HASAN KALYONCU UNIVERSITY
GRADUATE SCHOOL OF
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LATERAL LOAD RESISTING SYSTEMS IN HIGH-RISE REINFORCED CONCRETE BUILDINGS

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KAMIRAN ALI ALI
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Lateral Load Resisting Systems in High-rise Reinforced Concrete Buildings

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Supervisor
Assist. Prof. Dr. Dia Eddin NASSANI

By
Kamiran Ali Ali
June 2014

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Kamiran Ali Ali Hasnaki

T.C.
HASAN KALYONCU UNIVERSITY
GRADUATE SCHOOL OF
NATURAL & APPLIED SCIENCES
CIVIL ENGINEERING DEPARTMENT

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Prof. Dr. Mehmet KARPUZCU
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Assist. Prof. Dr. Kasım MERMERDAŞ
Head of Department

This is to certify that we have read this thesis and that in our consensus/majority opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science

Assist. Prof. Dr. Dia Eddin NASSANI
Supervisor

Examining Committee Members	Signature
Prof. Dr. Mehmet KARPUZCU	....
Assist. Prof. Dr. Dia Eddin NASSANI	....
Assist. Prof. Dr. Kasım MERMERDAŞ	....

ABSTRACT

LATERAL LOAD RESISTING SYSTEMS IN HIGH-RISE REINFORCED CONCRETE BUILDINGS

Ali Ali Kamiran
M.Sc. in Civil Engineering
Supervisor: Assist. Prof. Dr. Dia Eddin NASSANI
June 2014, 90 Pages
The high-rise building becomes very important in construction because every day the prices of land are increasing and the demand is also increased. The more concern matter in high-rise building is lateral loads due to earthquake loads and wind loads.

In this study, the classification of lateral load resisting systems has been discussed in chapter 2 for steel structures and reinforced concrete structures. The researcher focused on the reinforced concrete structures (moment resisting system, shear wall system, shear frame system, frame tube system). In chapters 3 and 4, the effects of lateral load (earthquake and wind) were taken in the behavior of building.

In the present study, the high-rise reinforced concrete building was analyzed which consisted of 28 floors and it was symmetrical from story 1 up to story 28. The area of building was 625 m^2 (25m × 25m), applied dead load is equal 0.5 ton/m^2, live load is 0.3 ton/m^2 . The well-known structure program ETABS has been used to analyze the structure. The equivalent static method has been used to calculate the seismic load. Tables and charts of displacements and maximum drifts story were obtained.

Keywords: lateral load resisting system, high rise buildings, earthquake load, wind load, stiffness, displacements.

ÖZET

YÜKSEK KATLI BETONARME BİNALARDA YANAL YÜK DİRENÇ SİSTEMLERİ

Ali Ali Kamiran
Yüksek Lisans Tezi, İnşaat Mühendisliği bölümü
Tez Yöneticisi: Doç. Dr. Dia Eddin NASSANI
Haziran 2014, 90 Sayfa

Yüksek katlı binaların yapımı, arazi fiyatlarının artışı ve konut gereksinimine olan taleplerin artışından dolayı oldukça önem arz etmektedir. Fakat yüksek katlı binalarda deprem yükleri ve rüzgar yüklerinden kaynaklanan yanal yükler söz konusudur. Bu çalışmada, Çelik ve betonarme yapılardaki yatay yük direnç sistemlerinin sınıflandırılması ikinci bölümde yapılmıştır. Araştırmacı betonarme yapılar üzerinde durmuştur (moment direnç sistemi, perde duvar sistemi, makaslama çerçeve sistemi, çerçeveli boru sistemi). 3. ve 4. bölümde , yanal yüklerin etkileri (deprem ve rüzgar) yapının özelliklerine göre ele alınmış ve incelenmiştir.

Çalışmada, 28 katlı ve 1. kattan 28. kata kadar simetrik olarak yükseldiği öngörülen yüksek katlı bir betonarme binanın analizi yapılmıştır. Üzerinde çalışılan binanın alanı 625 m^2 (25m × 25m), binaya yüklenen hareketsiz yük 0.5 ton/m^2 ve hareketli yük 0.3 ton/m^2 olarak hesaplamalar yapılmıştır. Bina analizi için, sıklıkla kullanılan ETABS programı kullanılmıştır. Sismik yükün hesaplanması için eşdeğer statik yöntem kullanılmıştır. Yer değiştirmelerin ve maksimum sürüklenme miktarlarının tabloları ve grafikleri bu şekilde elde edilmiştir.

Anahtar kelimeler: yatay yük direnç sistemi, yüksek katlı binalar, deprem yükü, rüzgar yükü,sertlik,yer değiştirme

DEDICATION

I dedicate this study to the soul of my dear father, who could not see my effort and graduation. May Allah bless his soul.

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My heartfelt and sincere thanks to the Almighty God "ALLAH" Who granted me all these graces to fulfill this task and Who supported me in all my life.

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D. L	Dead load
L. L	Live load
Wx	Wind load due to x-direction
Qx	Earthquake load due to x-direction
My	Moment about Y-axis
V	Shear base
T	Torsion
Ux	Lateral displacement with x-direction
Fc¯	Compressive strength of concrete
Fy	Bending Reinforcement, yield stress
Fys	Shear Reinforcement, yield stress
E	modulus of elasticity
R	Response modification
I	Occupancy importance

CHAPTER I

INTRODUCTION

1.1 Introduction

High-rise building is defined as a building 35 meters or greater in height, which is divided at regular intervals into occupiable levels (Konapure, 2013). The primary purpose of all kinds of structural systems used in the building type of structures is to support gravity loads. The most common loads resulting from the effect of gravity are dead load, live load and snow load. Besides these vertical loads, buildings are also subjected to lateral loads caused by wind, blasting or earthquake. Lateral loads can develop high stresses, produce sway movement or cause vibration. Therefore, it is very important for the structure to have sufficient strength against vertical loads together with adequate stiffness to resist lateral forces (Kevadkar and Kodag, 2013).

Increasing in population in most countries raises land area prices, so tall building has been growth and number of stories increases and reaches 100 to 200 stories and will increase to more for high rise towers. In the early structures at the beginning of the 20th century, structural members were assumed to carry primarily the gravity loads. Today, however, by the advances in structural design/systems and high-strength materials, building weight is reduced, and slenderness is increased, which necessitates taking into consideration mainly the lateral loads such as wind and earthquake. Understandably, especially for the tall buildings, as the slenderness, and so the flexibility increases, buildings suffer from the lateral loads resulting from wind and earthquake more and more. As a general rule, when other things being equal, the taller the building, the more necessary it is to identify the proper structural system for resisting the lateral loads (Gunel and Ilgin, 2006).

The structural system of a high-rise building often has a more pronounced effect than a low rise building on the total building cost and the architecture. As a result, those faced with an initial venture into tall building design need to be aware of concepts that are not emphasized for low-rise design. The simplified model for the behavior of a tall building is a vertical cantilever out of the ground. In this model, the moment of inertia of the cantilever is calculated considering each of the vertical elements, such as core walls and perimeter columns, active in the lateral system. Deflection is due primarily to axial shortening and elongation of these elements.

Concrete has become universal building material and more appropriate structural forms such as shear wall and tube structures. The high dead load characteristics are no limited on the height of concrete building. Otherwise, the dead load from the concrete tends to be more significant in minimizing the sway deflection and floor vibration as well as instability problem. Tall building cannot be defined in specific terms related to height or number of floor. Building to be considered as tall when the structural analyses and design are affected by the lateral loads. The lateral loads begin to dominate the structural system and take on increasing importance in the overall building system when the building heights increase. Vertical load, lateral load effects on building are quite variable and increase rapidly with increase in height. The strength, rigidity and stability were three major factors to consider in design of such structures. Basically there are two ways to satisfy these requirements that may be by increasing the size of the member beyond to achieve the strength requirement or change the form of the structure into something more rigid and stable.

In tall building the lateral loads due to earthquake are a matter of concern. These lateral forces can produce critical stresses in the structure, induce undesirable stresses in the structure, induce undesirable vibrations or cause excessive lateral sway of the structure. Sway or drift is the magnitude of the lateral displacement at the top of the building relative to its base. Hence it is necessary to take in to account the seismic load for the design of high-rise structure. Many multi-story RC frame structures built prior to 1970and located in seismic zones have been designed only for gravity loads without any consideration of lateral loads. These structures are referred to as gravity load designed (GLD) frames (Sadjadi, Kianoush and Talebi, 2006)

The structure in high seismic areas may be susceptible to the severe damage. Along with gravity load structure has to withstand to lateral load which can develop high stresses. The earthquakes cause many events such as (ground shaking, ground displacement, fire, and flood); therefore it is very important to prevent the negative results which are coming from earthquake. The primary objective of earthquake resistant design is to prevent building collapse during earthquakes thus minimizing the risk of death or injury to people in or around those buildings. Because damaging earthquakes are rare, economics dictate that damage to buildings is expected and acceptable provided collapse is avoided.

In earthquake-resistant design of reinforced concrete (RC) frame multistoried buildings; identification of lateral force-resisting system presents a major challenge. Certain structural elements are identified to carry the lateral forces generated during strong earthquake shaking. The stiffness and configuration of those identified elements play a major role in determining the design force levels in the elements. Structures are classified as rigid and flexible. Tall structures are more flexible and susceptible to vibrations by wind induced forces (Suresh, Panduranga and Kalyana, 2012).

Mostly, in the north of Iraq it has used the reinforced concrete as a construction materials and it is one of the researcher's reason to focus in this study on the reinforced concrete systems. The construction of high rise building has started in the north of Iraq since 5 years. In this study the researcher will employ two lateral loads which are earthquake and wind, because these two forces become big problem now a days all over the world.

The resistance of tall buildings to wind as well as to earthquakes is the main determinant in the formulation of new structural systems that evolve by the continuous efforts of structural engineers to increase building height while keeping the deflection within acceptable limits and minimizing the amount of materials (Gunel and Ilgin, 2006). Thanks to the sophisticated computer technology, modern materials and innovative structural concepts, structural systems have gone beyond the traditional frame construction of the home insurance building and have allowed skyscrapers to grow to heights of Taipei 101 never dreamed of in Jenney's day (Gunel and Ilgin, 2006).

Most of the tallest buildings in the world have steel structural system, due to its high strength-to-weight ratio, ease of assembly and field installation, economy in transport to the site, availability of various strength levels, and wider selection of sections. Innovative framing systems and modern design methods, improved fire protection, corrosion resistance, fabrication, and erection techniques combined with the advanced analytical techniques made possible by computers, have also permitted the use of steel in just any rational structural system for tall buildings. Although concrete as a structural material has been known since early times, the practical use of reinforced concrete was only introduced in 1867 (Gunel and Ilgin, 2006).

The invention of reinforced concrete increased the significance and use of concrete in the construction industry to a great extent. Particularly, because of its mold ability characteristics, and natural fireproof property, architects and engineers utilize the reinforced concrete to shape the building, and its elements in different and elegant forms. Besides this, when compared to steel, reinforced concrete tall buildings have better damping ratios contributing to minimize motion perception and heavier concrete structures offer improved stability against wind loads. New innovations in construction technology, methods of design and means of construction, have all contributed to the ease of working with concrete in the construction of tall buildings. Moreover, high-strength concrete as in the case of the Petronas Towers (Malaysia, 1998) and the Jin Mao Building (China, 1999), and lightweight structural concrete as in the case of the

One Shell Plaza (Texas, 1971) allow using smaller member sizes and less steel reinforcement (Gunel and Ilgin, 2006).

Similar to steel or composite construction, reinforced concrete offers a broad range of structural systems for tall buildings. Concrete and steel systems evolved independently of each other until 1969, the year in which the composite construction, basically described as a steel frame stabilized by reinforced concrete, of a 20-storey building was done by Khan (1972). All tall buildings can be considered as composite buildings since it is impossible to construct a functional building by using only steel or concrete. That is, in a critical sense, using mild steel reinforcement can make a concrete building a composite structure, and in the same way, reinforced concrete slabs can make a steel building a composite building. Namely, the frame and bracing or shear walls—but not the floor slabs— are the determining parameters for the building type. On the other hand, here, the term composite system means any and all combinations of steel and reinforced concrete elements (Gunel and Ilgin, 2006).

Steel has many advantages when compared to other structural materials such as concrete, timber, plastics and newer composite materials. Steel is one of the friendliest environmental building material-steel is 100% recyclable. Development in the structural systems of tall buildings has been a continuously evolving process since the growth in tall buildings began in1880s. From structure engineer's point of view tall buildings may be defined as one that, because of its height, it is affected by the lateral forces due to wind or earthquake to an extent that they play an important role in the structural design. The factors are responsible for the high-rise building development are availability of urban land, advances in construction technology and high strength materials, efficient structural systems and computational techniques etc. In case of tall structure, stiffness is more important than its strength. It is necessary to ensure that the top story displacement, lateral drift and human comfort level in tall structure are within the permissible limit

1.2 Literature review

The resistance of tall buildings to wind as well as to earthquakes is the main determinant in the formulation of new structural systems that evolve by the continuous efforts of structural engineers to increase building height while keeping the deflection within acceptable limits and minimizing the amount of materials. Therefore, the researchers especially in the second half of the 20^{th} century conducted many studies in this area or sector in order to make the buildings safer and more comfortable.

Jinghai and Xinhua (2006) conducted a study about latticed shell tube–reinforced concrete (RC) core wall structures. Authors used two types of structures systems in same building, one of them was located in the interior which is RC core wall and the other was located in the exterior faces of building, and concluded that arranging a number of diagonal braces reasonably can enhance the lateral resisting capability of latticed shell tube effectively.

Massumi and Absalan (2012) conducted a study about Interaction between bracing system and moment resisting frame in braced RC frames. The authors investigated the results of two experimental models of reinforced concrete frames and developed a new numerical model. They concluded that the interaction between RC frame and bracing system has a positive and significant impact on improving the behavior of dual system. The results of numerical analyses indicate an increase of 18.34% in the ultimate strength of the dual system, resulting from the interaction between two systems

Sadjadia et al. (2006) conducted a study about Seismic performance of reinforced concrete RC moment resisting frames (MRF). He conducted four structural cases which are (ductile, nominally ductile, GLD-Gravity Load Designed- and retrofitted GLD), In this study a typical 5-story frame is designed for all cases and presents an analytical approach for seismic assessment of RC frames using nonlinear time history analysis and push-over analysis. It is concluded that both the ductile and the nominally ductile frames behaved very well under the considered earthquake, while the seismic performance of the GLD structure was not satisfactory. After the damaged GLD frame was retrofitted the seismic performance was improved.

Ghade (2013) conducted a study about the Equivalent Static Analysis of high- Rise building with different lateral load resisting systems. The different lateral load resisting systems used in high-rise building are: 1. Bare frame 2.Brace frame 3.Shear wall frame. The effect of bracing, shear wall is studied under the earthquake loading. The results are studied for equivalent static method. The main parameters considered in this study to compare the seismic performance of different models are storey drift, base shear, story deflection, time period, bending moment, shear force, and axial force. All of the mentioned parameters are evaluated for all these models and compared with equivalent static method. After modeling and analyzing, the results show that an improvement in most parameters when they subjected to earthquake and especially in the braced frame and shear wall frame.

Kian et al. (2001) was another researcher who conducted a study about the use of outrigger and belt truss system in high rise reinforced concrete systems, he used two buildings in different heights, he concluded that by using outrigger and belt truss system it showed a pronounced enhancement in displacement for both cases.

Suresh et al. (2012) conducted a study about the Influence of diagonal braces in reinforced concrete construction RCC multi-storied frames under wind load. The present investigation deals with the calculation of wind loads using static and gust factor method for a sixteen story high rise building and results are compared with respect to drift. He concluded that the stability can be achieved by suitably adding the dimensions of the corner columns with corner diagonal X-bracings and Provision of X- bracings reduces the amount of drift and bending moments in the structure.

1.3 Scope and aims

The main purpose of the present study is to show the performance of each lateral load resisting systems due to lateral loads (Earthquake and Wind) by finding the lateral displacements with structure program ETABS.

CHAPTER II

TYPES OF LATERAL LOADS RESISTING SYSTEMS

2.1 Introduction

The essential role of lateral resisting frame systems is to carry the wind and earthquake loads, as well as to resist P-Delta effects due to secondary moments in the columns. Currently, there are many structural systems that can be used for the lateral resistance of tall buildings. Choosing the proper structural system for high rise multistory buildings is very important to carry loads and transfer them to the foundation safely and to be able to resist the lateral loads. Choosing the type of system for multistory or high rise buildings depend on number of stories or the whole size of structure (means horizontal dimensions or number of bays for each of horizontal direction). Type and intensity of loads property of material, geometry and other architectural requirements also forced to change the system.

Above 12 up to 120 stories buildings are high rise buildings. When increasing the height of any building, some forces are impact to that building structure. Some forces act vertically such as gravity loads and some forces act horizontally such as stability, wind and seismic events. Therefore, high buildings structures should have lateral loads resisting systems to avoid the effect of the lateral loads. Lateral loads resisting systems should be selected early in the planning stage according to the structure of the proposed building.

Nowadays, shear wall in R.C. structure and steel bracings in steel structure are most popular system to resist lateral load due to earthquake, wind, blast…. etc. The shear wall is one of the best lateral load resisting systems which is widely used in construction world but use of steel bracing will be the viable solution for enhancing earthquake resistance.

Actually lateral loads resisting systems has more than one classification with respect to authors or with respect to the material type. The structural classification by khan(1972) has been used in this study and the following classification is proposed for the structural systems of tall buildings for all the types, namely steel structure, reinforced concrete structures and composite structures.

2.2 Types of structural systems

The structural system of a high-rise building often has a more pronounced effect than a low rise building on the total building cost and the architecture. As a result, those faced with an initial venture into tall building design need to be aware of concepts that are not emphasized for low-rise design. High-rise design comes into play when a structure's slender nature makes it dynamically sensitive to lateral loads, such that a premium is associated with its lateral system development (Figure 2.1).

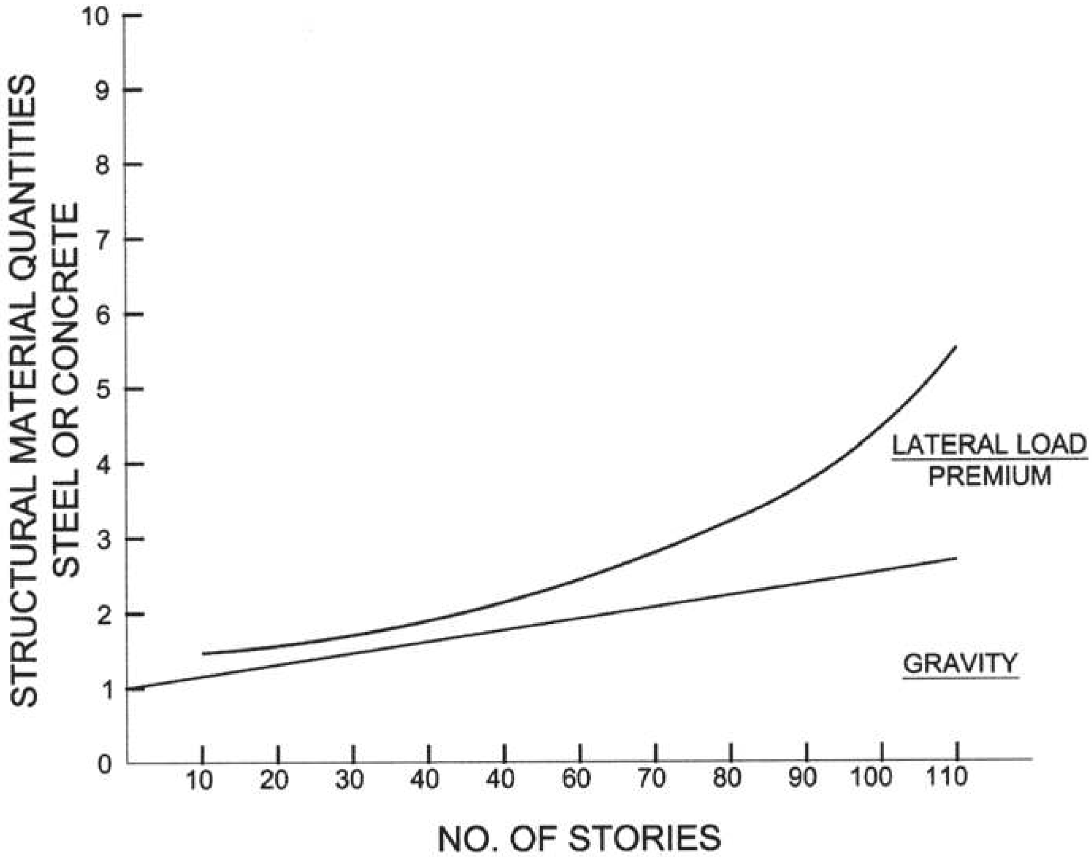
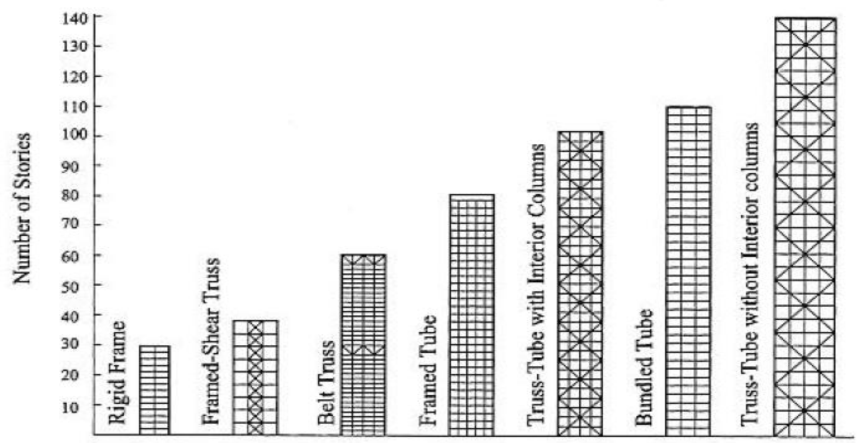


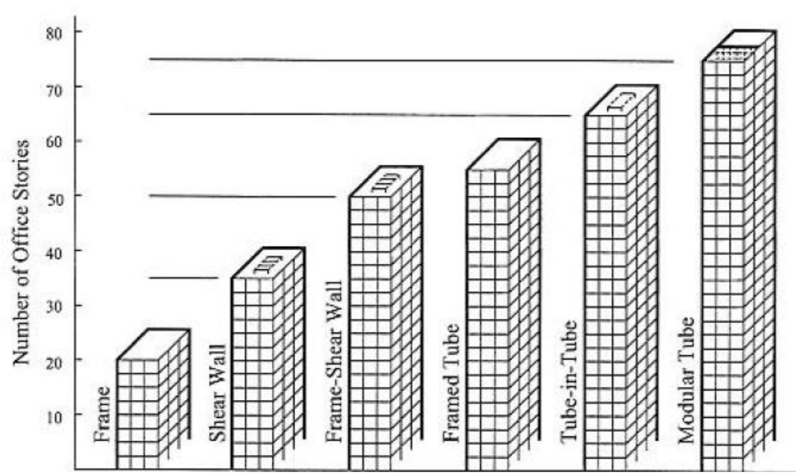
Figure 2.1 High Rise Premium (John Zils and John Viise, 2003)

The simplified model for the behavior of a tall building is a vertical cantilever out of the ground. The moment of inertia of the cantilever is calculated considering each of the vertical elements, such as core walls and perimeter columns, active in the lateral system. Deflection is due primarily to axial shortening and elongation of these elements.

Each lateral system choice brings its own practical limits. For the two main structural materials, steel and reinforced concrete, suggested practical ranges are illustrated in figure (2.2 a and b) While steel systems offer speed in construction and less self-weight, thereby decreasing demand on foundations, reinforced concrete systems are inherently more resistant to fire and offer more damping and mass, which is advantageous in combating motion perception by occupants. Composite systems can exploit the positive attributes of both.



(a)



(b)

Figure 2.2 a- Steel structure classification (Fazlur Khan, 1972)

b- Reinforced concrete structures classification (Fazlur Khan, 1972)

The following classification is proposed for the structural systems of tall buildings for all the types, namely, steel buildings, reinforced concrete buildings, and composite buildings:

1. Rigid frame systems
2. Braced frame and shear-walled frame systems
3. Outrigger systems
4. framed-tube systems
5. braced-tube systems
6. bundled-tube systems

2.2.1 Rigid frame systems

Rigid frame systems are utilized in both steel and reinforced concrete construction. Rigid frame systems for resisting lateral and vertical loads have long been accepted for the design of the buildings. Rigid framing, namely moment framing, is based on the fact that beam-to-column connections have enough rigidity to hold the nearly unchanged original angles between intersecting components. Owing to the natural monolithical behavior, hence the inherent stiffness of the joist, rigid framing is ideally suitable for reinforced concrete buildings. On the other hand, for steel buildings, rigid framing is done by modifying the joints by increasing the stiffness in order to maintain enough rigidity in the joints. For a rigid frame, strength and stiffness are proportional to the dimension of the beam and the column dimension, and inversely proportional to the column spacing and to the story height (Gunel and Ilgin, 2006).

Moment resisting frames typically comprise floor diaphragms supported on beams which link to continuous columns [Fig. 2.3 a and 2.4]. The frames are expected to carry the gravity loads through the flexural action of the beams and the propping action of the columns. Their ability to resist lateral loads is entirely due to the rigidities of the beam-column connections and the moment-resisting capacities of the individual members

(Pellai and Menon, 2005) Framed buildings often employ moment resistant frames in two orthogonal directions, in which case the column elements are common to both frames. Moment resisting frames are well suited to accommodate high levels of inelastic deformation.

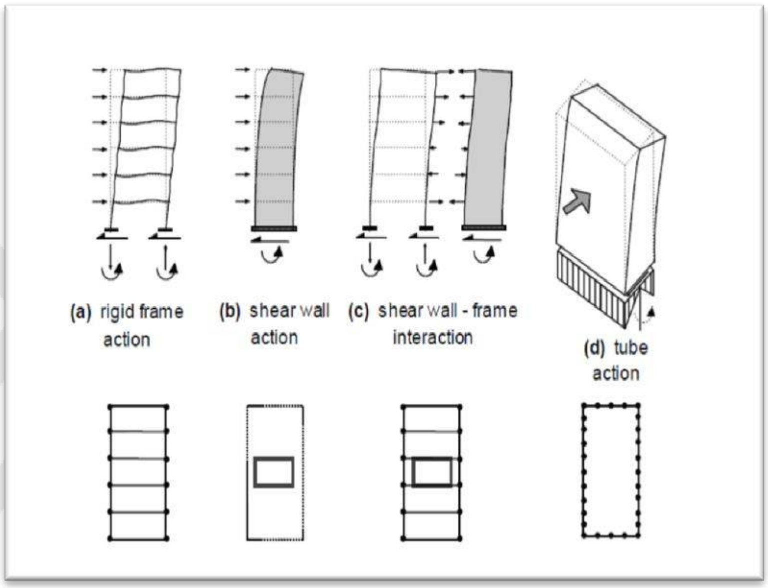


Figure 2.3 Classification of tall structural systems (Fazlur Khan, 1972)

Columns are placed where they are least disturbing to the architecture, but at spacing close enough to allow a minimum depth of floor. Thus, in order to obtain an efficient frame action, closely spaced columns and deep beams at the building exterior must be used. Especially for the buildings constructed in seismic zones, a special attention should be given to the design and detailing of joints, since rigid frames are more ductile and less vulnerable to severe earthquakes when compared to steel braced or shear-walled structures (Gunel and Ilgin,2006) Refer to figure 2.4

In buildings up to 30 stories, frame action usually takes scare of lateral resistance except for very slender buildings. For buildings with over 30 stories, the rigidity of the frame system remains mostly insufficient for lateral sway resulting from wind and earthquake actions. The 21-storey-highLever House (1952) (Fig. 2.5) in New York, built with steel is a good example of the frame system (Gunel and Ilgin,2006).

Moment resisting frames typically comprise floor diaphragms supported on beams which link to continuous columns. The joints between beam and columns are usually considered to be ‘rigid’. The frames are expected to carry the gravity loads through the flexural action of the beams and the propping action of the columns. Lateral loads, imposed within the plane of the frame, are resisted through the development of bending moments in the beams and columns (King, 2011).

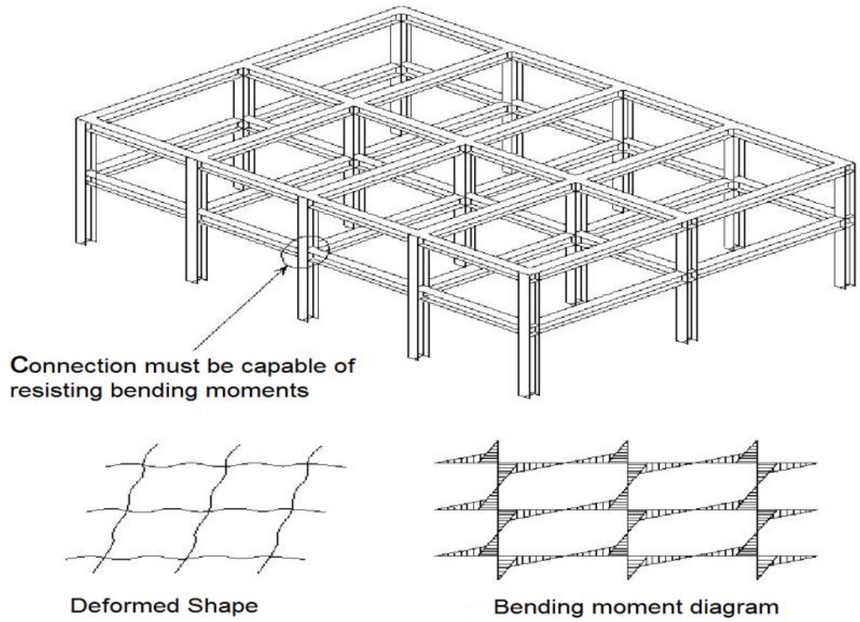


Figure 2.4 Moment resisting frame (Ali, 2013)

Figure 2.5 Lever House, New York, USA, 1952 (Gunel and Ilgin,2006)

In steel structures, Moment Resisting Frame is an assembly of the columns and girders, connected by the moment resistant connection. The main advantage of this system is that the internal planning is not obstructed because of its rectangular arrangement. Lateral stiffness of the system depends on the bending stiffness of the girders, columns and connections. Moment resistant connection is costly in steel building compare to concrete building. Lateral loads are resisted by the rigid frame action that is by the development of the shear forces and bending moments in the frame members and joints. Storey shear is generally resisted by the columns by the bending in double curvature with points of contra flexure at approximately mid storey height levels. The moments acting on a joint are resisted by the bending of the attached girders in double curvature with points of contra flexure at approximately mid span. This type of deformation generally has shear configuration as shown in Fig 2.6 The overall moment due to lateral load is resisted by the couple generated by the axial tensile and compressive forces in the columns, this type of deformation has flexural configuration as shown in Fig 2.7 Generally deflected shape of a high-rise moment resisting frame has a shear configuration as shown in Fig. 2.8.

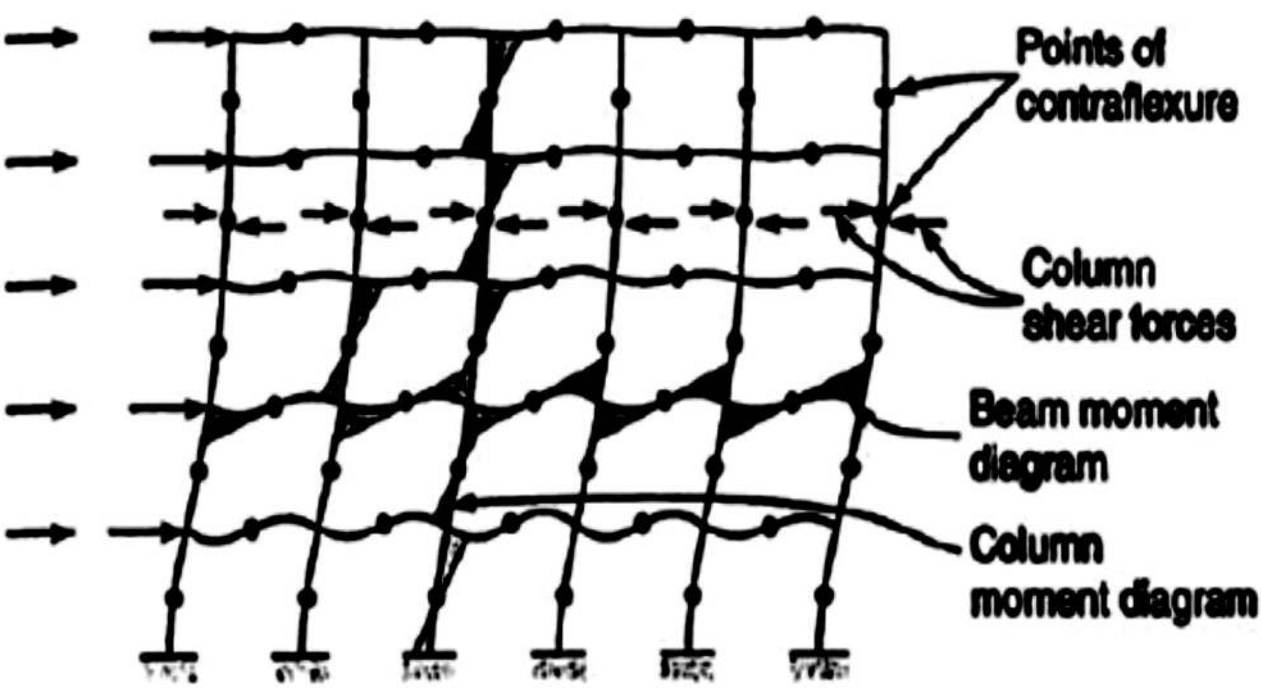


Figure 2.6 Shear deformation of structure (Bungale, 2004)

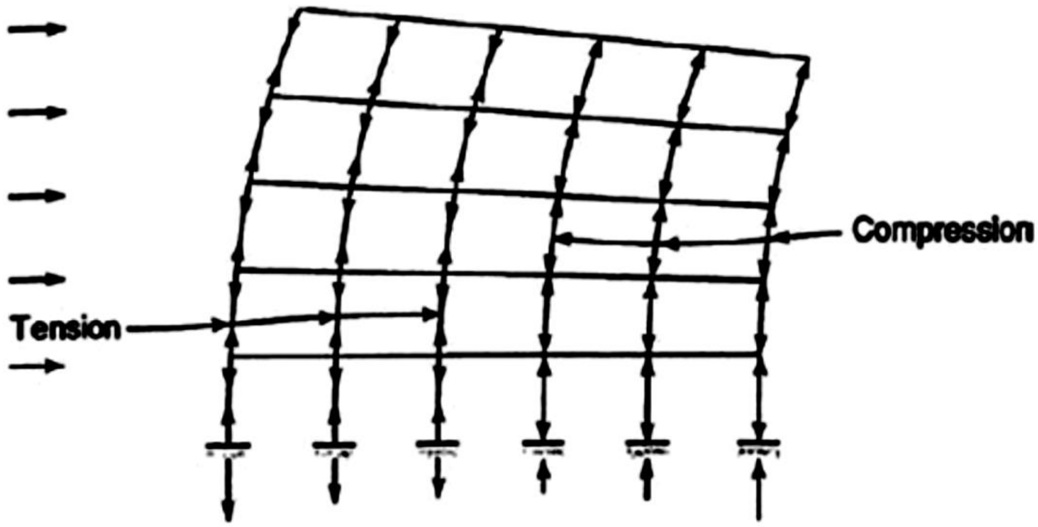


Figure 2.7 Bending deformation of structure (Bungale, 2004)

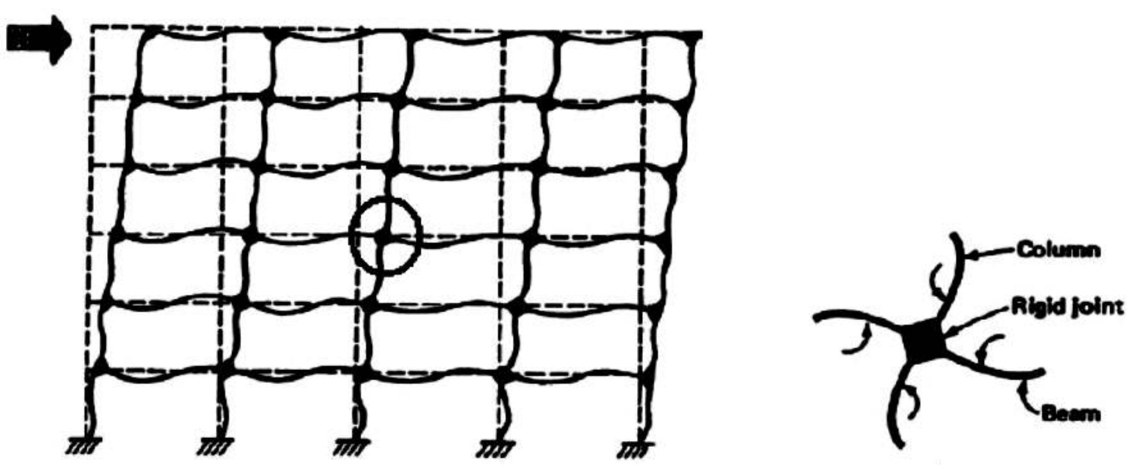


Figure 2.8 Deformation of rigid frame under lateral loading (Bungale, 2004)

2.2.2 Braced frame and shear-walled frame systems

Rigid frame systems are not efficient for buildings taller than 30 stories, because lateral deflection due to the bending of columns causes the drift to be too large. On the other hand, steel bracing or shear walls with or without rigid frame (brace systems and shear wall systems), increases the total rigidity of the building and the result in system is named as braced frame or shear-walled frame system. Namely, systems composed of steel bracing or shear walls alone, or interacting with the rigid frames can be accepted as an improvement of the rigid frame system. These systems are stiffer when compared to the rigid frame system, and can be used for buildings over 30 stories, but mostly applicable for buildings about 50 stories in height. However, there are examples for these systems reaching over 100-storey height. While braced frame system is utilized in steel construction, shear-walled frame system is utilized in both reinforced concrete and composite construction (Gunel and Ilgin, 2006).

2.2.2.1. Braced frame systems

Braced frame systems are utilized in steel construction. This system is a highly efficient and economical system for resisting horizontal loading, and attempts to improve the effectiveness of a rigid frame by almost eliminating the bending of columns and girders, by the help of additional bracings. It behaves structurally like a vertical truss, and comprises of the usual columns and girders, essentially carrying the gravity loads, and diagonal bracing components so that the total set of members forms a vertical cantilever truss to resist the horizontal loading. Depending on architectural and structural characteristics, braces can be classified as follow as shown in Figure 2.9 (Gunel and Ilgin, 2006).

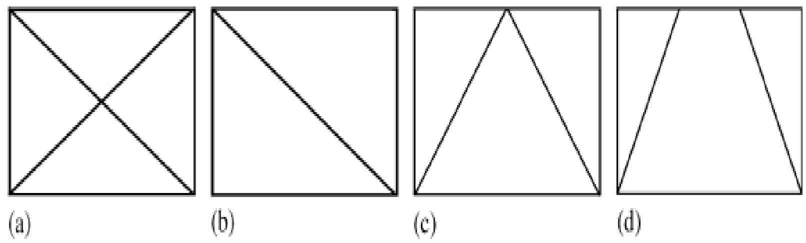
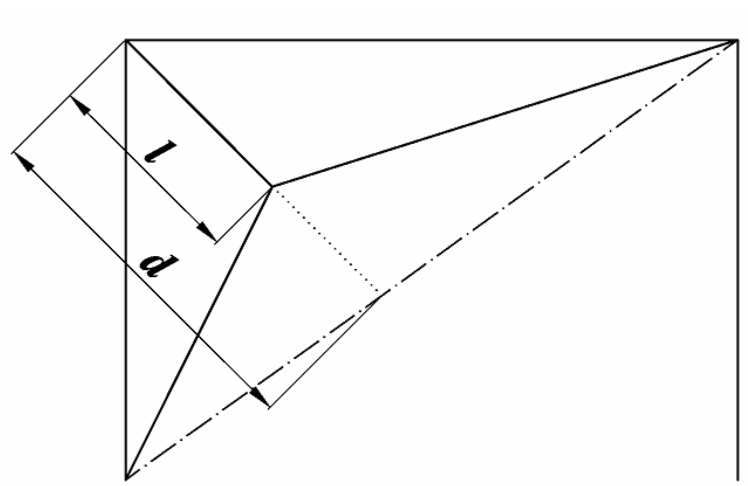
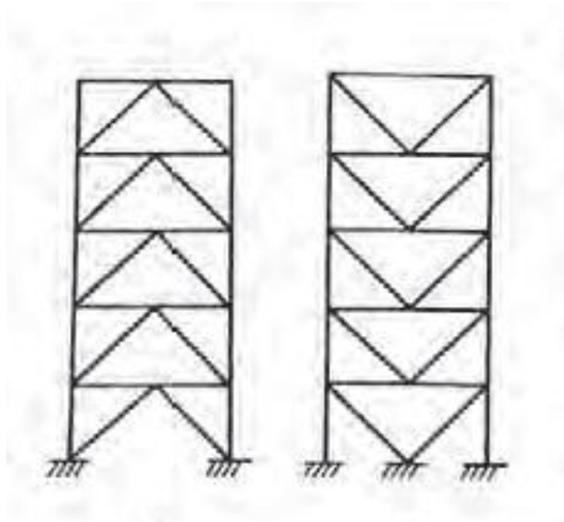


Figure 2.9 Types of braces: (a) X – the least available space; (b) diagonal – less available space; (c) K – openings possible; (d) Knee – larger openings. (Gunel and Ilgin,2006)

There are some other types of braces



(e) General view of Y brace (Zamani and Rasouli, 2006)



(f) (g)

Figure 2.9 Types of braces: (f) is inverted V brace (g) is V brace (Bungale, 2004)

The areas around elevator, stairs, and service shafts, where frame diagonals may be enclosed within permanent walls, are the most preferable places for the braces; and the arrangement of the bracing is generally dictated by the requirements for openings.

Historically, bracing has been utilized to stabilize the building laterally in many of the world’s tallest structures, including 77-storey-high Chrysler Building (1930) (Figure 2.10).

Figure 2.10 Chrysler Building, New York, USA, 1930 (Gunel and Ilgin,2006)

A braced frame is a truss system of the concentric or eccentric type in which the lateral forces are resisted through axial pressures in the members. Just as with a truss, the braced frame depends on diagonal members to provide a load path for lateral forces from each building component to the foundation to the earth. Also braced frame can be located on the exterior or interior of a building and may be located in one structural bay or several. A diagonal compression member in one bay can be used to brace against lateral loads coming from either direction. Tension diagonals can be used alternately to achieve the same result, but they must be run both ways to account for the load coming from either direction as shown in figure 2.11. Braced frame system has some advantages; this system can apply continuously to top of the building height with the positive economy. Also this system is resistive component against to the lateral forces. Another advantage is, beams are not participate mostly for distribute the lateral forces. Also there have some short comings. This system is obstacle to internal planning and cannot create the doors and windows where we want. Also, diagonal design is little bit expensive for erect and fabricate.

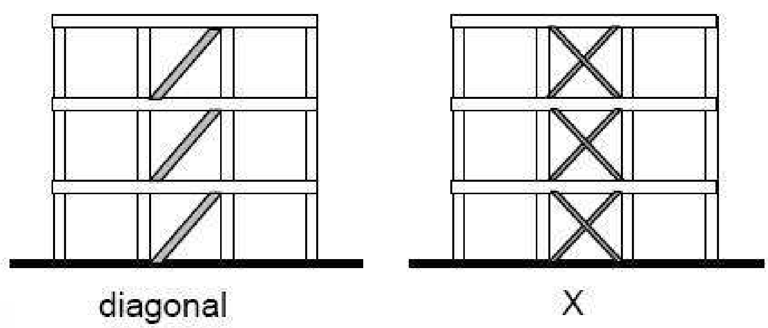


Figure 2.11 Diagonal and X braced frames (http://archinect.com/)

2.2.2.2 Shear-walled frame systems

In this type of structures, all the vertical members are made of structural walls, generally called shear walls. Shear-walled frame systems are utilized in both reinforced concrete and composite construction. Shear walls may be described as vertical cantilevered beams, which resist lateral wind and seismic loads acting on a building and transmitted to them by the floor diaphragms. Shear walls are generally parts of the elevator and service cores, and frames to create a stiffer and stronger structure. These elements can have various shapes such as, circular, curvilinear, oval, box-like, triangular, or rectilinear. This system structurally behaves like a concrete building with shear walls resisting all the lateral loads. The 68-storeyhigh Metropolitan Tower (1987) (Fig. 2.12) in New York is a good example of this system (Gunel and Ilgin, 2006).

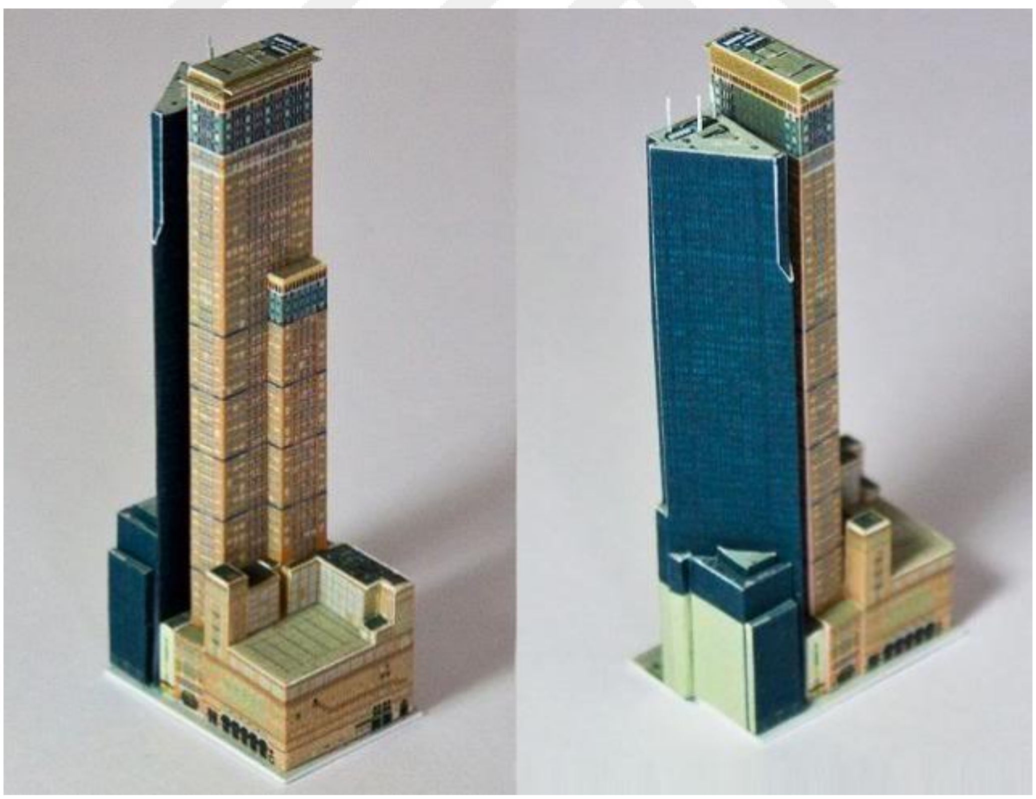


Figure 2.12 Metropolitan Tower, New York, USA, 1987 (Gunel and Ilgin, 2006)

Shear walls are called *bearing walls* if their main structural function is to support gravity loads, and are referred to as *shear walls* if they are mainly required to resist lateral loads due to wind and earthquake. The thickness of reinforced concrete bearing walls varies from 125 mm to 200 mm; however, shear walls may be considerably thicker in the lower stories of tall buildings. The walls around the lift cores of a building often serve as shear walls (King, 2011).

Shear walls are solid walls, which usually extend over the full height of the building. They are commonly located at the lift/staircase core regions. Shear walls are also frequently placed along the transverse direction of a building, either as exterior (facade) walls or as interior walls. The walls are very stiff, having considerable depth in the direction of lateral loads [Fig. 2.3(b)]; they resist loads by bending like vertical cantilevers, fixed at the base (King, 2011).

Shear walls, in particular, must be strong in themselves and also strongly connected to each other and to the horizontal diaphragms. In a simple building with shear walls at each end, ground motion enters the building and creates inertial forces that move the floor diaphragms. This movement is resisted by the shear walls and the forces are transmitted back down to the foundation.

Properly designed and detailed buildings with shear walls have shown very good performance in past earthquakes. Shear walls in high seismic regions require special detailing. However, in past earthquakes, even buildings with sufficient amount of walls that were not specially detailed for seismic performance (but had enough well-distributed reinforcement) were saved from collapse (Kevadkar and Kodag, 2013).

Most RC buildings with shear walls also have columns; these columns primarily carry gravity loads (i.e., those due to self-weight and contents of building). Shear walls provide large strength and stiffness to buildings in the direction of their orientation, which significantly reduces lateral sway of the building and thereby reduces damage to structure and its contents. Since shear walls carry large horizontal earthquake forces, the overturning effects on them are large. Thus, design of their foundations requires special attention. Shear walls should be provided along preferably both length and width. However, if they are provided along only one direction, a proper grid of beams and columns in the vertical plane (called a moment-resistant frame) must be provided along the other direction to resist strong earthquake effects (Kevadkar and Kodag, 2013).

Shear wall structures are generally quite stiff and, as such inter-storey drift problems are rare and generally easily contained. The shear wall tends to act as a rigid body rotating about a plastic hinge which forms at the base of the wall. Overall structural deformation is thus a function of the wall rotation. Inter-storey drift problems which do occur are limited to the lower few floors. A major shortcoming with shear walls within buildings is that their size provides internal (or external) access barriers which may contravene the architectural requirements. This problem can be alleviated by coupling adjacent more slender shear walls. The coupling beams then become shear links between the two walls and with careful detailing can provide a very effective, ductile control mechanism.

The interacting wall-frame combination is appropriate for the building in the 40 –50 story range, carefully tuned structure, the shear of the frame can be made approximately uniform over the height, allowing the floor framing to be repetitive. Well beyond that of rigid frames or shear walls alone is the advantage of this method. The various walls and co-existing frames in a building are linked at the different floor levels by means of the floor system, which distributes the lateral loads to these different systems appropriately (King, 2011)

The interaction between the shear walls and the frames is structurally advantageous in that the walls restrain the frame deformations in the lower stories, while the frames restrain the wall deformations in the upper stories [Fig. 2.3(c)] (King, 2011).

The Following are some shapes of shear walls :

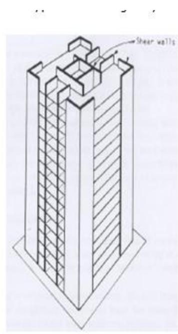


Figure 2.13 Shear wall system

Figure 2.14 frame wall system

(https://www.google.com.tr/search?q=shear+frame+system&tbm)

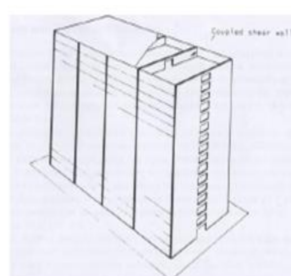


Figure 2.15 coupled wall system

(https://www.google.com.tr/search?q=shear+frame+system&tbm)

Shear walls generally start at foundation level and are continuous throughout the building height. Their thickness can be as low as 200mm or as high as 400mm in high rise buildings (Kevadkar and Kodag, 2013). Shear walls are usually provided along both length and width of buildings. Shear walls are like vertically-oriented wide beams that carry earthquake loads downwards to the foundation. A shear wall is a vertical structural element that resists lateral forces in the plane of the wall through shear and bending. Such a wall acts as a beam cantilevered out of the foundation and just as with a beam, part of its strength derives from its depth. Because walls enclosing stairways, elevator shafts, and mechanical shafts are mostly solid and run the entire height of the building, they are often used for shear walls. Although not as efficient from a strictly structural point of view, interior shear walls do leave the exterior of the building open for windows which is a more realistic situation because both wind and earthquake forces need to be resisted in both directions. Shear walls do not need to be symmetrical in a building, but symmetry is preferred to avoid torsional effects.

Advantages of shear wall are strong concrete will decrease the wall thickness, and number of columns will decrease therefore user can get maximum space inside the building. Also, that will provide resist lateral loads reduce is depend with percentage of open area. No need of complex bolted connections.

Disadvantages of this method are time for the construction is there must do daily survey checking about the right vertical of the shear walls are within tolerance. Sometimes cannot expect good finishing from the shear wall. So must have to do rendering or any other process for get good finishing.

Essentially, a shear wall is a rigid vertical plate that is oriented parallel with the direction of force that acts like a vertical cantilever beam as shown below in figure 2.16 a and b .

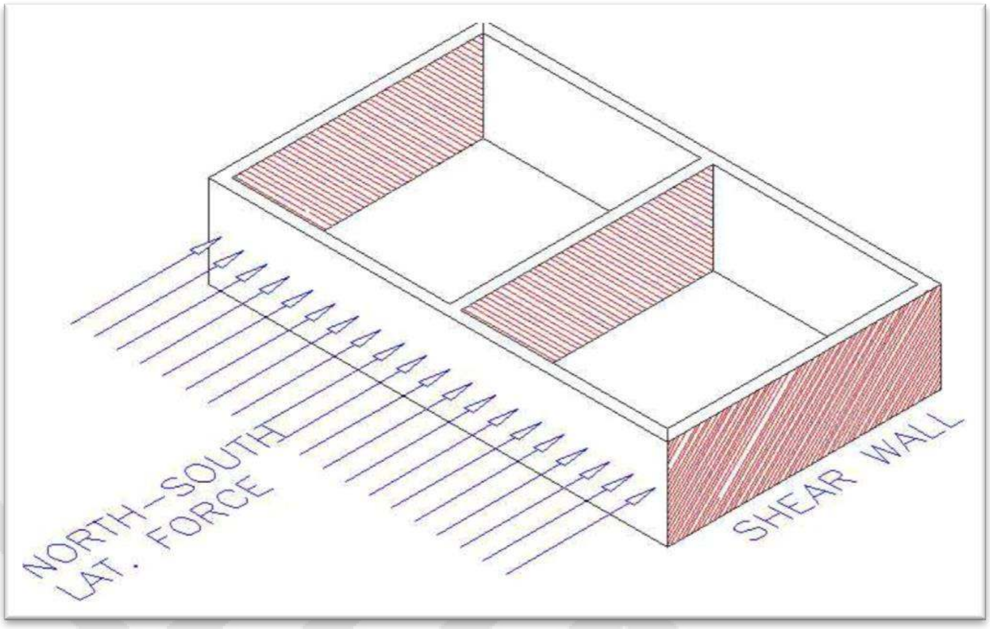


Figure 2.16 a- orientation of lateral force (http://scholar.google.com.tr/scholar)

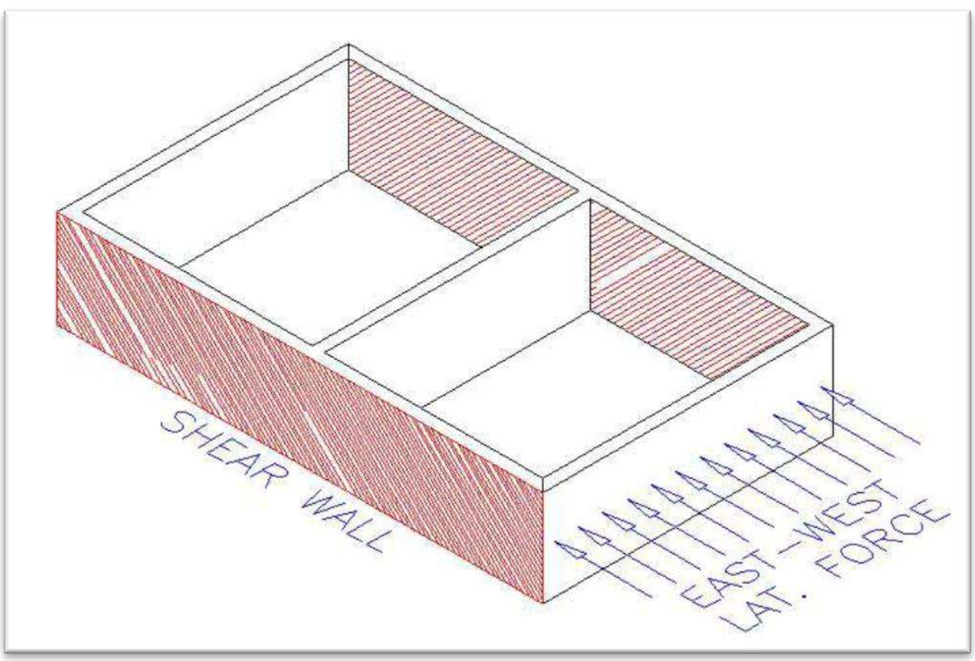


Figure 2.16 b- orientation of lateral force (http://scholar.google.com.tr/scholar)

2.2.3 Outrigger systems

Outrigger systems are modified form of braced frame and shear-walled frame systems, and utilized in steel and composite constructions. As an innovative and efficient structural system, the outrigger system comprises a central core, including either braced frames or shear walls, with horizontal ‘‘outrigger’’ trusses or girders connecting the core to the external columns. Furthermore, in most cases, the external columns are interconnected by exterior belt girder. If the building is subjected to the horizontal loading, the rotation of the core is prevented by the column-restrained outriggers. The outriggers and belt girder (Figure 2.17 a and b) should be at least one and often two stories deep to realize adequate stiffness. Thus, they are generally positioned at plant levels to reduce the obstruction they create (Gunel and Ilgin, 2006). Depending upon the number of levels of outriggers and their stiffness, the perimeter columns of an outrigger structure perform a composite behavior with the core. When compared to single-storey outrigger structures, multi-storey outriggers have better lateral resistance, and thus efficiency in the structural behavior. However, each extra outrigger storey enhances the lateral stiffness, but by a smaller amount than the previous one. Outrigger structures can be used for buildings with over 100 stories. the 101-storey-high Taipei refer to figure 2.18 (2004) with its composite structure in Taipei is excellent example of this system (Gunel and Ilgin, 2006).

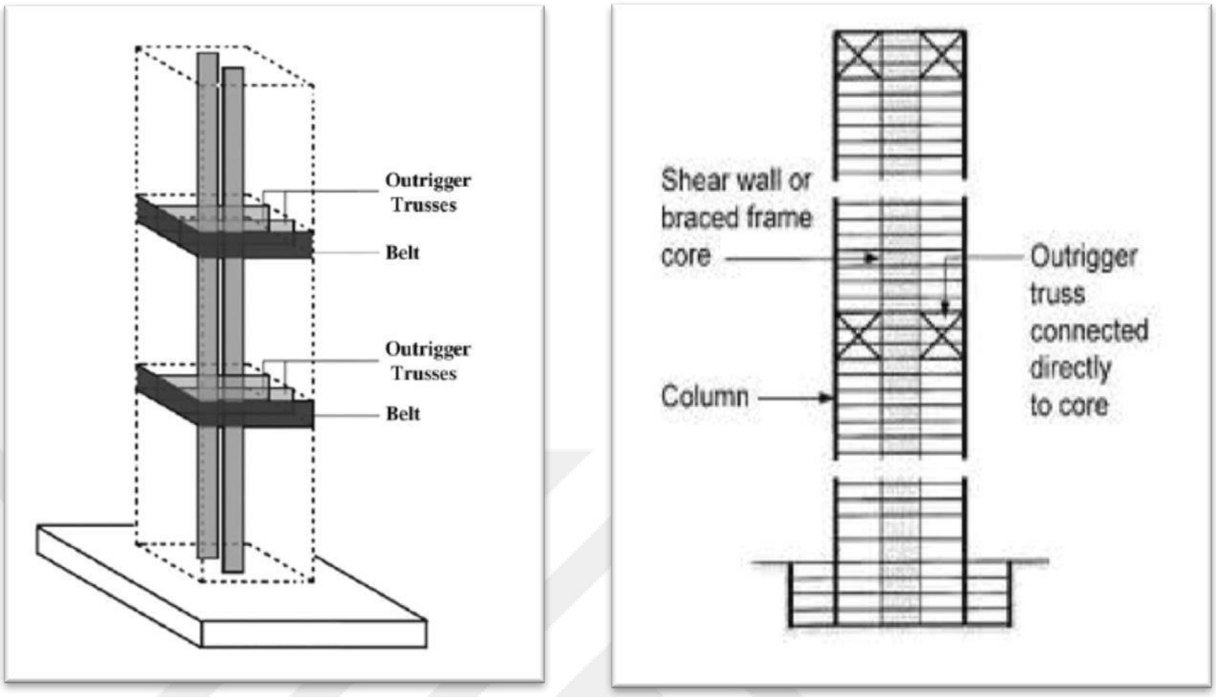


Figure 2.17 a- core and outrigger system (Seng and Torang, 2001)

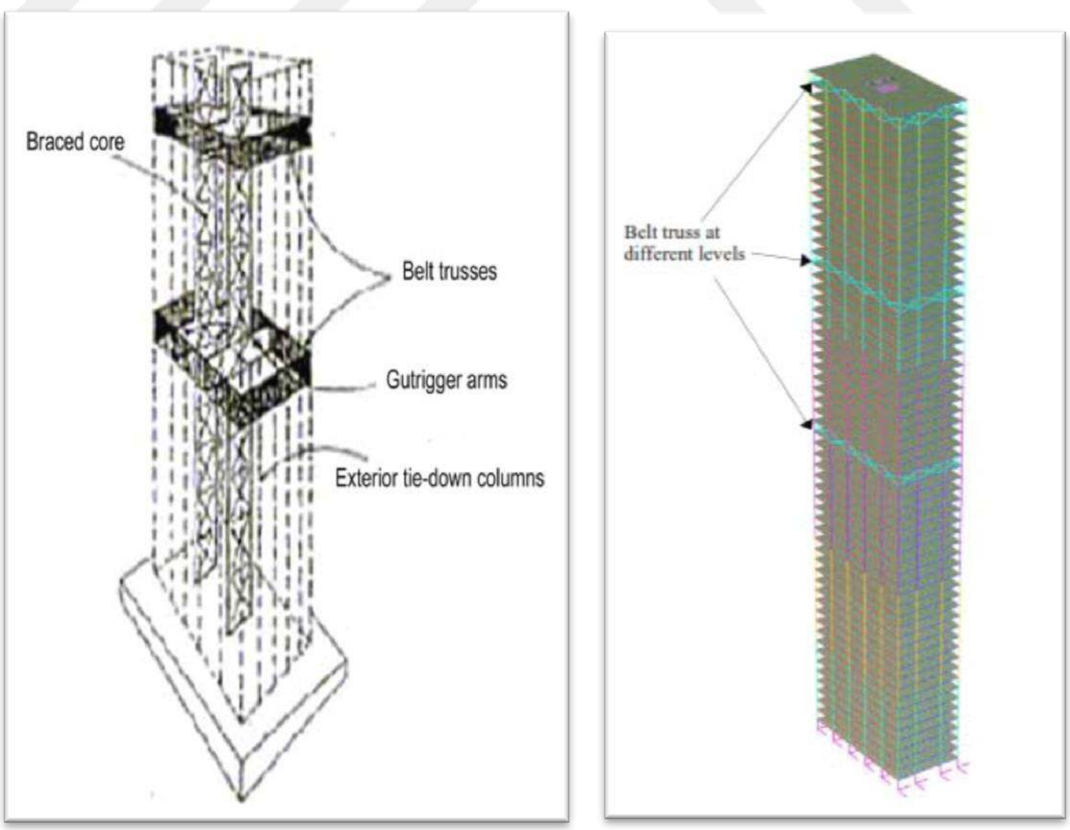


Figure 2.17 b- core and outrigger system (Ali, 2013)

Figure 2.18 Taipei 101, Taipei, Taiwan, 2004 (Gunel and Ilgin, 2006)

Outrigger serve to reduce the overturning moment in the core that would otherwise performance as a pure cantilever and to transfer the reduced moment to columns outside the core by the way of tension compression coupled which take advantage of the increase moment arm between these columns. In high rise building the same benefit is realized by a reduction of the base core over turning moments and the associated reduction in the potential core uplift forces.

Some advantages of this system are outrigger systems may be formed in any combination of steel, concrete or composite construction. Also, significant reduction and possibly the complete elimination of uplift and net tension forces throughout the column and the foundation systems. Another advantage is exterior column spacing is not driven by structural considerations and can easily netting with beautiful and functional considerations. Exterior framing can consist of simple beam and column framing without the need for rigid frame type connections resulting in economies.

Here also have some disadvantages. The most significant drawback with use of outrigger systems is their potential interference with occupied and rentable space. The incorporation of an outrigger at intermediate or upper levels can and if not approached properly may have a negative impact on the erection process.

Outriggers have been historically used in the sailing ships to resist the wind loading and the same concept has been used in the high-rise structure as a lateral load resisting system. In case of lateral loading, the rotation of the central core will be restrained by the deep outrigger by producing tension in the windward columns and compression in the leeward columns as shown in Figure 2.19. The restraining action of columns will produce the restoring moment in the structures. This restoring moment reduce the bending moment in core and lateral displacement of the structure. If this outrigger truss is assumed to be infinitely rigid then axial deformation of the columns is equal to rotation of the core multiplied by their distances from the center of the core.

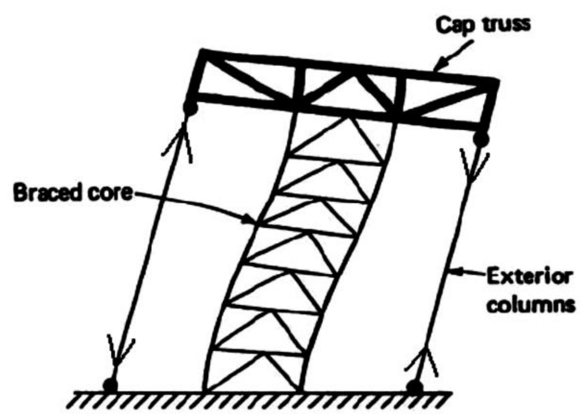


Figure 2.19 Outrigger-braced structure (Bungale, 2004)

2.2.4 Framed-tube systems

Framed-tube systems, are proper for steel, reinforced concrete and composite construction, and represent a logical evolution of the conventional frame structure. Since braced frame and shear-walled frame systems become inefficient in very tall buildings, framed tube becomes an alternative of these systems. The primary characteristic of a tube is the employment of closely spaced perimeter columns interconnected by deep spandrels, so that the whole building works as a huge vertical cantilever to resist overturning moments. It is an efficient system to provide lateral resistance with or without interior columns. The efficiency of this system is derived from the great number of rigid joints acting along the periphery, creating a large tube. Exterior tube carries all the lateral loading. The gravity loading is shared between the tube and the interior columns or walls, if they exist (Gunel and Ilgin, 2006).

Besides its structural efficiency, framed-tube buildings leave the interior floor plan relatively free of core bracing and heavy columns, enhancing the net usable floor area thanks to the perimeter framing system resisting the whole lateral load. Because of the closely spaced perimeter columns, on the other hand, views from the interior of the building may be hindered. The method of achieving the tubular behavior by using columns on close centers connected by a deep spandrel is the most common system because of the rectangular windows arrangement.

The primary lateral load resistance of the frame tube is provided by the overall bending of the tube by introducing the tensile and compression forces in the tube windward and leeward faces. The perimeter column can be considered as continuous wall elements were look like square hollow. Under lateral load, the perimeter columns were predominant the bending mode of the building.

The efficiency of the tube system is directly related to the geometry of the shape building, such as the overall depth-to-width ratio and the height-to-width ratio. The behavior of the tube can be compared to hollow cantilever, the overall action of the cantilever bending due to lateral load because of shortening on leeward column and elongation on windward columns plus a shear deformation brought about by the local bending of column and spandrel.

There are two popular versions used currently for this system for composite construction: one system utilizes composite columns and concrete spandrels while the other utilizes structural steel spandrels instead of concrete ones. The difficult access to the public lobby area resulting from the closely spaced column configuration at the base could be overcome by using a large transfer girder or an inclined column arrangement as was the case in the World Trade Center Twin Buildings (Gunel and Ilgin, 2006).

Height-to-width ratio, plan dimensions, spacing, and size of columns and spandrels of the buildings, directly affect the efficiency of the system. Even though the tube form was developed originally for rectangular or square buildings, and probably it's most efficient use in those shapes, circular, triangular and trapezoidal forms could be employed as well. Framed-tube systems can be categorized into three groups:

1. Systems without interior columns, shear walls, or steel bracings;
2. Systems with interior columns, shear walls, or steel bracings;
3. tube-in-tube systems.

When lateral sway is critical and starts controlling the design, the ‘‘framed tube’’ can be supplemented by a tube in the core to create ‘‘tube-in-tube’’ system, which can be constructed over 100 stories height. The stiffness of a hollow tube system is very much improved by using the core not only for gravity loads but to resist lateral loads. The floor structure ties the exterior and interior tubes together, and they respond as a unit to lateral forces. The 110-storey-high World Trade Center Twin Towers (1972) (Fig. 2.20) with its ‘‘tube-in-tube’’ steel structure and the DeWitt Chestnut Apartment Building (1965)

(Fig. 2.21) with its reinforced concrete structure are good examples of the framed-tube system (Gunel and Ilgin, 2006).

Figure 2.20 World Trade Center Twin Towers, New York, USA, 1972 (Gunel and Ilgin, 2006)

Figure 2.21 DeWitt-Chestnut Apartment Building, Chicago, USA, 1965.
(Gunel and Ilgin, 2006)

As mentioned previously, the lateral resistant of the framed-tube structures is provided by very stiff moment resistant frames form a tube around the perimeter of the building. The frames consist of closely-spaced (between 2-3 meters) exterior columns are located along the periphery of a building. Deep spandrel beams (deep edge beams with depth usually 0.5-1.5meters), located on the exterior surface of the building, interconnect these columns (Ali, 2013) The entire system behaves like a perforated box or framed tube with a high flexural rigidity against lateral loads [Fig. 2.3(d)] (King, 2011)

Vertical gravitational forces are resisted partly by the exterior frames and partly by some inner structure such as interior columns or an interior core. Tubular structures can be commonly square or rectangular in shape, or sometimes circular, triangular and trapezoidal shaped cross– sections can also be chosen (Ali, 2013). Sometimes the closely spaced column arrangement makes access difficult to the public area at the base. It can be avoided by using a large transfer girder to collect the vertical loads from the closely spaced columns and distribute them to a smaller number of larger more widely spaced columns at the base (fig. 2.23). The framed tube allows the core framing to be constructed independently therefore the exterior can be constructed while the interior layout is being finalized (Ali, 2013). Refer to figure 2.22 a and b

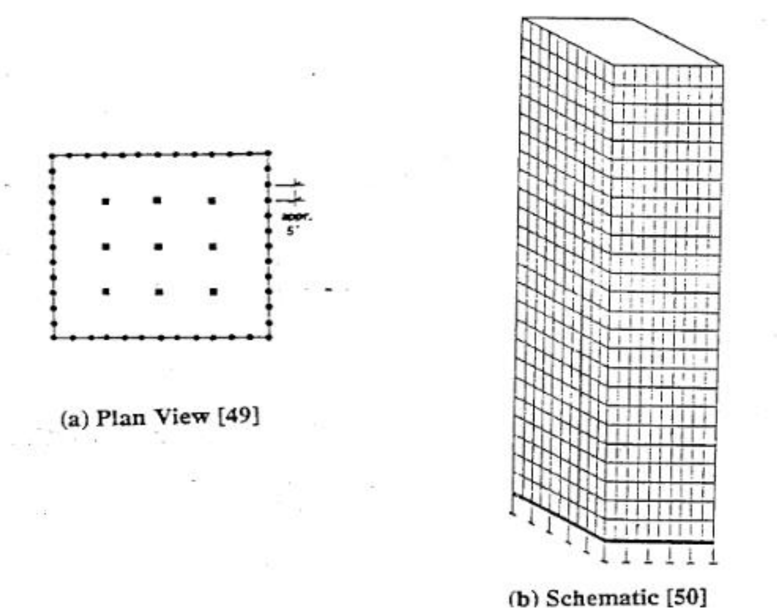


Figure 2.22 Frame tube system (a) plan view, (b) three dimension views (Ali, 2013)

Figure 2.23 Framed Tube (Gunel and Ilgin, 2006)

In steel structure, the framed tube is one of the most significant modern developments in high-rise structural form. This structural form offers an efficient, easily constructed structure appropriate for buildings having *40* to*100* storey. When lateral loads act, the perimeter frames aligned in the direction of loads act as the webs of the massive tube cantilever and those normal to the direction of the loading act as the flanges. Even though framed tube is a structurally efficient form, flange frames tend to suffer from shear lag. This results in the mid face flange columns being less stressed than the corner columns and therefore not contributing to their full potential lateral strength. Aesthetically, the tube looks like the grid-like façade as small windowed and is repetitious and hence use of prefabrication in steel makes the construction faster.

When the (outer) framed tube is combined with an 'inner tube' (or a central shear core), the system is called a tube-in-tube fig. 2.26. A tube-in-tube system or Hull-Core structures is a variation of the framed tube created by the shear walls, or as it is known from its name tube in tube and the outer tube consisting of the closely spaced column system as in Figure 2.24 and Figure 2.25. The tube in tube system has the advantages of both of the shear wall type structures and the framed tube structures. The shear deflection of the columns of the framed tube is considerably reduced by the shear wall inner tube; thereby enhancing the structural characteristics of the exterior framed tube. The tube-in tube system is a refined and unique version of the shear wall-frame interaction type structures (Ali, 2013).

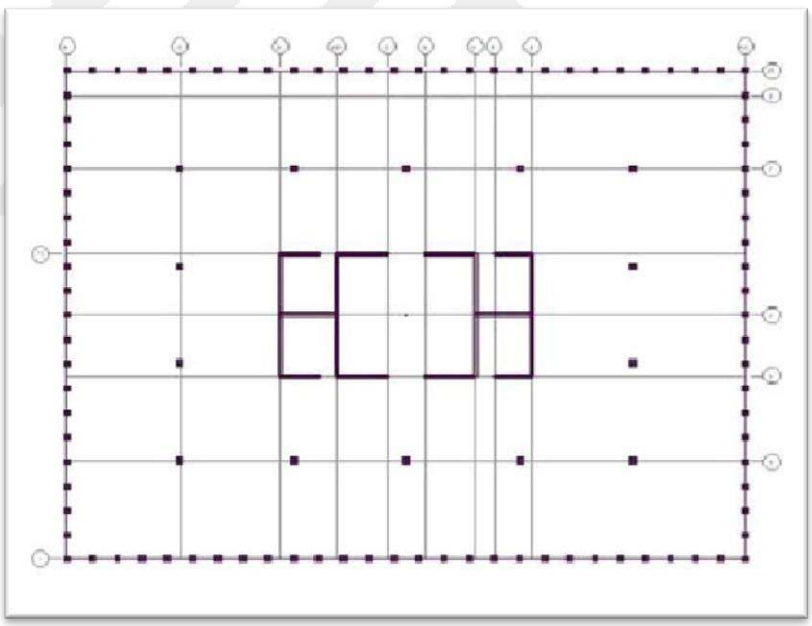


Figure 2.24 Internal sections in frame tube in tube system (Ali, 2013)

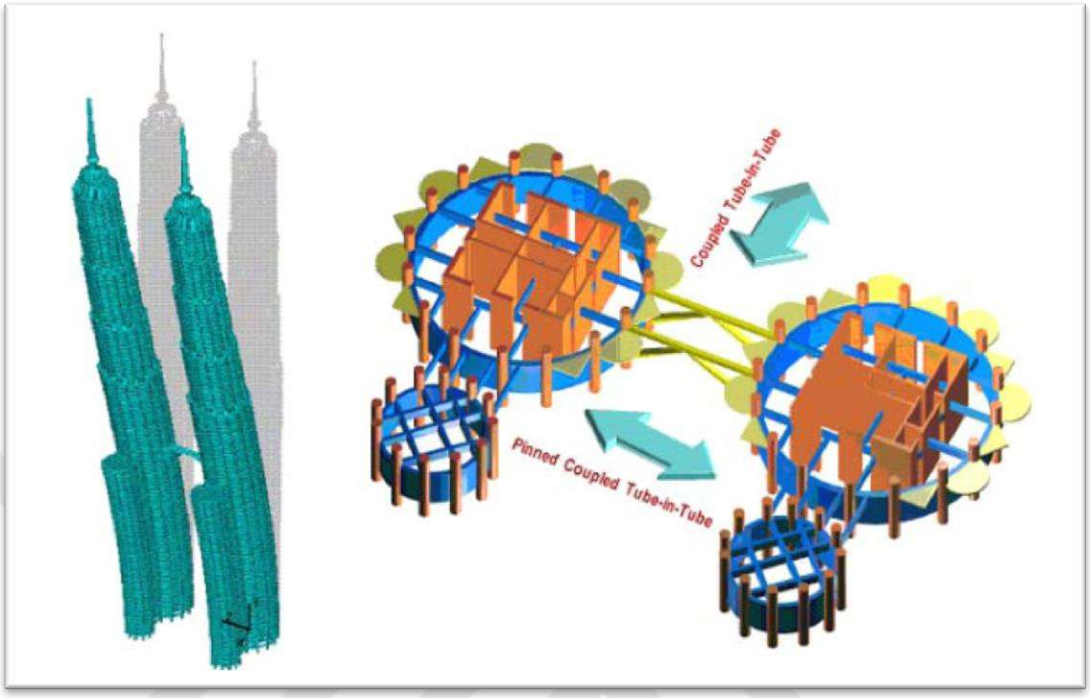


Figure 2.25 Inside section of frame tube in tube system showing joining between Tubes (Ali, 2013)

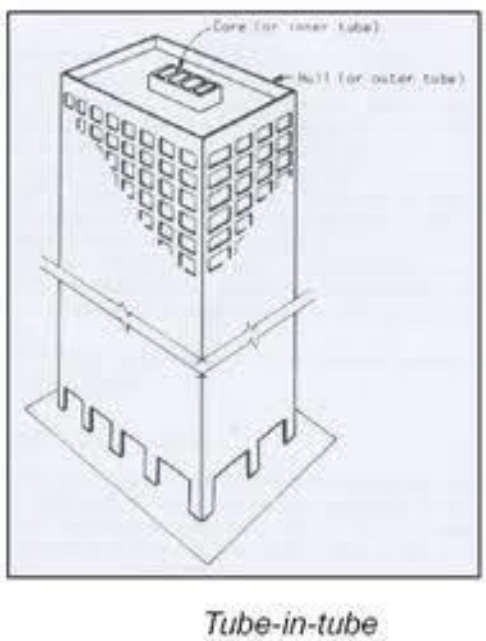


Figure 2.26 Tube-in-Tube
(https://www.google.com.tr/search?q=tube+in+tube+structure&tbm)

When the sectional plan of the building comprises several perforated tubular cells, the system is called a bundled tube or 'multi-cell framed tube'.

The bundled tube systems consist of frame tubes, which are bundled together one with each other as in Figure 2.31 and Figure 2.27

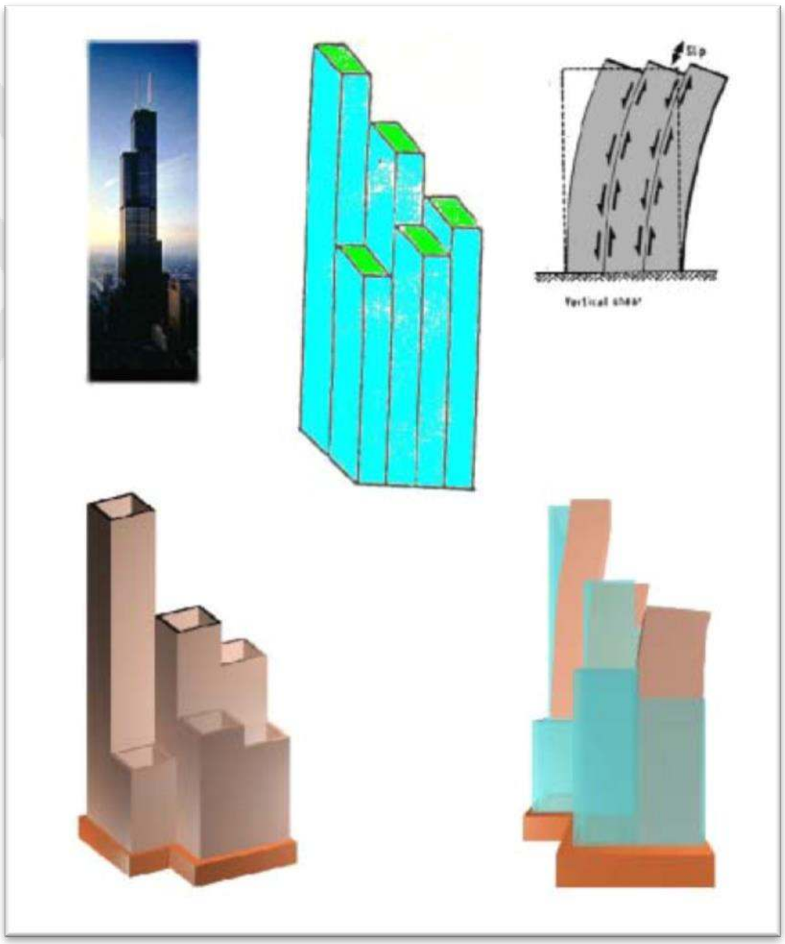


Figure 2.27 3D views of bundle tube system (Ali, 2013)

Tube in tube building is combination of shear wall and framed tube with closely spaced column and deep spandrels. This system is general accepted as a very efficient structural system for tall building. The simplicity of tube system was first introduced by Khan (1973) of the architectural and engineering firm of Skidmore, Owings and Merrill. The tube system only needed to employ the very basic elements structures, namely beams and strategically deploying the locations of column. What more important is that it is not requires new method of analysis.

The tube has become the workhorse of the high rise construction system because it minimizes the structural premium for lateral strength and stiffness, simultaneously accommodating recent trends in architectural forms.

2.2.5. Braced-tube systems

Braced-tube systems can be utilized in steel, reinforced concrete, and composite construction. By adding multistory diagonal bracings to the face of the tube, the rigidity and efficiency of the framed tube can be improved, thus obtained braced-tube system, also known as trussed tube or exterior diagonal-tube system, could be utilized for greater heights, and allows larger spacing between the columns. It offers an excellent solution by utilizing a minimum number of diagonals on each face of the tube intersecting at the same point as the corner columns. In steel buildings, steel diagonals/trusses, are used, while in reinforced concrete buildings, diagonals are created by filling the window openings by reinforced concrete shear walls to achieve the same effect as a diagonal bracing (Gunel and Ilgin, 2006).

New York’s 50-storey-high 780 Third Avenue Building (1985) (Fig. 2.38) was the first reinforced concrete building to use this concept. The 58-storey-high Onterie Center (1986) in Chicago is another example of such a system in concrete. On the other hand, the bracing guarantees that the perimeter columns act together in carrying both gravity and horizontal wind loads. Therefore, a very rigid cantilever tube is generated whose behavior under lateral load is very close to that of a pure rigid tube (Gunel and Ilgin, 2006).

This configuration is well suited for tall, slender buildings with small floor areas and was firstly used in a steel building, the 100-storey-high John Hancock Center (1969) (Fig. 2.29) by the great structural engineer Fazlur Khan, developer of trussed tube concept. A braced tube eliminates the risk of the excessive axial load taken by the corner columns. In this context, one of the main problems in the framed tube can be overcome by stiffening the exterior frames. Although replacing vertical columns with closely spaced diagonals in both directions is the most effective braced-tube action, braced-tube system is not widely used due to its problems in curtain wall details. This system can be used for buildings with over 100 stories (Gunel and Ilgin, 2006).

Figure 2.28 The 780 Third Avenue Building, New York, USA, 1985 (Gunel and Ilgin, 2006)

Figure 2.29 John Hancock Center, Chicago, USA, 1969 (Gunel and Ilgin, 2006)

2.2.6. Bundled-tube systems

Bundled-tube systems are proper for steel, reinforced concrete, and composite construction. A single framed tube does not have an adequate structural efficiency, if the building dimensions increase in both height and width. Namely, the wider the structure is in plan, the less effective is the tube. In such cases, the bundled tube, also known as modular tube, with larger spaced columns is preferred. This concept, being created by the need for vertical modulation in a logical fashion, can be defined as a cluster of tubes interconnected with common interior panels to generate a perforated multicell tube (Gunel and Ilgin, 2006).

Since this system is originated from the arrangement of individual tubes, a variety of floor configurations could be achieved by simply terminating a tube at any desired height without sacrificing structural stiffness. This feature makes the setbacks with different shapes and sizes possible (Gunel and Ilgin, 2006).

This concept is described for wider column spacing in the tubular walls than would be possible with only the exterior frame tube form. Spacing which make it possible to place interior frame lines without seriously compromising interior space planning. Also the ability to modulate the cells vertically can create a powerful vocabulary for a variety of dynamic shapes therefore offers great latitude in architectural planning of a tall building. Advantage of the bundle tube system is the huge torsional resistance which is helpful in absorbing torsional lateral forces due to inconsistency. Refer to figure 2.30

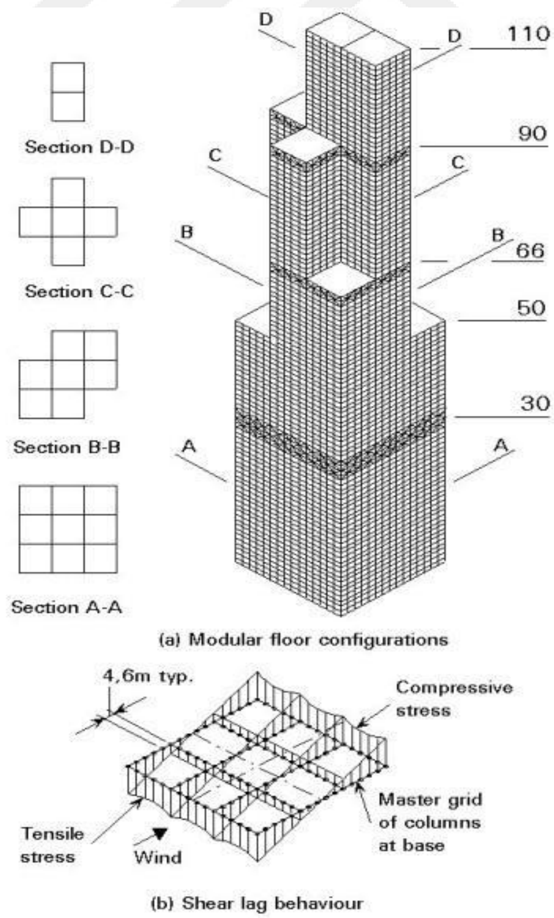


Figure 2.30 bundle tube structure (Bungale, 2004)

Bundle tube system has advantages in structuring unsymmetrical shapes. Since the ‘‘bundled-tube’’ design is derived from the layout of individual tubes, the cells can be in different shapes such as triangular, hexagonal, or semicircular units. The disadvantage, however, is that the floors are divided into tight cells by a series of columns that run across the building width. Thanks to its larger spaced columns, and thinner spandrels, this system allows bigger window openings when compared to the single-tube structure. Moreover, this system also makes the architectural planning of the building more flexible since any tube module can be dropped out whenever required by the planning of the interior spaces (Gunel and Ilgin, 2006).

Two versions are possible using either framed or diagonally braced tubes, as well as a mixture of the two. The (165)-stories Burj khalife building (Fig. 2.20) in Dubai is a good example of bundled-tube system and it is a tallest building all over the world tell the date of this research. Bundled-tube concept has a broad application because of its modular quality. The tubes or cells can be organized in a variety of ways to create different massing.

Figure 2.31 The Burj khalife – dubai (http://www.panoramio.com)

CHAPTER III

CASE STUDY

3.1 The structural software

ETABS is a sophisticated, yet easy to use, special purpose analysis and design program developed specifically for building systems. Although quick and easy for simple structures, ETABS can also handle the largest and most complex building models, including a wide range of nonlinear behaviors, making it the tool of choice for structural engineers in the building industry.

ETABS belong the group of three programs; SAP, ETABS and safe which created by Computers and Structures, Inc. (CSI) company. From these three programs, ETABS is one of the most usable programs that is used in buildings and this program is not used for any other purposes except buildings. ETABS has the biggest amount of using from other programs such as sap, safe, STAAD pro ……. etc.

ETABS offers the widest assortment of analysis and design tools avail-able for the structural engineer working on building structures. The following list represents just a portion of the types of systems and analyses that ETABS can handle easily:

- Multi-story commercial, government and health care facilities
- Parking garages with circular and linear ramps
- Staggered truss buildings
- Buildings with steel, concrete, composite or joist floor framing
- Complex shear walls with arbitrary openings
- Buildings based on multiple rectangular and/or cylindrical grid systems
- Flat and waffle slab concrete buildings
- Buildings subjected to any number of vertical and lateral load cases and combinations, including automated wind and seismic loads

- Multiple response spectrum load cases, with built-in input curves
- Automated transfer of vertical loads on floors to beams and walls
- P-Delta analysis with static or dynamic analysis
- Explicit panel-zone deformations
- Construction sequence loading analysis
- Multiple linear and nonlinear time history load cases in any direction
- Foundation/support settlement
- Large displacement analyses
- Nonlinear static pushover
- Buildings with base isolators and dampers
- Drift optimization for steel and concrete frames
- Floor modeling with rigid or semi-rigid diaphragms
- Automated vertical live load reductions

Etabs is considered as the easiest programs among the others because it is used in one area of structure and the process of inserting information is also easy and the same data is required to be interred. Another advantage of this program is that all the international codes are available in it. Because of the reasons that are mentioned above, the researcher wanted to use this program in his study.

3.2 Lateral Loads

Most lateral loads are earthquake and wind loads whose main component is horizontal force acting on the structure. Typical lateral loads would be a wind load against a façade, an earthquake, the earth pressure against a beach front, retaining wall or the earth pressure against the basement wall. Most lateral loads vary in intensity depending on the buildings geographic location, structural materials, height and shape. The dynamic effects of wind and earthquake loads are usually analyzed as an equivalent static load in most small and moderate sized buildings. Others must utilize the iterative potential of the computer. The way that wind or earthquake loads act on a building is completely different, but they have the same general effect. These two sources of lateral load are discussed below.

3.2.1Wind Loads

Buildings and their components are to be designed to withstand the code specified wind loads. Calculating wind loads is important in design of the wind force-resisting system, including structural members, components, and cladding against shear, sliding, overturning and uplift actions. The most common lateral load is a wind load. The Eiffel Tower is one of the examples of a building which has a structure that was designed to resist a high wind load. Wind against a building builds up a positive pressure on the windward side and a negative pressure (or suction) on the leeward side. Depending upon the shape of the structure it may also cause a negative pressure on the side walls or even on the roof. The pressure on the walls and roof is not uniform, but varies across the surface.

Winds can apply loads to structures from unexpected directions. Thus, a designer must be well aware of the dangers implied by this lateral load. The magnitude of the pressure that acts upon the surfaces is proportional to the square of the wind speed. Wind loads vary around the world. Meteorological data collected by national weather services are one of the most reliable sources of wind data. Factors that affect the wind load includes the geographic location, elevation, degree of exposure, relationship to nearby structures, building height and size, direction of prevailing winds, velocity of prevailing winds and positive or negative pressures due to architectural design features (atriums, entrances or other openings). All of these factors are taken into account when the lateral loads on the facades are calculated. It is often necessary to examine more than one wind load case.

Wind load is really the result of wind pressures acting on the building surfaces during a wind event. This wind pressure is primarily a function of the wind speed because the pressure or load increases with the square of the wind velocity (i.e., doubling of wind speed results in a four-fold increase in wind load or pressure)

3.2.2 Earthquake Loads

Earthquake loads are another lateral load. They are very complex, uncertain and potentially more damaging than the wind loads. It is quite fortunate that they do not occur frequently. The earthquake creates ground movements that can be categorized as a shake, rattle and a roll. Every structure in an earthquake zone must be able to withstand all three of these loadings of different intensities. Although the ground under a structure may shift in any direction, only the horizontal components of this movement are usually considered critical in a structural analysis. It is assumed that a load-bearing structure which supports properly calculated design loads for vertical dead and live loads are adequate for the vertical component of the earthquake. The static equivalent load method is used to design most small and moderate-sized buildings.

The lateral load resisting systems for earthquake loads are similar to those for wind loads. Both are designed as if they are horizontally applied to the structural system. The wind load is an external force, the magnitude of which depends upon the height of the building, the velocity of the wind and the amount of surface area that the wind attacks. The magnitude earthquake load depends upon the mass of the structure, the stiffness of the structural system and the acceleration of the surface of the earth. It can be seen that the application of these two types of loads is very different.

Earthquake forces experienced by a building result from ground motions (accelerations) which are also fluctuating or dynamic in nature, in fact they reverse direction somewhat chaotically. The magnitude of an earthquake force depends on the magnitude of an earthquake, distance from the earthquake source (epicenter), local ground conditions that may amplify ground shaking (or dampen it), the weight (or mass) of the structure, and the type of structural system and its ability to withstand abusive cyclic loading. In theory and practice, the lateral force that a building experiences from an earthquake increases in direct proportion with the acceleration of ground motion at the building site and the mass of the building (i.e., a doubling in ground motion acceleration or building mass will double the load).

3.3 The Seismic Analyses

The aim of structural analysis under seismic action is to compute the design actions (forces and displacements) on the building components and the entire system. Engineers need to know the maximum probable actions for design.

Dynamic analysis shall be performed to obtain the design seismic force, and its distribution to different levels along the height of the building and to the various lateral load resisting elements. There are three types of analyses as mentioned below;

3.3.1 Equivalent Static Method ESM

All design against earthquake effects must consider the dynamic nature of the load. However, for simple regular structures, analysis by equivalent linear static methods is often sufficient. This is permitted in most codes of practice for regular, low- to medium-rise buildings and begins with an estimate of peak earthquake load calculated as a function of the parameters given in the code.

Equivalent static analysis can, therefore, work well for low- to medium-rise buildings without significant coupled lateral–torsional modes, in which only the first mode in each direction is of significance. Tall buildings (over, say, 35 m), where second and higher modes can be important, or buildings with torsional effects, are much less suitable for the method, and both Eurocode 8 and IBC require more complex methods to be used in these circumstances.

Regular buildings up to around 15 stories in height can usually be designed using equivalent static analysis; tall buildings or those with significant irregularities in elevation (sudden changes in mass or stiffness with height) or plan (separation between the centres of stiffness and mass at any level) require modal response spectrum analysis.

3.3.2 Response Spectrum Method RSM

With the advent of powerful desktop computers, this type of analysis has become the norm. It involves calculating the principal elastic modes of vibration of a structure. The maximum responses in each mode are then calculated from a response spectrum and these are summed by appropriate methods to produce the overall maximum response. This method can give more accurate results than an equivalent static approach. This increase in accuracy is largely due to combining specific vibratory modes from the structure with the spectral accelerations determined for the site. The result is a much more accurate description of the seismic effects on a given structure, for a specific site location.

It is a dynamic method of analysis. In the calculation of structural response (whether modal analysis or otherwise), the structure should be so represented by means of an analytical or computational model that reasonable and rational results can be obtained by its behavior. When response spectrum method is used with modal analysis procedure, at least 3 modes of response of the structure should be considered except in those cases where it can be shown qualitatively that either third mode or the second mode produces negligible response. When appropriate, the model maxima should be combined using the square root of the sum of the squares of the individual model values.

The basic mode superposition method, which is restricted to linearly elastic analysis, produces the complete time history response of joint displacements and member forces. In the past there have been two major disadvantages in the use of this approach. First, the method produces a large amount of output information that can require a significant amount of computational effort to conduct all possible design checks as a function of time. Second, the analysis must be repeated for several different earthquake motions in order to assure that all frequencies are excited, since a response spectrum for one earthquake in a specified direction is not a smooth function.

There are computational advantages in using the response spectrum method of seismic analysis for prediction of displacements and member forces in structural systems. The method involves the calculation of only the maximum values of the displacements and member forces in each mode using smooth design spectra that are the average of several earthquake motions. Engineers, however, should clearly understand that the response spectrum method is an approximate method used to estimate maximum peak values of displacements and forces and that it has significant limitations.

3.3.3 Time-History Method THM

A linear time-history analysis of this type overcomes all the disadvantages of RSM, provided non-linear behavior is not involved. The method involves significantly greater computational effort than the corresponding RSM and at least three representative earthquake motions must be considered to allow for the uncertainty in precise frequency content of the design motions at a site. With current computing power and software, the task of performing the number crunching and then handling the large amount of data produced has become a non-specialist task.

3.4 System selection

The selection of the seismic force resisting system (SFRS) for s specific building is clearly a design decision of fundamental importance, yet there is no system that is best for all buildings (Seaoc, 2009). Factors to consider when selecting a seismic force resisting system include:

1. Performance: all of the code-prescriptive systems are expected to meet the performance objective of the code. For enhanced performance objectives, however, some systems might be better than others. For examples, some systems are better able to meet tight drift limits or assure speedy repair.
2. Architectural and nonstructural coordination: A moment resisting frame system can accommodate open spaces and unrestricted bays between columns. Braced frame and shear wall systems generally offer less flexibility in space planning and fenestration. The spacing of gravity columns, fire-rated partitions, and utility cores can also affect the relative efficiency of certain systems.
3. Construction cost: the project budget might dictate systems for certain materials, or cost-effective fabrication and erection procedures.
4. Design budget: some systems can be analyzed and designed effectively with simple hand calculations, while others require more expensive and time-consuming procedures.

Acceptable earthquake performance is a function of more than the selected structural system (Seaoc, 2009). Configuration of the SFRS within the building is fundamental to good design, concerning such issues as structural irregularities, torsion, redundancy, and the combination of systems.

3.5 Modeling and Analyzing

This part is discussed on modeling and analyzing four models which are used in this study. ETABS program which is specifically used for analyzing and designing of buildings and is used for analyzing the static analysis method which is (equivalent static method) because the building is completely symmetrical and there is no weak floors, and because the vertical direction is also symmetrical.

In this study, four models will be used in analyzing the structural systems (moment resisting system, shear wall system, shear frame system, and tube frame system) all of these buildings are reinforced concrete structures (RC). The researcher will compare the results of all models in chapter four by curves and tables.

In this part, the researcher will mention all the properties and conditions for the used materials (concrete, steel …. etc.) and also will define the sections and dimensions of all members and elements which are used in these models and the strength values of different materials which are used for analyzing and design.

The international codes which are used for analyzing these models (International Building Code and American Society of Civil Engineering), the international building code (IBC 2006) is used for analyzing earthquake load on buildings and American society of civil engineering code (ASCE 705) is used for analyzing the wind load.

3.5.1 Material properties

The four structural systems are analyzed with same materials properties and in same circumstances; therefore, the following properties are used for models;

- Compressive strength of concrete (Fc¯) = 3000 ton/m^2
- Bending Reinforcement, yield stress, Fy = 42500 ton/m^2
- Shear Reinforcement, yield stress, Fys= 42500 ton/m^2
- Modulus of Elasticity = 2600000 ton/m^2
- Poisson’s Ratio = 0.2
- support (fixed)

3.5.2 Lateral load Coefficients and factors

3.5.2.1 Seismic load

- Time period = 0. 028, 0.8
- Ecc. Ratio = 0.5
- Response modification, R;
- For moment resisting system = 3
- For shear wall system = 4.5
- For shear frame system = 6
- For frame tube system = 6
- Occupancy importance, I =1
- Ss =2.29
- S1 = 0.869
- Long- period transition period = 8
- Site class = B
- SDs = 1.5267
- SD1 = 0.5793

3.5.2.2 Wind load

- Wind speed (mph) = 110
- Exposure type = C
- Importance factor = 1
- Topographical Factor, Kzt = 1
- Gust Factor = 0.85
- Directionally Factor, Kd = 0.85
- Wind direction Angle (for Wx) = 0
- Wind direction Angle (for Wy) = 90
- Windward Coeff. =0.8
- Leeward Coeff. = 0.5
- Exposure height from base to story 28

3.5.3 Describe the structural systems

3.5.3.1 Moment Resisting System

Dimensions of building (25*25) m
Number of stories (28)
Spacing between columns (5) m
Bottom height story (4.4) m
Typical height story (3.4) m
Height of building (96.2) m
Thickness of slab (0.2) m
Beam dimensions b*d (0.65*0.75) m
Column dimensions (0.65*0.65) m
After entering the above mentioned data to ETABS, the program will make the model and analyze the building after checking the entering process also by ETABS, the model that has been made by program is show as below;

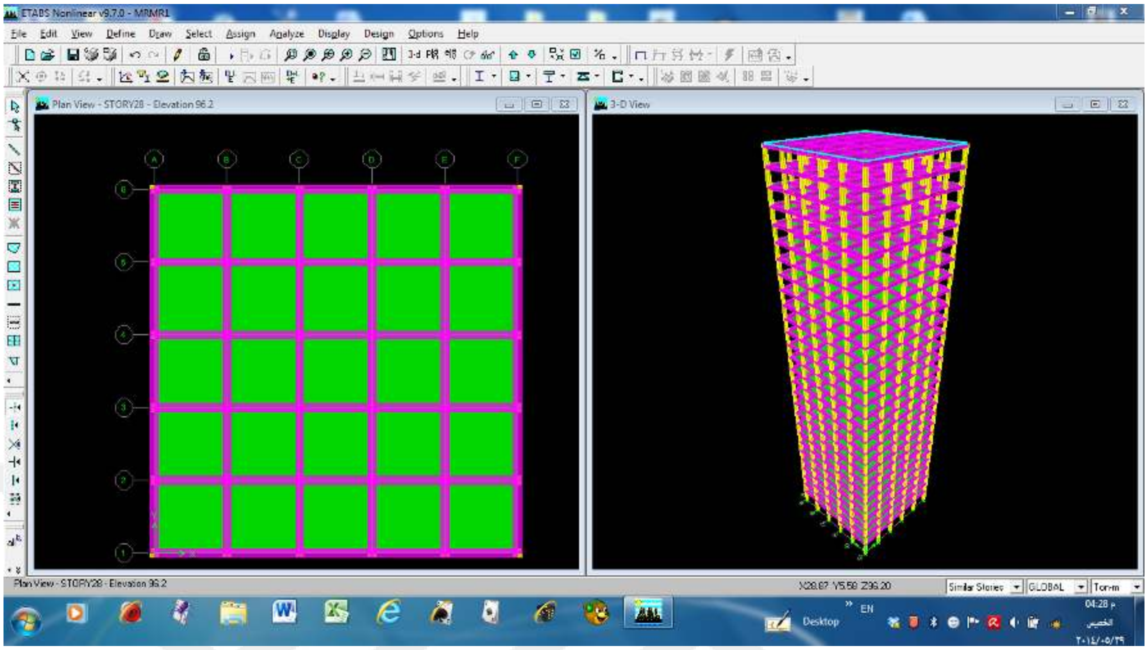


Figure 3.1 Making models of moment resisting

3.5.3.2 Shear wall system

Dimensions of building (25*25) m

Number of stories (28)

Bottom height story (4.4) m

Typical height story (3.4) m

Height of building (96.2) m

Thickness of slab (0.2) m

Thickness of shear wall (0.4) m

And the obtained model by ETABS is as follow

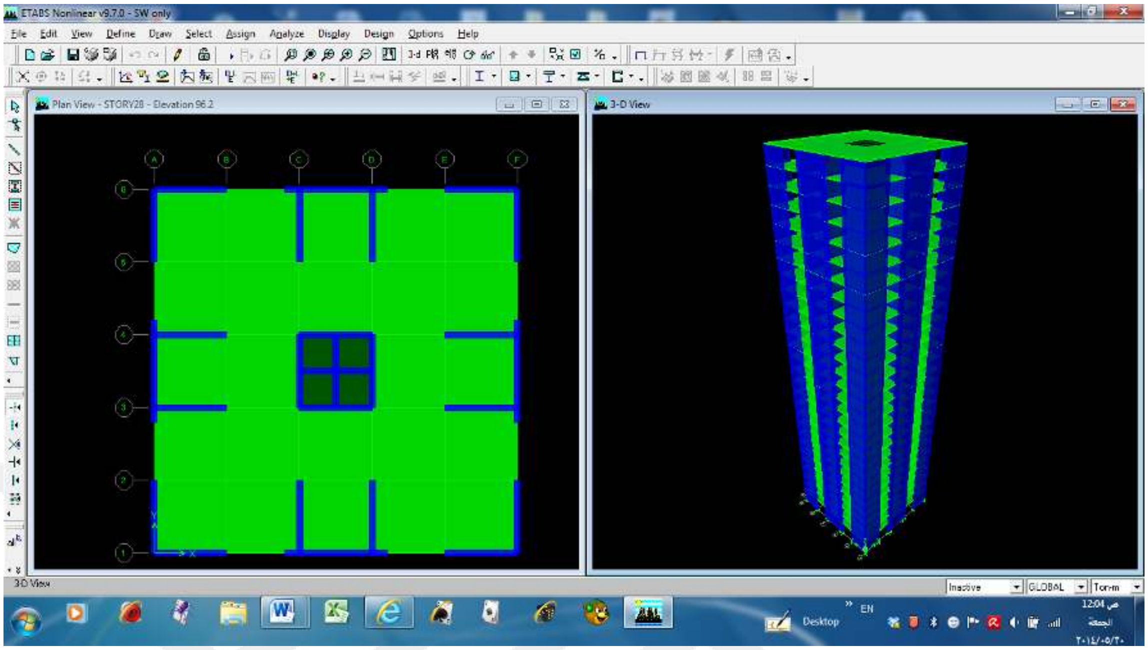


Figure 3.2 Making model for shear wall

3.5.3.3 Shear Frame System

Dimensions of building (25*25) m

Number of stories (28)

Spacing between columns (5) m

Bottom height story (4.4) m

Typical height story (3.4) m

Height of building (96.2) m

Thickness of slab (0.2) m

Thickness of shear wall (0.4) m

Beam dimensions b*d (0.4*0.5) m

Column dimensions (0.4*0.4) m

And the modes show as below

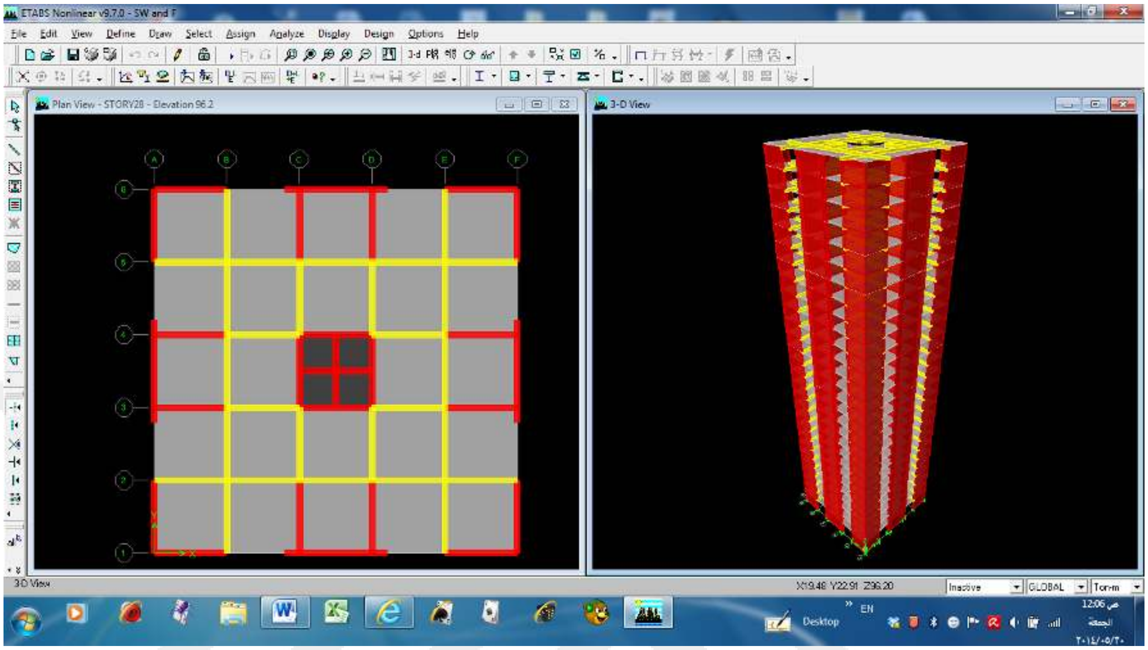


Figure 3.3 Making models for shear frame

3.5.3.4 Tube System

Dimensions of building (25*25) m

Number of stories (28)

Spacing between columns (5) m

Bottom height story (4.4) m

Typical height story (3.4) m

Height of building (96.2) m

Thickness of slab (0.2) m

Thickness of shear wall (0.4) m

Beam dimensions –B1– b*d (0.4*0.5) m

Beam dimensions –B2– b*d (0.4*1.2) m

Column dimensions –C1– (0.4*0.4) m

Column dimensions –C2– (0.4*1.2) m

And the modes show as below

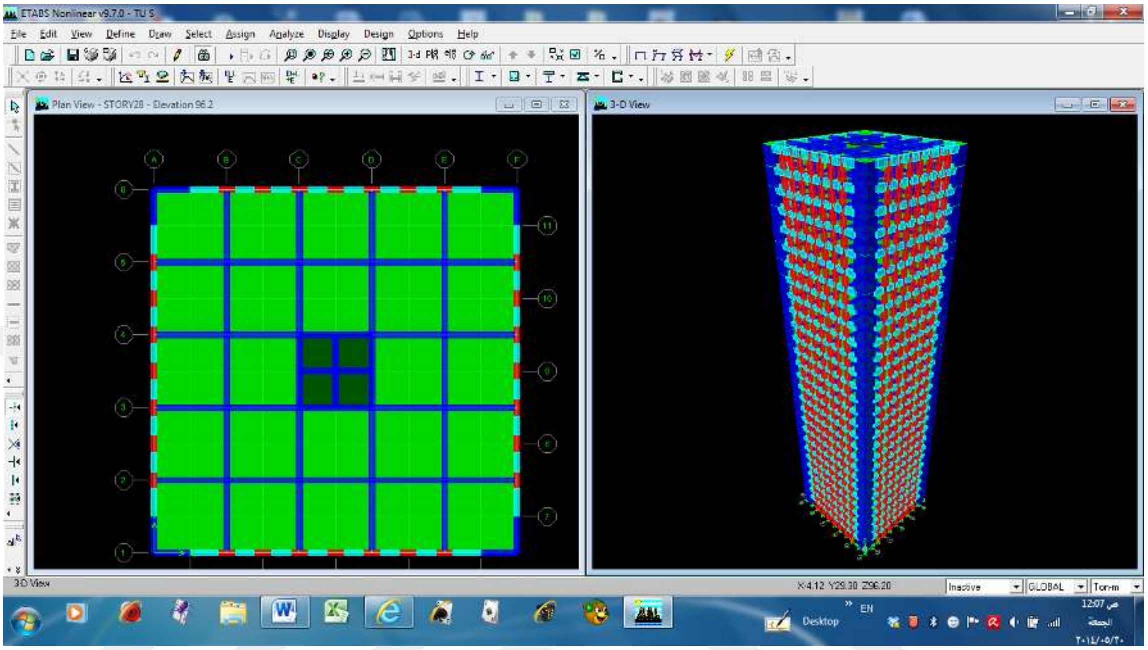


Figure 3.4 Making model of tube system

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Introduction

The four models are analyzed in the same situations and the same properties, either the material properties or the factors which have relations with lateral loads (quake and wind). Meanwhile, they were analyzed in the same (seismic zone, type class, wind speed, exposure type,…etc). They were analyzed in so symmetrical plane, homogeneous vertical height, and there is no weak floor from the base floor up to upper floor, it means the models have been analyzed in an ideal case.

The results of this study showed that the displacements in all structural systems are in the permitted limitation according to the international codes except moment resisting that the results show that it is not possible for this level (28 floors), but there are some dislike cases that should be solved. The researcher will mention these cases in this chapter and will recommend the methods to avoid these problems.

In all models, there are not any problems with the rotation displacements because the symmetric is available in all models. The outputs of these models are too much because the structure is high-rise building and contains many points in every floor, therefore, there is no need to show all of these outputs. For instance, in every floor, point number one was selected for comparison when dealing with displacement, but for story drift, the researcher showed the maximum value in each floor.

4.2 The results of the structural buildings

The output of this study is shown by tables and charts:

4.2.1 Moment Resisting System

Below are the results of displacements in (mm) due to Earthquake (Qx)

Table 4.1 Point drifts due to Qx

Story number	Point	Displacement Ux (mm)
Story 28	1	840.2
Story 27	1	821.8
Story 26	1	801.4
Story 25	1	779
Story 24	1	754.7
Story 23	1	728.7
Story 22	1	701.1
Story 21	1	672.1
Story 20	1	641.9
Story 19	1	610.6
Story 18	1	578.4
Story 17	1	545.4
Story 16	1	511.9
Story 15	1	477.8
Story 14	1	443.5
Story 13	1	409
Story 12	1	374.5
Story 11	1	340.1
Story 10	1	306.1
Story 9	1	272.4
Story 8	1	239.3
Story 7	1	206.9
Story 6	1	175.2
Story 5	1	144.5
Story 4	1	114.9
Story 3	1	86.5
Story 2	1	59.3
Story 1	1	33.2

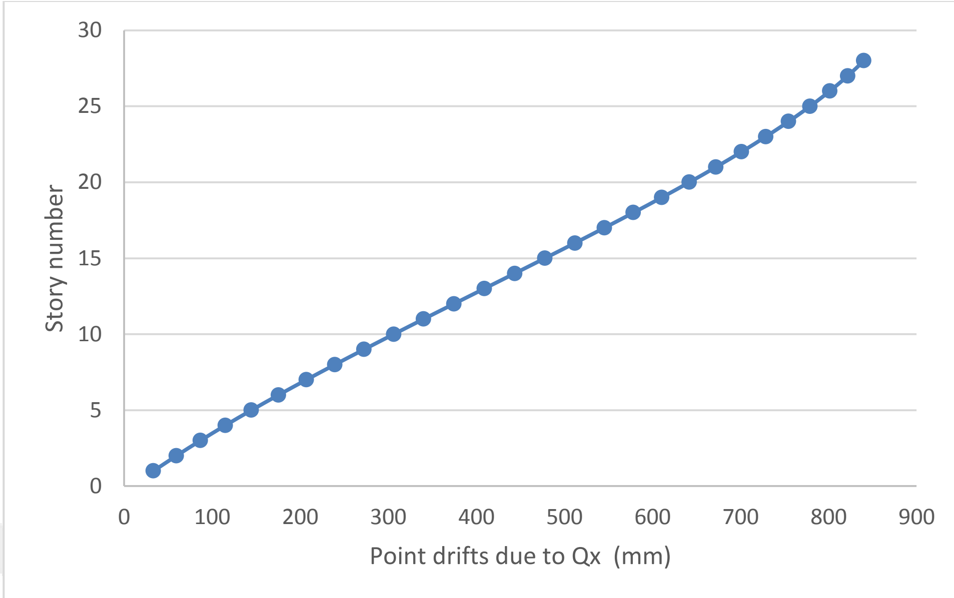


Figure 4.1 Point drifts due to Qx

Below are the results of displacements in (mm) due to wind load (Wx)

Table 4.2 Point drifts due to Wx

Story number	Point	Displacement Ux (mm)
Story 28	1	61.6
Story 27	1	60.5
Story 26	1	59.4
Story 25	1	58.1
Story 24	1	56.7
Story 23	1	55.2
Story 22	1	53.6
Story 21	1	51.9
Story 20	1	50.2
Story 19	1	48.3
Story 18	1	46.3
Story 17	1	44.3
Story 16	1	42.1
Story 15	1	39.9
Story 14	1	37.6
Story 13	1	35.2
Story 12	1	32.8
Story 11	1	30.3
Story 10	1	27.7
Story 9	1	25.1
Story 8	1	22.5
Story 7	1	19.8
Story 6	1	17.1
Story 5	1	14.4
Story 4	1	11.7
Story 3	1	9
Story 2	1	6.3
Story 1	1	3.6

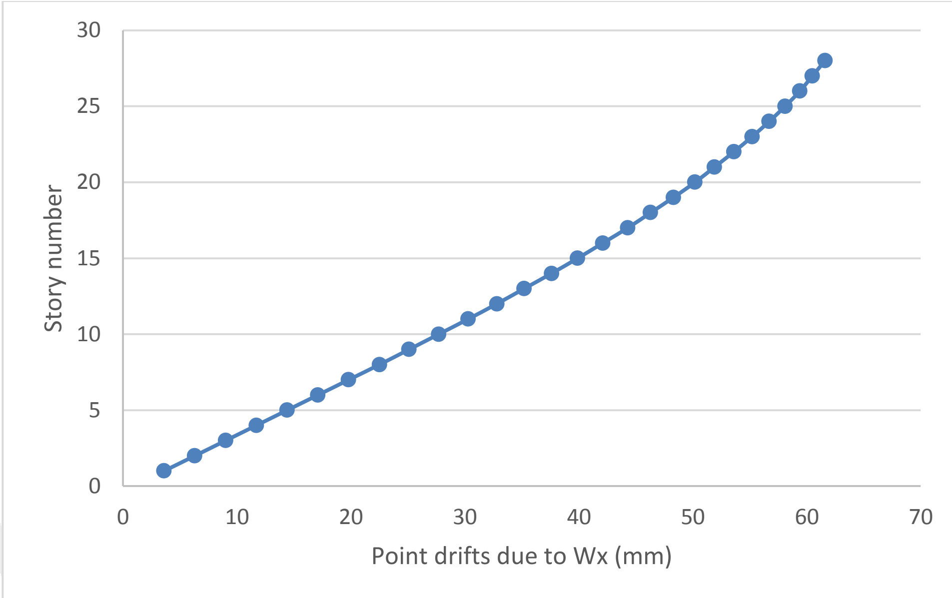


Figure 4.2 Point drifts due to Wx

In the above tables and charts, the selected point is number one and it has been noted from tables (4.1) and (4.2), charts (4.1) and (4.2) that displacements due to Qx was exceed the specified limitations according to the international codes due to earthquake loads so this type of building should not be constructed on this height with these factors and situations.

4.2.2 Shear Wall System

Below are the results of displacements in (mm) due to Earthquake (Qx)

Table 4.3 Point drifts due to Qx

Story number	Point	Displacement Ux (mm)
Story 28	1	509.7
Story 27	1	488.4
Story 26	1	466.9
Story 25	1	445.3
Story 24	1	423.4
Story 23	1	401.3
Story 22	1	379
Story 21	1	356.6
Story 20	1	333.9
Story 19	1	311.2
Story 18	1	288.5
Story 17	1	265.9
Story 16	1	243.3
Story 15	1	221
Story 14	1	199
Story 13	1	177.5
Story 12	1	156.5
Story 11	1	136.2
Story 10	1	116.7
Story 9	1	98.1
Story 8	1	80.7
Story 7	1	64.5
Story 6	1	49.6
Story 5	1	36.4
Story 4	1	24.9
Story 3	1	15.3
Story 2	1	7.9
Story 1	1	2.7

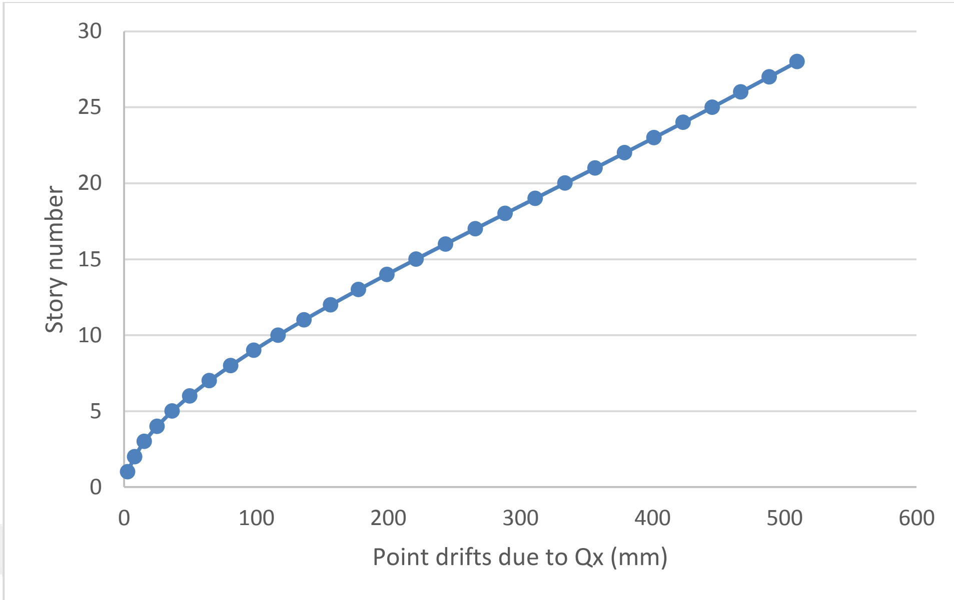


Figure 4.3 Point drifts due to Qx

Below are the results of displacements in (mm) due to wind load (Wx)

Table 4.4 Point drifts due to Wx

Story number	Point	Displacement Ux (mm)
Story 28	1	51.8
Story 27	1	49.8
Story 26	1	47.8
Story 25	1	45.8
Story 24	1	43.7
Story 23	1	41.7
Story 22	1	39.6
Story 21	1	37.4
Story 20	1	35.3
Story 19	1	33.1
Story 18	1	30.9
Story 17	1	28.7
Story 16	1	26.4
Story 15	1	24.2
Story 14	1	22
Story 13	1	19.8
Story 12	1	17.6
Story 11	1	15.4
Story 10	1	13.4
Story 9	1	11.3
Story 8	1	9.4
Story 7	1	7.6
Story 6	1	5.9
Story 5	1	4.4
Story 4	1	3
Story 3	1	1.9
Story 2	1	1
Story 1	1	0.4

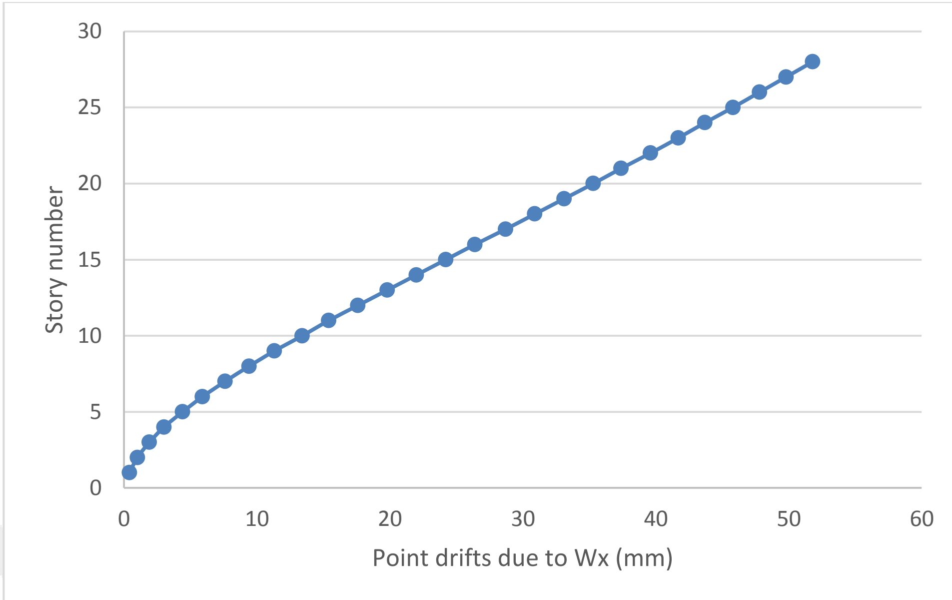


Figure 4.4 Point drifts due to Wx

In the tables (4.3) and (4.4), charts (4.3) and (4.4) as showed above, the displacements due to earthquake did not exceed the limited values according to the international codes except two upper floors were critical and these floors needed to be braced just due to earthquake and it is safe due to wind load Wx.

4.2.3 Shear Frame System

Below are the results of displacements in (mm) due to Earthquake load (Qx)

Table 4.5 Point drifts due to Qx

Story number	Point	Displacement Ux (mm)
Story 28	1	262.4
Story 27	1	252.8
Story 26	1	242.9
Story 25	1	232.9
Story 24	1	222.7
Story 23	1	212.3
Story 22	1	201.6
Story 21	1	190.8
Story 20	1	179.7
Story 19	1	168.5
Story 18	1	157.1
Story 17	1	145.6
Story 16	1	134.1
Story 15	1	122.5
Story 14	1	111
Story 13	1	99.6
Story 12	1	88.4
Story 11	1	77.4
Story 10	1	66.8
Story 9	1	56.6
Story 8	1	46.9
Story 7	1	37.7
Story 6	1	29.3
Story 5	1	21.7
Story 4	1	15
Story 3	1	9.3
Story 2	1	4.9
Story 1	1	1.7

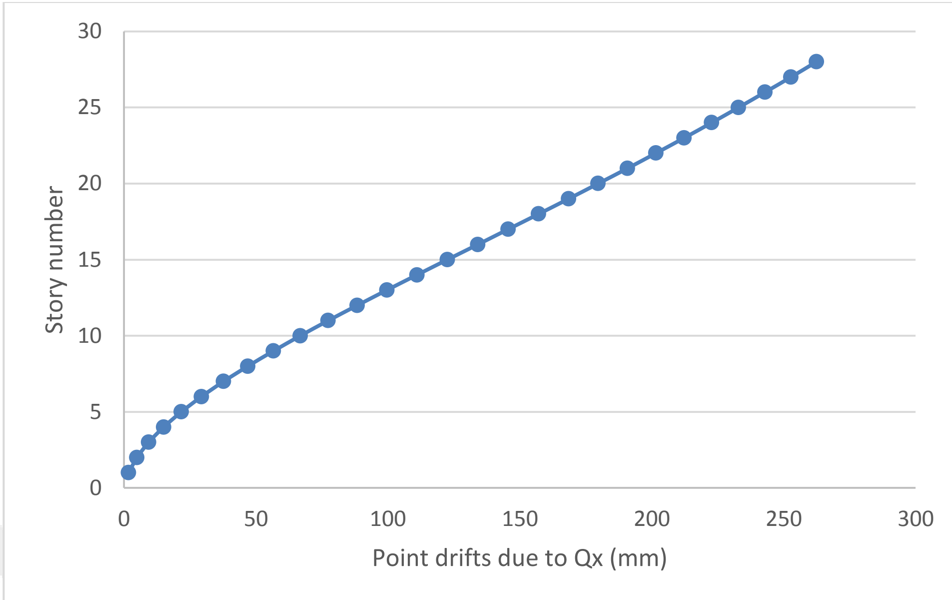


Figure 4.5 Point drifts due to Qx

Below are the results of displacements in (mm) due to wind load (Wx)

Table 4.6 Point drifts due to Wx

Story number	Point	Displacement Ux (mm)
Story 28	1	33.7
Story 27	1	32.6
Story 26	1	31.5
Story 25	1	30.4
Story 24	1	29.2
Story 23	1	28
Story 22	1	26.8
Story 21	1	25.5
Story 20	1	24.2
Story 19	1	22.9
Story 18	1	21.5
Story 17	1	20.1
Story 16	1	18.7
Story 15	1	17.2
Story 14	1	15.8
Story 13	1	14.3
Story 12	1	12.8
Story 11	1	11.3
Story 10	1	9.9
Story 9	1	8.5
Story 8	1	7.1
Story 7	1	5.8
Story 6	1	4.5
Story 5	1	3.4
Story 4	1	2.4
Story 3	1	1.5
Story 2	1	0.8
Story 1	1	0.3

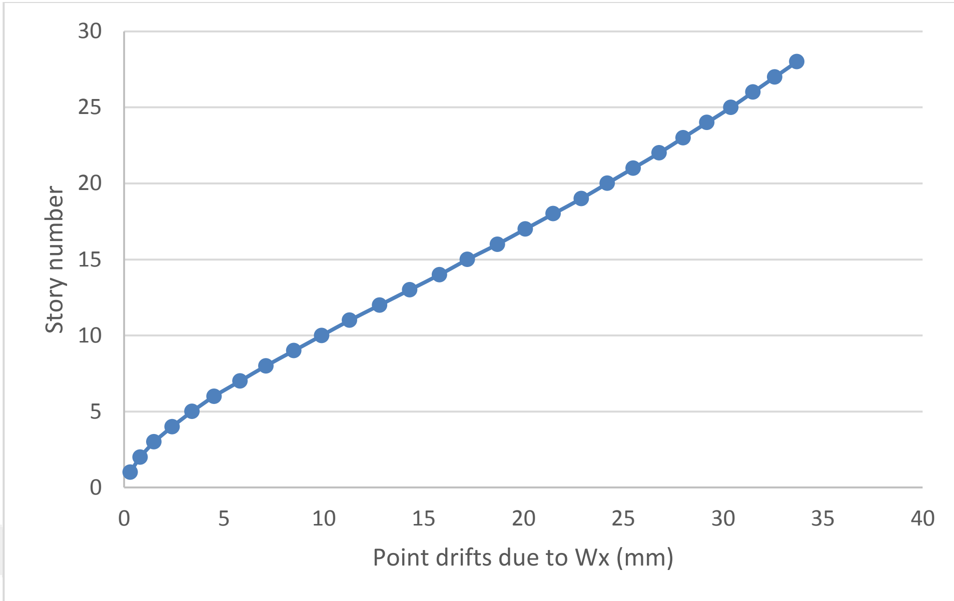


Figure 4.6 Point drifts due to Wx

From tables (4.5) and (4.6), charts (4.5) and (4.6) above, it showed that there is no problem due to earthquake and wind load to construct a building with this height and with these factors and situations. The stiffness of this structure has been improved due to the use of this system with ratio about 48% for earthquake load and about 35% for wind load if it compares with the shear wall system.

4.2.4 Tube System

Below are the results of displacements in (mm) due to Earthquake load (Qx)

Table 4.7 Point drifts due to Qx

Story number	Point	Displacement Ux (mm)
Story 28	1	109.2
Story 27	1	106.2
Story 26	1	103
Story 25	1	99.8
Story 24	1	96.3
Story 23	1	92.7
Story 22	1	88.9
Story 21	1	85
Story 20	1	80.8
Story 19	1	76.6
Story 18	1	72.2
Story 17	1	67.8
Story 16	1	63.2
Story 15	1	58.5
Story 14	1	53.9
Story 13	1	49.2
Story 12	1	44.4
Story 11	1	39.7
Story 10	1	35.1
Story 9	1	30.5
Story 8	1	26
Story 7	1	21.7
Story 6	1	17.5
Story 5	1	13.5
Story 4	1	9.9
Story 3	1	6.6
Story 2	1	3.7
Story 1	1	1.5

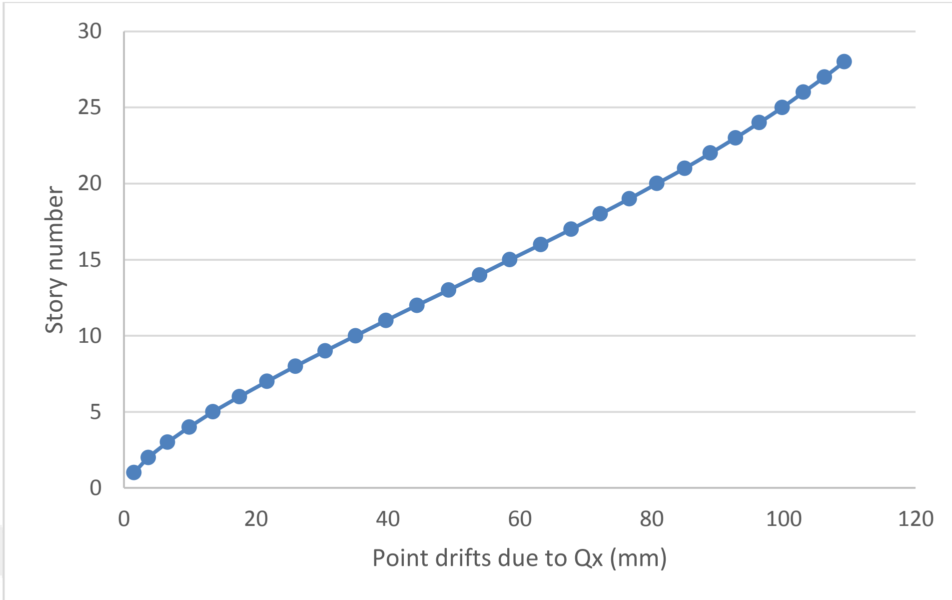


Figure 4.7 Point drifts due to Qx

Below are the results of displacements in (mm) due to wind load (Wx)

Table 4.8 point drifts due to Wx

Story number	Point	Displacement Ux (mm)
Story 28	1	23.1
Story 27	1	22.5
Story 26	1	22
Story 25	1	21.4
Story 24	1	20.7
Story 23	1	20.1
Story 22	1	19.4
Story 21	1	18.7
Story 20	1	17.9
Story 19	1	17.1
Story 18	1	16.3
Story 17	1	15.5
Story 16	1	14.6
Story 15	1	13.6
Story 14	1	12.7
Story 13	1	11.7
Story 12	1	10.7
Story 11	1	9.7
Story 10	1	8.7
Story 9	1	7.7
Story 8	1	6.6
Story 7	1	5.6
Story 6	1	4.6
Story 5	1	3.6
Story 4	1	2.7
Story 3	1	1.8
Story 2	1	1.1
Story 1	1	0.4

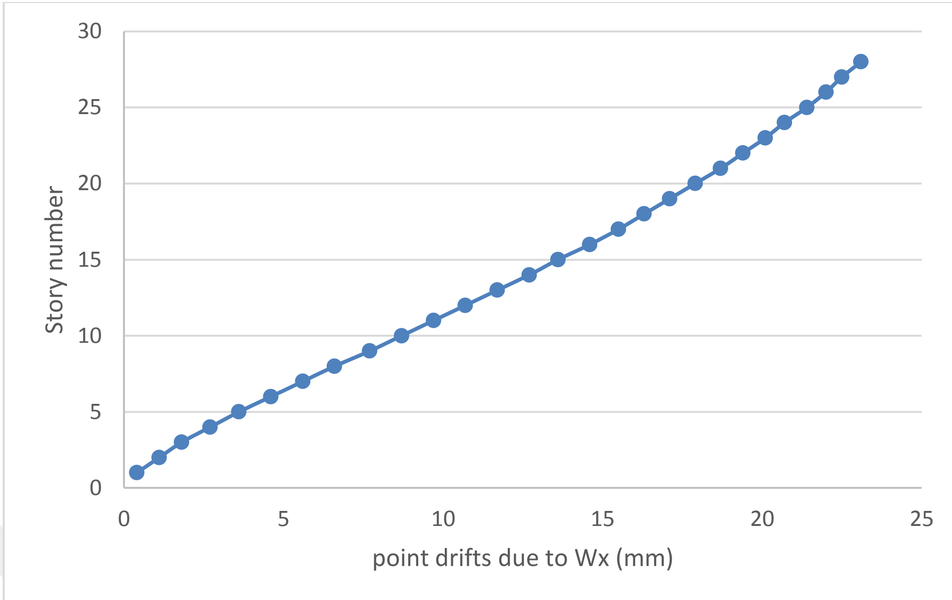


Figure 4.8 point drifts due to Wx

Tables (4.7) and (4.8), charts (4.7) and (4.8) showed that the displacement due to lateral loads (earthquake and wind) was decreased if they compare to the displacements of shear frame system. it has been a good improvement in the value of displacements, this due to exterior columns which located in the perimeter of the building and the ratio of decrease is about 62% for earthquake load and about 38 % for the wind load if it compares with shear frame system.

The following tables and charts show the results of two samples of forces (earthquake Qx and wind Wx) of all the structure systems:

Table 4.9 Comparison between four systems of Qx in X direction

Story number	Point	Moment Resisting	Shear Wall	Shear Frame	Tube System
Story 28	1	840.2	509.7	262.4	109.2
Story 27	1	821.8	488.4	252.8	106.2
Story 26	1	801.4	466.9	242.9	103
Story 25	1	779	445.3	232.9	99.8
Story 24	1	754.7	423.4	222.7	96.3
Story 23	1	728.7	401.3	212.3	92.7
Story 22	1	701.1	379	201.6	88.9
Story 21	1	672.1	356.6	190.8	85
Story 20	1	641.9	333.9	179.7	80.8
Story 19	1	610.6	311.2	168.5	76.6
Story 18	1	578.4	288.5	157.1	72.2
Story 17	1	545.4	265.9	145.6	67.8
Story 16	1	511.9	243.3	134.1	63.2
Story 15	1	477.8	221	122.5	58.5
Story 14	1	443.5	199	111	53.9
Story 13	1	409	177.5	99.6	49.2
Story 12	1	374.5	156.5	88.4	44.4
Story 11	1	340.1	136.2	77.4	39.7
Story 10	1	306.1	116.7	66.8	35.1
Story 9	1	272.4	98.1	56.6	30.5
Story 8	1	239.3	80.7	46.9	26
Story 7	1	206.9	64.5	37.7	21.7
Story 6	1	175.2	49.6	29.3	17.5
Story 5	1	144.5	36.4	21.7	13.5
Story 4	1	114.9	24.9	15	9.9
Story 3	1	86.5	15.3	9.3	6.6
Story 2	1	59.3	7.9	4.9	3.7
Story 1	1	33.2	2.7	1.7	1.5

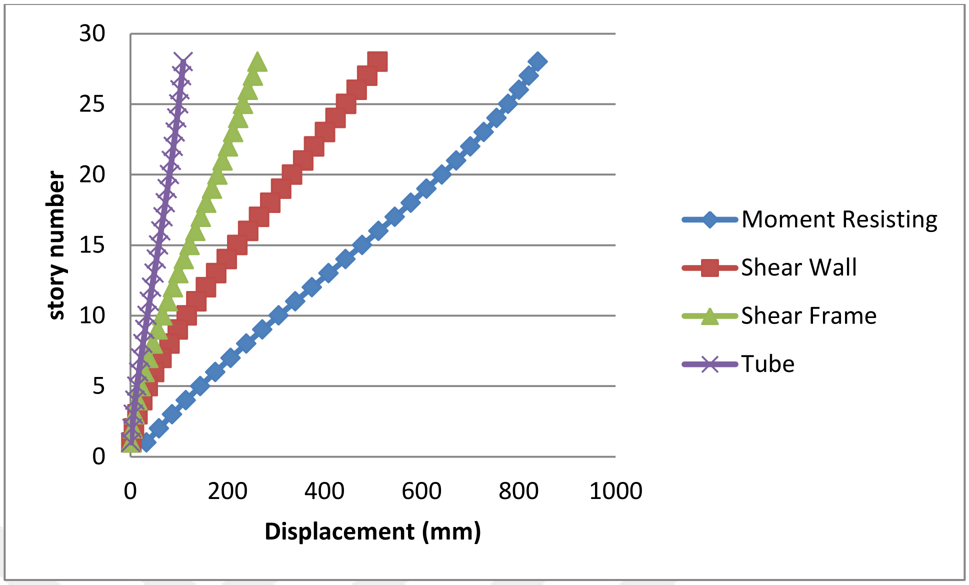


Figure 4.9 Comparison between four systems of Qx in X direction

Table 4.10 comparison between four systems of Wx in X direction

Story number	Point	Moment Resisting	Shear Wall	Shear Frame	Tube System
Story 28	1	61.6	51.8	33.7	23.1
Story 27	1	60.5	49.8	32.6	22.5
Story 26	1	59.4	47.8	31.5	22
Story 25	1	58.1	45.8	30.4	21.4
Story 24	1	56.7	43.7	29.2	20.7
Story 23	1	55.2	41.7	28	20.1
Story 22	1	53.6	39.6	26.8	19.4
Story 21	1	51.9	37.4	25.5	18.7
Story 20	1	50.2	35.3	24.2	17.9
Story 19	1	48.3	33.1	22.9	17.1
Story 18	1	46.3	30.9	21.5	16.3
Story 17	1	44.3	28.7	20.1	15.5
Story 16	1	42.1	26.4	18.7	14.6
Story 15	1	39.9	24.2	17.2	13.6
Story 14	1	37.6	22	15.8	12.7
Story 13	1	35.2	19.8	14.3	11.7
Story 12	1	32.8	17.6	12.8	10.7
Story 11	1	30.3	15.4	11.3	9.7
Story 10	1	27.7	13.4	9.9	8.7
Story 9	1	25.1	11.3	8.5	7.7
Story 8	1	22.5	9.4	7.1	6.6
Story 7	1	19.8	7.6	5.8	5.6
Story 6	1	17.1	5.9	4.5	4.6
Story 5	1	14.4	4.4	3.4	3.6
Story 4	1	11.7	3	2.4	2.7
Story 3	1	9	1.9	1.5	1.8
Story 2	1	6.3	1	0.8	1.1
Story 1	1	3.6	0.4	0.3	0.4

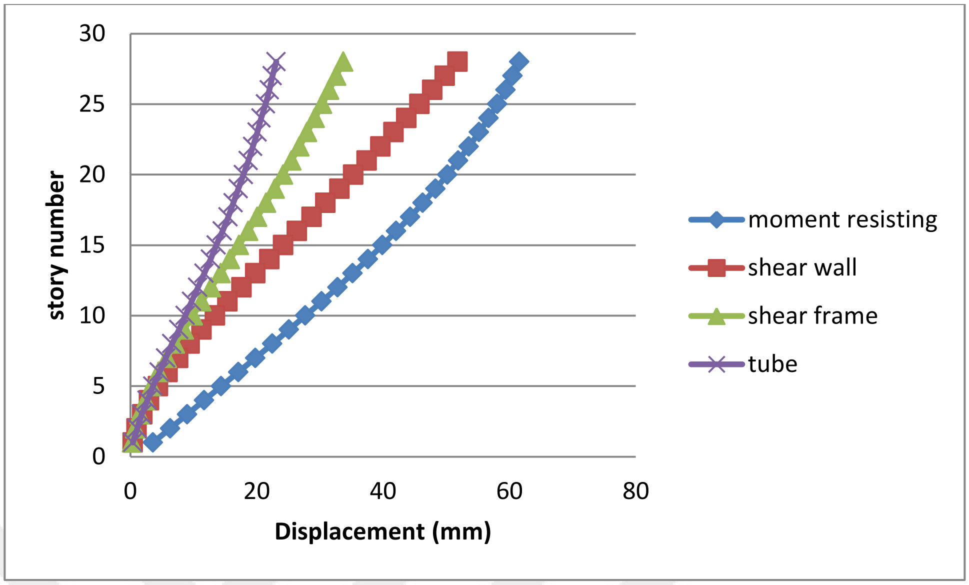


Figure 4.10 Comparison between four systems of Wx in X direction

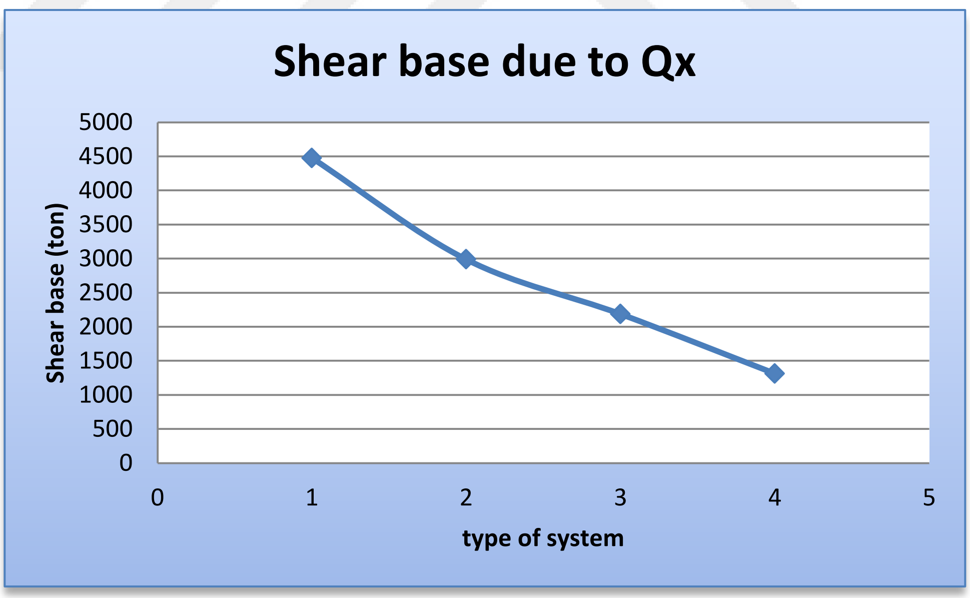


Figure 4.11 Comparison between four systems in base shear

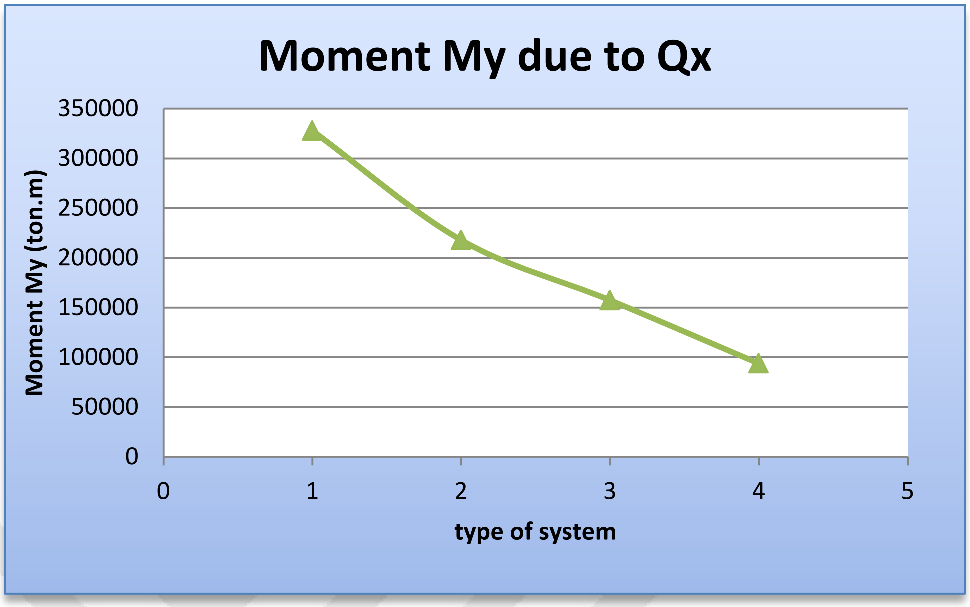


Figure 4.12 Comparison between four systems in moment

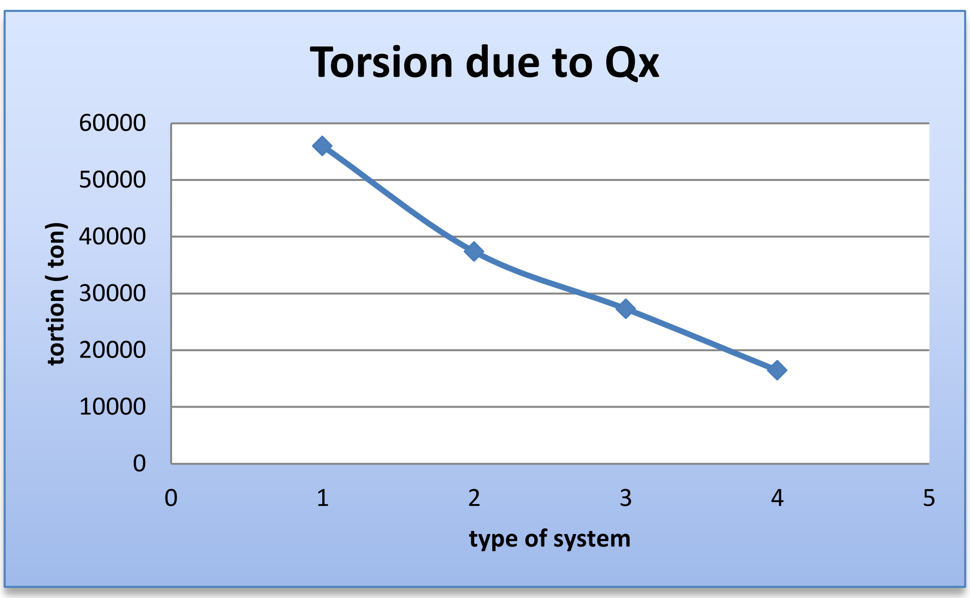


Figure 4.13 Comparison between four systems in torsion

It has been noted that the displacements values for both loads (Qx and Wx) were decreased from the moment resisting system to the shear wall system, and the shear frame has less values than moment resisting and shear wall. It was also shown that the tube system has the least values from the other systems.

From the mentioned results, the researcher found out these points:

- The first system, which is (moment resisting system), is not possible for this height (28 floors) because the values of all floors that were obtained were very high and exceed the limitation values which were in the (UBC 97) code.
- The results of the two systems (shear wall system and shear frame system) showed that they were very suitable for this height and did not exceed the limitation values which were in the (UBC 97) code.
- The results of the fourth system (tube system) showed that they were very low and were in the limitations but it is not recommended to be used in this height because it is too costly (expensive).

CHAPTER V

CONCLUSION AND FUTURE WORKS

5.1 Conclusion

The building for all types of structures has been analyzed in the same situations (circumstances) and the plan is symmetric. Therefore, the study showed that the effect of earthquake on the structure was greater than the effect of wind on the building.

From the second type (shear wall system), the study noted that the maximum drift story due to earthquake load (Qx) in the X-direction for the two upper floors was critical, so there was more than one solution for this problem. This can change all the system to another one or this can increase the stiffness of structure by increasing the compressive strength of concrete, but these two mentioned solutions were somehow costly (expensive), so the best solution is to make bracing only for weak two floors.

The study noted that the results of displacements from the type 4 (frame tube system) for all lateral loads (earthquake and wind) was decreased very much if it compares to the other structure systems because there were stiff columns with deep beams (spandrels) on the exterior of the building work as rigid members and connections and give the building a high stiffness against lateral loads, but this system is expensive (costly) for this heights and it recommends to be used in higher buildings, for example more than 60 stories.

The main purpose for this study was to prove that the changing in the type of structural system from the moment resisting system to the tube system had positive results in the performance of the structure behavior, and this purpose is satisfied in this study as it was shown in tables (4.9 and 4.10) and charts (4.9 and 4.10). The researcher was taken the samples from these two tables randomly which were Qx and Wx in X-direction and the results showed that the deflections were decreased with changing the type of structure from the first system (moment resisting) to the fourth system (tube).

5.2 Future works

The field of lateral load resisting system is very wide and it can be deal with it in many processes for comparison. It will be useful if it changes with a specified system (any system), the compressive strength of concrete because when the concrete compressive strength increase, the modulus of elasticity also increase, then the stiffness of structure against lateral load also increase.

The researcher recommends for the further researchers to conduct the effect of blast loads on the buildings and how this problem is solved because nowadays this becomes a big problem in Iraq and it is very important to study on this area.

The researcher recommends for the further researchers to conduct specifically on the bundled tube system because it is very popular and it is interesting system in engineering science.

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