. [14]. (GÜLLÜ and Pala, 2014).

Normal that whether S.S.I has beneficial or negative impact on structural reaction. From the kinematic interaction point of view, its beneficial effect in terms of reduction in lateral response. From inertial interaction point of view despite the dominant nature of this effect. Its impact on the response is case dependent (Mylonakis and Gazetas, 2000).

Assuming an increase in the effective period for the interacting system, when using typical seismic design, soil structure interaction can increase, reduce or have no influence on demand forces depending on the location at the spectrum (Bielak (1975); Jennings and Bielak, 1973; Veletsos, 1977; Veletsos and Meek, 1974; Veletsos and Nair, 1975; Veletsos, 1993).

Design assessment based on reduced values of base shear and moment due to S.S.I. (FEMA450, 2003). Of the levels used to that of fixed base theory may lead to unsafe design when compared with site specific procedures (Fig. 2.4). Moreover; it should be noted that decrease in the base shear due to S.S.I, effects at the design stage is only for elastic response of the structure. As will be discussed at the succeeding paragraphs, interaction effects tend to decrease with increasing inelastic action in the structure. In the light of these circumstances, it is a common tendency, even a recommendation by code procedures, to ignore S.S.I effects at the design phase. From structural deformations point of view, assessment of soil-structure-interaction effects may provide clearance limits for controlling pounding of closely spaced buildings due to increased translation and rocking deformations, second order effects (P-Delta), and yielding of the structural system may influence exposed deformation and ductility demands at structural members of primary importance. (Mylonakis and Gazetas 2000)

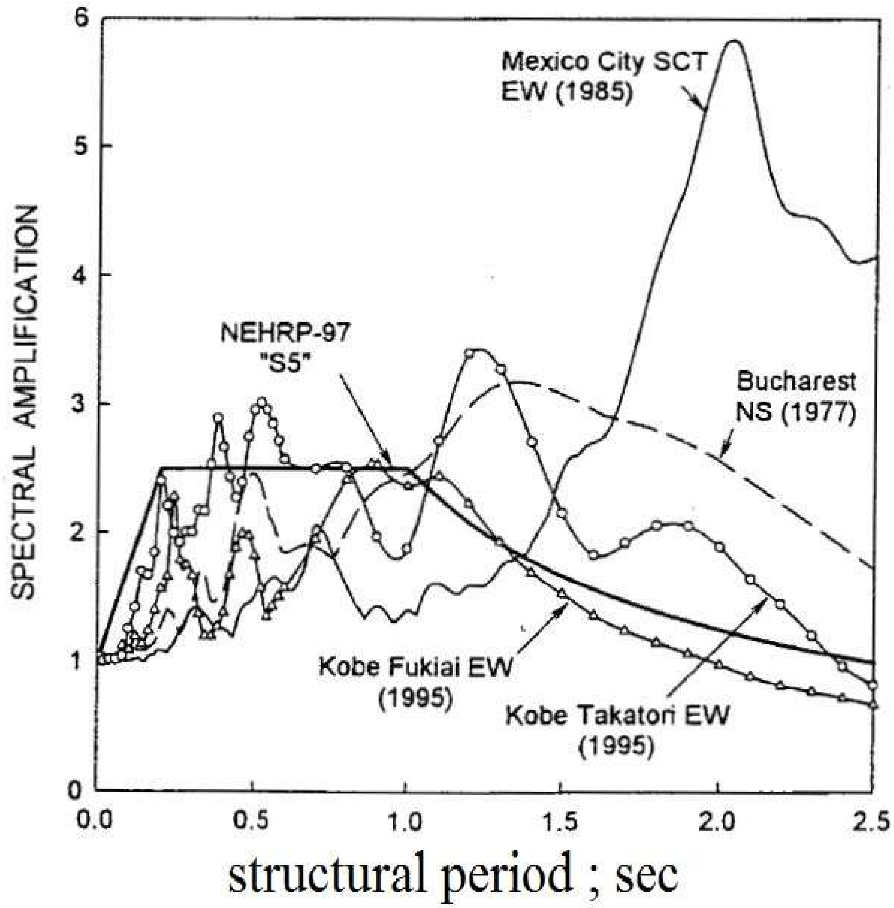


Figure 2.4 Comparison of a typical seismic code design spectrum to actual site-specific spectra from various earthquakes; β=5% of (Mylonakis and Gazetas 2000).

S.S.I effects on yielding structural systems (resting on elastic half space) have been first studied by (Veletsos and Verbic (1973) and later by (Priestley and Park (1987), (Miranda and Bertero (1994), (Ciampoli and Pinto (1995), (Elnashai and McClure 1996), (Bernal and Youssef 1998),(Mylonakis and Gazetas 2000), (Aviles and Perez-Rocha, 2003). From them studies it has been observed that yielding, which may be globally viewed as decreasing the rigidity of the structure results in a decrease in interaction.

Soil structure model including stiffness sand it has a shorter time period compared to weak sand and high tall structure, but it has a longer time period compared to the lower structure. These two combinations can determine the amount of gain for each earthquake. (Matinmanesh and Asheghabadi, 2011).

Equivalent dynamic infinite elements can be influence practice for the soil structure interaction analytical. (Jincheng Su n, YouqingWang).

By comparing the spectrum of the typical code design to the real response spectrum, it is possible to increase the basic natural period of structure, it does not necessarily require a smaller reaction and this general idea in construction technology that always plays an advantageous role of S.S.I., Simplification that leads to unsafe design. (Mylonakisa and Gazetasa, 2000).

Dynamic (S.S.I) is also important in designing big superstructure projects for structural author and insurance companies, trying to introduce the concept of performance based design into the engineering community requires a more sophisticated model to maintain engineering requirements parameters. Therefore, the superior numerical model of the S.S.I., system helps to save money by not only collapsing and damaging the structure but also optimizing the design to withstand the earthquake at restoration during a certain period time. (Jie, et al. 2007).

Field characteristics based on their comprehensive set of study on simple yielding systems, (Ciampoli and Pinto, 1995) reported that increased deformations due to S.S.I effects are mostly based on rigid body motions, and not because of greater inelastic demands originating from foundation. Moreover, they have found that inelastic demands in terms of curvatures remained essentially unaffected by S.S.I. however, a tendency to decrease which is mostly bound to decreasing trend of base shear imposed by design response spectra. research by (Priestley and Park, 1987), (Bernal and Youssef 1998). (Mylonakis and Gazetas 2000).

On inelastic bridge piers, it is shown that increasing the flexibility of the elastoplastic bridge pillar reduces the ductility capability of the system due to its compatibility

Also, they noted that increase in period due to S.S.I cause to higher relative deflection, which in turn can cause an increase in seismic demand with (P-Delta) influences. On the contrary, this effect is regarded as of subordinate importance. (FEMA450, 2003).

Under strong earthquake excitation nonlinearity of soil, has been identified as an additional issue to be considered. Although lumped parameter models are depend on the evaluation that soil domain in elastic half space, validity of this assumption is surely questionable for the affected soil region near the foundation. It is a well-known fact, that stress strain relations for soils are nonlinear. Noting that foundation parameters are functions of shear wave velocity, utilization of secant shear modulus, (G) instead of initial shear modulus, G_o (corresponds to small amplitude strains) is a common approach (FEMA356 (2000); FEMA440, 2004; FEMA450, 2003; ATC-40, 1996; Veletsos, 1993).

Mainly through seismic retrofit projects using the S.S.I analysis to gain a better understanding of the structural performance and to improve the accuracy in the analytical simulation of important structural responses [1].

An advantageous influence of S.S.I. The analysis is mostly observed in the longitudinal direction of nearly equal peak stresses, which slightly reduce in the transverse direction as comparison with the fixed base theory. The stress concentrations at the arch element for the fixed case are observed to be shifted to the bottom of spandrel walls due to the SSI consideration that likely results in safer response for design purposes. Collective of stress on the arch sheet member when it is fixed is shifted from the SSI point of view to the bottom of the arches wall, resulting in a safer reaction for design. (GÜLLÜ and Jaf. 2016)

CHAPTER 3
CASE STUDY

3.1 Description of 12 storey reinforcement concrete building

Structure is a real residential 12 floor reinforcement concrete building consist mat foundation , column, beam, shear wall and slab design by Eurocode standard (EN 1993 -1-1 PER EN 10025-2), compressive strength of concretes are (FC = 30 MPa.), and tensile strength of steel (FY= 420 MPa.), Mat foundation is (20.6 * 12.3 * 1) m, length , width and depth respectively , 6 number of column with average cross section dimension (90 * 40) cm, with three shear wall box for lift and stair and different cross section of beam contain ((80 * 40), (60 *40) , (50 * 40) , (50 * 40) (15 * 40)) cm , height of each floor equal (3.23m), total length of building equal (38.76m). From Eurocode 2-2004 With Eurocode 8-2004 specialist for SAP2000 showed property in table (3.1)

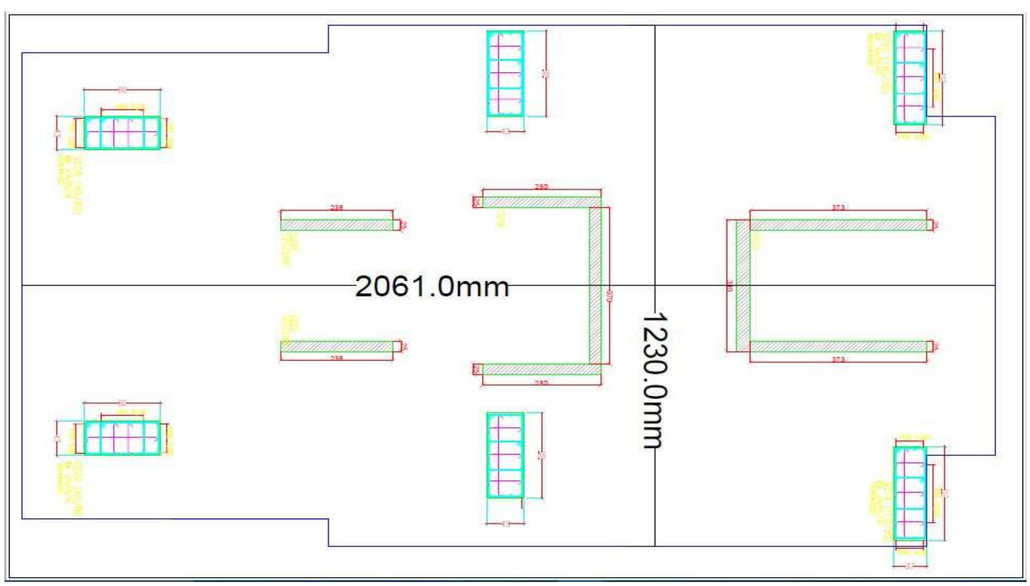


Figure 3.1 first floor plane illustrate location of column and shear wall on the raft mat foundation

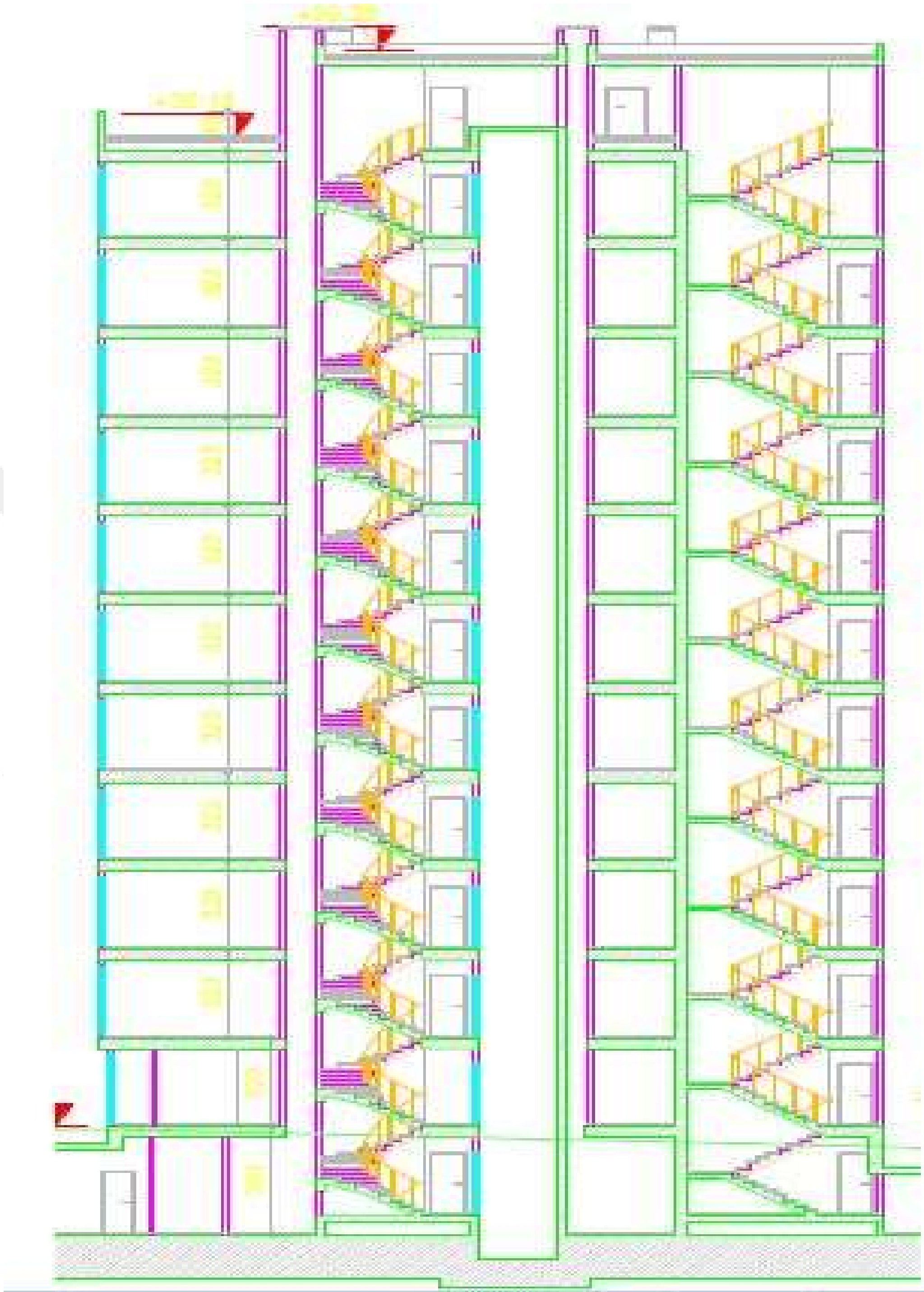


Figure 3.2 cross section plane of real 12 storey residential building

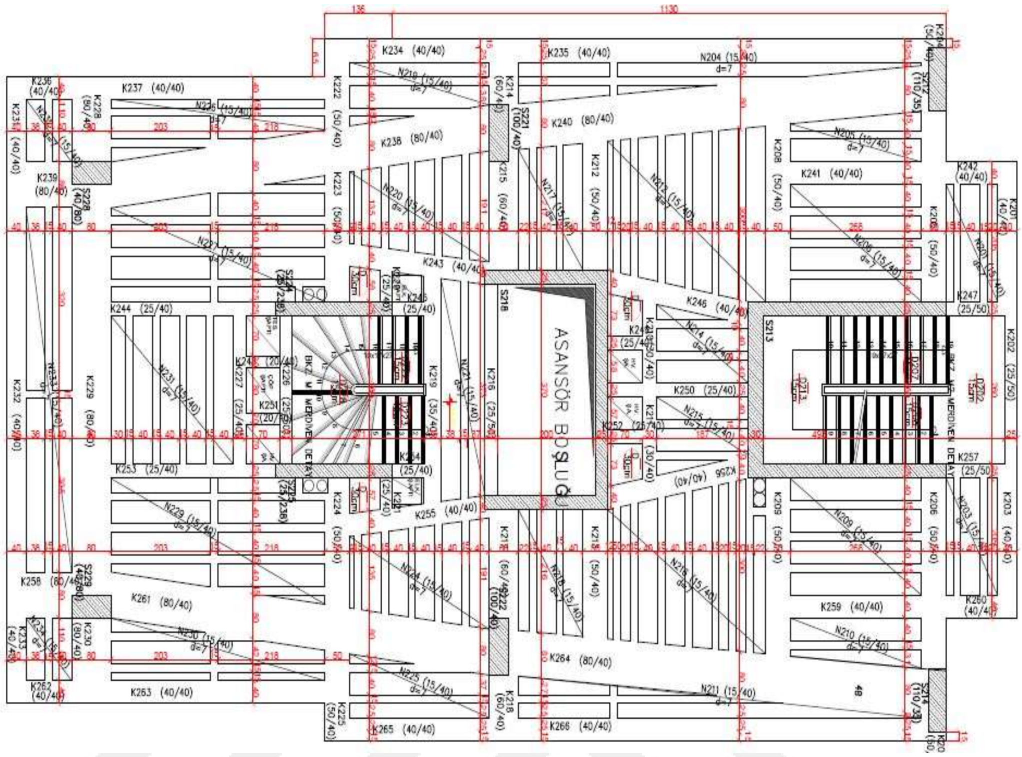


Figure 3.3 ground floor illustrate cross section of beam and type of deviation

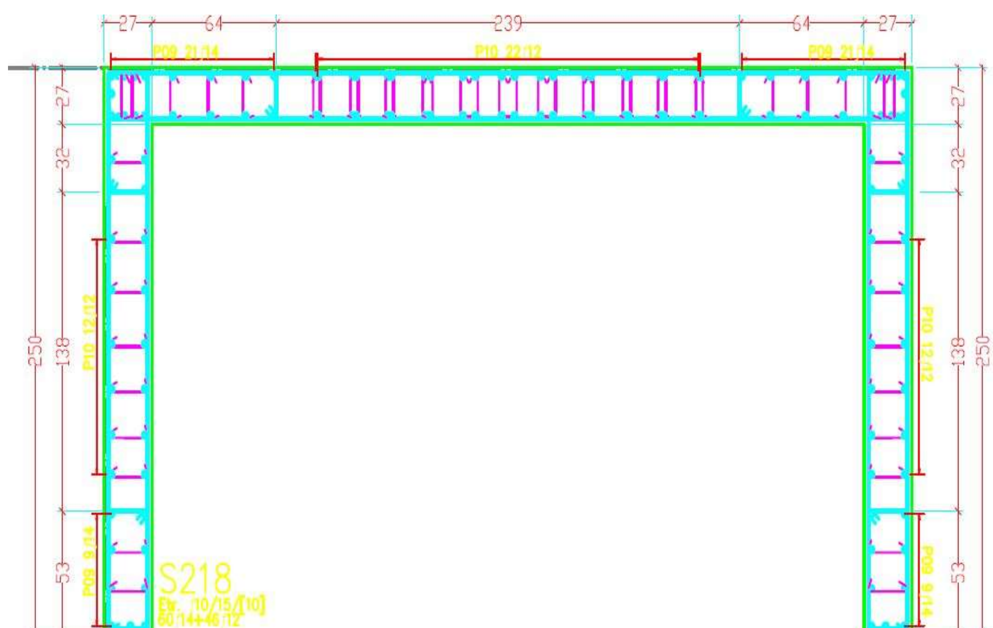


Figure 3.4 One of the box shear wall illustrate reinforcement detail

Table 3.1 property of material used to build structure

Type of section	Section (length * width *height) (m)	Poisson ratio ν	Density γ (KN/m^3)	elasticity Modulus (KPa)	Shear modulus (KPa)
Mat foundation	20,6 * 12.3 * 1	0.2	25	33000000	13750000
Column	0.90 * 0.40 * 3.23	0.2	25	33000000	13750000
Shear wall	0.23 * 2.50 * 3.23	0.2	25	33000000	13750000
Steel (reinforcement)	-	0.3	77	21000000	80769231

3.2 Different type of soil investigate in this research

Typical earthquake design conditions obtained by dividing zones based on shear wave velocity (Vs) of the upper 30m of the ground profile (VS30) For zone classified, (Vs30) is calculated as the time of the shear wave moving from the ground plane depth (30 m), It is not an arithmetic mean of Vs up to 30 m in depth. As shown in (Eq. 3.1), the time average (Vs 30) is a value obtained by dividing 30 m by the sum of the moving time of the shear wave passing through each layer. Each travel time is calculate by thickness of the layer (d) divided to (Vs).

$$V_s30 = \frac{30}{\Sigma\,(d/V_s)} \quad \text{(Eq. 3.1) [18]}$$

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

Such as, (Vs30) for the soil topography, 18 m weak clay (Vs=90 m/sec) over (12 m) of stiff clay (Vs=260 m/sec) was be calculated: (30/(18/90 + 12/260)=122 m/sec [Dobry et al. 2000]. The time-average method conventional results in a lower (Vs30) than the weighted average of the velocities of individual layers. {(90*18) + (260*2)}/30=158m/sec. [16].

For understanding effect of different type of soil on behaver of the soil-structure-interaction, indicate three type of soil according classification of PEER, at the University of California 2012, this classification depend on shear wave velocity, first hard soil (very dense soil) shear wave velocity are between (360 – 760 m/sec) in this study selecting (Vs= 500 m/sec) , second medium soil , shear wave velocity are between (180 – 360 m/sec) , in this study selecting (Vs = 250m/sec), third soft ,weak and loose soil shear wave velocity smaller than (180 m/sec) , in this study selecting (Vs = 120 m/sec).in (Table 3.1) show all necessary property of soil needed to define in sap2000 application.

The shear modulus was calculated using the formula (Eq. 3.2) [17].

$$G_{max} = \rho (V_s)^2 \quad (3.2)$$

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

Modulus of elasticity were calculated using the formulation of (Eq. 3.3) [17].

$$E_{max} = 2(1+v)G_{max} \quad (3.3)$$

Where (ν= Poison ratio)

Table 3.2 property of three different type of soil under foundation of building

Type of soil	Shear wave velocity (m/sec)	Poisson ratio (ν) [19]	Density γ (KN/m^3) [18]	elasticity Modulus (KPa)	Shear modulus (KPa)
Hard (very dense soil)	500	0.3	18	1192600	458692.3
Medium stiffness	250	0.35	16.5	283800	105111.11
Soft and loose	120	0.4	15	61600	22000

3.3 earthquake records (Time history)

In the event of an earthquake, as soon as it emits a seismic wave from the source, it moves through the Earth's crust, when this wave arrives at the soil surface, it can be followed by shaking manufacturing from seconds to minutes , strength and the duration of seismic at a specific position can define; (1) Magnitude, value and location of the earthquake (2) site property., In the area close to the neighbor of a big earthquake ground movement There is a possibility of giving big damage. In fact, ground shaking can be considered to be the most important of all seismic hazard because all the other hazards are caused by ground shacking. Moreover, the ground movement is considered the most significant of all the seismic hazard because all the other damages caused by the earthquake, if the ground shakes are low, these other seismic hazards may be slight or absent. However, there is a possibility that the strong earthquake ground can cause a massive damage from the variety of earthquake disasters. On another hand, Seismic waves pass through the rock with the overwhelming majority of their journey from the epicenter of the earthquake to the earth surface, The last part of this trip is often through the ground, and Characteristics of soil may greatly influence the nature of the shake on the ground.

Ground Soil sediment tends to act as a "filter" for seismic waves by attenuating motion at certain frequencies and amplifying it at other frequencies. Soil conditions often change dramatically at short distances, the level of soil shaking can vary considerably within the small zone, one of the most significant aspects of ground seismic engineering practice is to evaluate the influence of strong ground motion and local soil conditions. (steven L. Kramer) [24].

The input earthquake in this research is based on the actual seismogram at the foundation bedrock, It was recorded to shaking event at Altadena earthquake For the time history analysis of the 12 building storey concrete frame investigated, the strong ground motion record (Fig. 3.5) (recorded at station ID NO. 24402) and station sequence number 339. with the coordinates hypocenter latitude (34.5981 deg.), hypocenter longitude (-116.2645) which, One of the strong record earthquakes that caused severe damage in 1999, the magnitude equal (7.13MW), The vertical component of strong ground motion of Earthquake that has the maximum acceleration equal (439 cm/sec2) was selected as the dynamic linear analysis for the behavior of different type of soil include soil-structure-interaction system. In this research we have a deal only with behavior of earthquake motion on structure not investigate on different type of earthquake due to only this seismic motion that define above used to this study .

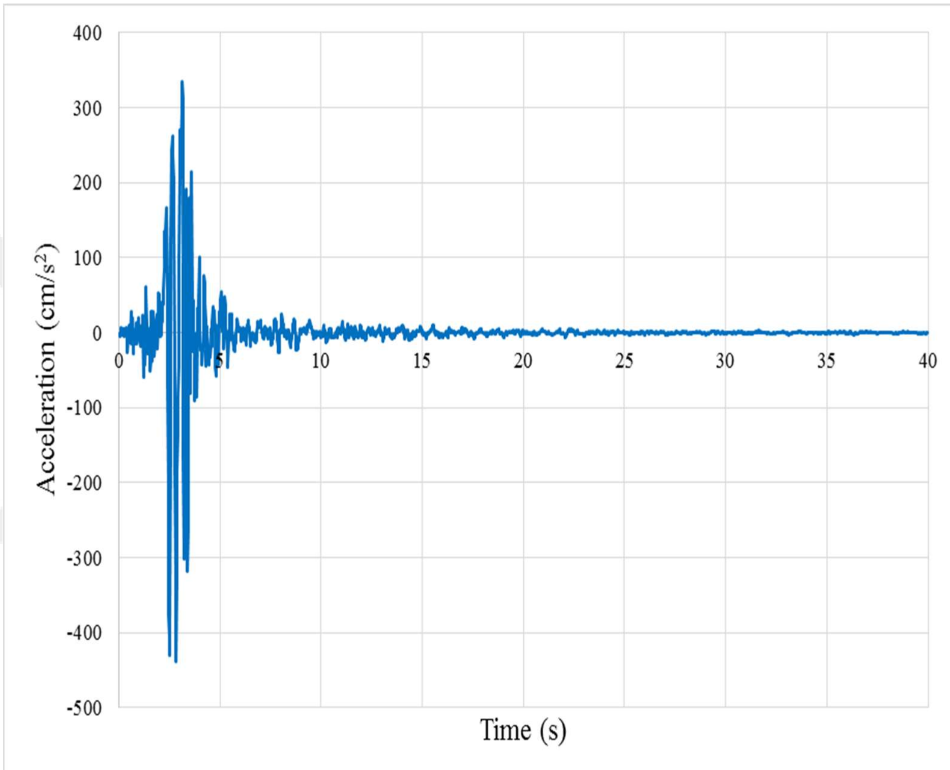


Figure 3.5 Altadena earthquake acceleration time period record

It is well known that the shaking intensity reduce as the distance from the earthquake fault where the earthquake ground motion occurred decreases [21].

Moreover; High frequency components absent energy faster than low frequency components while moving on the ground. Near field earthquakes produce high ground peak acceleration and frequency components compared to earthquakes that happened in far zone. Characteristics above earthquake proposed by the International Structural Control and Monitoring Association for benchmark seismic survey. [22]

The geotechnical engineer, sphere of influence extends through the upper 30 meters of the soil and beyond that the seismologist is chiefly involved. Geotechnical engineers, being civil engineers, understand the needs of their civil engineering colleagues, the structural engineers, better than the earth scientists, and geotechnical engineers collaborate closely with the structural engineers on design projects, especially concerning foundations and retaining walls. [23]

3.4 Modelling the structure and soil

To model the residential building analyses with soil-structure-interaction and with fix base model in this thesis the engineering program application SAP2000 software, version 19 was used. The software is based on the finite element method and is widely used to solve problems within the field of analysis of structures. The software can perform static and dynamic structural analysis for both linear and nonlinear behavior of structures.

3.4.1 Modelling the building (structure)

The model is based on the real and exists design of the building as well as on a site was built in Istanbul city from turkey, carried out to verify fundamental dimensions of structural elements. (Figure 3.1) illustrate building plane show location of column and shear wall that build on one meter depth of raft mat foundation and (Figure 3.2) illustrate building height that each floor height equal (3.23 m) also (Figure 3.3) show beam and slab dimension. The model contains all elements with all specific and property that are considered to affect the structural behavior, such as reinforced concrete walls and slabs column and beam with foundation. Also include all dimension of cross-section, length and height of all element with floor height. The non-concrete and non-structure such as floor tile and block wall is considered to have no contribution to the overall stiffness of the building and is therefore omitted, except as mass. The concrete walls and slabs are modelled as shell elements. Define all property of structure material from (Table 3.1) in sap2000.

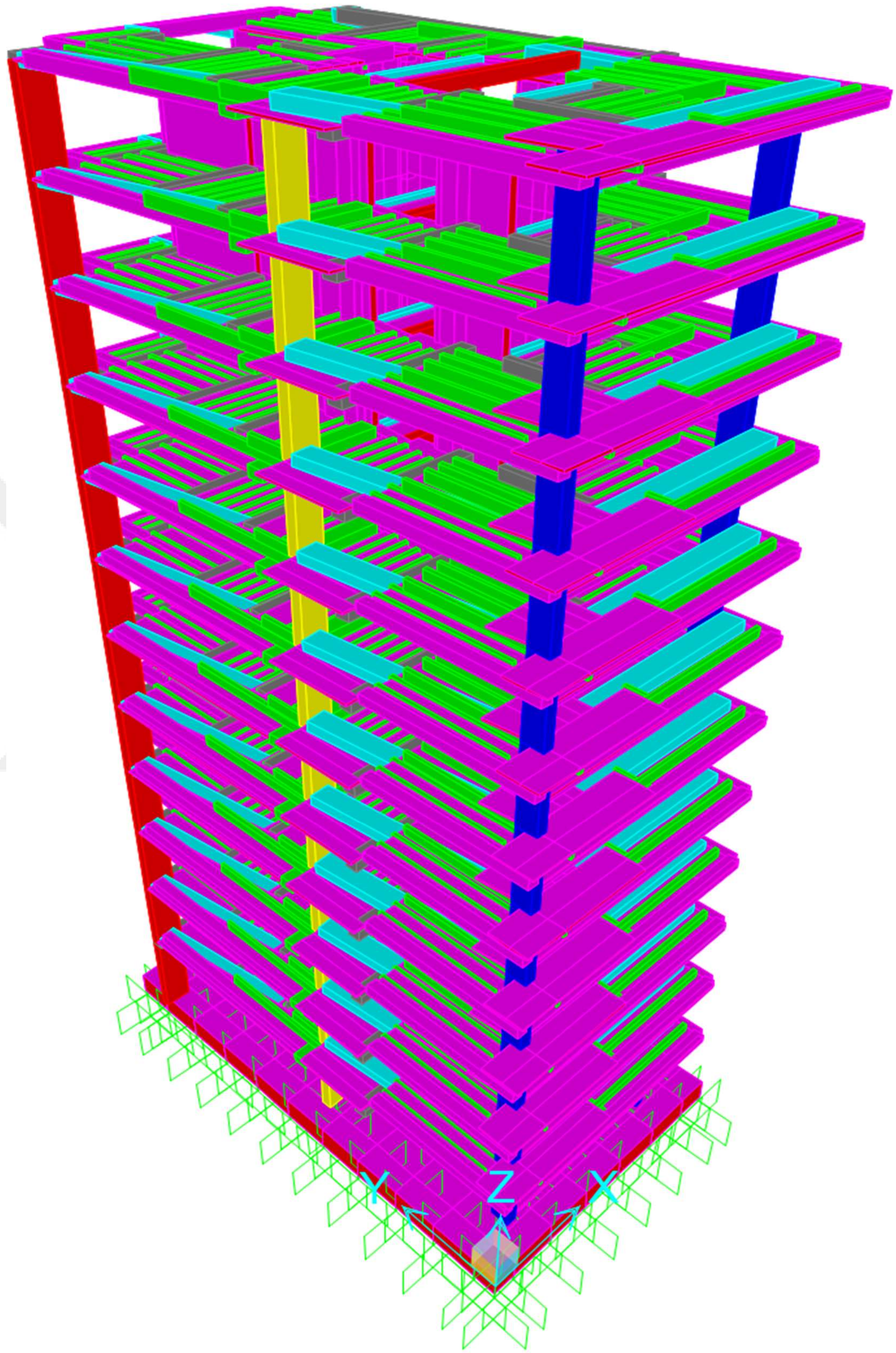


Figure 3.6 View in 3D of 12 storey building with fix base was modelled in SAP2000.

3.4.2 Modelling the building with soil (soil-structure-interaction) finite element model

The simplest type of idealized soil response is to assume the behavior of supporting soil medium as a linear elastic continuum. The idealized and simplest type of ground response is to assume that behavior of supports soil media as a linear elastic sequence In Elastic sequence or finite element model, the finite soil mass is considered based on convergence study, with boundary far beyond a region where structural loading has no effect. This model can be considered as an approximation of real soil behavior. In continuum idealization, soil is assumed to be semi-infinite and isotropic for the sake of simplicity. [26]

3.4.2.1. Idealization of soil–structure system in direct method

Way to solve the basic equations of the movement of the structure of the foundation interaction, these equations are relatively complex. Using the direct method, it is necessary a computer program that can handle the behavior of both the soil and structures as closely [27].

The side edges of the main grid are coupled to the free field grid simulated by viscous dashpots, which represent quiet boundaries on the sides of the model and unequal forces from the free field grid are applied to the main grid edge. (Roesset and Ettouney. 1977) [28]. as shown in (Figure. 3.7)

Numerical analysis performed by researchers such as, [29, 30]. the edges condition for the bedrock is assumed to be stiff, boundary of stiff bedrock conditions are represent in numerical models of soil structure interaction, on another hand, Earthquake acceleration records are straight applied to grid points along the stiffness base of the finite element in the soil. [31]

Distance between soil boundaries, concluded that the horizontal distance of the soil lateral boundaries should be at least five times the width of the structure. Distance between the ground edges, concluded that the horizontal distance of the ground side boundaries should be at least five times the foundation width of the structure boundary. (Rayhani and Naggar). [32]

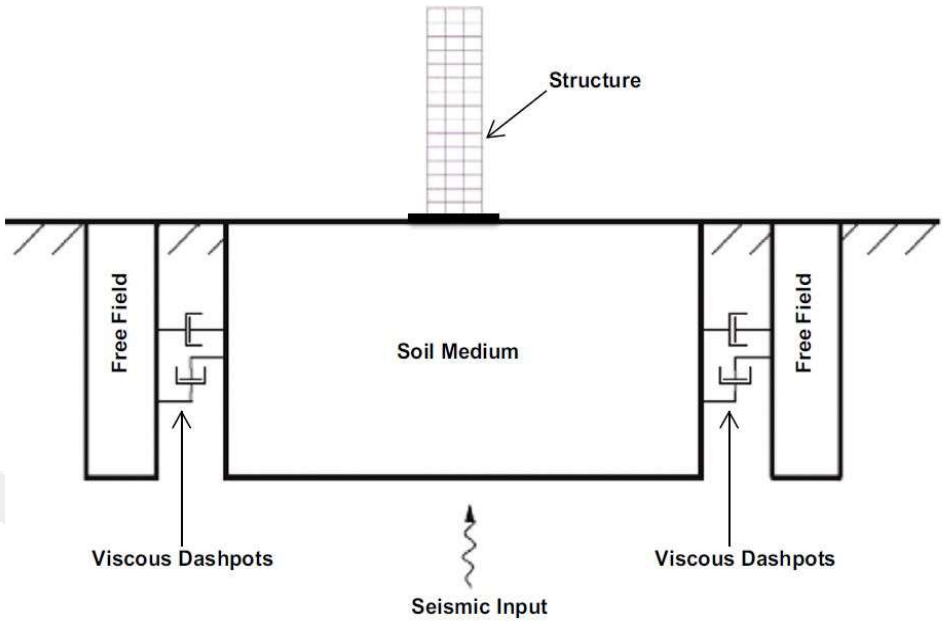


Figure 3.7 illustrate lateral boundary conditions for soil–structure-interaction Model. (Roesset and Ettouney [28]).

After comprehensive numerical modeling and centrifuge model test, since the most amplification occurs within the first (30 m) of the soil profile, recommended as the maximum depth of bedrock in numerical analysis is (30 m). Although; new codes of earthquake such as [33, 34]. Evaluate local site effects just based on the properties of the top 30 m of the soil profile. Evaluate the local site influence based on the characteristics of the top 30 m of the soil profile start from surface. Due to in this research, the Max. Bedrock depth equal (30 m), While the horizontal distance of the ground side boundaries is equal (61.5) m (five times the foundation width of the structure which is (12.30) m in x-axis)., And the horizontal distance of the ground-length boundaries is equal to (103) m (five times the foundation length of the structure which is equal to (20.61) m in Y-axis). The representation of the three-dimensional soil–structure-interaction system by two-dimensional models may lead to underestimation of the maximum response. Representation of three dimensional (3D) soil structure interaction system with two dimensional (2D) model may lead to under estimation of maximum response. (Luco and Hadjian-1974) [35].

In this study investigate full three dimension (3D) for both structure model and soil foundation model. In (Fig. 3.8) View in 3D of 12 storey building with soil-structure-interaction was modelled in SAP2000. For all soil type first very dense soil, second medium soil and third weak soil.

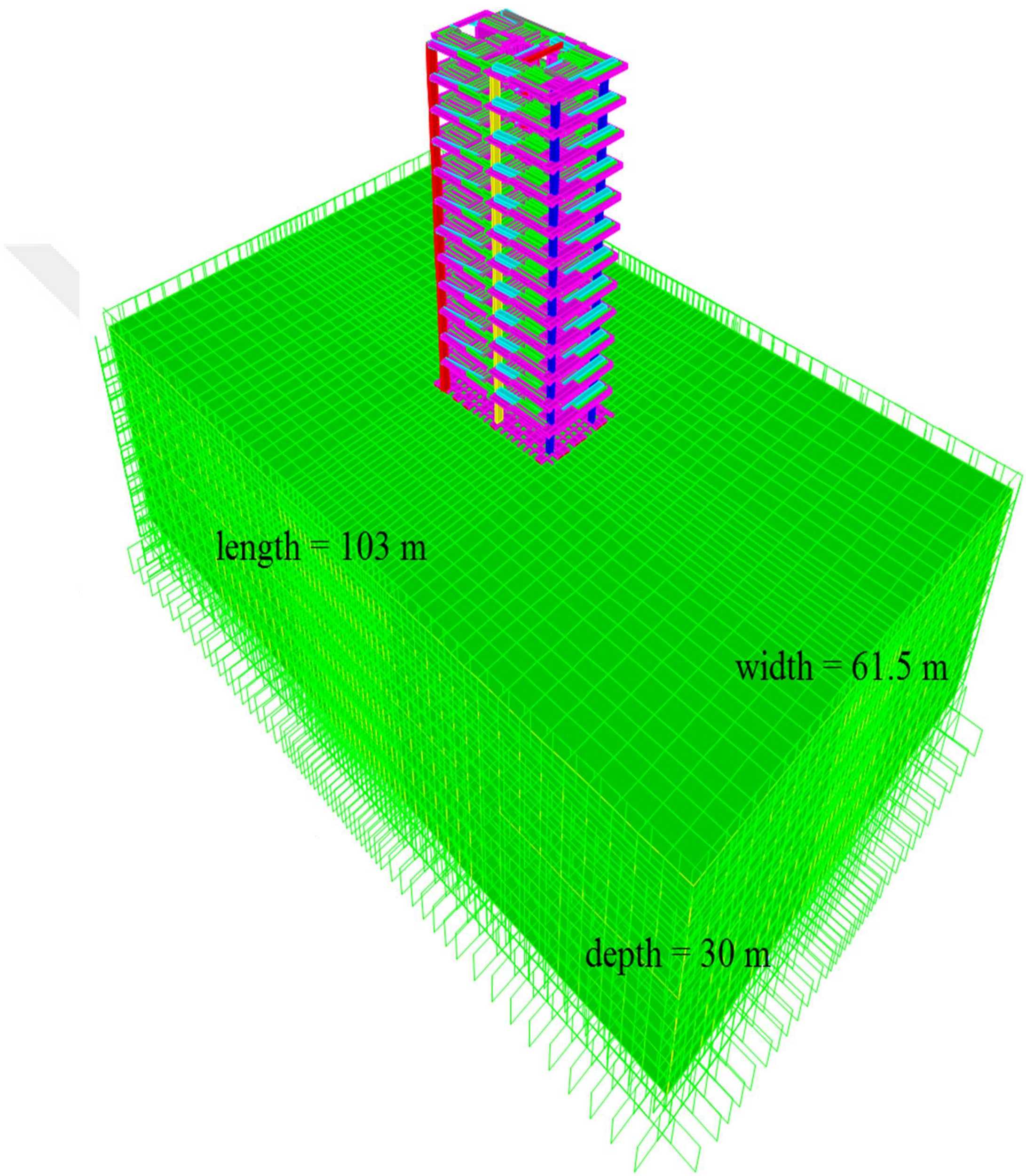


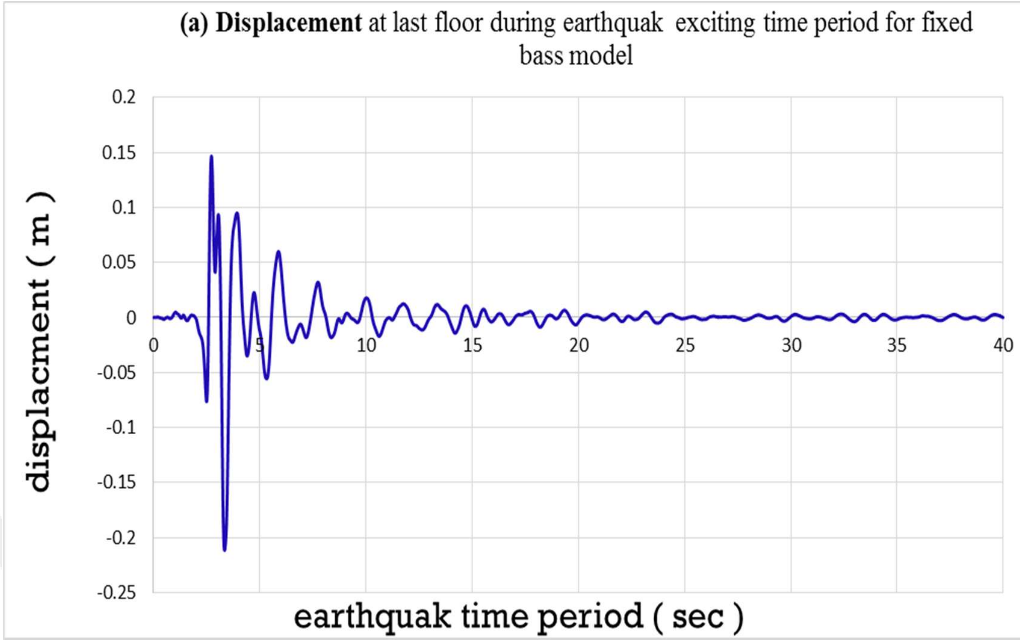
Figure 3.8 View in full there dimension (3D) of 12 storey building with soil-structure-interaction was modelled in SAP2000. For three type of soil, first very dense soil, second medium soil and third weak soil

CHAPTER 4
RESULT AND DISCUSSION

This chapter presents the results of analysis of real twelve storey reinforcement concrete residential building. The linear dynamic analysis with strong earthquake record were carried out using sap2000 its integrated software for structural analysis and design. In this study have four model; First, analysis of typical design fix base. Second analysis of structure with very dense soil together (direct method of soil structure interaction). Third, analyze of structure with medium soil stiffness. Four, analysis of structure with weak or loose soil. All of the results displayed in x-directions of the structure. All of the parameters of structure stay the same and the only parameter which changes at each step are type of soil that structure built on it. From the analysis result; storey displacement, storey drift, shear force, bending moment and torsion were obtained for each model.

4.1 Displacement

The displacement refers to the distance that points on the ground are moved from their original locations through the seismic waves. Change type of soil that structure built on it, the stiffness and strength of the soil have big rule for decreases or increase displacement of structure. Maximum storey displacement is always one of the most important considerations in design and it is very important to consider in which type of soil can play a role in the lateral displacement and how effect on structure. In this case study, the all models are analyzed for different type of soil foundation and the results of maximum displacement at last floor (12th floor) during earthquake period , figure 4.1 show displacement of last floor and variation with earthquake magnitude acceleration and time period .also in figure 4.2 illustrate comparison maximum value of displacement between each type of soil.



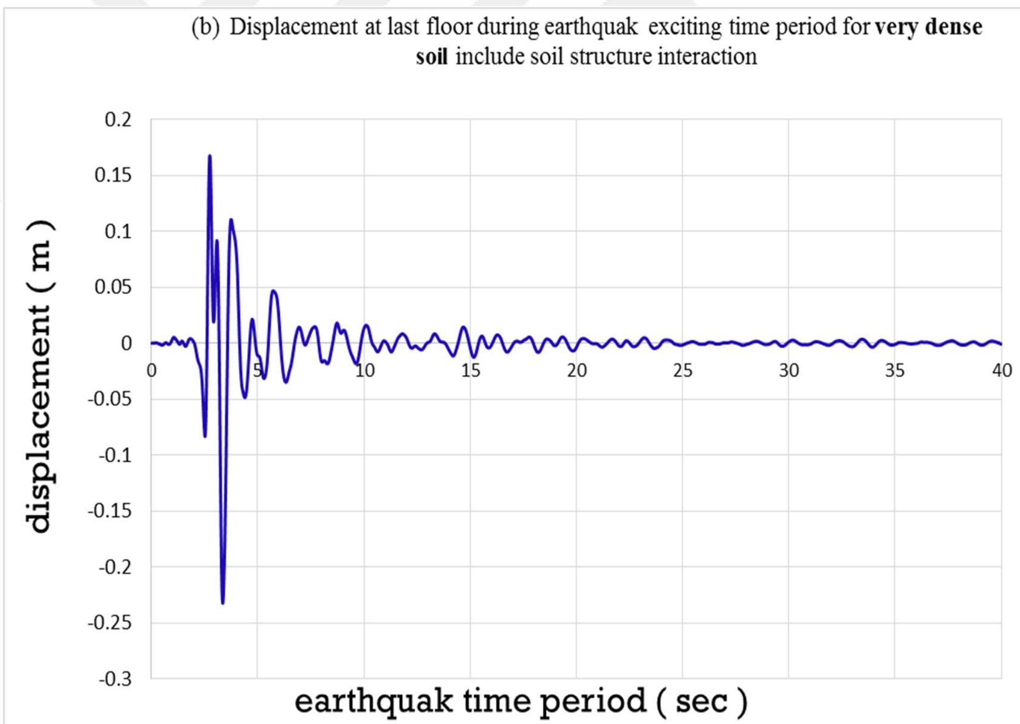


Figure 4.1 (a) for fix base model, (b) very dense soil illustrate displacement of top floor (12th floor) and variation with earthquake magnitude acceleration and time period

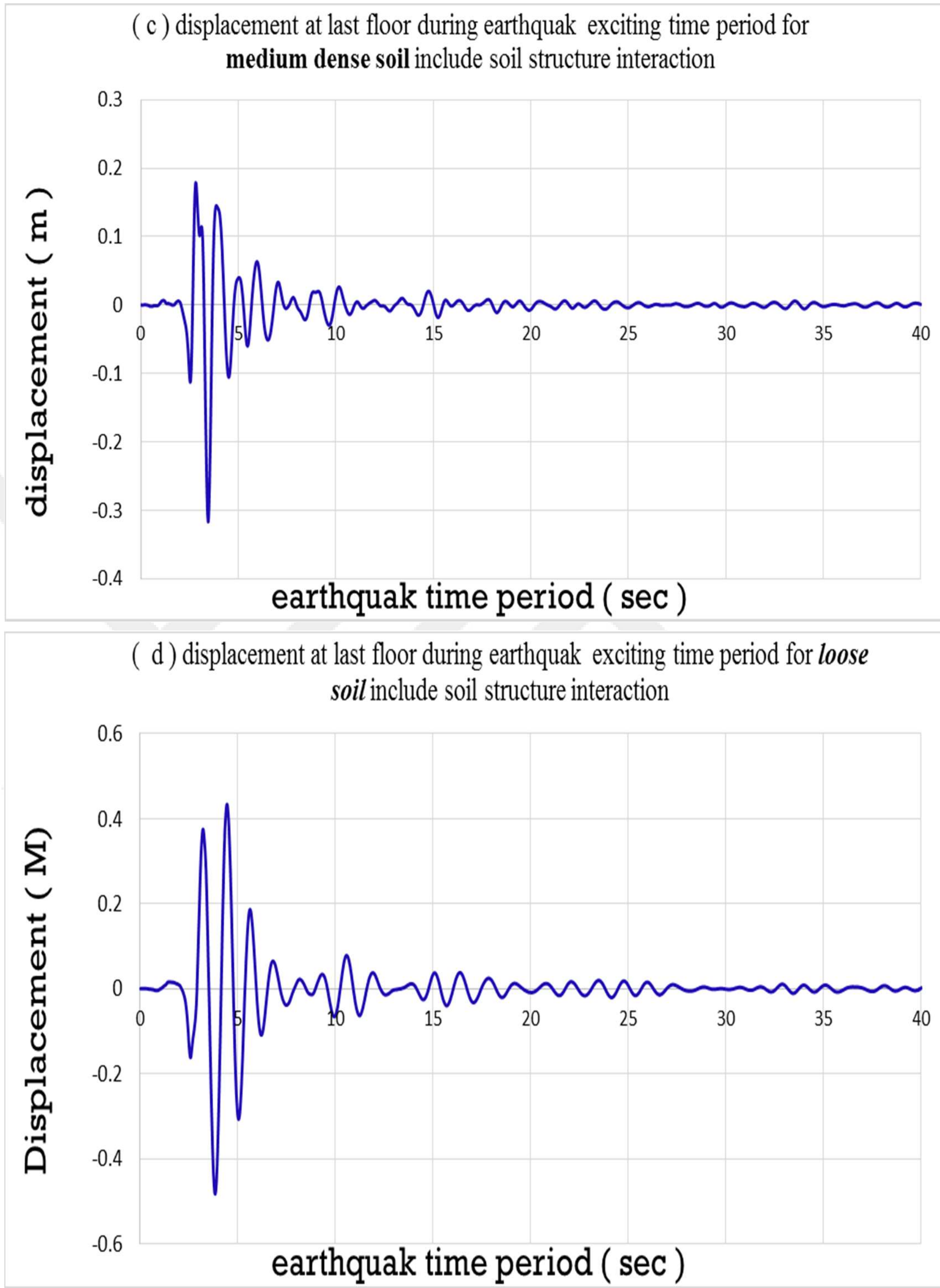


Figure 4.1 (C) medium stiffness, (D), Weak and loose soil illustrate displacement of top floor (12th floor) and variation with earthquake magnitude acceleration and time period

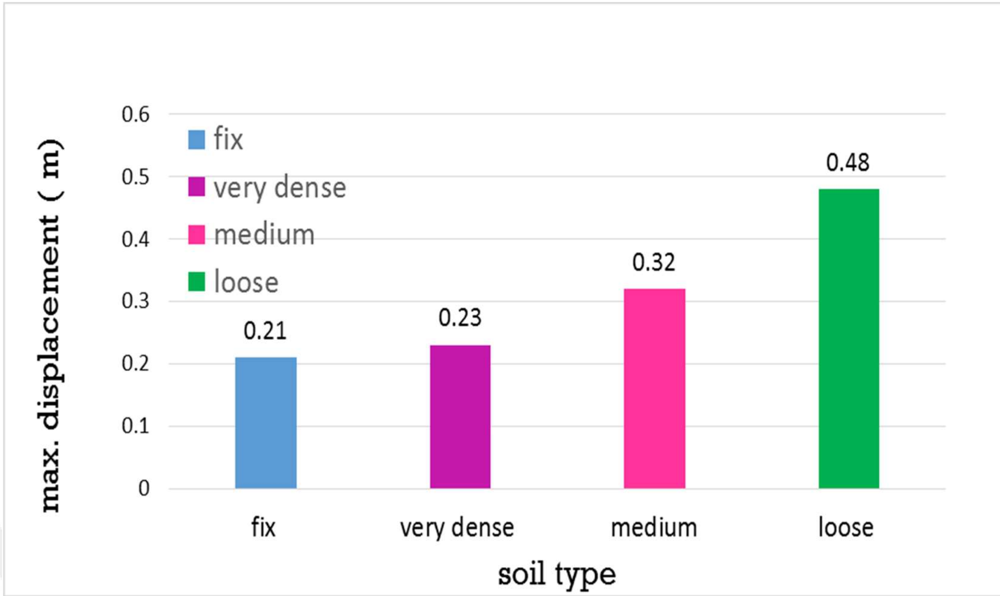


Figure 4.2 comparison of maximum displacement for different type of soil during earthquake exciting

For all storey building displacement, from ground floor, first floor, until last floor summarized maximum displacement in case of seismic exciting in each floor inside (Table 4.1) and illustrate in (Figure 4.3)

Table 4.1 value of maximum displacement for each floor in x-direction

floor number	**fix**	**very dense soil**	**Medium soil**	**Weak soil**
No.	m	m	m	m
0	0	0.019	0.076	0.146
1	0.008	0.027	0.08	0.158
2	0.021	0.031	0.081	0.172
3	0.037	0.041	0.096	0.189
4	0.054	0.056	0.105	0.207
5	0.074	0.074	0.115	0.226
6	0.093	0.092	0.134	0.259
7	0.114	0.115	0.166	0.299
8	0.133	0.14	0.198	0.339
9	0.153	0.165	0.23	0.377
10	0.174	0.189	0.261	0.414
11	0.193	0.212	0.29	0.448
12	0.211	0.232	0.317	0.483

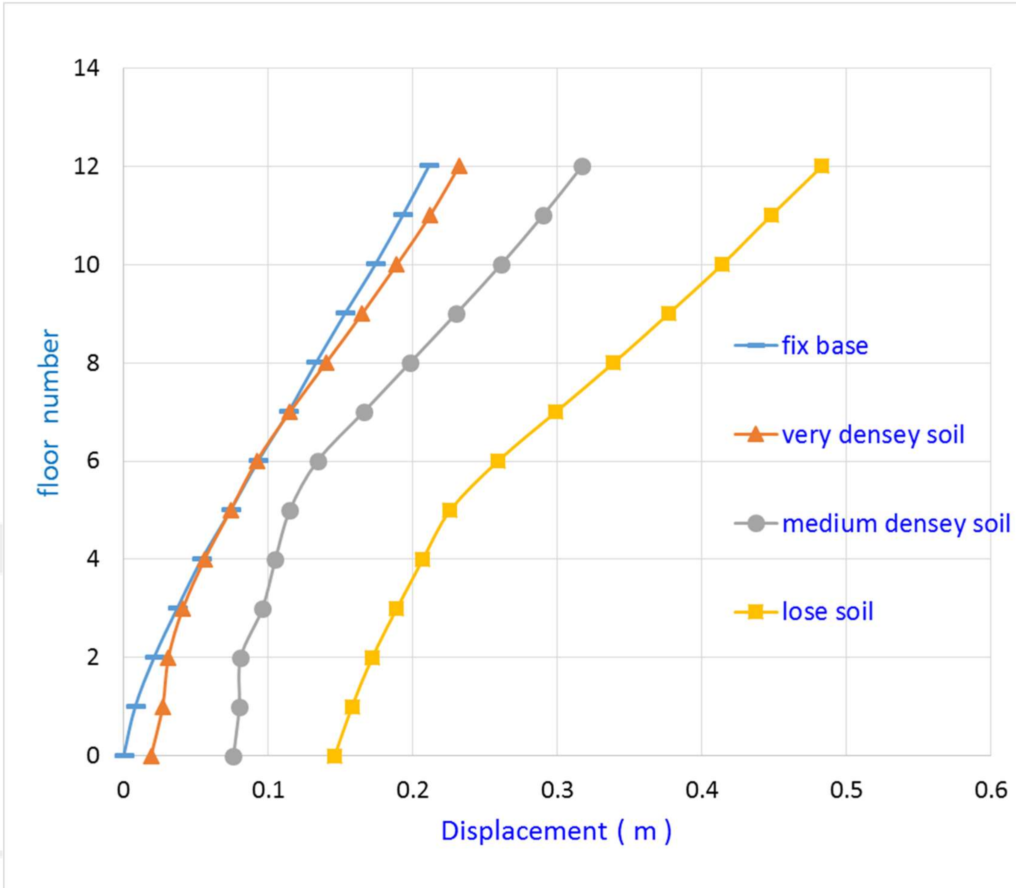


Figure 4.3 illustrate of maximum displacement for each floor in x-direction

Results show from (Figure 4.1 and 4.2), that displacement change when type of soil models are change, displacement increase when decrease stiffness and dense of soil, between fix base model and very dense soil demonstration not huge value happened, increase only (2 cm) compare between fix base and very dense soil its very close value, its mean that for displacement soil-structure-interaction on very dense soil or rocky soil not have big rule for change result due to can neglect. For medium stiffness soil enlarge displacement compare very dense soil and fix base due to SSI consider , enlarge (11 cm) more than fix base , (52 % increase more than fix base) , and (9 cm) more than very dense soil (39% increase more than very dense soil) . for weak soil increase displacement more than fix base , very dense soil and medium soil due to SSI consider, enlarge (27 cm) more than fix base , (128 % more than fix base), increase (25 cm) more than very dense soil (108 % increase more than very dense soil) , increase (16 cm) more than medium stiffness soil (50 % increase more than medium stiffness soil. Weak or loose soil showed from this research result that big warning about displacement when any structure built in weak or loose soil must be considering soil-structure-interaction special strategy super structure like high rise building, dam, and nuclear project …. Etc. This result its match with study of (VANEELA et al. 2016), (GÜLLÜ, Jaf. 2016), and (Mahadev 2015).

4.2 Inner Storey drift

Inner storey drifts are determined from the similar maximum values of the lateral deflections for each two adjacent stories using

Drift = (di+1 – di)/hi ……………………………….. (Eq. 4.1). (AS1170.4. 2007)

Where (di+1) is displacement at (i+1) level,

di is deflection at (i) level,

h is the storey height.

In practical designs, it is often assumed that the deflection is equal to the horizontal displacement of the nodes on the level which may be due to translation, rotation, and distortion. Comparing the results for lateral deflections and inner drifts (Tabatabaiefar and Fatahi, 2014). Moreover, the other important parameter in the design and analysis which is similar to displacement is drift. Drift is the displacement of one level relative to the other level above or below.

According to the building code (UBC 97) and (international building code 2000), the allowable inner drift for buildings is limited to (0.020 times the total height). Values of peak drifts and different floor height for each model are record in (Table 4) along x-direction. From (Fig. 10). Influence S.S.I for drift are bigger than fix base model, drift significant increase when soil going weaker. Researchers (Tabatabaiefar, Fatahi. 2014) in them researcher observed that structure go to collapse in weak soil, But which was not seen in this analysis study for all four models because in this structure exist many different beam and shear wall to control drift. Results in this study are much with (Hokmabadi, et al. 2014) and (Roopa et al. 2015). All researcher recommended to careful about built structure in weak soil.

Table 4.2 inner storey drift value for all different storey height and each model

storey number	height of storey	fix base	very dense soil	medium soil	weak soil
0	3.23	0.00247678	0.00247678	0.00123839	0.00371517
1	3.23	0.004024768	0.00123839	0.000309598	0.00433437
2	3.23	0.00495356	0.003095975	0.004643963	0.00526316
3	3.23	0.005263158	0.004643963	0.002786378	0.00557276
4	3.23	0.00619195	0.005572755	0.003095975	0.00588235
5	3.23	0.005882353	0.005572755	0.005882353	0.01021672
6	3.23	0.006501548	0.007120743	0.009907121	0.0123839
7	3.23	0.005882353	0.007739938	0.009907121	0.0123839
8	3.23	0.00619195	0.007739938	0.009907121	0.01176471
9	3.23	0.006501548	0.007430341	0.009597523	0.01145511
10	3.23	0.005882353	0.007120743	0.008978328	0.01052632
11	3.23	0.005572755	0.00619195	0.008359133	0.01083591

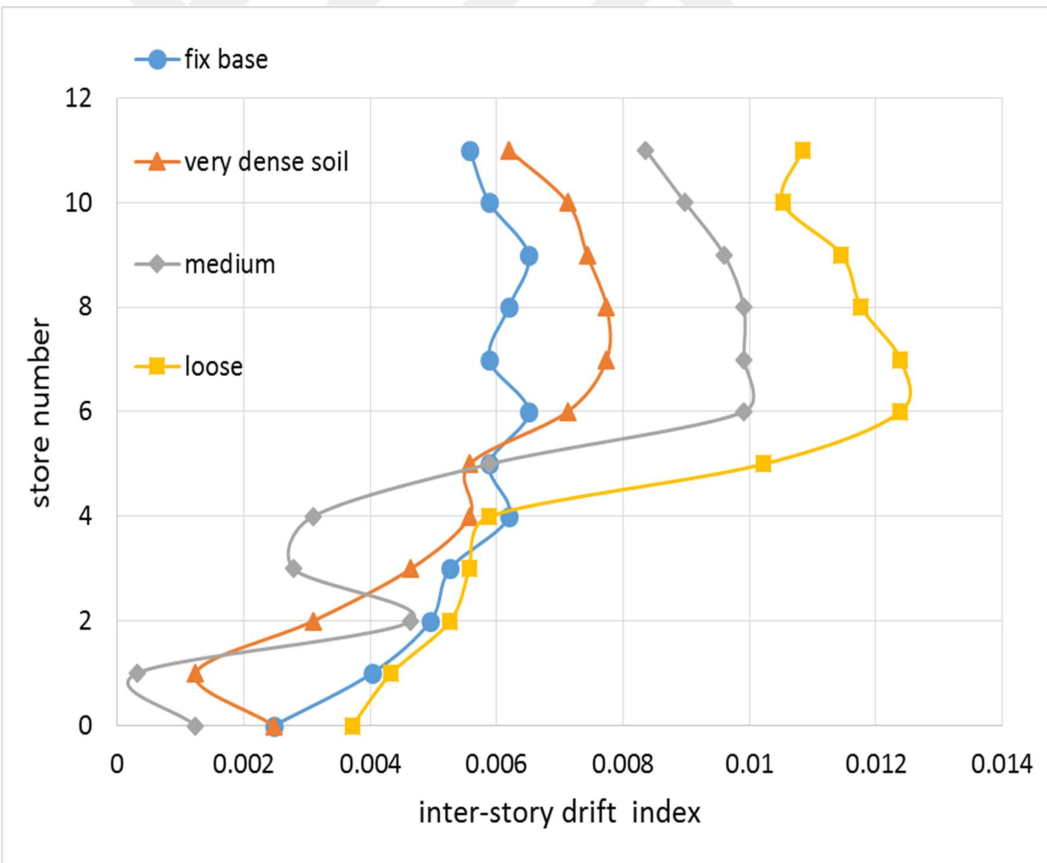


Figure 4.4 illustrate inter storey drift index for each floor and each model

4.3 Effect of S.S.I on the amount of shear force for beam

For understanding effect of soil-structure-interaction on the beam that indicate from ground floor building with cross section (40 * 60) cm with clear span equal (7.5 m) at the base of frame building, all result record for it during applied earthquake for building for each model and indicate maximum shear force for each model, showing result in (Figure 4.5 and 4.6). Results similar to previews study of (Roopa, et al. 2015) and (Patil, et al. 2016).

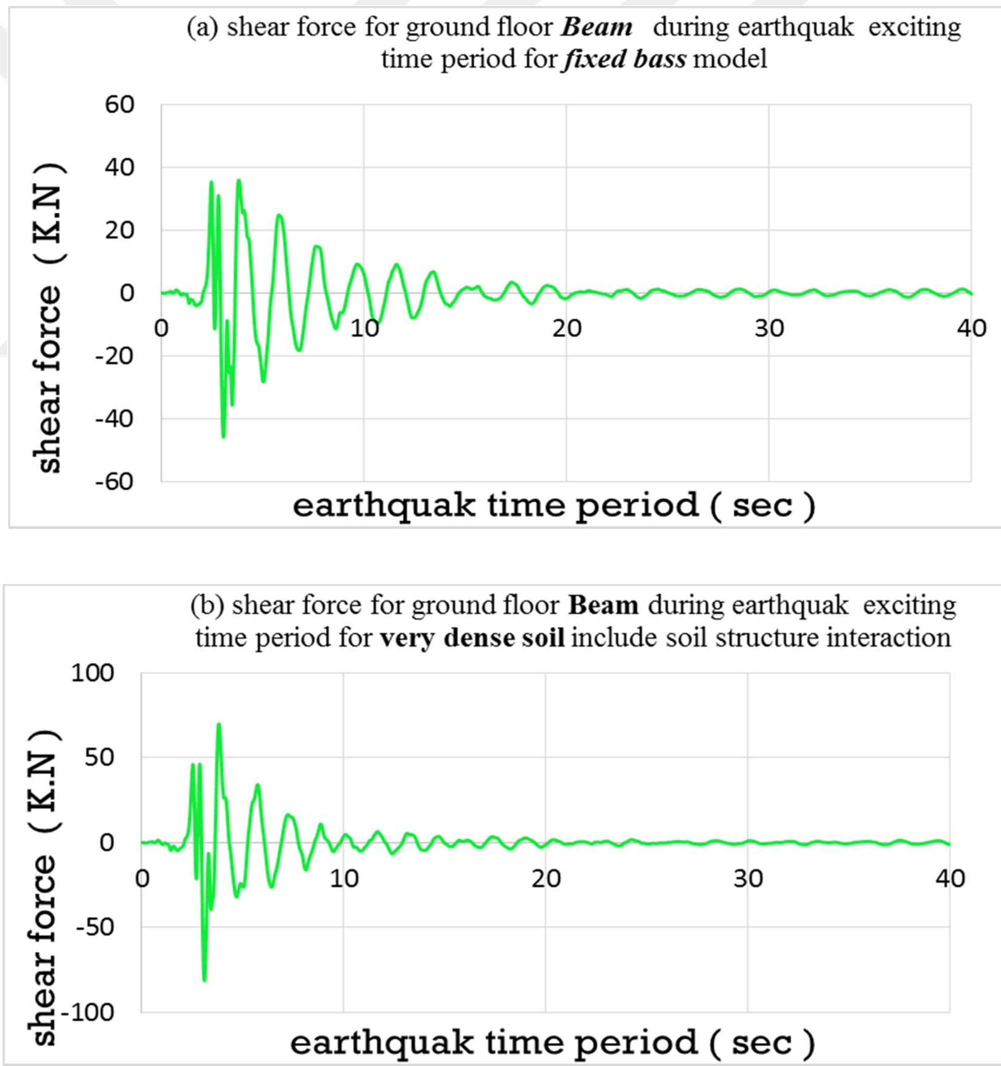
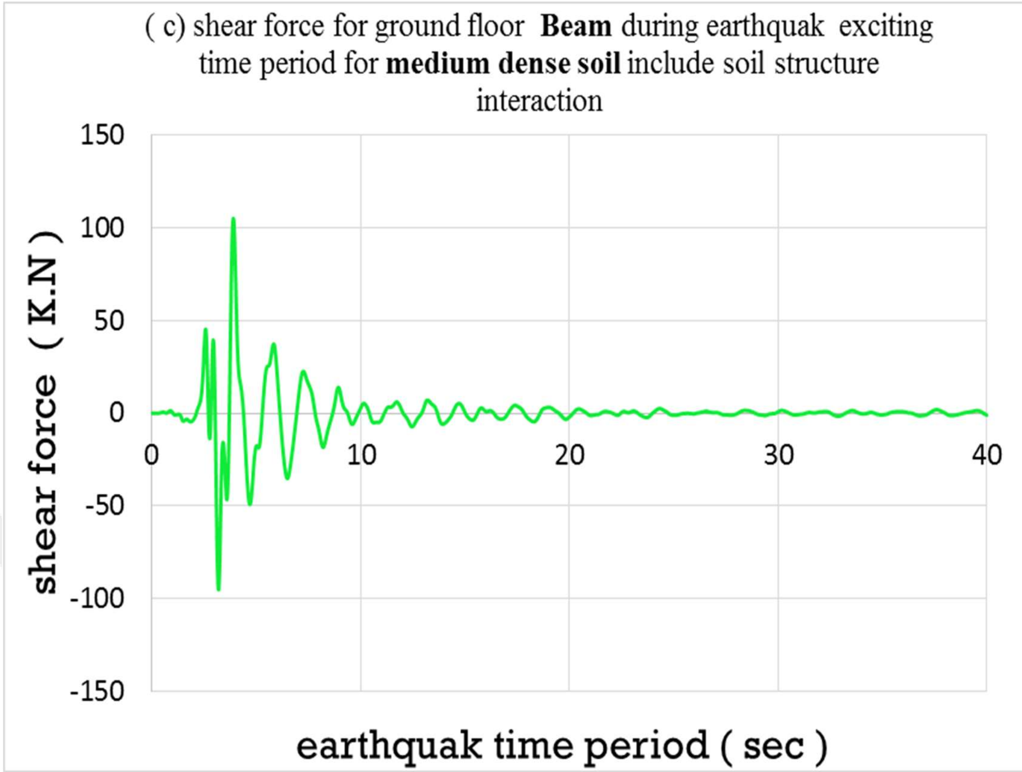


Figure 4.5 (a and b) illustrate shear force for ground floor beam during earthquake exciting time period effecting by S.S.I



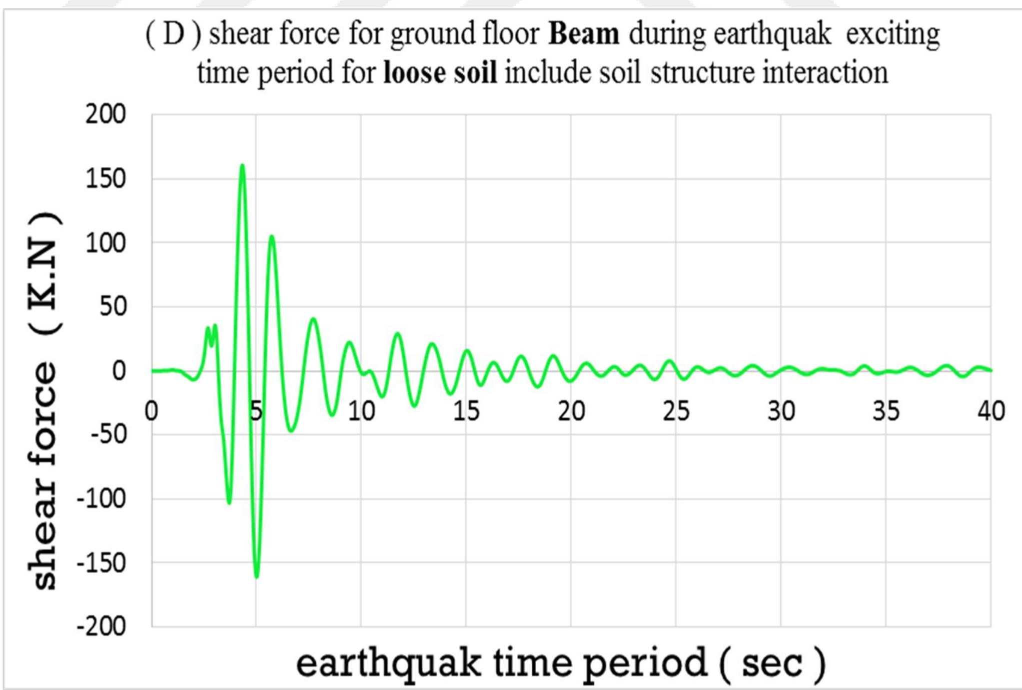


Figure 4.5 (c, and d) illustrate shear force for ground floor beam during earthquake exciting time period effecting by S.S.I

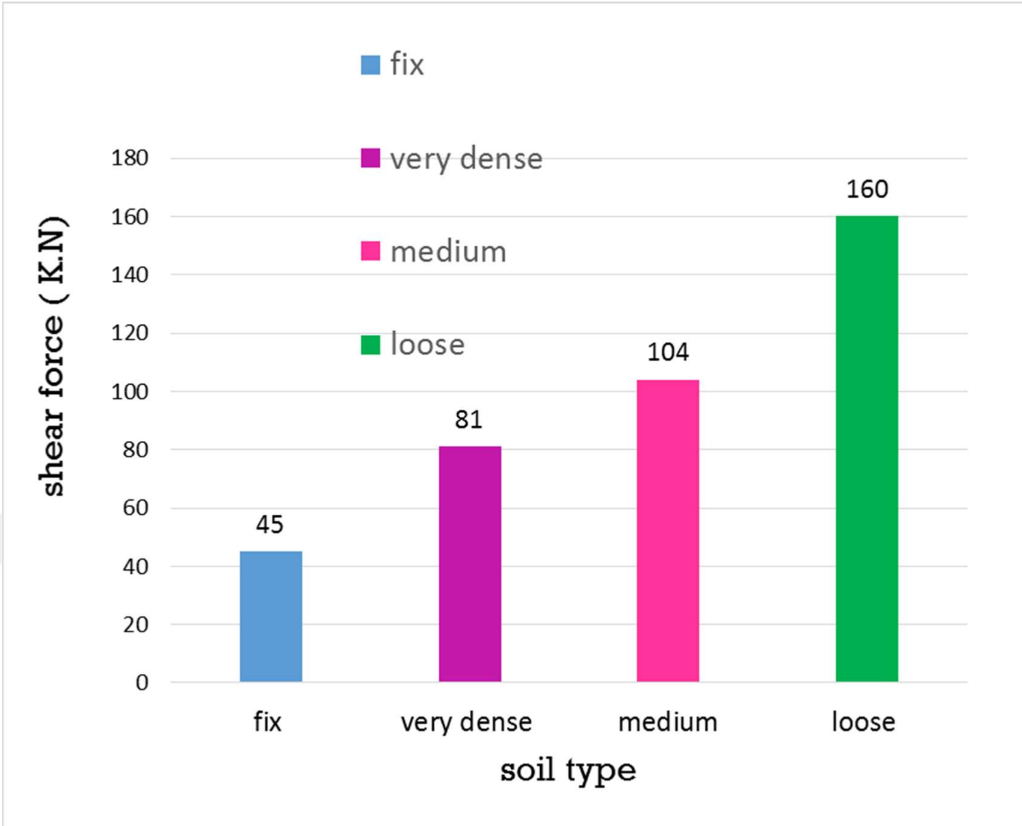


Figure 4.6 comparison of maximum shear force for ground floor beam in different type of soil during earthquake exciting

Observed in the result from figure 4.5 and figure 4.6 that the loose soil had Maximum Shear force more than all model, for very dense soil shear force bigger (36 KN) more than fix base, increased (80 %). For medium stiffness soil shear force bigger (59 KN) more than fix base, increased (131 %), and bigger (23 KN) more than very dense soil, increased (28 %). For loose soil shear force bigger (115 KN) more than fix base, increase (255 %), bigger (79 KN) more than very dense soil, increase by (97 %) and bigger (56 KN) more than medium stiffness soil, increased (53 %). Results match to previews study of (Roopa, et al. 2015) and (Patil, et al 2016).

4.4 Effect of S.S.I on the amount of shear force for base column

For understanding influence of soil structure interaction on the shear force in base column that indicate from front of building with cross section (40 * 80) cm with height equal (3.23 m) at the base of frame building, all results record for it during applied earthquake for building for each model and indicate maximum shear force for each model, showing result in (Figure 4.7 and 4.8)

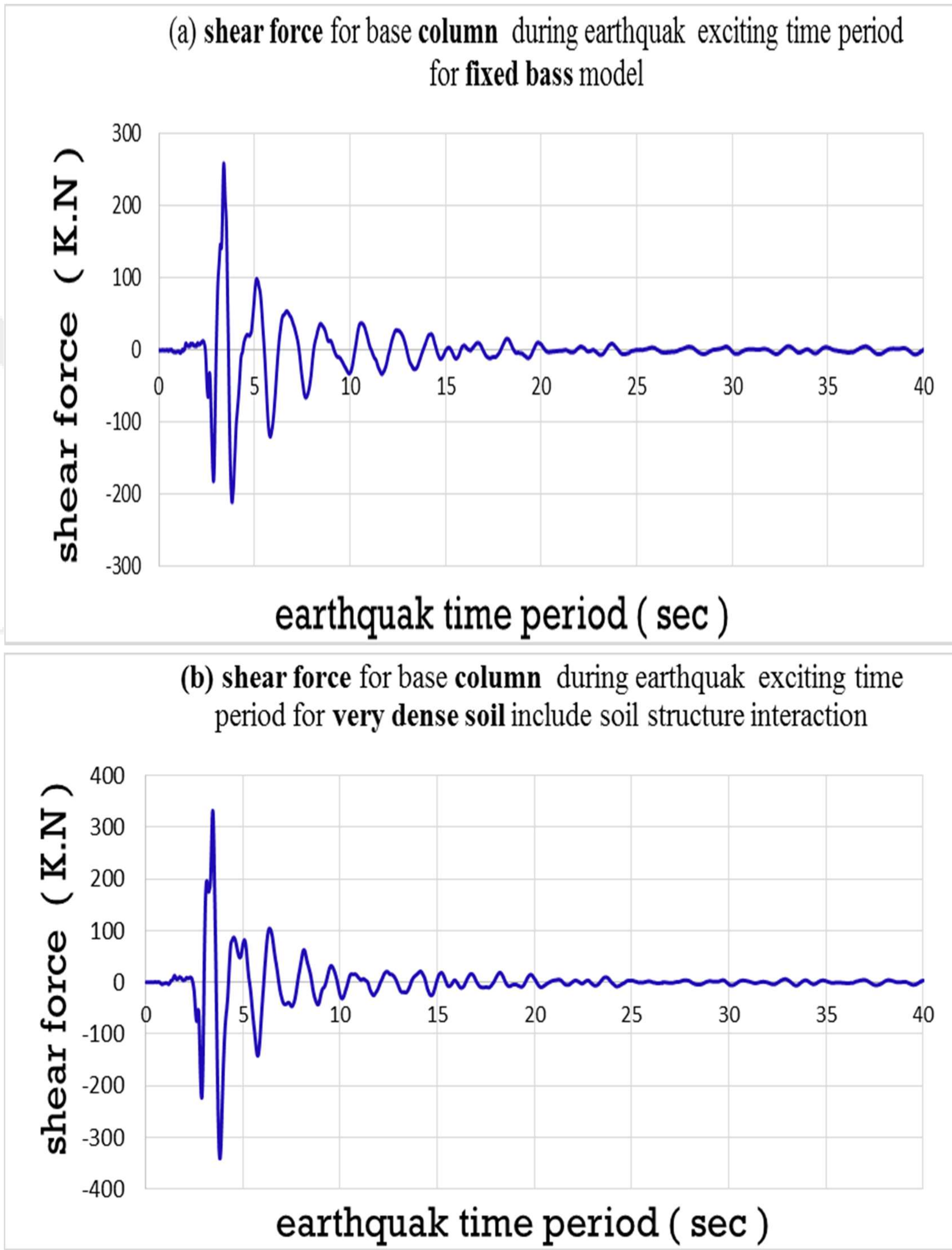


Figure 4.7 (a and b) illustrate shear force for base column during earthquake exciting time period for each model

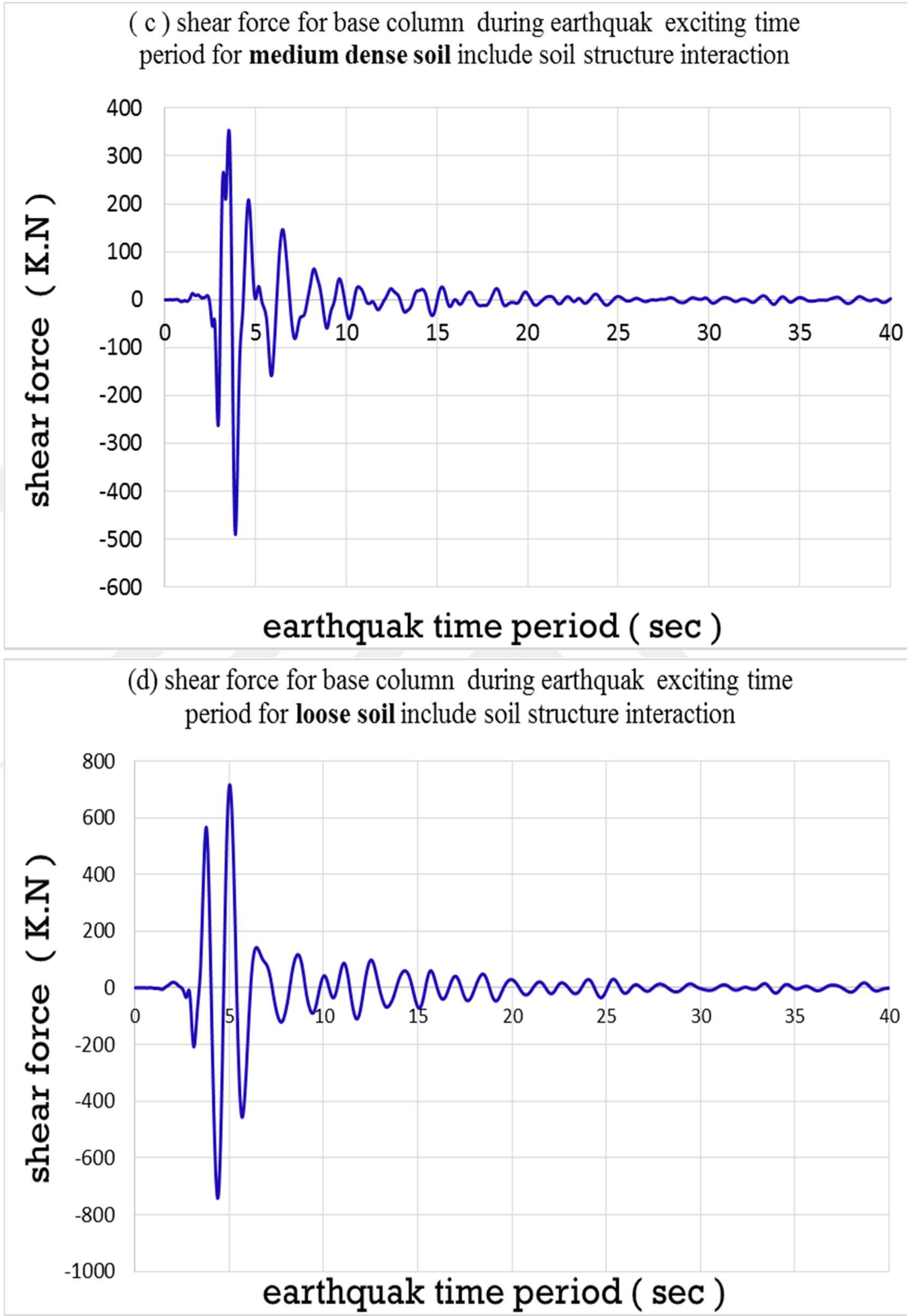


Figure 4.7 (c and d) illustrate shear force for base column during earthquake exciting time period for each model

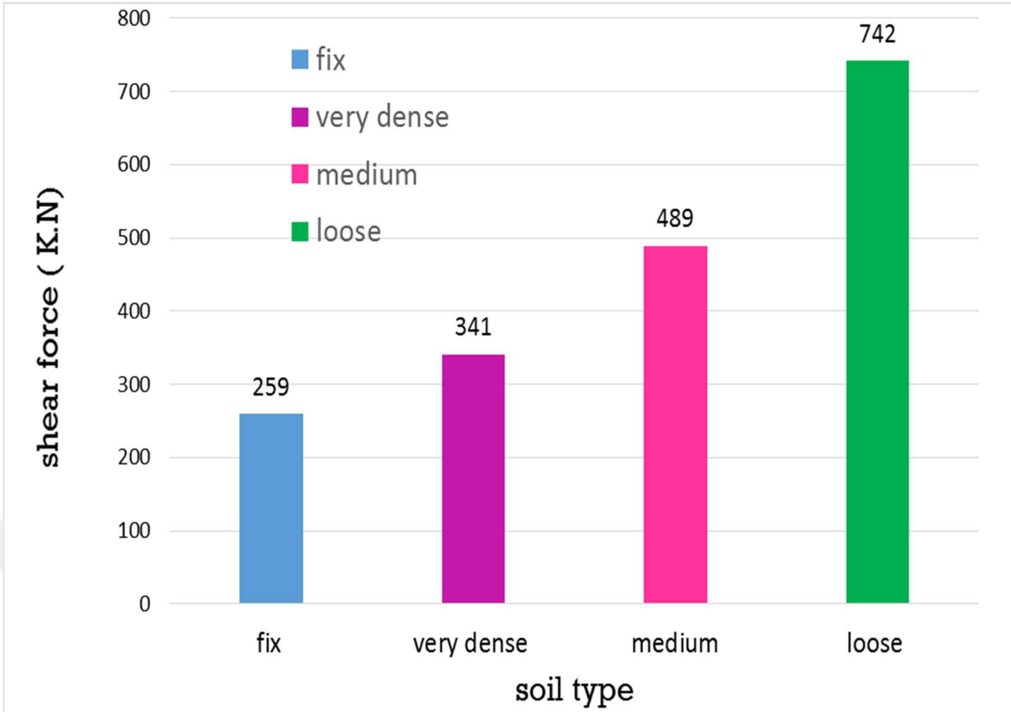


Figure 4.8 comparison of maximum shear force for base column in each model during earthquake

Observed from figure 4.7 and 4.8 that enlarge variation between fix base model and other model increase very dense soil by (31 %) more than fix base, medium soil increase by (43 %) more than fix base and loose soil increase by (186 %) more than fix base model. For both shear force in column and beam the amount of shear force are hysterical changing by effect of S.S.I that analysis by direct analysis, it should be very carefully using soil-structure-interaction in analysis and design for future study can research with different model of soil structure in laboratory and numerical program. Results match to previews study of (Roopa, et al. 2015) and (Patil, et al 2016).

4.5 Moment for ground floor beam.

Summaries all result for bending moment during earthquake exciting for the ground floor beam of structure for each model, showed results in (Figure 4.9 and 4.10).

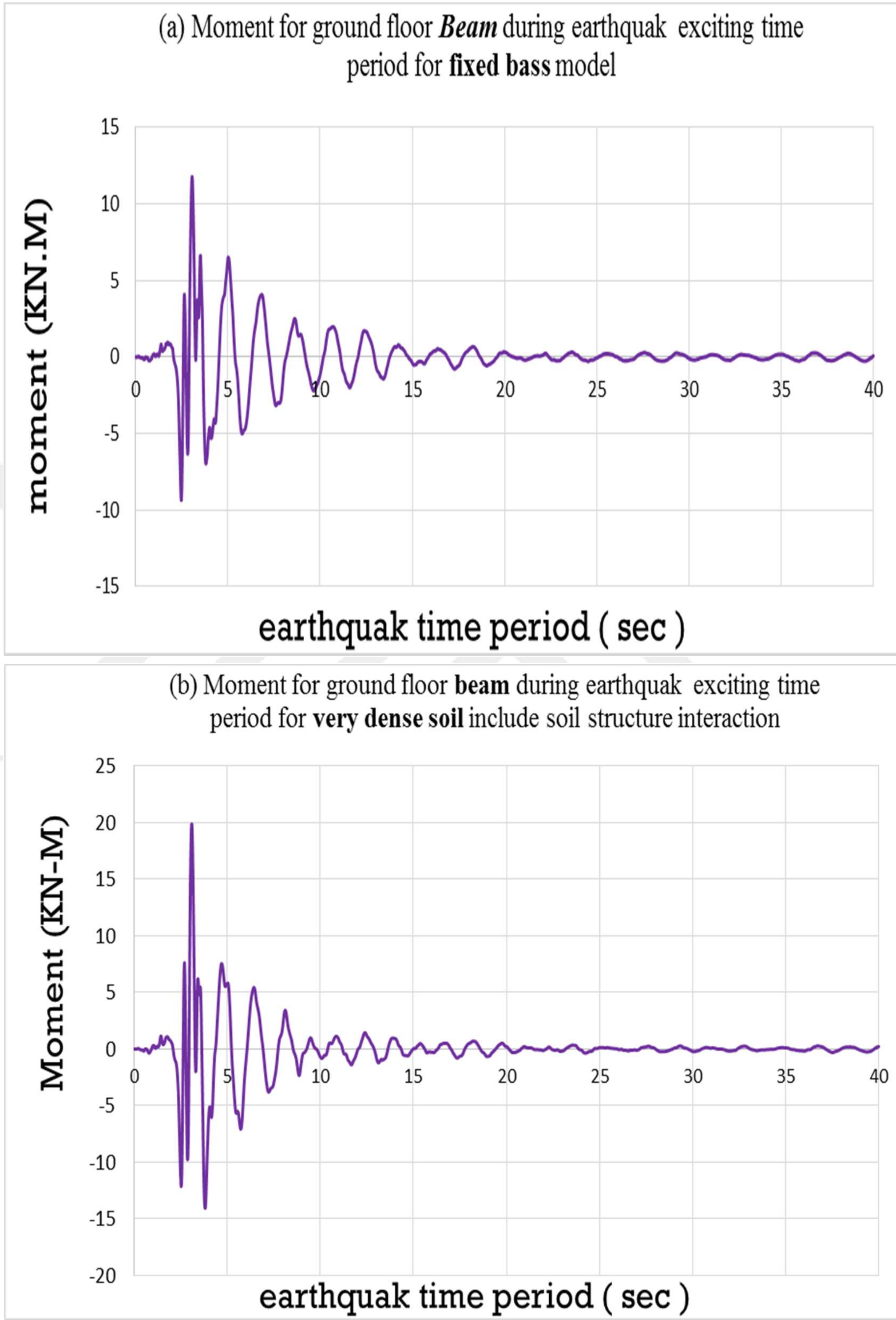
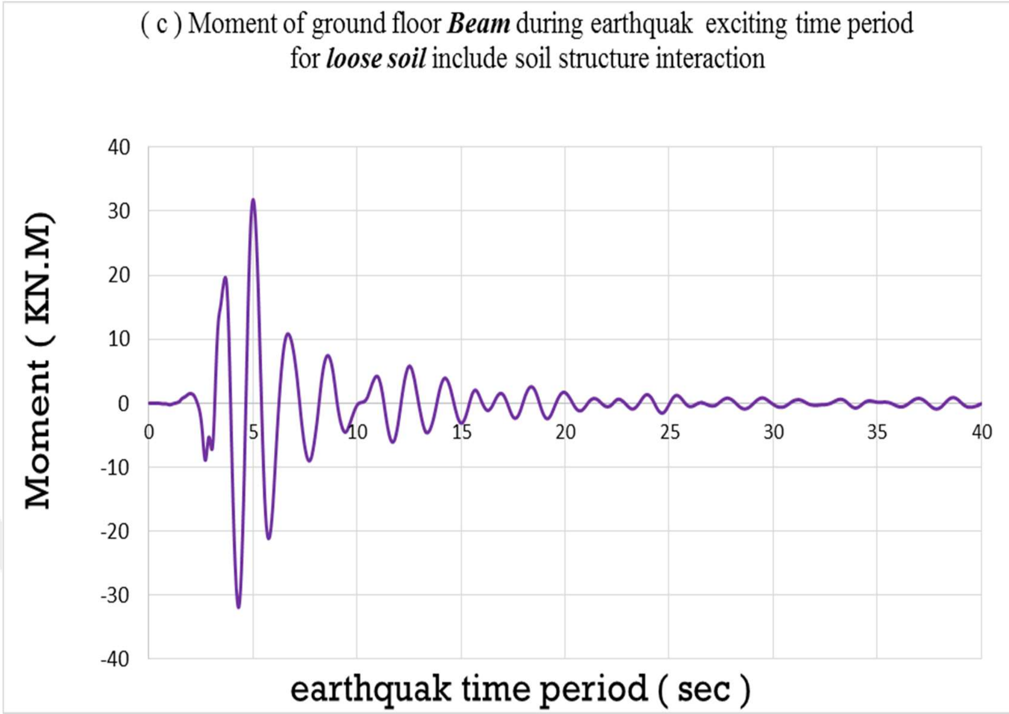


Figure 4.9 (a and b) illustrate change moment values for ground floor beam during earthquake exciting



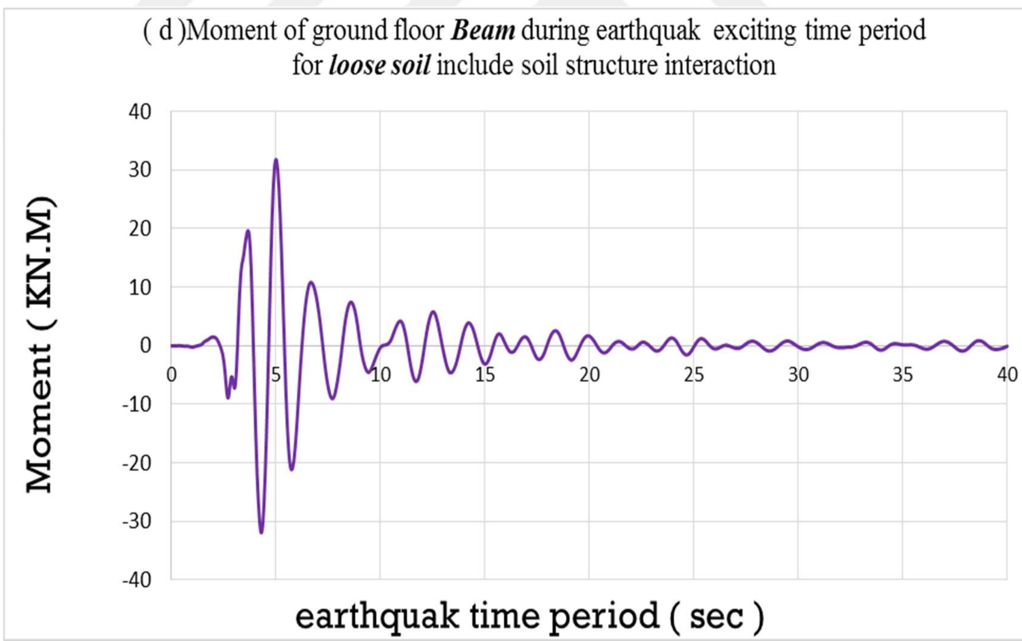


Figure 4.9 (c and d) illustrate change moment values for ground floor beam during earthquake exciting for medium soil and weak soil.

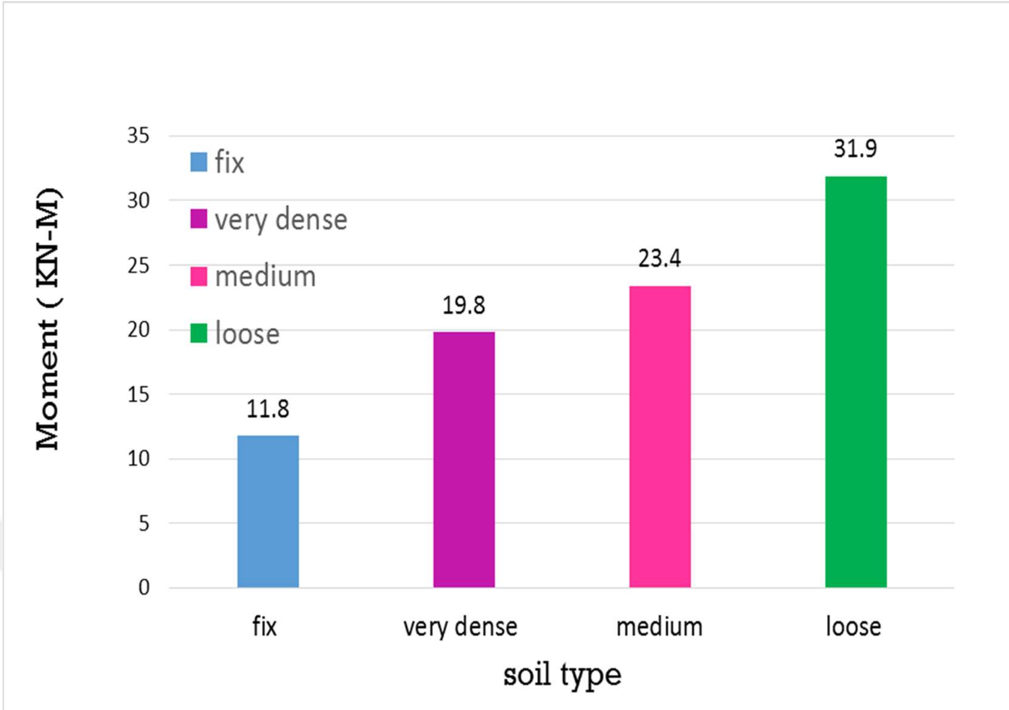


Figure 4.10 comparison between maximum moments for beam in each model

Observed from figure 4.9 and 4.10 increase moment if considering soil-structure-interaction, increase bending moment with decrease stiffness of soil. Very dense soil greater than fix base by (67 %). Medium soil greater than fix base by (98 %), loose soil greater than fix base by (170 %). Results match for previews study of (Kumar and Praveen. 2016) and (Jie, et al.2007)

4.6 Moment for base column.

Summaries all results for bending moment during earthquake exciting for the base column in front of structure for each model, showed results in (Figure 4.11 and 4.12). From results observed that increase moment when S.S.I are consider. Moreover increase moment when soil went weaker. Results match for previews study (Kumar and Praveen. 2016) and (Jie, et al.2007)

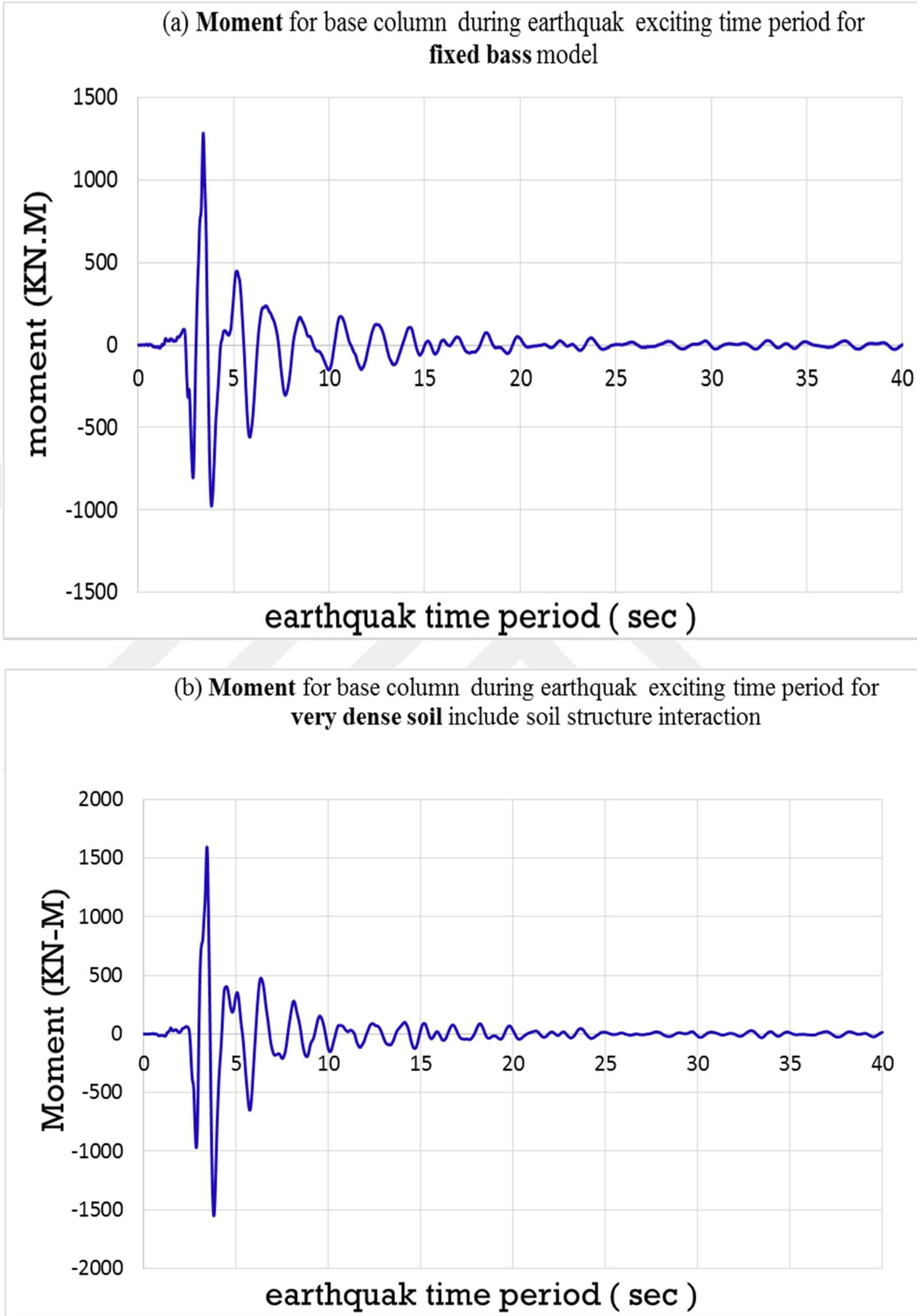
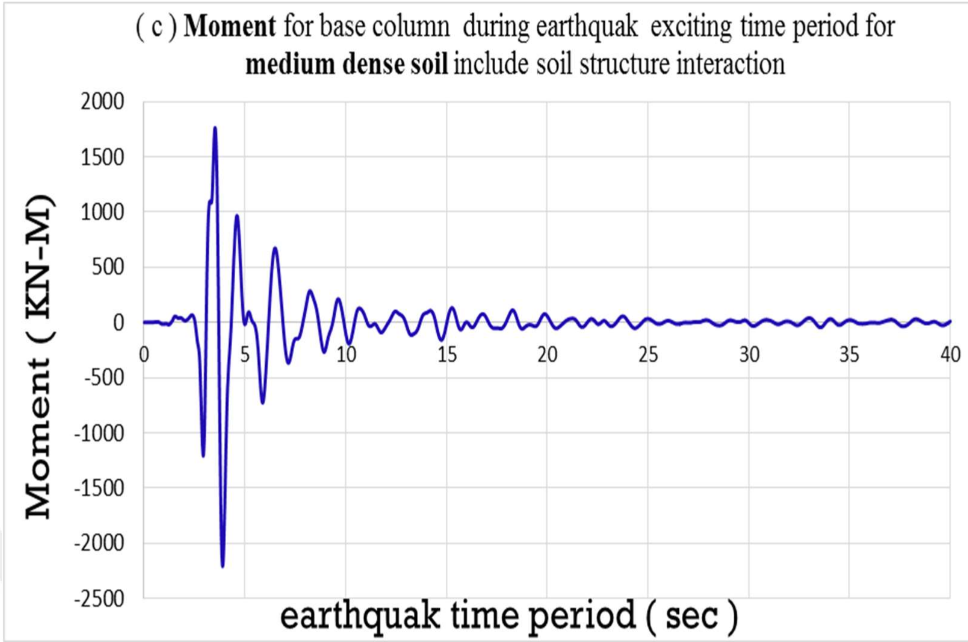


Figure 4.11 (a and b) illustrate moment for base column during earthquake exciting time period for fix base and dense soil



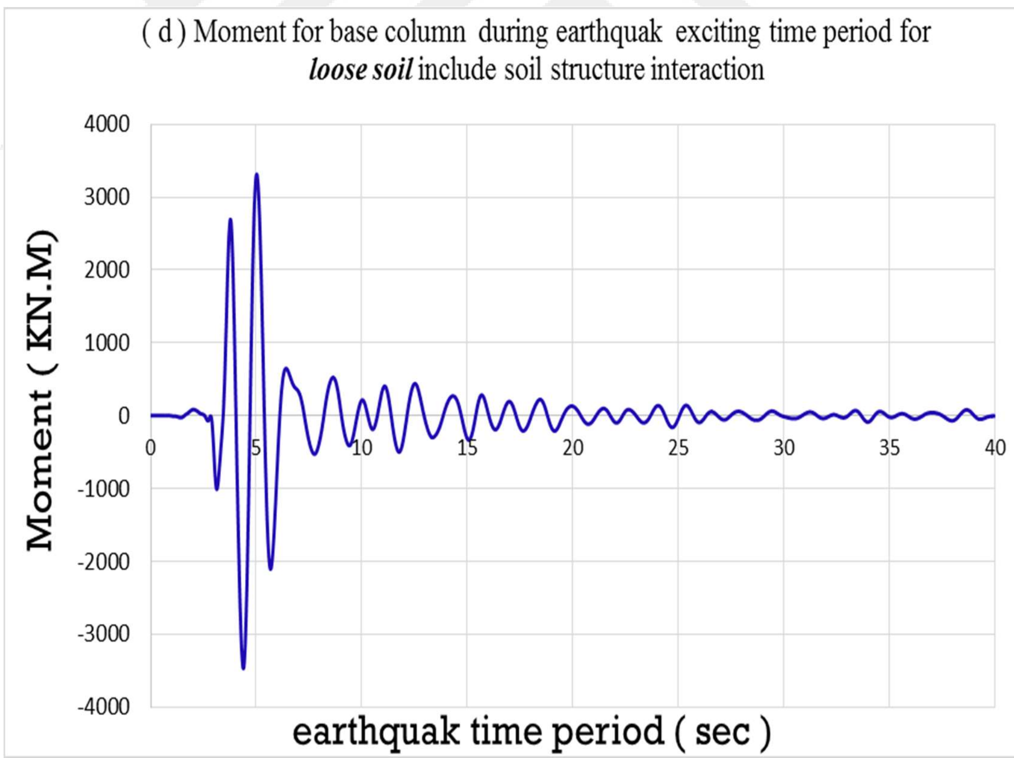


Figure 4.11 (c and d) illustrate moment for base column during earthquake exciting time period for medium soil and weak soil model

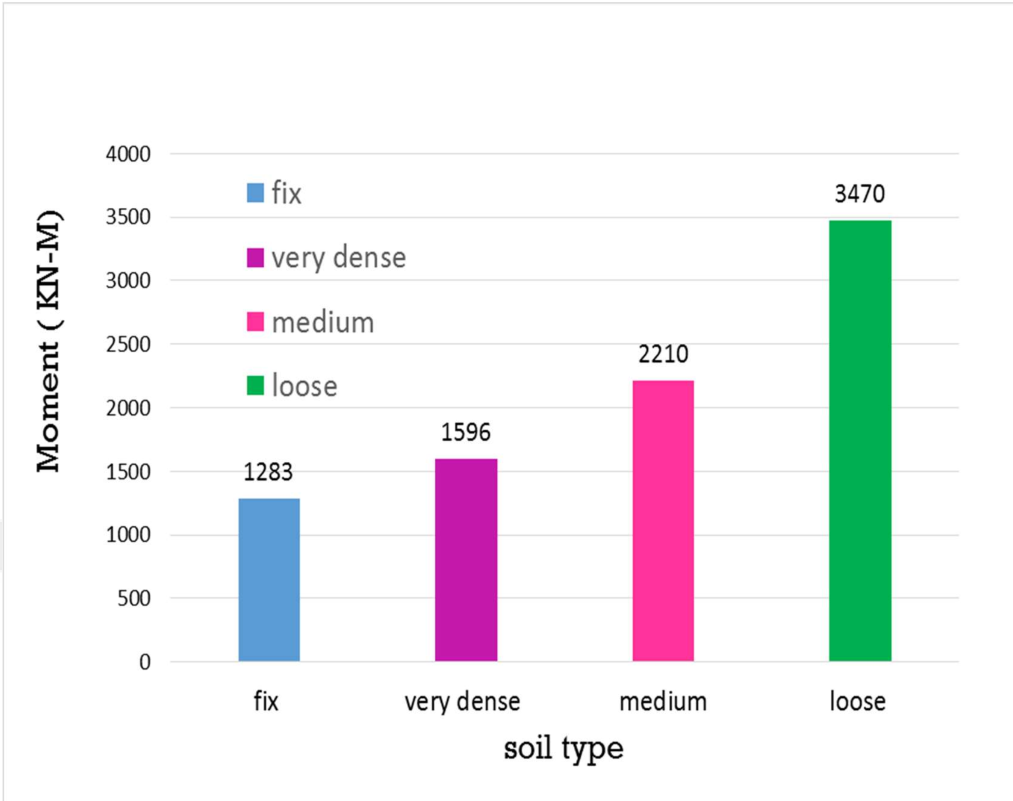


Figure 4.12 comparison between maximum moments for base column in each model

4.7 Torsion

Torsion is one of characters that designer care about it, all values of torsion are recorded during earthquake applied to structure and showed results for ground floor in (Figure 4.13 and 4.14).

Observed from results that Increase torsion for loose soil model more than all model, dense soil increase (84% more than fix base), medium soil increase (50% more than very dense soil) and weak soil increase (50% more than medium soil), when soil went weaker the torsion of column going rise. Results match with study of (vaneel et al. 2016)

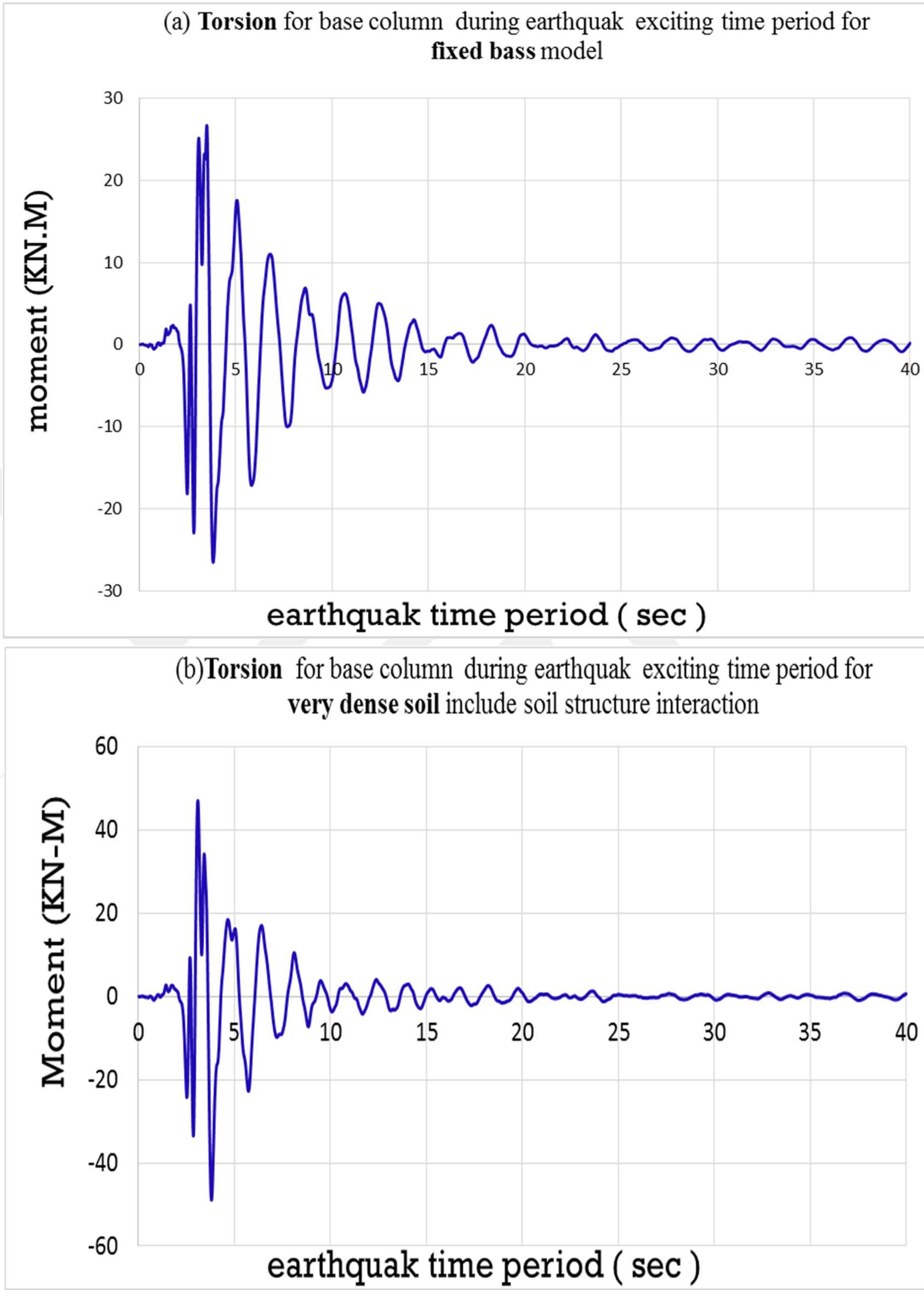
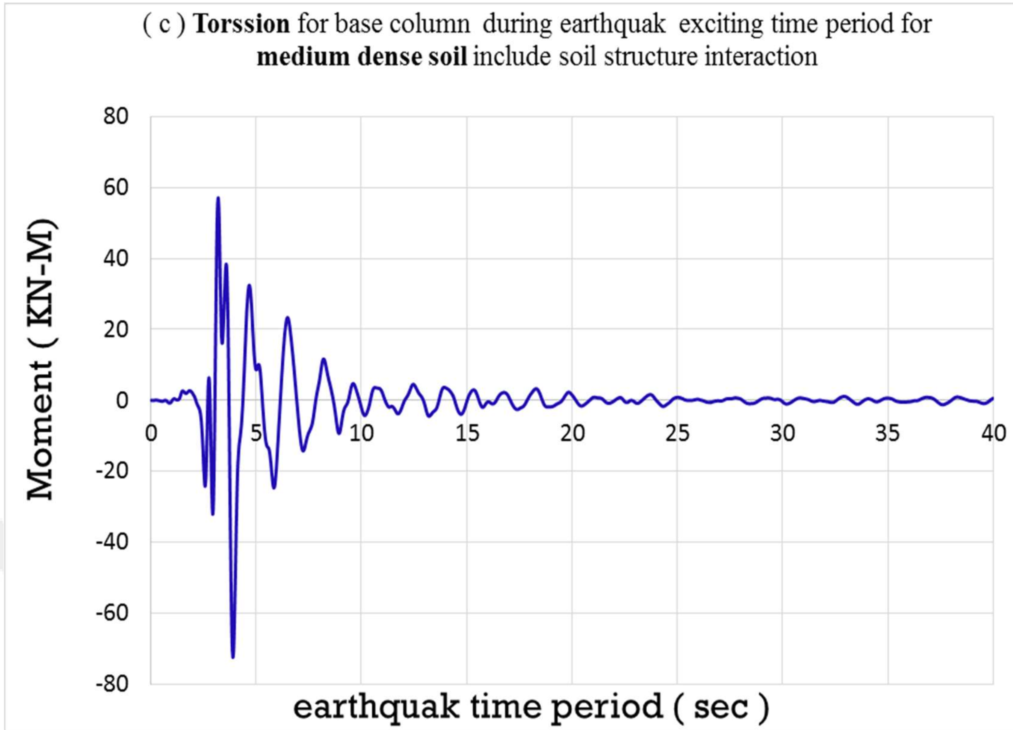


Figure 4.13 illustrate torsion for base column during earthquake for (a) fix base model (b) very dense soil



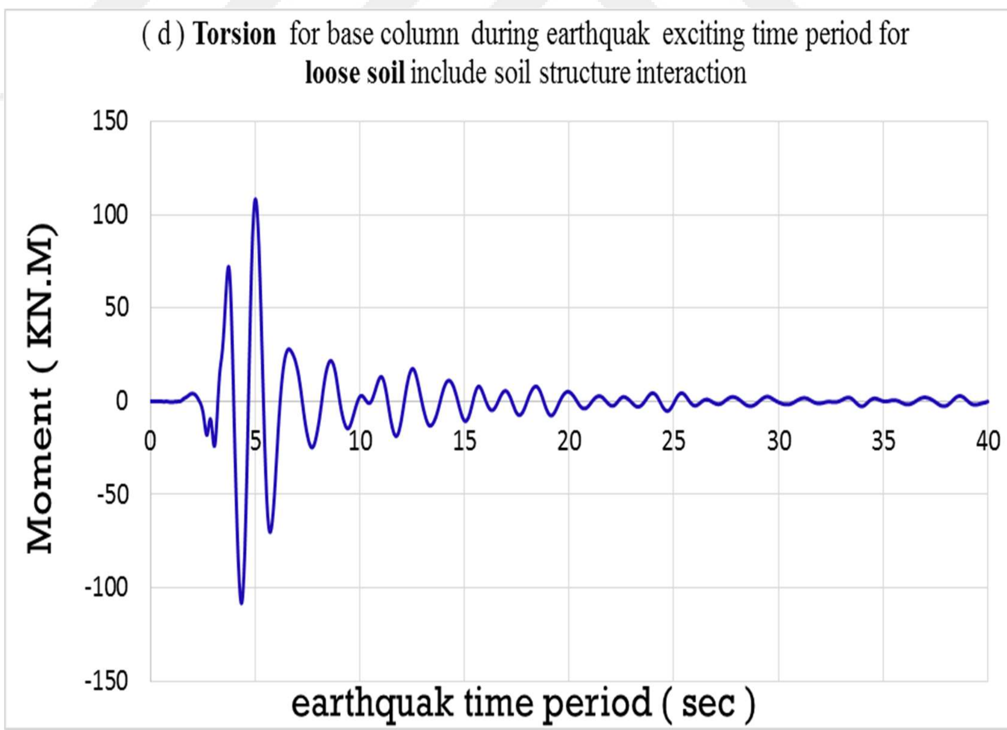


Figure 4.13 illustrate torsion for base column during earthquake for (c) medium soil stiffness (d) loose soil

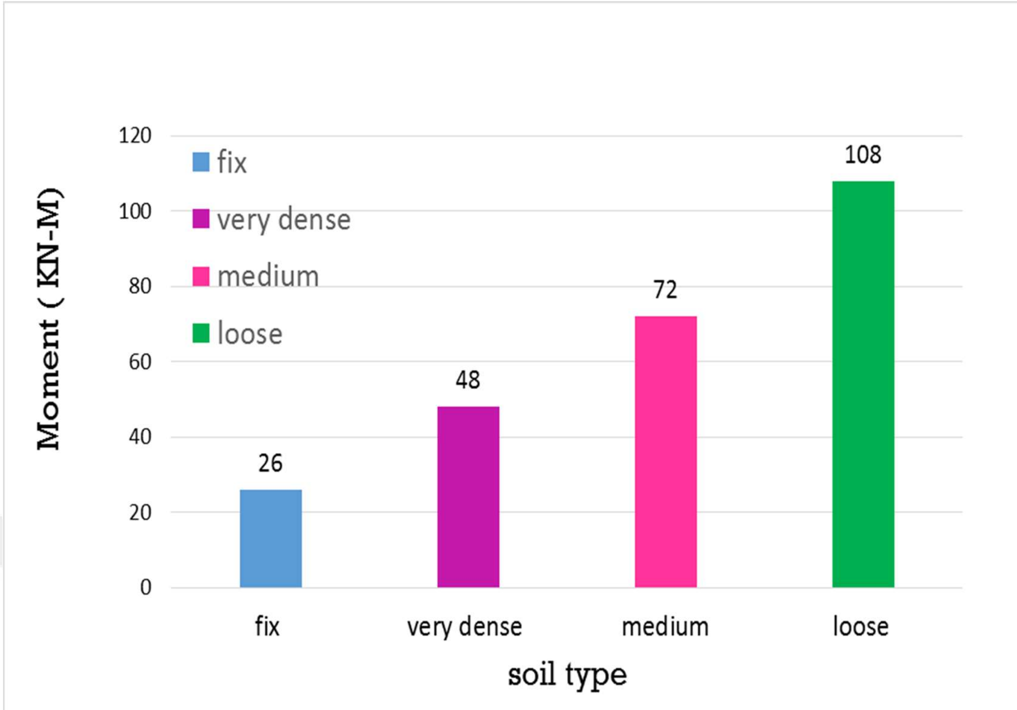


Figure 4.14 comparison maximum torsion for each model during seismic applied to structure

4.8 Spectral velocity

Maximum pseudo velocity reaction of a single degree (SD) of freedom oscillator subjected to ground motions due to an earthquake [36].

Spectral velocity is another character for known the behavior of structure during earthquake exciting. In (Figure 4.15 and 4.16) illustrate spectral velocity for all model. Increase spectral velocity when S.S.I are consider for analysis, moreover increase spectral velocity when soil went weaker the result similar to previews research of

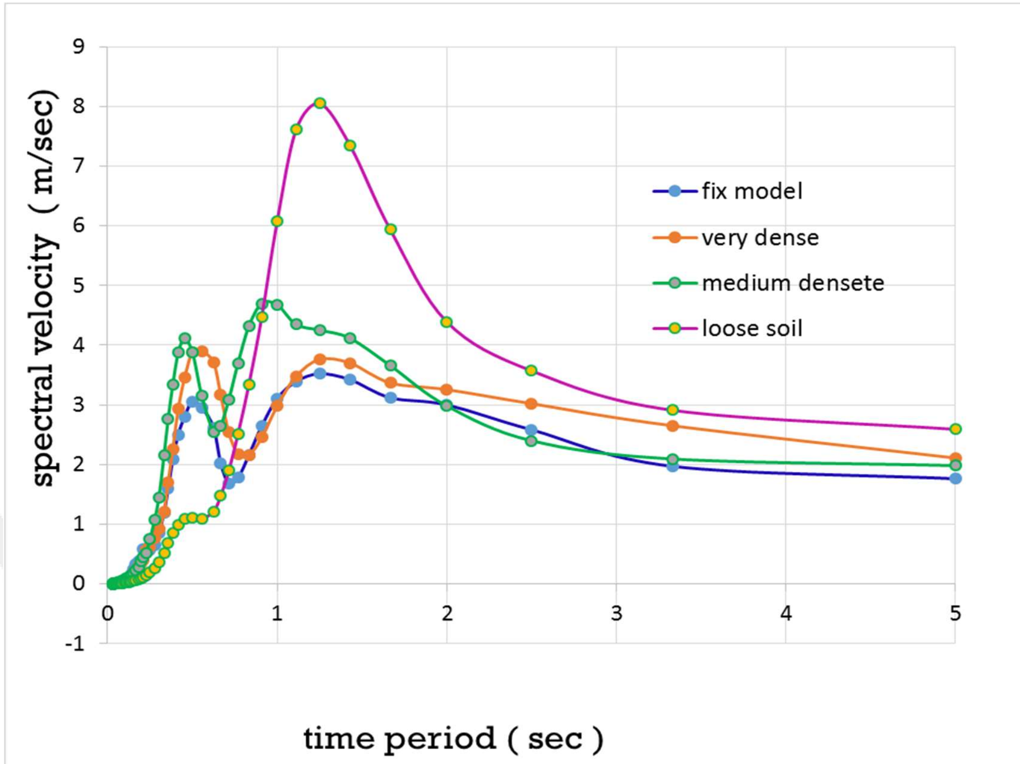


Figure 4.15 spectral velocity for the top floor (12th) during earthquake period

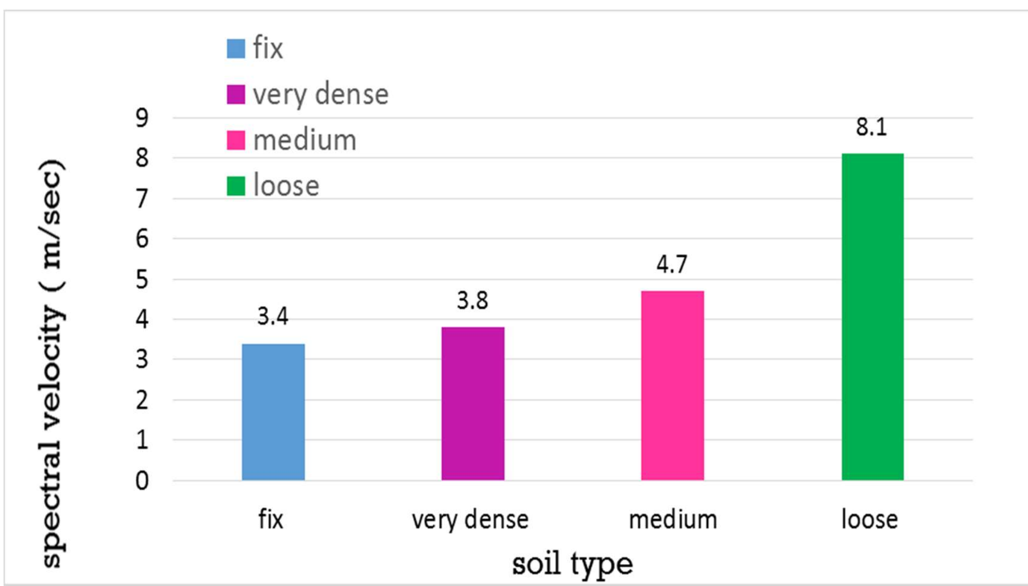


Figure 4.16 Comparison of maximum spectral velocity for each model

CHAPTER 5
CONCLUSION

A big number of article and large books had been wrote for soil Structure interaction analytic and design, filed and structure response during earthquake exciting. The main of this research have been indicated to the full three dimension linear dynamic analysis of (12^{th}) real storey building with fix base model and include influence and behavior of soil structure interaction by using numerical engineering sap2000 for three type of soil, based on the pervious result in chapter four, summaries some important points.

* Seen in peak of structure parameters from figure in chapter four like maximum Displacement, drift, shear force, moment, torsion, spectral velocity were very significant variation during earthquake exciting when soil structure interaction include for structural analysis, increase magnitude of all them when S.S.I have used compare with typical design fix base, increased value of all them when soil going to weaker.

* Observed soil have high value of shear wave velocity had good engineering property and safer for structure. When shear wave velocity went to low less than (Vs< 180 m/sec), soil going to weak, must be careful about specification of soil and special design need for structure

* Soil structure interaction must be consider in analysis and design when super structure and strategic project built such as high rise building, dam, nuclear power.

* To accurately estimate the influence of soil structure interaction is required for known all property of soil from earth surface until bed rock such as shear wave velocity, modulus of elasticity, density and Poisson ratio with all property of structure such as cross section of beam, column and slab with specification for

reinforcement of concrete and reinforcement steel bar with know very well use numerical application.

* Using SAP2000 numerical engineering program was provide widely integrated analysis solution for structure and soil together. But needs ultra-property of computer otherwise your run analysis get to much time until run and obtain data recorded.

* Observed in direct method analysis (linear dynamic) for soil structure interaction the values are hysterical increase more than typical design (fix base), it's one reason that very rarely used in practice. In typical design process of structure is normally neglect the soil-structure-interaction effect assume structure is fix at foundation, Therefore, the structure must be carefully designed by considering the S.S.I include in design proses until safe and economy in design, must be check by other software and structural design code.

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