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EFFECTS OF DIFFERENT LOAD-BEARING SYSTEMS FOR MULTI-STORY REINFORCED CONCRETE BUILDINGS

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I hereby declare that all information in this document been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

Effects of different load-bearing systems for multi-story reinforced concrete buildings

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M.Sc. in Civil Engineering

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An efficient and economical tall building cannot be designed without a thorough understanding of the significant factors affecting the selection of the structural system and knowledge of how the structural system will interrelate with architectural, structural aspects. Usually two to three different structural systems will be selected for comparison. The selection of ETABS In this study, among the much commercial software goes back to the many reasons**,** the previous studies show that programs internationally approved, More specialized and accuracy in the design of shear walls, The possibility of using more than one code in a single program, all these reasons and more lead to use ETABS in this study.

Religious and monumental architecture was first started in high structures, with the growing technology of today has taken shape. High structures, especially in densely populated, so as much as possible on the smaller areas are located in large urban centers and the establishment required more housing solutions. The construction of high rise building is seen to increase in the coming years. High structures, building design, horizontal loads and withstand the vertical loads to be effective, relocation and operation of structures designed according to the criteria defined. Due to the effectiveness of horizontal loads, structural load bearing system selection and placement of structures is very important. Load bearing system is the important factor affecting the behavior of structure. In this study, the effect of different load bearing system systems studied the behavior of the structure of different heights.

Keywords: Tall buildings, Bearing systems, Lateral loads, Effective area, Codes.

ÖZET

Çok katli betonarme yapilarda farklı taşiyici sistem etkisi

HAZIM, Mohammed Faris
Yüksek lisans tezi, İnşaat Mühendisliği
Danışman: Y.Doç.Dr. M. TOLGA GÖĞÜŞ
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Verimli ve ekonomik bir yüksek bina taşıyıcı sistemi, mimari ve yapısal yönleri arasındaki ilişkiyi ve yapı sistemi seçimini etkileyen önemli faktörleri anlamadan tasarım yapılamaz. Genellikle iki veya üç farklı taşıyıcı sistemler, karşılaştırma için seçilmektedir. Bu çalışmada ticari yazılım arasından yazılım olarak ETABS seçilmiştir. Bu seçimde ETABS'ın önceki çalışmalarda kullanılmış olması ve uluslararası tasarım kodlarını başarılı bir şekilde uygulayabilmesi ve perde duvarların tasarımını etkin ve doğru olarak yapabilmesidir.

Yüksek yapılar dini ve anıtsal yapılar ile başlamış, günümüzde gelişen teknoloji ile bugünkü halini almıştır. Yüksek yapılar özellikle nüfusun yoğun olduğu şehir merkezlerindeki küçük alanlarda daha fazla konuta ihtiyaç duyulduğundan tercih edilmektedir. Yüksek yapıların inşası gün geçtikçe artmaktadır. Yüksek yapıların tasarımında düşey yüklerin yanında yatay yüklerinde etkili olarak düşünülmesi için önceden belirlenmiş kriterlere göre tasarlanmalıdır. Yatay yüklerin etkinliği nedeniyle taşıyıcı sistem seçimi ve yerleşimi çok önemli bir faktördür. Taşıyıcı sistem yapısı davranışını etkileyen önemli bir faktördür. Bu çalışmada, farklı taşıyıcı sistem sistemlerinin etkisi, farklı yüksekliklerde yapısının davranışı incelenmiştir.

Anahtar kelimeler: Yüksek yapılar,taşıyıcı sistemler, etkili alan, tasarım şartnamleri

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CHAPTER 1

1. INTRODUCTION

1.1 Introduction

Human nature has all of the time been challenging natural and physical laws. Thousands of years past, high-rise constructions were made to base a nearer relationship with deities. Because of an articulation of significant milestones specified industrialization and the actualization of physical boundaries for urban development, this incorporeal concept gradually interpreted into a civic and influential symbol. At present, the role of tall buildings is a combination of social, semi political and economic characteristics that meditates a metropolis's wealth and ability. In this context, the relationship between engineering and architecture becomes critical therefore, architects should be able to understand the properties and manage the applications of construction and non-construction materials and systems, in order to do the most proper choice when designing and planning a building. Aspiring to grow the same power, designers must take into account not just artistic considerations, but also structural efficiency. Additionally, the exposure of tall buildings to natural phenomena has foregrounded structural limitations.

1.2 Developments of Tall Buildings

The development of tall buildings and tall building structural systems closely follows that of material, analysis and non-structural system, (mechanical), developments.

The first tall buildings of an all steel frame was constructed during the same year as the advent of riveting, 1889. Shortly thereafter the first use of an actual lateral bracing system to counter wind loads was developed for the Masonic temple in Chicago by E.C. Shankland.

The earliest buildings were constructed of masonry. Chicago's sixteen stories Monadnock building (1981) is the tallest masonry structure ever built. At the base its walls were over six feet thick. Such seemingly ridiculous proportions were required by code. The taller the building, the greater the volume of masonry was required per unit area of floor space. These early structures provided inherent stability against overturning moments in their extreme dead loads.

The concentration of commerce in the constricted area of Manhattan and the subsequent increase in land values spurned taller and taller buildings and in 1931 the 102 stories Empire State Building was opened. This building had incorporated the states of the art in structural system, a braced steel frame in conjunction with a rigid concrete and masonry exterior. It was the rigid exterior which allowed the braced frame to be carried to such a height.

In the late 1940's, when adequate air conditioning and artificial lighting became available, a decrease in core size no longer required a corresponding decrease in over-all floor size. This resulted in the "slab" building and it was this time that concrete use increased in tall buildings. Shear walls in conjunction with flat slabs were first used on the Lake Meadows Housing Project in Chicago at 1949. This type of construction became very popular for apartment buildings because the walls could be used to separate living space. The advent of computer use in the 1950's now eliminated some of the tedium of structural calculations and subsequently economic structures could be more readily designed.

Encouragement from the architectural community now forced engineers to exercise ingenuity in design. Shear wall-frame interaction was an extension of the use of shear walls with simply supported exterior framing. The 38-stories Brunswick Building is considerate the first use of such a system (1962).

The John Hancock Center consists of 100 stories and reaches a height of 344 m (443 m including antennas). The building accommodates office, residential and retail use. The diagonal bracing stiffened the perimeter framed-tube, because of which the windows could be larger than in a normal framed-tube. This tapering steel building was completed in 1970.

The famous World Trade Center twin towers were completed in 1973 in New York. The architect was Yamasaki and the design of towers achieved by Leslie E. Robertson Associates (LERA). The twin towers had a respective height of 415 m and 417 m.

During the nineties, Asia starts to take over the, historically, leading role of the United States. New tall buildings have been built in a short period of time in the Far East and Middle East. This development is still lasting.

The Bank of China Tower is an exceptional high-rise building, designed by I.M. Pei & Partners (architect) and LERA (structural engineer). They have come up with a highly efficient three-dimensional, triangulated structure that dominates the architectural appearance. This office building is 367 m high, consists of 70 above-grade stories and was completed in 1989 in Hong Kong.

Petronas Towers in Kuala Lumpur that completed in 1999, the tower stood 452 m tall. A skybridge connects the two towers at approximately mid-height. The architectural design was carried out by Cesar Pelli & Associates, whereas the structural engineering firm was Thornton-Tomasetti Engineers.

The tallest building in the world Burj Dubai or "Khalifa tower" in the United Arab Emirates, The design of this residential building was carried out by Skidmore, Owings & Merrill LLP (SOM) and the lateral load system comprise of a reinforced concrete so called buttressed core, as in a tripod-like stance. The spiraling setbacks have been adopted to reduce across-wind building motion. The height of this tower is 829.8 m consist of 160 floor and opened in 2010.

Day by day development of the tall buildings is growing, as a result of computer technology development, material, science, etc. for civil engineering point of view, design of tall buildings depend on material combination choice and structural forms. In fallowing section material type and structural forms will be discussion.

1.3 Tall Building Materials

Concrete, steel and composite are generally used as a construction materials of tall buildings main advantage of the steel framing is its strength over weight ratio and this advantage has an important role in the improvement of the tall building construction advantages using at large spans, prefabrication at workshop and rapidly construction at site this advantage of the steel framing is fire resistance, erosion and cost bracing. On the other hand, concrete with shear walls stand the horizontal loads, development on concrete technology and improvement at the structural shapes have admitted the height of the building reaches the hundred floors.

1.4 Structural Forms

Numerous structural forms can be selected by design engineer. Choosing best structural form is responsibility of the design engineer. Selection of structural form affected by material and the type of construction, architectural project, position of construction site, significance of horizontal and vertical loads and height and proportion of the building. Taller buildings become slender and it is subjected to its structural form. Usage of the building is main factor affected the structural form. Commercial buildings needs open inner spaces. As a result of this needs, construction materials located outer perimeter and around the lifts, wellholes and installation channels of buildings.

If the height of the building higher than ten floors, it needs additional material calculation for resisting loads. Structural shapes of buildings are formed such that they support the different types of loads;

- Gravity loads
  - Dead loads
  - Live loads
  - Snow loads
- Lateral loads
  - Wind loads
  - Seismic loads

- Other loads
    - Support settlement or displacement
    - Fire
    - Corrosion
    - Blast

These demands should be achieved as economically as achievable. Tall buildings behave as cantilever beam, in the event of horizontal loadings. They may contain of single members acting in the form of a cantilever, such as shear wall or cores, each bending about its own axis acting harmony through the horizontal in plane inflexibility of the story slab. It may also consist of a number of vertical columns and walls all acting compositely which is created potential by utilizing suitable shear resistant connectors, there by each member act as chord of a heavy cantilever. Furthermore, within the chosen structural shape advantage can be gotten by locating chief vertical elements in plane so then the dead load of the building can counter balance some all or a portion of the tensile stresses evolved in members due to horizontal load. This keeps off net tension happening in vertical members and forbids this lifting up force to split of the foundation. There are different structural forms

- Braced frame structures
- Rigid-frame structures
- In filled-frame structures
- Flat-plate and flat-slab structures
- Shear wall structures
- Coupled wall frame structures
- Wall frame structures
- Framed-tube structure
- Tube-in-tube structures
- Bundled-tube structures
- Braced-tube structures
- Outrigger-braced structures
- Suspended structures

- Space structure
- Hybrid structure

As a result, a change of structural systems has been designed for buildings to resist lateral motion made by wind and seismic action. A building requires to be stiff adequate to resist such forces, while keeping a certain level of ductility to absorb and break up the energy. To help defeat the knowledge gap in the relationship between architectural design and braced frame choice, this study will document the factors that lead to the most appropriate selection of a system in the circumstance of lateral load design, and its architectural significances.

1.5 Objective of Problem

This study is concerned with tall building forms created by digital tools (ETABS) based on the structural criteria. It explores potential formed forms, and also suggests an innovative analysis process using digital methods. The following objectives have been identified for this purpose:

- Identify the analysis considerations in tall building analysis and define the relationship with overall building form.
- Explore the various systems for tall building forms and provide created concepts of those systems.
- Suggest formed forms and concepts of tall building that meet the analysis criteria
- Provide various useful explored tall building form diagrams for architect and engineers in the schematic design phase.

This research discusses the effective of a tall building forms and innovative analysis process using digital tools that are based on a parametric design approach. In tall building analysis, geometry plays a critical role in the created of building forms and structures. This research explores potential geometries.

1.6 Layout of Thesis

This dissertation is comprised of five chapters. The research is carried out in an evolving style, which means that some chapters are trying to solve hurdles that were introduced in the previous chapter(s).

Chapter 1 introduces the motivation for the present research and makes clear the objectives to be pursued in this M.Sc. thesis

Chapter 2 contains a review of the relevant literature that covers previous studies conducted on tall buildings in general, like analysis of tall buildings under lateral loads (seismic and wind), analysis of tall buildings for different structural form, analysis of tall buildings for different codes and software that using in analysis of tall buildings.

Chapter 3 deals with explaining the tall buildings extensively, which includes definition of tall buildings, development of tall buildings, effecting factors on tall buildings, loadings on tall buildings, lateral loads resistance systems, gravity system in tall buildings and stability of tall buildings.

Chapter 4 will include a description of the problem, as will be display codes that used in the analysis of models and codes for applied loads, also it will show capabilities of program (ETABS) that will use in analysis of models, the numerical models and the numerical results will display and finally discussion of result it will be done in this chapter.

Chapter 5 summarizes the main conclusions achieved in this thesis from studying the identification of the more effective and the most economical structural system to resist the effect of lateral load (wind and seismic) under same conditions for all models.

CHAPTER 2

2. LITERATURE REVIEW

2.1 Introduction

An efficient and economical tall building cannot be designed without a thorough understanding of the significant factors affecting the selection of the structural system and knowledge of how the structural system will interrelate with architectural, mechanical and electrical aspects. Usually two to three different structural systems will be selected for comparison.

Tall buildings structural system can be classified into four basic groups; rigid and semi-rigid frames, shear wall or braced frames structures, shear wall or truss-frame interactive structures, and tube structures. Tube structures can be further categorized into frames tube systems and high efficiency tube systems. High efficiency tube systems evolved from the basic frame tube. Figure 2.1 shows a comparison of tall building systems versus number of stories [1].

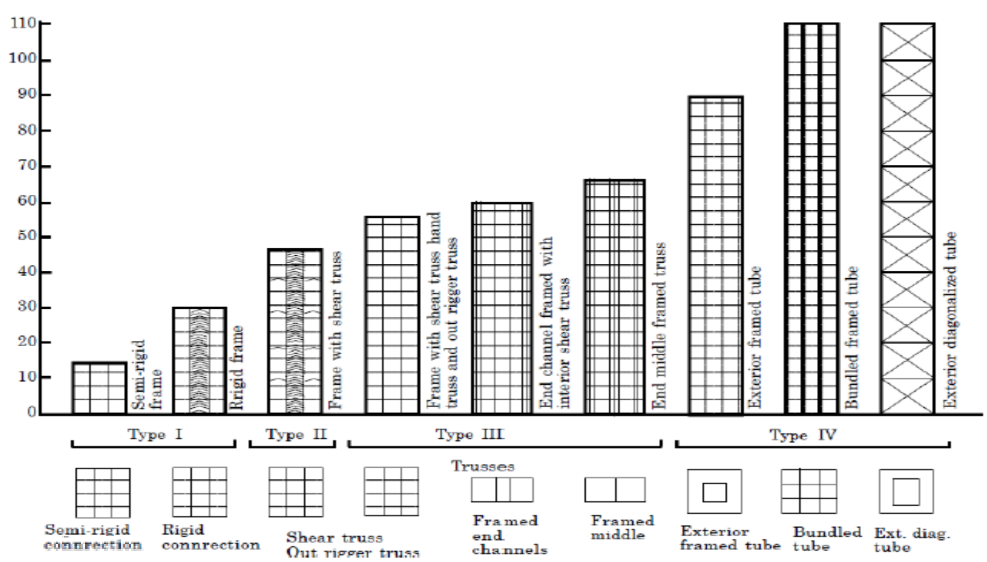


Figure 2.1 Comparisons of Structural Systems [1]

In order to control building response to lateral loading structural engineers may utilize efficient shapes and increase stiffness of the system and building weight. One of the most rapid and remarkable recent technologies is the use of the computer to analyze complex structural systems of tall buildings and produce construction documents. However, digital tools to assist in structural analysis to generate innovative tall building forms have not progressed at a comparable rate.

The focus of this study is to demonstrate bearing systems in new concepts of tall building forms and investigate an analysis process that integrates structural with digital methods.

2.2 Tall Buildings

Much has been researched and published regarding the history of tall buildings. These organize represent tall building history in several different phases.

Ning [2] searched an exact numerical technique for the analysis of tall reinforced concrete constructions in the usableness boundary state. This process does not consider ultimate strength boundary states. It emphasis chiefly located on the appraisal of the lateral bending and valuation of the stiffness decrease of the structures due to crack establishment within the members, which is the basic data required by engineers.

An effective technique is suggested by Lee et al. [3] to analyze tall box system structures taking the effects of floor slabs. The suggested technique will decrease computational time and memory in the analysis by utilizing the substructuring method and matrix condensing. Through the suggested technique, it will be more effective to enquire the seismic response of box system structures with getting into account the effect of the flexural stiffness of slabs.

Zhou [4] studied the vibration-based seismic damage identification of high-rise building structures. This study deals with data on the location(s) of the damage, an recognition of the rigorousness, as well as a general valuation of the post-earthquake damage.

Comejo [5] concluded that the strength of a building not just gets from the material's severity, it also gets from the technique the building is organized and how its elements are set up, therefore the system makes as an all.

Ali and Moon [6] reviewed the development of high-rise building's structural systems and the technical driving force behind high-rise building evolutions. For the basic constructive systems, a Modern categorization - inside structures and outside structures is presented.

The evolution of a Modern displacement-based seismic design technique for apply within performance-based is presented by Panagiotou [7]. Displacement-based seismic design technique applied within performance-based. Capability design is applied to ensure the mechanism of inflexible deformation. Established on rules of plastic analysis and structural dynamics this Modern formulation admits the calculation of the effects of system over strength and of the higher modes of response. Equivalent emphasis is applied to displacement, force and acceleration demand parameters.

An extensive structural analysis is carried out with regard to the along-wind response in the serviceableness boundary state by Hoogendoorn [8], also he compared the lateral load resisting systems of the studied buildings. An arranged of comparing Standards is drawn up, including the structural response, to find the attractiveness of each alternate from the financial point of view of an actual estate investor.

An investigation has been carried out by El-Leithy et al. [9] to examine the most common structural systems that are used for reinforced concrete tall buildings under the action of gravity and wind loads. These systems include "Rigid Frame", "Shear Wall/Central Core", "Wall-Frame Interaction", "Outrigger", and "Tube in Tube".

Lee et al. [10] presented an effective procedure for finding optimum solution for construction of tall buildings. This procedure achieve optimum design solutions and decrease the bias induced by the rework that usually arise in point based and set based design procedure. These proposed procedures and its applications to construction of tall buildings has been comprehensively examined.

Carpinteri et al. [11] presented a study evaluation of global displacements and lateral load distribution of external effects on tall buildings. Proposed analytical method that evaluate behavior of tall buildings retained types of bracings is reviewed with regarding to Intesa Sanpaolo Tower.

2.3 Design Codes of Tall Buildings

Every region in the world has a special design code, the code for every region is supported on the rules and conditions of that region. Therefor there are a many codes in the world some of them are international like American code, Euro code, and others not international like New Zealand Loadings Standard, Draft NZ/Australian Standard etc. this section present the previous studied that used different codes to design tall buildings.

Series of reinforced concrete ductile moment resisting frame structures are designed according to earthquake design codes. Aforementioned codes are draft version of New Zealand/Australian Loadings Standard, New Zealand Loadings Standard-NZS 4203-1992, Uniform Building Code-UBC1997, the International Building Code-IBC2000-1998 and Eurocode8-1998. Reinforced concrete ductile moment resisting frame structures are evaluated on high and low seismic areas. For the high seismic areas, New Zealand Loadings Standard-NZS 4203-1992 and draft version of New Zealand/Australian Loadings Standard are low results compared the other codes. Fenwick et al. [12] is recommended to increase design strengths at draft version of New Zealand/Australian Loadings Standard.

Displacement-based seismic design introduced and evaluated with emphasis on reinforced concrete shear wall buildings is presented by Burgos [13]. The proposed method is intended to be applied to reinforced concrete shear wall buildings with a regular plan configuration. Gravity loads are considered according to the provisions of the National Building Code of Canada 2005 (NBCC 2005).

Gabbai et.al in 2008 [14] deduced that the use of Minimum Design Loads for Buildings and Other Structures (ASCE 7-05) wind load factors for the design of tall flexible buildings results in safety levels that can be significantly lower than safety levels typical of common, rigid structures. Wind load factors incorporated in the ASCE 7-05 standard are based on rough approximations of wind effects and the uncertainties inherent in them.

Panagiotou [7] presented the experimental research program, with extensive shake table tests, of a full-scale 7-story reinforced concrete wall building slice, that was conducted at UCSD. The base shear coefficient obtained by the proposed method was 50% of that required by the equivalent static method prescribed by the Minimum Design Loads for Buildings and Other Structures ASCE-7code.

A comparative analysis has been aimed by El-Leithy et al. [9] to select the optimal structural system for a certain building height. The structural efficiency is measured by the volume of concrete of main elements, structural period, and base shear values, in this analysis Design considerations are made according to Building Code Requirements for Structural Concrete (ACI 318-05) and “ASCE 7-05” Standard.

Tuna [15] presented focus on examining the behavior, response, and modeling of shear walls, with the objective of improving our ability understand failure/collapse of reinforced concrete shear wall buildings under earthquake loading. The wall test database was used to assess the validity of the ACI 318- 11(S21.11.9) equation used to compute wall shear strength.

Kwon and Kareem [16] examined the differences and similarities about wind loads and their influence on tall buildings according to international wind design codes. Aforementioned these codes are ASCE, AS/NZ, AIJ, CNS, NBCC, EU, ISO and IWC and NatHaz Aerodynamic Loads Database (NALD) which is a database enabled method.

2.4 Structural Forms in Tall Buildings

There are a lot of structural forms that can be used in tall buildings according to needs and condition of the structures the types of structural form have been addressed in the first chapter, also it will be explained in detail in the next chapter, but in this section will be to focus on rigid frame and wall frame because used it in this study.

Park [17] evolved bettered design lateral load models for the abstract design of moment-resisting frame structures. These design lateral load models are based on inflexible demeanor and are a basic element of a suggested seismic design methodology to bounds the extent of structural damage in the system and spread this damage uniformly along the tallness. These load models are expectable to supply a consistent distribution of floor ductility ratios and a a lot of regular distribution of floor drift ratios when likened to the distributions got with moment-resisting frames designed based on code-compliant design lateral load patterns.

Rigid frame system analyzed by El-Leithy et al. [9] and they recommended that Only 10 stories structure (35 m high) has allowable wind drift. While, 20 stories structure (70 m high) and more have a drift more than the allowable limits, also the relatively high lateral flexibility calls for uneconomically large members. And it is not possible to accommodate the required depth of beams within the normal ceiling space in tall rigid frame.

A reliable system input–output relation identified and used by Modirzadeh et al. [18] to evaluate the performance criteria at untried design points (i.e., buildings with different modifier values) using a design of experiments technique. The proposed method of performance based evaluation is illustrated through consideration of the different structural deficiencies on a typical six-stories reinforced concrete building in Vancouver. Through the designed experiments, the main and interaction effects of the performance modifiers have also been studied.

Nollett and Smith [19] proposed a new concept to addition the lateral stiffness of wall-frame high-rise structures by rigidification a floor of the frame system either at the upper or at an mediate optimized stage. The shear inflexibility of the frame system is modified in a floor level by infilling one or a lot of bays of the frames in that floor with concrete or masonry boards, or supplying bracing to the floor, or expanding the sizing of the columns and girders encircling the floor. The efficiency of the conception and the valuation of the parameters regarded in the demeanor of a stiffened-story structure are incontestable with the serve of a continuum pattern solution. It is displayed that in a few structures the lateral stiffness could be raised by as much as 70%. The method is then utilized to an model structure which is examined both with the continuum pattern and a stiffness matrix solution.

A three-dimensional finite element computer analysis of high-rise building structures, created of perforated shear walls of open and/or unopen cross-sections and flat plates, is presented by Oztorun [20]. The commercial software evolved for this function supplies a particular and effective mesh creation procedure. A graphic program is also improved to make the data interactively by using a screen graphic selection. The structure pattern can be produced or expanded absolute easy with the utilize of the shown mesh creation program. The beams or columns can be added or deleted without any difficultness at all. The plate finite element evolved can exemplify the membrane as well as the deflection demeanor of shear wall and story elements. This program improved is used to find results to a few existent constructions to find the limits of the simplifying suppositions generally created for the analysis of high-rise building structures. The program is also adequate of doing analysis by utilizing formal easy patterns of high-rise structures and of affirming the limits placed for the suppositions.

An effective technique that may be applied for the analysis of a tall building construction with shear walls heedless of the number, size and position of openings in the wall is proposed by Kim et al. [21], The proposed technique applies super components, substructures and assumed beams. Static and dynamic analyses of model structures with different cases of holes were did to affirm the effectiveness and precision of the suggested technique. It was affirmed that the suggested technique can supply results with great accuracy needing importantly decreased computing effort.

A simplified model developed by Huang [22], termed as continuum MDOF model, for seismic analysis as well as for seismic evaluation of reinforced concrete wall-frame structures which is one of the most popular structural forms of tall buildings.

Resatoglu et al. [23] presented static analysis of out of plane unsymmetric coupled shear walls, applying uninterrupted joining technique in conjunction with Vlasov’s theory of thin-walled beams. The technique of analysis exhibited was likened with commercial structural analysis software (SAP 2000) by frame technique. The results found displayed effective accord, affirming the validity of the suggested technique, which can be effectively utilized in the preliminary calculations of high-rise buildings.

Boivin [24] proposed for CSA standard A23.3 new capacity design methods, considering higher mode amplification effects, for determining, for a SPH design, capacity design envelopes for flexural and shear strength design of regular ductile RC cantilever wall structures used as SFRS for multistory buildings. The research focusses on cantilever walls because higher mode amplification effects are usually much more important in cantilever walls than in coupled walls. Also he studied the influence of various parameters on the higher mode amplification effects, and hence on the seismic force demand, in ductile cantilever walls.

The studies showed by Tuna [15] concentrate on examining the demeanor, response, and modeling of shear walls, with the aim of ameliorating ability realize failure/collapse of reinforced concrete shear wall constructions under seismic loading. Break up examines were guided, two of which were purposed at evaluating and meliorating modeling of formal reinforced concrete (RC) buildings that use structural walls for lateral load resistance: one work concentrated on seismic performance of a RC double system high-rise building (core wall and moment frames) designed following different design approaches, whereas the other study concentrated on modeling and demeanor of a four-story RC building examined on the E-Defense. Two additional studies were carried to inquire and realize failure of shear walls: one that focused on specifying shear strength and deformation capability of the constructive walls by modernizing a comprehensive test database, and other that concentrated on potential causes for collapse of a 15-story shear wall building (Torre Alto Rio) in the 2010 Chile earthquake.

An analytical investigating on the demeanor and retrofit of aged medium-rise massive cast-in-place reinforced concrete shear walls under lateral loads is submitted by Jiang and Kurama [25]. an adjust of paradigm and parametric walls is designed to exemplify building structures from the 1960s and first 1970s in areas of the US with great seismicity. Analytical patterns of the walls are made utilizing a micro-plane fiber component that can catch axial–flexural–shear fundamental interaction in the nonlinear ambit. These patterns are then applied to lead nonlinear lateral load analyses to measure the next three wall retrofit techniques advisable by ASCE 41-06: (1) decrease of flexural strength; (2) increase of concrete confinement; and (3) raised shear strength. The solutions display that aged reinforced concrete shear walls are probable to showing bounded lateral deformation capacitance without retrofit or with the utilize of a individual retrofit go up. A compounding of dissimilar retrofit techniques perhaps required for meliorated demeanor.

2.6 Tall Buildings under Lateral Loads

Most lateral loads are live loads whose main component is a horizontal force acting on the structure. Typical lateral loads would be a wind load against a facade, an earthquake, the earth pressure against a beach front retaining wall or the earth pressure against a basement wall. Most lateral loads vary in intensity depending on the building's 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 design wind and earthquake loads on a building are substantially more complex than the following brief discussion and simple examples would indicate.

2.6.1 Tall Buildings under Wind Loads

15 typical tall building models of basic cross-sections and aspect ratios from 4 to 9 are tested by Gu and Quan [26] with high-frequency force balance technique in a wind tunnel to obtain their first-mode generalized across-wind dynamic forces. The effects of terrain condition, aspect ratio and side ratio of cross section and modified corner of the building models on the across-wind forces are investigated in detail. New formulas of the power spectra of the across-wind dynamic forces, the coefficients of base moment and shear force are derived.

Mingfeng [27] developed a design optimization technique that automatically seeks the most cost efficient design solution while satisfying all specified ultimate safety, serviceability and habitability design performance criteria formulated as deterministic and probabilistic design constraints. Time-variant reliability investigated of wind-excited building structures using extreme value statistical analysis. To identify and model the major uncertainties involved in wind loading conditions and structural systems for assessing the reliability of tall buildings against wind-induced motion. Also, reliability performance-based optimal design framework developed to solve the design optimization problems of wind-sensitive tall buildings subjected to both deterministic drift and probabilistic acceleration performance constraints.

An analysis of equal stable wind loads presented by Chan et.al [28] on high-rise buildings with 3D ways supplied that the wind tunnel calculated aerodynamic wind load spectra are applied. Then an merged wind load updating analysis and optimum stiffness design method is evolved for lateral displacement design of high a regular constructions requiring twinned lateral torsional movements. The solutions of a virtual 40-stories building example with important swaying and torsional effects are exhibited. Not just is the method capable to create the most cost effective component stiffness dispersion of the structure satisfactory multiplex usableness wind drift design standards, but a expected benefit of decrease the wind-induced loads can also be attained by the stiffness design optimization technique.

El-Leithy et al. [9] made comparative study, concerning the efficiency of five structural systems and the ability of each system in limiting the wind drift for a certain building height. Under the effect of wind loads, as the height of the structure increases, the lateral deflection and the overturning moment at the base increase. The key idea in limiting the wind drift in a tall building is by changing the structural form of the building into something more rigid and stable to confine the deformation and increase stability.

Zhao [29] presented Aerodynamic optimization studies were conducted to reduce the correlation of vortex shedding along the building height, and thus reduce the across-wind building response. The optimization results show that the across wind load can be effectively reduced with certain building configuration. Detailed wind tunnel studies, including HFFB and HFPI studies, high Reynolds number tests and aeroelastic model tests, were conducted to accurately capture the wind load on the building.

A component-wise performance-based design framework is proposed by Spence and Gioffrè [30], based on the concept of a directional fragility model that rigorously combines the directional building aerodynamics and climatological information. An efficient reliability-based design optimization scheme is then proposed, based on decoupling the traditionally nested optimization loop from the reliability analysis carried out through the proposed performance-based design framework. The decoupled optimization problem is solved by defining a series of approximate explicit sub-problems in terms of the second order response statistics of the constrained functions.

Li et al. [31] investigated the wind loads on the high-rise building and the wind velocity up factors in the tunnels for wind power generation founded on wind tunnel exams and wind clime information analysis. Wind- induced pressures and total forces on the building pattern with a geometrical scale of 1:150, including the average and unsteady elements, were specified and the wind velocity amplifications in the tunnels were calculated in the wind tunnel tests. Comparative analysis and discussions of the results for four examples were carried. The wind velocity amplifications measured in the tunnels for wind-power generation through the installing of wind turbines and to gain a better understanding of the wind effects on such a tall building with open holes. The results showed awaited to be of significant interest and virtual utilize to engineers and investigators involved in the design of high-rise buildings integrating wind turbines for ability generation.

2.6.2 Tall Buildings under Seismic Loads

An approximate earthquake analysis is presented by Tarjan and Kollar [32] for multistory building structures. The building is stiffened by an arbitrary combination of lateral load-resisting subsystems (shear walls, frames, trusses, coupled shear walls, cores).The analysis is based on the continuum method. The spatial vibration problem of the replacement beam is solved approximately. Simple formulas are given to calculate the periods of vibration and internal forces of a building structure subjected to earthquakes.

Lee et al. [33] proposed an improved analytical method based on the equivalent responses of multistory building structures to estimate the inelastic seismic responses efficiently and accurately. The proposed method can be used to accurately evaluate the seismic performance not only for the global inelastic behavior of a building but also for its local inelastic seismic responses. In order to demonstrate the accuracy and validity of the proposed method, inelastic seismic responses estimated by the proposed method are compared with those obtained from other existing methods. When the proposed method is applied in the pushover analysis more improved analytical results could be obtained than those from the conventional capacity spectrum method.

A shaking table test conducted by Fan et al. [34] to calculate the constitutive relationships and finite element types for the concrete filled steel tube columns and steel elements for generate the finite element model of the tall building. After that, seismic responses of the structure were investigated by numerical methods. An earthquake spectrum created for Taipei Basin was adopted to determine the lateral displacements and distributions of interior forces at the columns. Moreover, time dependent analyses of linear and nonlinear seismic response were implemented using proportioned accelerograms correspond earthquake results with return periods of 50, 100 and 950 years, respectively. The numerical solutions show that the structure with the mega frame system has significant additional strength, and the tall building would achieve the design standards under drastic earthquakes.

Assess seismic vulnerability using fragility analysis for high-rise buildings in the Mid-America region, which is presented by Leon [35]. Pushover analysis and nonlinear dynamic analysis are performed on a case study structure designed under the provisions of the current International Building Code (IBC 2003), Standard Building Code (SBC1999), and IBC with local Shelby County amendments, to evaluate its seismic performance. A probabilistic demand model is constructed using simulation data from structural analysis to develop fragility curves for the case study structure. Sets of proposed fragility curves are developed using spectral acceleration as an intensity measured.

Domínguez et al. [36] summarized the resultants of a survey consecrated to appraise, utilizing nonlinear dynamic analyses, the seismic demeanor of six reinforced concrete moment resisting chevron braced framed buildings. 2-D patterns that calculate for the fundamental interaction amid frames were applied for the nonlinear dynamic analyzes of the capacity-designed buildings utilizing RUAUMOKO software package. A lot unreal reads comparable to the maximal believable earthquake affiliated to the design spectra were used to carry out the nonlinear dynamic analysis. From the outcomes found, he is ended that if content design rules and particular design parameters for the Modern design of RC-MRCBFs are utilized, proper international ductility capabilities and over strength requirements are found, and an acceptable structural functioning is attained.

Epackachi et al. [37] analyzed the linear and nonlinear demeanor of one of the highest RC constructions, a 56-stories structure, placed in a high seismic area in Iran. In this tower, shear wall systems with asymmetric openings are used under both gravity and lateral loads and may resultant in a few particular events in the demeanor of structural components specified shear walls and coupling beams. The analytical methodological analysis and the resultants found in the valuation of life-safety and collapse prevention of the building are also talked about. The frail area of the structure established on the resultants are presented, and a elaborated talked about of a few significant structural views of the multi-stories shear wall system considerately of the concrete time dependance and constructional succession effects are also admitted.

2.7 Tall Building Analysis

This section focuses on previous work in analysis of tall buildings for different cases like displacement, fundamental period etc. Review this section helps to propose topics that will be discussed in this study later.

An estimate approach, termed finite story method, is suggested by Pekau et al. in 1995 [38] for the analysis of high-rise building structures under lateral loads. The technique is established on nodal drift fields found from two-story substructures and intended to approximate shear, flexing and torsion elements of global deformations. Because story slabs are counted in-plane inflexible, these deformations are identified by translational and rotational movement of the slabs. Thus, nodal movement are found by extrapolating the story slab movement, where the interposition coefficients get from the nodal movement areas. The latter displayed deformation models agreeing to unit proportional story slab movement of the two-story substructures. By acquainting this interposition, the general structural analysis is easy to just five primary unknowns per story. The efficiency and accuracy of the technique are presented for static and dynamic cases by comparison the resultants with criterion three-dimensional finite element analysis.

The finite story method is then utilized by Pekau et al [39] to obtain displacements, natural frequencies and modes of vibration for both symmetric and asymmetric tube-in-tube structures. The numerical results compare favorably with other solutions, including full finite element modeling, and demonstrate the high efficiency and acceptable accuracy of the method.

Elrodesly [40] Developed of a new displacement based design method for seismic design of unsymmetrical torsional stiff buildings and symmetric buildings with multiple shear walls in which the shear walls have different sizes that is simple and easy to use for a design office.

Balendra et al. [41] presented that easy appraisal process which calculates for elaboration mechanisms especially effects on dynamic torsional twinning. In the aimed technique, which was incontestable with a regular 16-stories wall-frame building, the eccentricity and stiffness parameters of the equal single-story building pattern were ascertained by calibrating its centre of rotation to agree with that of the high-rise building pattern. Despite the reality that the stiffness eccentricity in a wall-frame system is non-unique, a representative same pattern can be described by the technique. the displayed technique just needs static analyzes to be guaranteed by the designer. The accuracy of the story movement and inter-story drift need augured by the suggested process has been affirmed by comparing with resultants found from time-history analysis of the high-rise building. However, there were discrepancies in the vertical distribution of inter-story sways between push-over analysis and time-history analysis.

The effects of chosen parameters i.e. building tallness, numbers of bays, ratio of area of shear walls to area of story, percentage of infilled panels to whole number of boards and form of frame on the natural period of RC buildings was enquired by Kose [42]. 189 three dimensional finite element models were created and analyzed with chosen parameters. Due to the nonlinear demeanor of infill walls, a reiterative modal analysis was applied to find the natural period of patterns. It was got that RC frames with infill walls had a lower period, about 5%-10%, equated with RC frames without infill walls heedless of whether they had shear walls or not. The bearing of shear walls also resulted to a decrease in the natural period, roughly 6%-10%, between patterns with and without infill walls. The natural periods found by a reiterative modal analysis were also equated with modern code anticipations, which based on measures taken during earthquakes on actual buildings. It was imaged that the modern code equations under-predict the natural periods of the patterns from 2% to 47%, depending upon the pattern parameters.

Rahgozar et al. [43] presented a new and simple mathematical model that may be used to determine the optimum location of a belt truss reinforcing system on tall buildings such that the displacements due to lateral loadings would generate the least amounts of stress and strain in building's structural members. The proposed model shows a good understanding of structural behavior; easy to use, yet reasonably accurate and suitable for quick evaluations during the preliminary design stage which requires less time.

2.8 Software Analysis of Tall Buildings

There are many commercial software that are using in the structural analysis of the buildings in this section will focus on different studies that used different commercial software like ETABS, SAP2000 etc. to show the capabilities of each one to choose the best one and more useful for this study.

Lee et al. [3] used commercial software ETABS for the analysis of high-rise apartment buildings, assuming a rigid diaphragm for floor slabs. The flexural stiffness of slabs is generally ignored in that analysis. This assumption may be reasonable for the analysis of framed structures. box system structures, composed of only reinforced concrete walls and slabs, have been recently adopted for many high-rise apartment buildings.

COSMOS/M software is used to compare results with experimental results by Akhir [44]. The study is concentrated on behavior of the effects of floor slabs in the frame due to lateral loading and the transfer of the shear forces in the slab diaphragms. Ultimate failure load of frame which is softening point of frame obtained from nonlinear finite element analysis is determined.

The response spectrum, time history and linking slab in-plan stresses analysis were executed combined with a practical project with inclined columns by several programs such as ETABS, SAP2000, MIDAS/gen and SATWE, by Hu et al [45] All the results of response spectrum analysis calculated by different programs are basically similar also The results of time history analysis by SAP2000 and ETABS are roughly similar. And for the slab stress analysis, ETABS and MIDAS/Gen have their respective advantages: ETABS's good at preprocessing with automatically line constraint and area division, and MIDAS/Gen does well in the post-processing such as the stresses combinations.

As a result, the selection of ETABS In this study, among the much commercial software goes back to the many reasons**,** the previous studies show that programs internationally approved, More specialized and accuracy in the design of shear walls, The possibility of using more than one code in a single program, all these reasons and more lead to use ETABS in this study.

CHAPERT 3

3. TALL BUILDINGS

3.1 Introduction

The speedy growth of the city-born population and the resultant pressure on bounded place has considerably determined urban center residential growth. The high price of land, the desire to keep off a continuous urban sprawl, and the require to keep important farming production have all contributed to push residential buildings upward. In some urban center, for example, Hong Kong and Rio de Janeiro, local topographical limitations establish tall buildings the only executable solution for housing needs.

Ideally, in the first levels of planning a building, the entire design team, including the architect, structural engineer, and services engineer, should get together to agree on a shape of structure to meet their respective requirements of function, safety and serviceability, and servicing

Commercial tall buildings are mainly responding the need by commercial activity to be as near to each other and centrum as convenience hence setting excessive demand on the free land space. Moreover, commercial tall buildings often constructed as a status symbol for companies at centrums. In addition, work and tourists frequently demanded tall downtown hotel establishments. [47]

The present-day showiness in architecture has not deterred the structural engineer from getting hold with economical load bearing systems. Indeed, it has perked up the community to give approximately totality freedom in the architecture of the multi-story structures. Nowadays, buildings are planned and designed which have brief or no historical precedent by using computers. Current structural systems are formed and implemented to highly tall buildings in a functional presentation of the design engineer's assurance in the predictive power of the analysis, the techniques applied, and the confidence of computer results. Computers have made once hard analyses easily, letting the design engineer to try with modern forms in a total effort to keep down the structural cost. [48]

3.2 Definition of Tall Buildings

Description of tall building is hard to describe the features of a building which classify it as tall. The key idea to classify any building as tall building is the tallness matter. In big cities, such as Chicago, which are consisted of a huge number of tall buildings, a structure must transfix the sky about 70 to 100 stories if it is to look tall in compare with its nearest neighbors. In typically single story cities, a five story building classify as tall. In Europe, a 20 story building in a city perhaps called a tall, but the residents of a village may show off their skyscraper of six floors.

Others classification on the building is tall when the design of the structure goes from the interest of statics into the interest of structural dynamics. From the structural design perspective, it is easier to conceive a building as tall when its structural analyses and design are some ways agonistic by the lateral loads, principally sway caused by similar loads.

Sway or drift is the significance of the lateral displacement at the apex of the building reflection to its establish. As building heights increase, forces of nature start out to command the structural system and take on increasing importance in the general building system. Structural systems have to be formed around constructs related to entirely with resistance to agitated wind. Over the historical two decades, extraordinary improvement has been reached in the structural engineer's power to develop appropriate building systems. Equally important, the structural engineer has improved a far more all over understanding of these drives of nature, particularly atmospheric wind [48].

3.3 Effecting Factors on Tall Buildings

The feasibility and desirability of tall buildings have constantly subjected to the convenient materials, the degree of structure technology, and the state of evolution of the services requirement for the use of the building. As a consequence, important advances have happed occasionally with the coming of a Modern material. construction adeptness, or form of service. Tall buildings were a characteristic of old Rome: four-story wooden tenement buildings, of post and header construction, were basic. Those constructed after the great fire of Nero, all the same, used the current brick and concrete materials in the form of arch and barrelful hurdle structures. Through the following centuries, the two common construction materials were timber and masonry. The early missed strength for buildings of more than about five stories, and all of the time acquainted a fire adventure.

Different structural systems have step by step developed for residential and office buildings, chewing over their differing practical demands. In modem office buildings, the demand to meet the differing necessaries of person customers for floor space arrangements chaired to the planning of big column-free open areas to give up flexibility in planning. Developed levels of services have often needed the idolatry of entire floors to mechanical plant, but the places cursed can often be used also to adapt deep girders or trusses plugging in the outside and indoor structural systems. The cruder heavy inside segmentations and masonry cladding, with their donations to the allow of stiffness and strength, have largely given way to light demountable zones and glass curtain walls, forcing the common structure alone to supply the necessary strength and stiffness versus both vertical and lateral loads.

Other architectural characteristics of commercial buildings that have acted upon structural form are the big becharms and open anteroom areas at first floor, the high-rise atriums, and the high-level restaurants and showing galleries that may demand more extended elevator systems and related to sky halls.

A residential building's more common functional requisite is the provision of composed personal living units, classified by considerable segmentations that supply sufficient fire and acoustic insulation. Because the partitions are doubled from story to story, modem designs have used them in a structural content, directing to the shear wall, cross wall, or infilled-frame forms of construction [47].

3.3.1 Concept of Premium for Height

If there were no lateral loads such as wind or earthquake, any tall building could be designed principally for gravity loads. Such a design would not impose any premium for height. Since there is no way to evade the gravity loads sequent from dead and live loads, the lower limit workable material for a building of any number of stories cannot be less than that necessary for gravity loads alone. Qualitatively, from the structural viewpoint, this equates to the most effective or best system. Ideally, the structure requires to be designed for gravity loads only, whereas the stresses made by lateral loads will automatically be constricted to the 33 percent overstress allowed in most codes.

When the structure for a low- or mid-rise building is designed for gravity loads, it is very possible that the structure can carry most of the lateral loads. In all-purpose, this is not so for tall buildings because resistance to overturning moment and lateral deflection will almost all of the time demand extra material across and above that asked for gravity load exclusive. Assuming equivalent bay sizes, the material amounts asked for gravity floor framing in low- and high-rise structures are fundamentally indistinguishable it makes no difference in the demanded amounts whether the floor being framed is at the second level of a tall building or at the 70th level of a tall building.

The material demanded for floor framing is a function of the column-to-column span and not the building height. However, the material demanded for the vertical system, such as column and walls, in a tall structure is considerably more than that or a low-rise building. The quantity of materials needed for resisting lateral loads is even more pronounced and would soon far exceed all a different structural prices if rigid frame action were applied in very tall buildings. Wind begins to show its dominance at about 50 stories and becomes more and more important with bigger height [46].

3.4 Tall Buildings Structure

The two basic characters of vertical load-resisting components of tall buildings are columns and walls, the latter acting either independently as shear walls or in fabrications as shear wall cores. The building function will lead by nature to the supplying of walls to dissever and confine space, and of cores to comprise and carry services such as elevators. Columns will be furnished, in otherwise unbraced parts, to transmit gravity loads and. in a few types of structure, horizontal loads also. Columns may also attend architecturally as for example, frontal mullions.

The necessary basic function of the structural ingredients is to resist the gravity loading from the weight of the building and its contents. Since the loading on dissimilar floors inclines to be alike, the weight of the floor system per unit floor area is around stable, heedless of the building elevation. Because the gravity load on the columns increments down the height of a building, the weight of columns per unit area increments approximately linearly with the building height. The highly likely second function of the vertical structural ingredients is to withstand also the parasitic load caused by wind and peradventure earthquakes, whose magnitudes will be found from National Building Codes or wind tunnel studies. The bending moments on the building caused by these lateral forces increment with leastways the square of the height, and their effects will become increasingly more significant as the building height increments. On the base of the agents above, the proportional amounts of material needed in the floors, columns, and wind bracing of a traditional steel frame and the punishment on these due to raising height are just about as exemplified in figure 3.1.

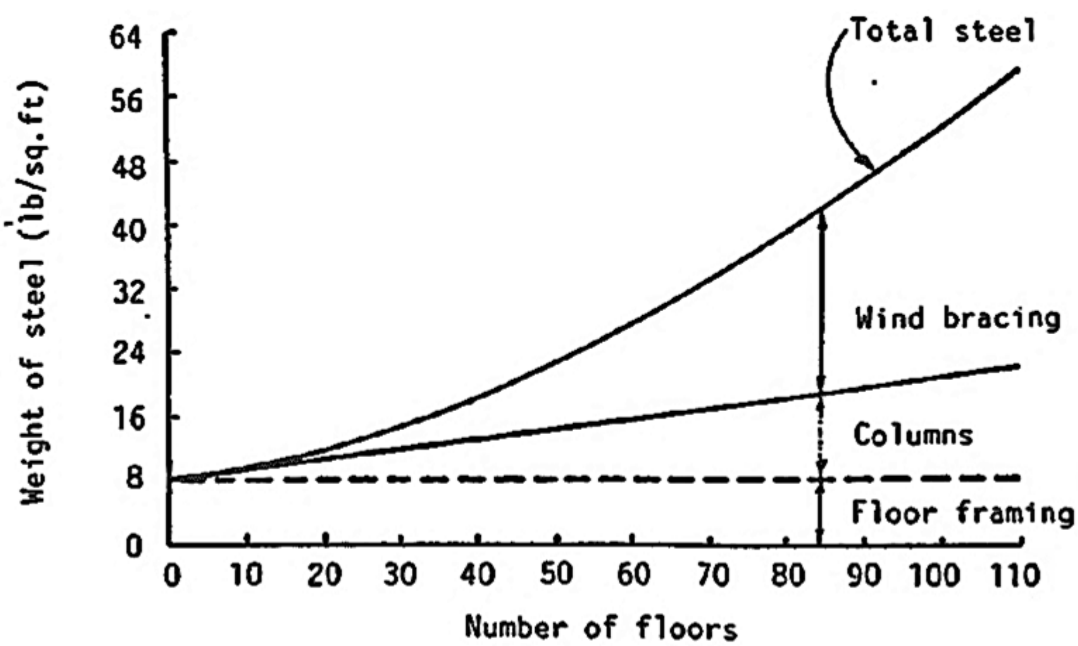


Figure 3.1. Weight of steel in tall buildings [47]

Because the worst conceivable effects of lateral forces happen rarely, if ever, in the life of the building, it is imperative to minimize the penalization for height to reach an best design. [47]

3.5 Functional Requirements of Tall Buildings

Building forms are hugely different, and their deriving appears to be random, at times even arbitrary, although the configuration adjudicates at the same time satisfy (1) the requirements of site, (2) the requirements of the building program, and (3) the requirements of appearance. The first demand enforces constraints of site geometry and position, the second exemplifies the demands obligatory by the preparation and occupancy requires, and the third exemplifies the designers' desires for physical images that show the ambitions of the building proprietor, the users and, of course, the designers themselves. Buildings of the 1950s and 1960s responded to the functionalist thoughts of the 1920s that the aesthetic and useful looks of the building are to be at the same time satisfied. Such an idea is still being applied, although currently functionalism is being hotly controversial.

For a building to be successful, it should do the following:

- Produce a friendly and attractive image that has advantageous values to building possessors, users, and observers.
- Fit the site, supplying correct nears to the plaza with a set out friendly for people to live, work, and play.
- Be energy-efficient, supplying place with governable climate for its users.
- For office buildings, allow flexibility in office layout with easily separable space.
- Offer spaces adjusted to supply the better views.
- Most of all, the building must make economical sensation, without which none of the New tall buildings evolution would be a reality [48].

3.6 Loading in Tall Buildings

Loading on tall buildings differs from loading on low-rise buildings in its assemblage into much bigger structural forces, in the raised implication of wind loading, and in the bigger importance of dynamic effects. The collection of gravity loading over a large number of stories in a tall building can create column loads of an order higher than those in low-rise buildings. Wind loading on a tall building behaves not only over a very big building surface, but also with bigger strength at the bigger heights and with a greater moment arm about the basic than on a low-rise building. Although wind loading on a low-rise building commonly has an unimportant act upon on the design of the structure, wind on a high-rise building can have a dominant influence on its structural system and design. In an uttermost type of a very thin or flexible structure, the movement of the building in the wind may have to be counted in evaluating the loading put on by the wind.

In earthquake regions, any inertial loads from the shaking of the ground may good overstep the loading due to wind and. therefore, be overriding in acting upon the building's structural form, design, and cost. As an inertial problem, the building's dynamic response acts as a big pan in acting upon, and in calculating, the impressive loading on the structure. With the exclusion of dead loading, the loads on a building cannot be evaluated precisely. While greatest gravity live loads can be expected roughly from former field notices, wind and earthquake loadings are random in nature, harder to valuate from ago cases, and even harder to prognosticate confidently. The application of probabilistic theory has served to rationalize. if not in every event to simplify, the comes near to calculating wind and earthquake loading.

3.6.1 Gravity Loading

Although the tributary fields, and therefore the gravity loading, propped by the beams and slabs in a tall building do not differ from those in a low-rise building.

The assemblage in the past of many stories of loading by the columns and walls can be very much bigger. As in a low-rise building, dead loading is accounted from the designed member sizes and calculated material concentrations. This is prone to minor inaccuracies such as differences between the actual and the designed sizes, and between the real and the put on concentrations.

Live loading is assigned as the loudness of a uniformly distributed floor load. According to the occupancy or utilize of the space. In certain situations such as in parking areas, offices, and plant rooms, the floors should be counted for the secondary lowest possibility of assigned concentrated loads.

The magnitudes of live loading assigned in the Codes are appraisals established on a combination of experience and the results of distinctive field studies. Model distribution of gravity live loading across abutting and cyclic spans should be counted in calculating the local maxima for member forces, while live load reductions may be let to account for the improbableness of total loading being used at the same time over bigger areas [47].

3.6.2 Lateral Load Design Philosophy

In contrast to vertical load, lateral load sets up on buildings are quite changeable and increment quickly with additions in height. For example, under wind load the overturning moment at the base of a building changes in proportion to the square of the height of the building, and lateral deflection changes as the fourth power of the height of the building, other things being equal.

There are three major agents to consider in the design of all structures: strength, rigidity, and stability. In the design of tall buildings, the structural system must also meet these necessaries. The strength demand is governing parameter in the design of low height structures. Besides, as height increments, the rigidity and stability demands become more of import, and they are frequently the ascendant parameter in the design. There are fundamentally two ways to meet these demands in a structure. The first is to increase the size of the members beyond and above the strength demands. However, this come on has its own boundaries, beyond which it becomes either impractical or uneconomical to increment the sizes. The second and more graceful come near is to modify the form of the structure into something more rigid and stable to bound the deformation and increment stability [46, 48].

3.6.2.1 Wind Loading

The lateral loading due to wind or earthquake is the major factor that reasons the design of tall buildings to differ from those of low- to medium-rise buildings.

For buildings of up to about 10 stories and of regular proportionalities, the design is rarely affected by wind loads. Above this height, however, the increment in size of the structural members, and the potential rearrangement of the structure to calculate for wind loading, obtains a cost premium that increment increasingly with height. With creations in architectural handling, increments in the strengths of materials, and advances in methods of analysis, tall building structures have get more effective and lighter and, consequently, more prone to deflect and even to sway under wind loading [47].

In designing for wind, a building cannot be took autonomous of its environment. The act upon of close buildings and of the land shape can be essential. The swaying of the top of a high building made by wind may not be found out by a passerby, but it may look essential to those who use up the top floors.

Without doubt, all buildings sway during windstorms, but the motion in earlier tall buildings with locked-in gravity forces from their big weight is commonly impalpable and surely has not been a cause for concern. Structural innovations and lightweight construction technology have stripped the new tall buildings of their stiffness. Wind action has become a major problem for the designer of today's tall buildings.

There is still a demand for understanding the nature of wind and its interaction with a tall building, with special reference to permissible deflections and comfort of occupants. In designing tall buildings to hold wind forces, the following are significant factors that must be advised:

- Strength and stability necessities of the structural system
- Fatigue in structural members and connections made by unsteady wind loads

- Unreasonable lateral deflection that makes cracking of partitions and outside cladding, misalignment of mechanical systems and doors, and conceivable permanent deformations
- Frequency and bountifulness of sway that can make uncomfortableness to the occupiers
- Conceivable battering that may increase the magnitudes of wind velocities on close to buildings
- Effects on pedestrians
- Annoying acoustical disturbances
- Resonance of building vibrations with the oscillations of elevator lift ropes Before discussing the details of the wind-related problems, it is useful to survey the nature of wind as referred to the behavior of tall buildings [46].

A) Nature of Wind

Wind is the term employed for air in movement and is commonly gave to the natural horizontal motion of the air. Movement in a vertical or close to vertical direction is named a current. Winds are created by differences in air pressure, which are principally referable to differences in temperature. These temperature differences are made mostly by nonequivalent distribution of heat from the sun, together with the difference in the thermal properties of land and sea surfaces. When temperatures of near areas become incommensurate, the heater and thus lighter air tends to rise and flow across the colder, cloggier air. Winds initiated in this direction are commonly greatly altered by the rotation of the earth. Motion of air close to the surface of the earth is three-dimensional in nature, with a horizontal movement which is much larger than the vertical movement. Movement of air is produced by solar radiation, which gives pressure differences in air masses. Vertical air movement is of large importance in weather forecasting but is of lower importance near the ground surface. The surface edge layer involving horizontal movement of wind carries upward to a certain height above which the horizontal flow of air is no longer acted upon by the ground effect. The wind velocity at this height is named the gradient wind velocity and commonly happens at an altitude bigger than 1500 ft (458 m). In this limit layer is accurately where most of the human action is conducted, and therefore how the wind effects are felt within this zone is of large interest in engineering [46].

B) Types of Wind

Of the some types of wind that cover the earth's surface, winds which are of occupy in the design of tall buildings can be categorized into three major types: the current winds, seasonal winds, and local winds.

- The frequent winds. Surface air traveling from the horse lines of latitude toward the low-pressure equatorial belt establishes the frequent winds or trade winds.
- The seasonal winds. The air over the land is hotter in summer and colder in winter than the air near to oceans during the same times of year.
- The local winds. Agreeing with the seasonal variation in temperature and pressure over land and water, day by day varies happen which have a same but local effect, penetrating to a distance of about 30 miles (48 km) on and off the shores [46].

C) Characteristics of Wind

Wind is a phenomenon of large complexness because of the a lot of flow situations moving up from the interaction of wind with structures. However, in wind engineering simplifications are formed to reach important anticipations of wind demeanor by characterizing the flow states into the pursuing identifying features:

- Variation of wind speed with height
- Turbulent nature of wind
- Probabilistic approach
- Vortex shedding phenomenon
- Dynamic nature of wind structure interaction [46].

D) Variation of Wind Velocity with Height

At the interface between a moving fluid and a solid surface, viscosity manifests itself in the conception of shear forces adjusted inverse to the direction of fluid movement. A same effect happens between the surface of the earth and the air. Viscosity keeps down the air speed near to the earth's surface to nearly zero. A delaying effect happens in the layers close to the ground, and these interior layers successively in turn decelerate the external layers. The slowing down is lower at each layer and finally goes negligibly little. It is apparent that the speed increment which happens along a vertical line must be uninterrupted from zero on the surface to a maximum at a few distance away. The height at which the speed ceases to increment is named the slope height, and the agreeing velocity, the slope velocity.

The shape and size of the curve depends less on the viscosity of the air than on the type and predominance of the turbulent and random swirling movements in the wind, which successively are impressed by the type of terrain over which the wind is blowing (see Figure 3.2). This significant characteristic of magnetic variation of wind speed with height is a evenhandedly well realized phenomenon and is reflected in higher design pressures afforded at higher elevations in most building codes [46].

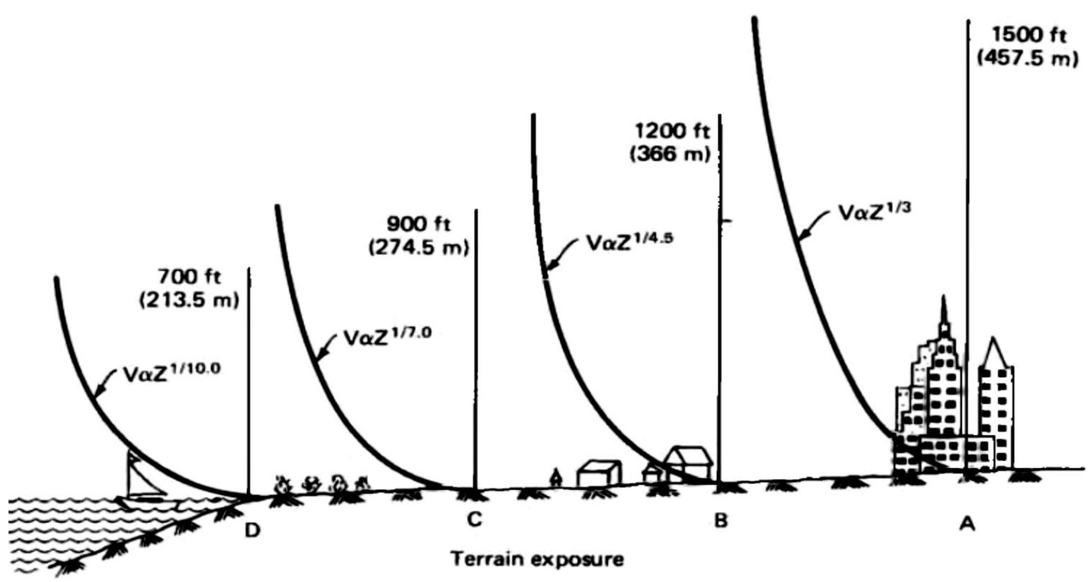


Figure 3.2. Alteration of wind velocity with respect to height [46]

3.6.2.2 Earthquake Loading

Earthquake loading comprises of the inertial forces of the building mass that result from the shaking of its foundation by a seismic commotion. Earthquake resistant design concentrates especially on the translational inertia forces, whose effects on a building are more important than the vertical or rotational quaking components. Other severe earthquake forces may live specify those due to land sliding. subsidence, active faulting under the foundation, or liquefaction of the local subgrade as a consequence of oscillation. Although it might be potential to design a building to resist the hardest earthquake without important damage, the improbable demand for such strength in the lifetime of the building would not rationalize the high extra cost. Accordingly, the general philosophy of earthquake-resistant design for buildings is established on the principles that they should

- Resist minor earthquakes without damage:
- Resist moderate earthquakes without structural damage but accepting the probability of nonstructural damage:
- Resist average earthquakes with the probability of structural as well as nonstructural damage, but without collapse.

Few modifications are created to the above principles to realize that certain buildings with a lively function to do in the case of an earthquake should be stronger [47].

A) Nature of Earthquakes

Catastrophic earthquakes come out in the headlines with discomforting frequency, getting thousands of lives to be lost and attribute damage running into hundreds of millions of dollars. This genuinely global phenomenon has barely started to be understood, and significant emphasis is being placed on the analytical analyses of earthquake response of buildings, supported by experimental analyses both in the laboratory and in the field in an attempt to keep much of this destruction and deprivation of life. Bills of destructive earthquakes come out all through recorded history. Early humans, in their unfitness to apprehend such a unusual and destructive phenomenon, imputed the whole mechanism of earthquake to the furious work of gods. Although in old times it was tempting to think of earthquakes as in some way otherworldly, they are as a matter of fact, among the more common of the earth's phenomena [46].

3.7 Relative Structural Cost

The structure commonly calculates for 20 to 30 percentage of the cost of a tall building. For buildings higher 50 stories, the cost of a commonsensible wind bracing system may elaborate, at most, to one-third of the structural cost. Therefore, compared to the total cost of the building, wind bracing costs, which are in the ambit of 7 to 10 percent, present far from an overwhelming part of the total structure dollar. The cost of the exterior wall lonely can be half as much or may even be in overabundance of the cost of the total structure, hinging on its complexity and authorship. The warming, airing, and air conditioner system frequently excels in the cost picture. So to be economically emulous with low rises, tall buildings must offer economies other than in the structural system. Structural optimization to hold the attached loads with minimum material may not admit a decrease in the overall cost of the building. The destination, therefore, is to optimize the overall cost, a technique that generally takes place in the ahead of time levels of the project evolution. High occupy costs and scarcity of capital are extra factors needing leaner designs [46].

3.8 Structural Systems for Tall Buildings

Structural forms specified shear walls and tube structures, the high dead-load features are no more a limitation on the height of concrete buildings. The coming of super plasticizers and high-strength and lightweight concrete has took out all economical restraints on the height of concrete buildings.

The next factors have added importantly to the cost-competitiveness of reinforced concrete for tall buildings.

- New improvements in concrete forming methods such as flying forms, tunnel forms, dislocate forms, and pack forms.
- Apply of quicker concrete-placing equipment such as concrete pumps.

- The implicit fire impedance of concrete, which eliminates the required for fireproofing materials.
- Lower limit thickness of floor system, which keeps down the floor-to-floor height, thereby keeping down the quantity of materials required to confine the building.
- Grade 60 and 75 ksi (413.7 and 517 MPa) soft-cast steel reinforcement in combination with high-strength concrete outcomes in the apply of littler and fewer columns, thereby increasing rentable floor space.
- Advent of super plasticizers to increment the workability and the strength of concrete.
- Buildings framed with pan joist or additional types of construction with a uniform structural depth do it potential to apply a easier automatic distribution system.
- Exterior shear walls, columns, and spandrels can be shaped with textured fin-form liners to reach architectural finish without another handling or painting.

Such factors include building geometry, stiffness of exposure to wind, seismicity of the part, ductility of the frame, and bounds imposed on the size of the structural members. A lot of tall buildings may expeditiously apply some or many of the systems depending upon the individual needed of the building. Frequently, systems mixing the characteristics of two or more systems can be used to fulfill the particular project necessary [46].

But elsewhere throughout this work. An abbreviated description of the major systems are as comes.

3.8.1 Braced-Frame Structures

In this type of structure the lateral resistance of the structure is supplied by diagonal members that, conjointly with the girders, form the " web" of the vertical truss, with the columns acting as the " chords" . Since the horizontal shear on the building is held out by the horizontal components of the axial tensile or compressive actions in the web members, bracing systems are extremely effective in resisting lateral loads.

Bracing is usually esteemed an only steel system because the diagonals are inescapably subjected to tension for one or the different ways of lateral loading. Concrete bracing of the twice diagonal form is some of the times applied, however, with each diagonal designed as a compression member to hold the full external shear.

The efficiency of bracing, in being capable to make a laterally real stiff structure for a lower limit of added material, makes it an economical structural form for any height of building, up to the very highest. An another advantage of fully triangulated bracing is that the girders generally participate just minimally in the lateral bracing action: therefore, the floor framing design is unconditional of its level in the structure and. therefore, can be repetitious up the tallness of the building with apparent economy in design and assembly. A major disadvantage of diagonal bracing is that it impedes the inside planning and the location of windows and doors. For this cause, braced bents are generally merged internally along wall and segmentation lines, and particularly around elevator, stair, and service shafts. A different drawback is that the diagonal connections are costly to manufacture and erect. The traditional apply of bracing has been in story-height. Bay width modules that are fully concealed in the finished building [47].

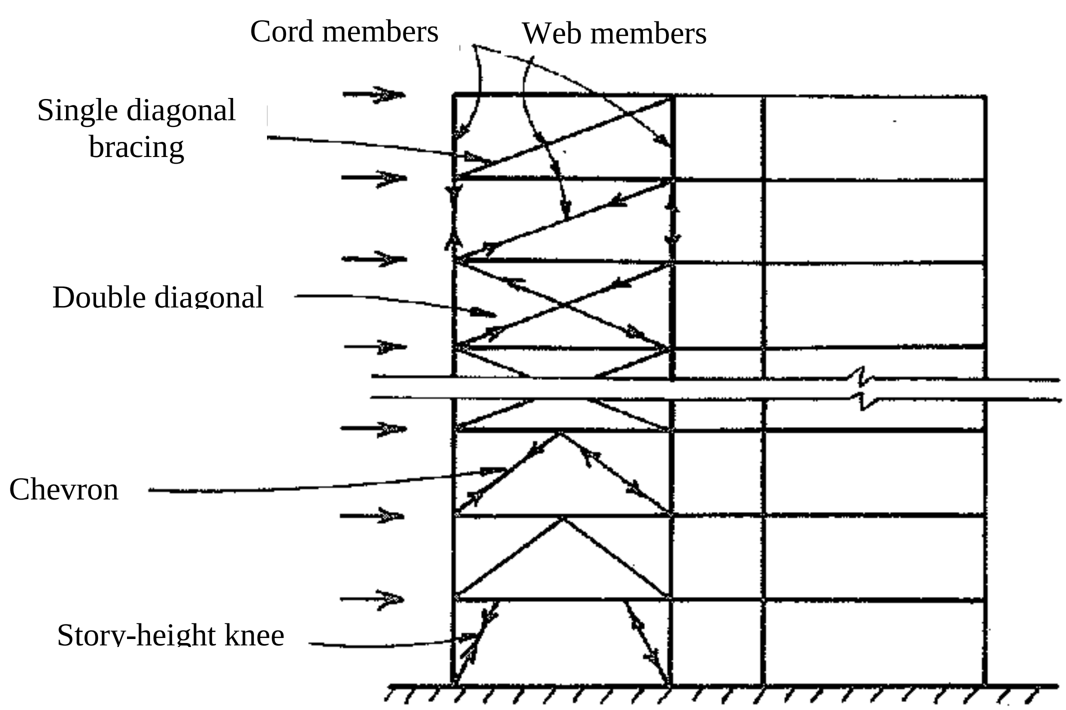


Figure 3.3. Braced-Frame- showing different types of bracing [47]

3.8.2 Rigid-Frame Structures

This type of structures consists of columns and girders. Connections of these columns and girders are has to be moment resistant. The lateral stiffness of this type of structures subject to bending rigidity of the columns, girders and assembling in plan of bend main advantage of rigid frame is its open rectangular arrangement. This provides easily planning of architectural details such is placement of stairs, doors and windows.

If the rigid frames are only used in the lateral resistance of buildings. For instance, 6-9m span length and up to 25 floors buildings is an economical solution more than 25 floors highly lateral loads will create uneconomical huge members. The reinforcement concrete buildings suitable form for rigid frame construction due to rigidity of the joints. Steel frame buildings can be constructed as rigid frame. In this case moment resistance connections will be expensive.

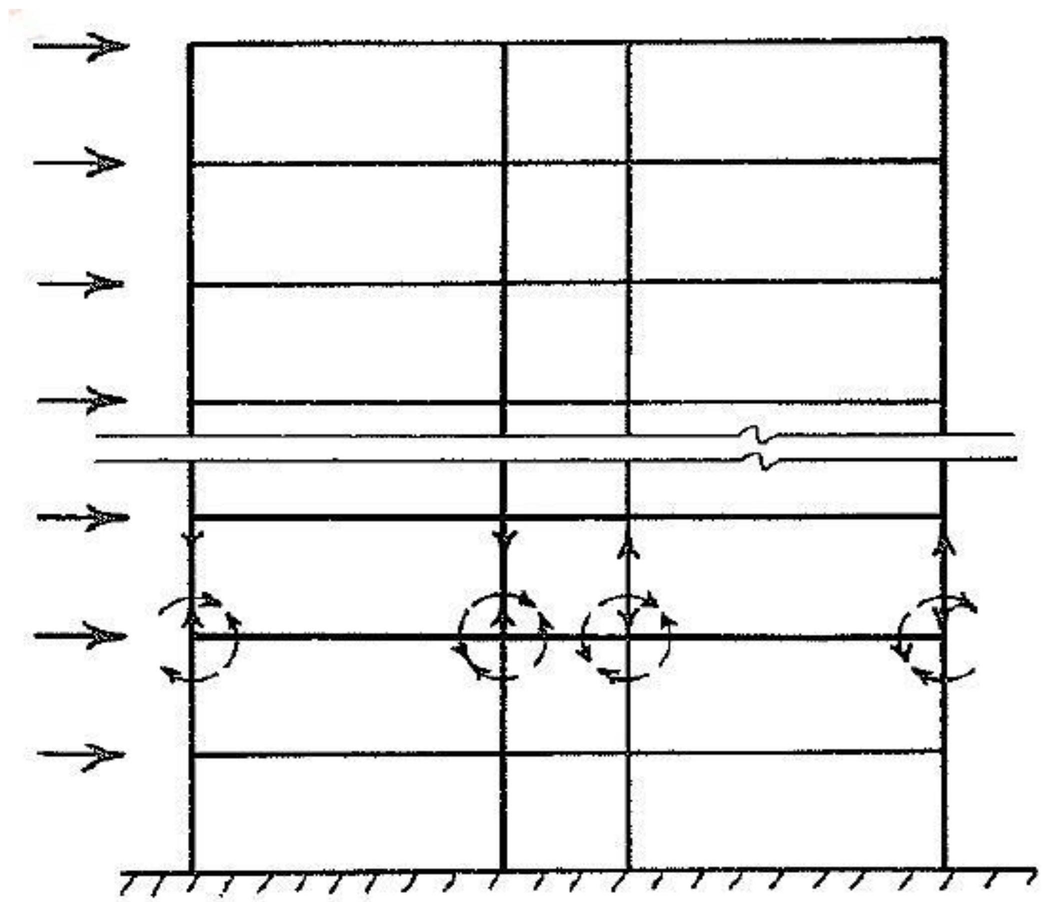


Figure 3.4. Rigid frame [47]

Rigid frame action is resists gravity loads. Negative moments are composed in girders near to frame columns composing the mid span positive moments will be significantly less than in simple supported span. When the gravity loads has a major role in desing of structures, economical member sizes will be affected from gravity loads tend to be offset by the greater price of the rigid joints.

Economic height of rigid frames that provide alone to resist lateral loads up to 25 floors. Midrise rigid frames in the form of a perimeter tube, or usually scaled rigid frames in integration with shear walls or braced bents, can be efficient up to higher heights [47].

3.8.3 Infilled-Frame Structures

Commonly used form of construction is infilled frames for tall building up to 30 floors in a lot of countries. Column and girders can be made up reinforced concrete sometimes steel. Infilled can be made by bricks, block work or prefabricated concrete. The infills behave as a compression stud along its diagonal direction for bracing the frame against lateral loads. The infills located as outer side wall or partition walls. This system is appropriate choice for strengthening the structure against lateral loads.

Complicated behavior of infills in the frame is difficult to predict with accurate rigidity and strength of infilled frame. Besides, there is no general accepted design rule for analyzing infilled frames. For these reasons, and because of the right of the unplanned remotion of bracing infills at some time in the life of the building, the utilize of the infills for bracing tall buildings has principally been additional to the rigid-frame activity of concrete frames [47].

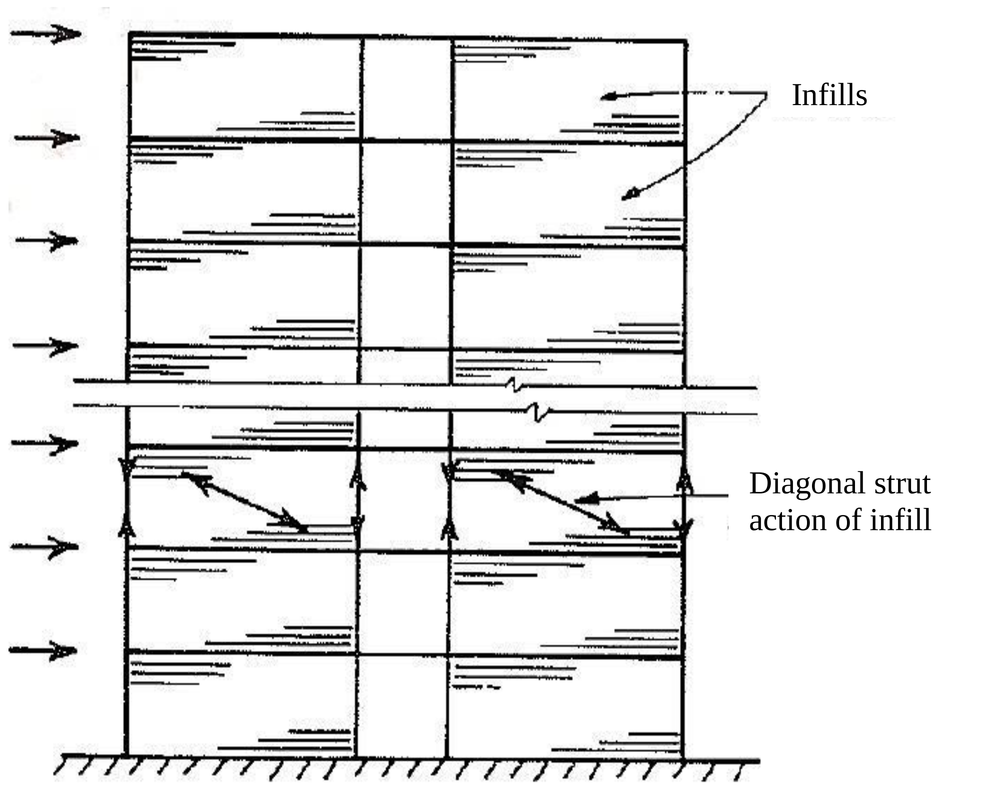


Figure 3.5. Infilled-Frame Structures [47]

3.8.4 Flat-Plate and Flat-Slab Structures

The flat plate slabs are commonly used in all structural forms which have uniform slabs with thickness between 10-25cm, connected to load bearing columns. The flat plate system is especially constructed with reinforced concrete. This is an economical in having flat base with simple formwork. This base can be used as ceiling and bottom limit of the floor depth.

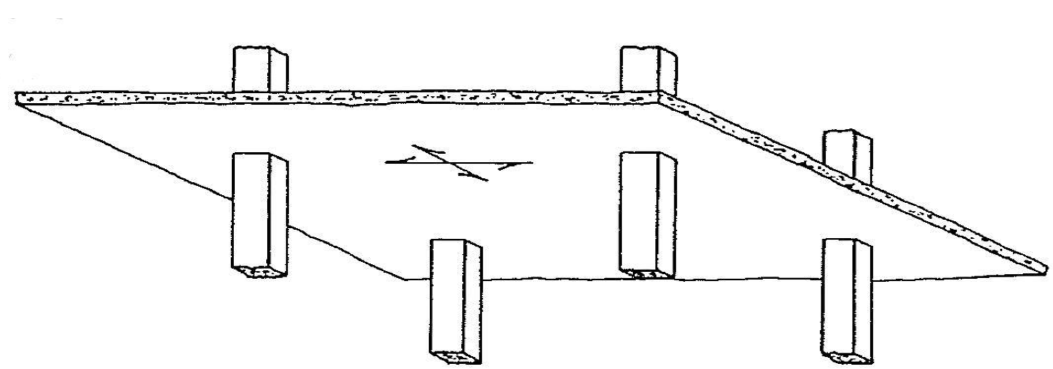


Figure 3.6. Flat-Plate [47]

Behavior of flat plate structures is similar to rigid frames under lateral loads. Its lateral stiffness subjected to flexural stiffness of the members and their connections. These are slabs to connect the girders of the rigid frame. These systems frequently preferred for commercial office and hotel buildings for their advantages. In these systems ceiling spaces are not required and slab can be used as the ceiling. Economical span length for flat plate structures up to eight meters. Higher span lengths can be constructed by using drop panels up to 12 m.

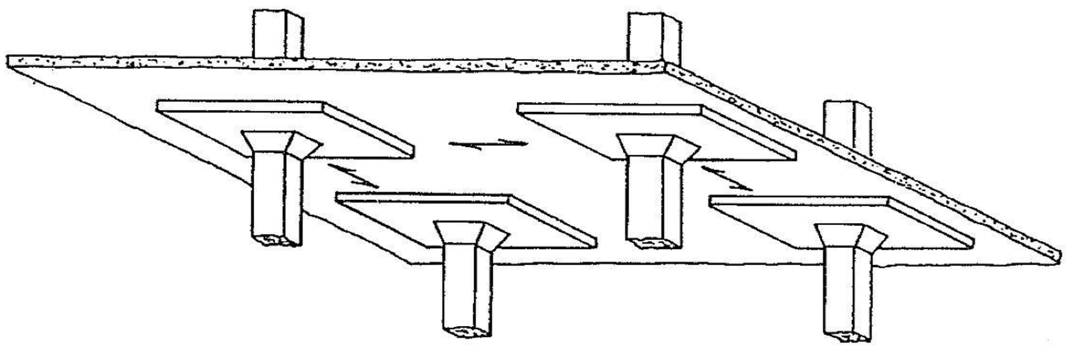


Figure 3.7. Flat-Slab [47]

Flat slab action is subject to lateral loads are economical up to 25 floors. When design codes are less violent to wind loads, flat-plate buildings can be constructed up to 40 floors [47]**.**

3.8.5 Shear Wall Structures

Concrete or masonry uninterrupted vertical walls may serve both architecturally as segmentations and structurally to hold gravity and lateral loading. Their very high in plane stiffness and strength causes them ideally befitted for bracing tall buildings. In a shear wall structure, such walls are completely responsible for the lateral load resistance of the building. They act as vertical cantilevers in the form of break up planar walls, and as non-planar gatherings of joined walls around elevator, stair, and service shafts . Because they are much stiffer horizontally than rigid frames, shear wall structures can be economical adequate to about 35 stories. in low to medium-rise buildings, shear walls are blended with frames, it is commonsensical to assume that the shear walls pull in all the lateral loading so that the frame perhaps designed for just gravity loading. It is particularly significant in shear wall structures to try to plan the wall set out so that the lateral load tensile stresses are restrained by the gravity load stresses. This gives up them to be designed to have just the lower limit reinforcement. Shear wall structures have been presented to do well in earthquakes, for which case ductility gets an significant consideration in their design.

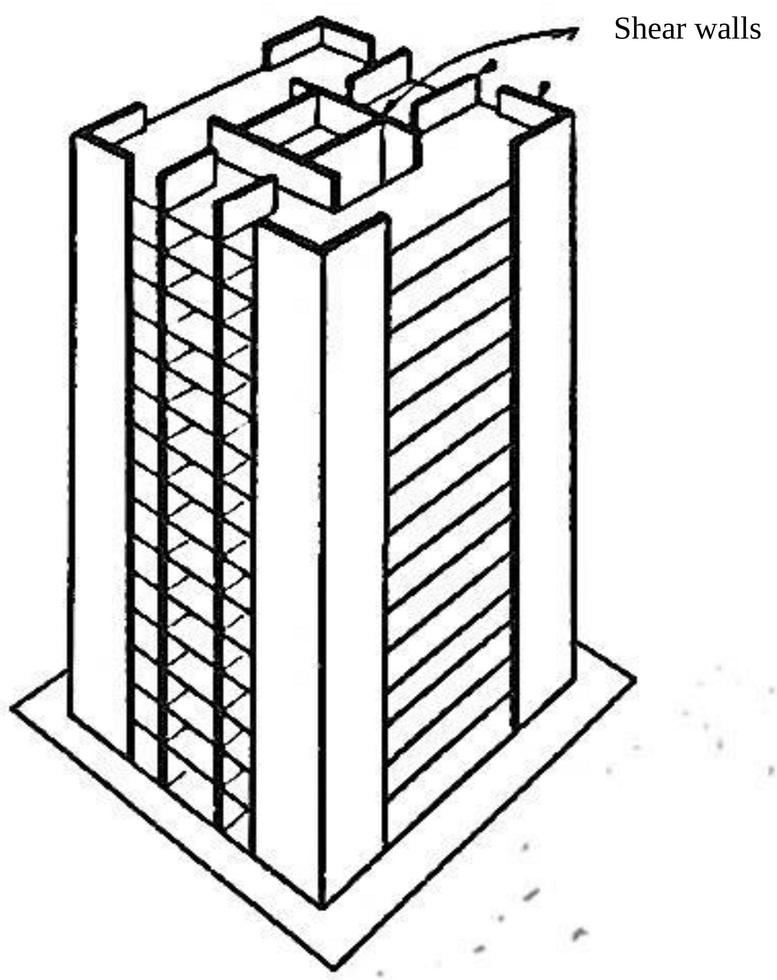


Figure 3.8. Shear wall structure [47]

Coupled Wall Structures. A coupled wall structure is a especial, but very usual, form of shear wall structure with its own particular problems of analysis and design. It consists of two or further shear walls in the same plane, or almost the same plane, joined at the floor levels by beams or stiff slabs. Although shear walls are apparently more appropriate for concrete construction, they have sometimes been constructed of heavy steel plate, in the style of massive vertical plate or box girders, as parts of steel frame structures. These have been designed for locations of exceedingly heavy shear, such as at the base of elevator shafts [47].

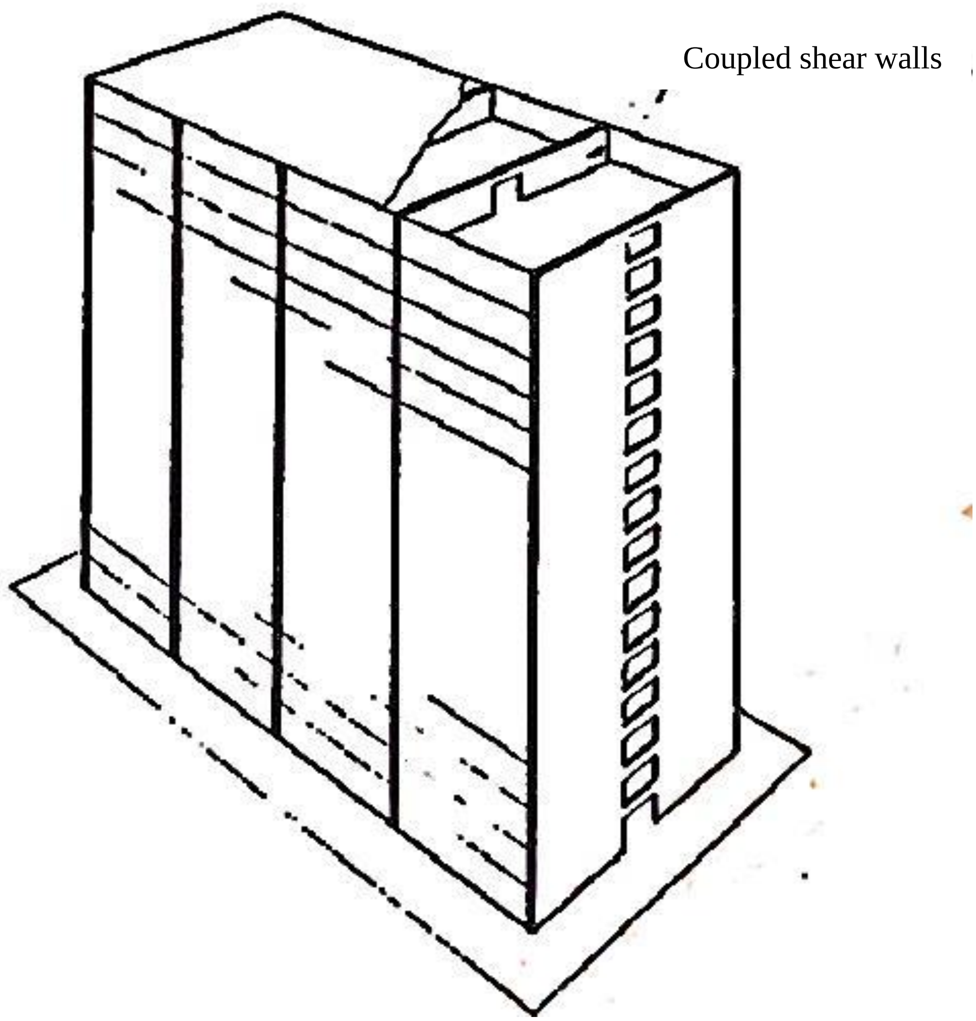


Figure 3.9. Coupled shear Wall Structures [47]

3.8.6 Wall-Frame Structures

When shear walls are mixed with rigid frames the walls, which tend to deflect in a flexural form, and the frames, which tend to deflect in coupled shear wall structures.

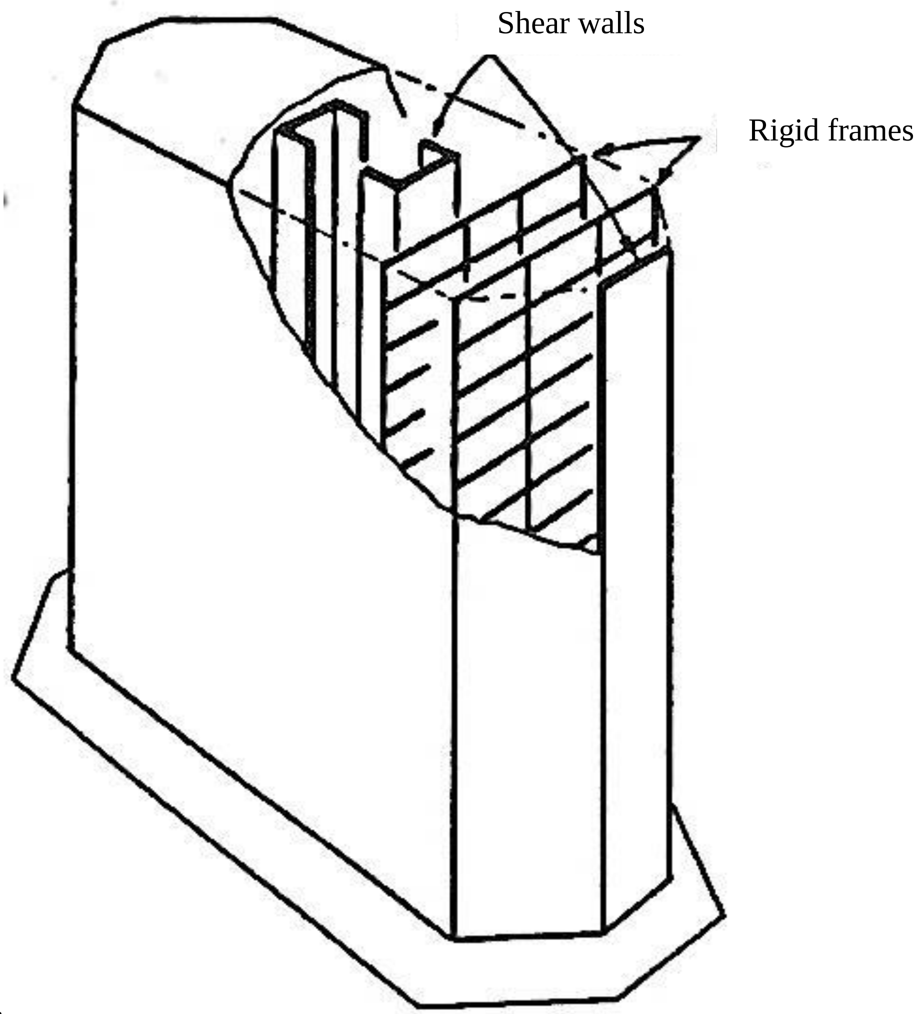


Figure 3.10. Wall-frame structures [47]

a shear way, are forced to take in usual deflected shape by the horizontal rigidity of the girders and slabs. As a result, the walls and frames interact horizontally, particularly at the top. to make a stiffer and stronger structure. The interacting wall-frame combination is advantageous for buildings in the 40- to 60-story range, well on the far side that of rigid frames or shear walls lonely. An another, less well known feature of the wall-frame structure is that, in a cautiously "adjusted " structure, the shear in the frame can be formed roughly regular over the height, allowing the floor framing to be repetitive. Although the wall-frame structure is commonly detected as a concrete structural; form, with shear walls and concrete frames, a steel similitude utilizing braced frames and steel rigid frames provides like advantages of horizontal interaction. The braced frames comport with an general flexural tendency to interact with the shear style of the rigid frames. [47]

3.8.7 Framed-Tube Structures

The lateral resistance of framed-tube structures is supplied by absolute stiff moment resisting frames that form a “tube “around the perimeter of the building. The frames comprise of nearly spaced columns. 2-4m between centers, connected by thick spandrel girders. Although the tube holds all the lateral loading. the gravity loading is apportioned between the tube and inside columns or walls. When lateral loadin Shear walls ıeter frames adjusted in the direction of loading act as the "webs" of the heavy tube cantilever, and those common to the direction of the loading act as the "flanges."

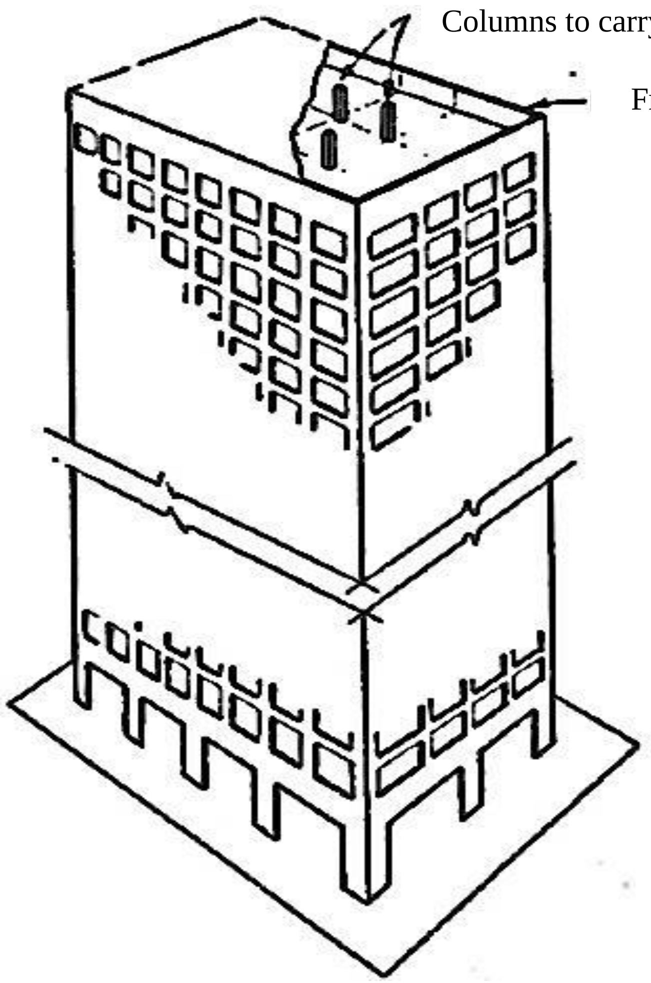


Figure 3.11. Framed-Tube Structures [47]

The near spacing of the columns throughout the height of the structure is commonly impossible at the entry floor. The columns are therefore immixed, or ended on a transfer beam, a some stories above the base so that only a few. Bigger, a lot of widely spaced columns go on to the base The tube is proper for both steel and reinforced concrete construction and has been utilized for buildings ranging from 40 to more than 100 stories. The extremely repetitive model of the frames lends itself to prefabrication in steel, and to the apply of speedily portable bunch forms in concrete, which create for speedy construction.

Tube-in-Tube or Hull-Core Structures. This variation of the framed tube consists of an external framed tube, the "Cordell Hull." Conjointly with an inside elevator and service core. The hull and core act together in resisting both gravity and lateral loading. In a steel structure, the core may comprise of braced frames, whereas in a concrete structure it would comprise of an gathering of shear walls.

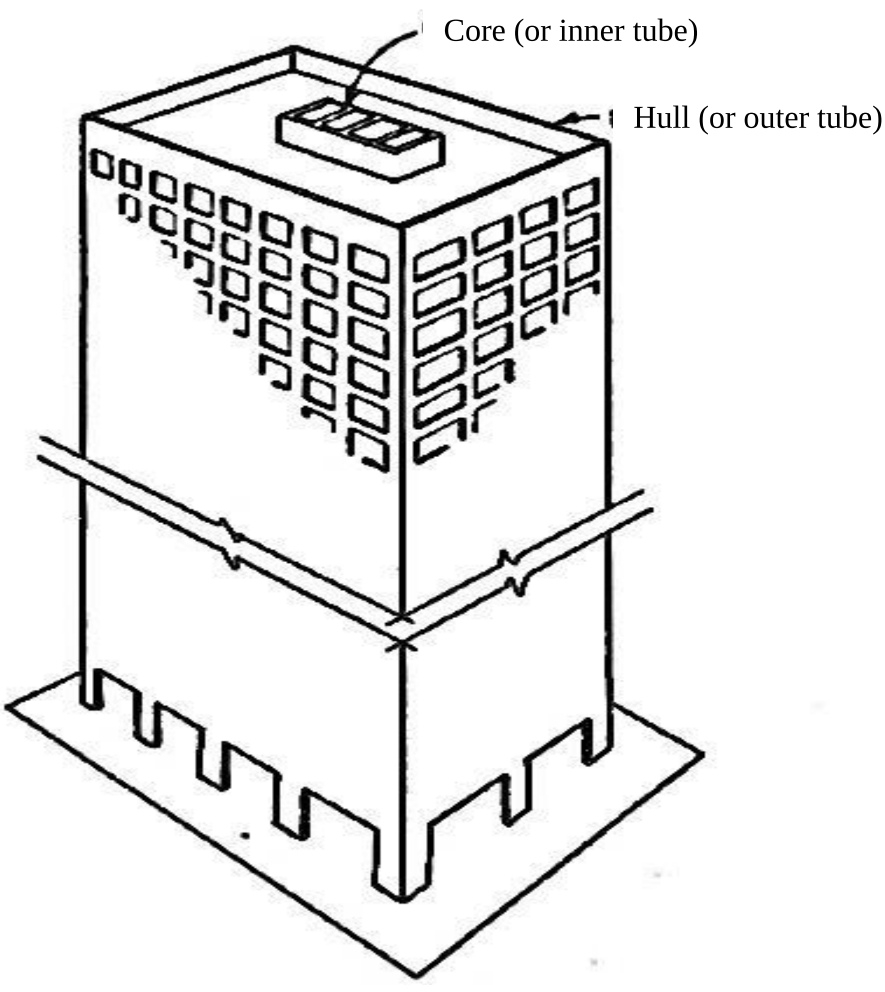


Figure 3.12. Tube-in-Tube or Structures [47]

Braced-Tube Structures. Some other way of rising the efficiency of the framed tube, thereby raising its expected for utilize to even larger heights as well as providing larger spacing between the columns, is to add diagonal bracing to the fronts of the tube. [2]

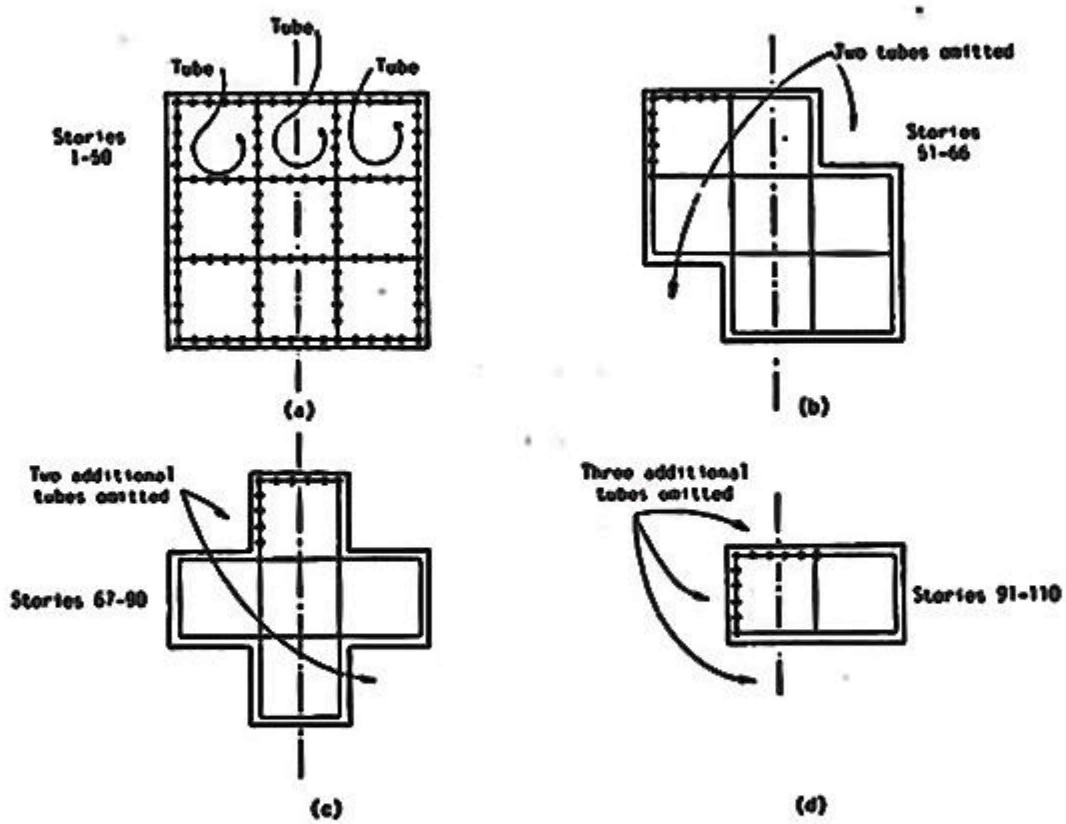


Figure 3.13. Braced-Tube Structures [47]

3.8.8 Outrigger-Braced Structures

This effective structural form comprises of a central core, containing either braced frames or shear walls, with horizontal cantilever “outrigger” trusses or girders joining the core to the external columns. When the structure is loaded horizontally, the outriggers through tension in the windward columns and compression in the leeward columns confine vertical plane gyrations of the core. The efficient structural depth of the building is greatly modified, thus augmenting the lateral stiffness of the building and shortening the lateral deflections and moments in the core. In effect, the outriggers connect the columns to the core to cause the structure behave as a partly composite cantilever.

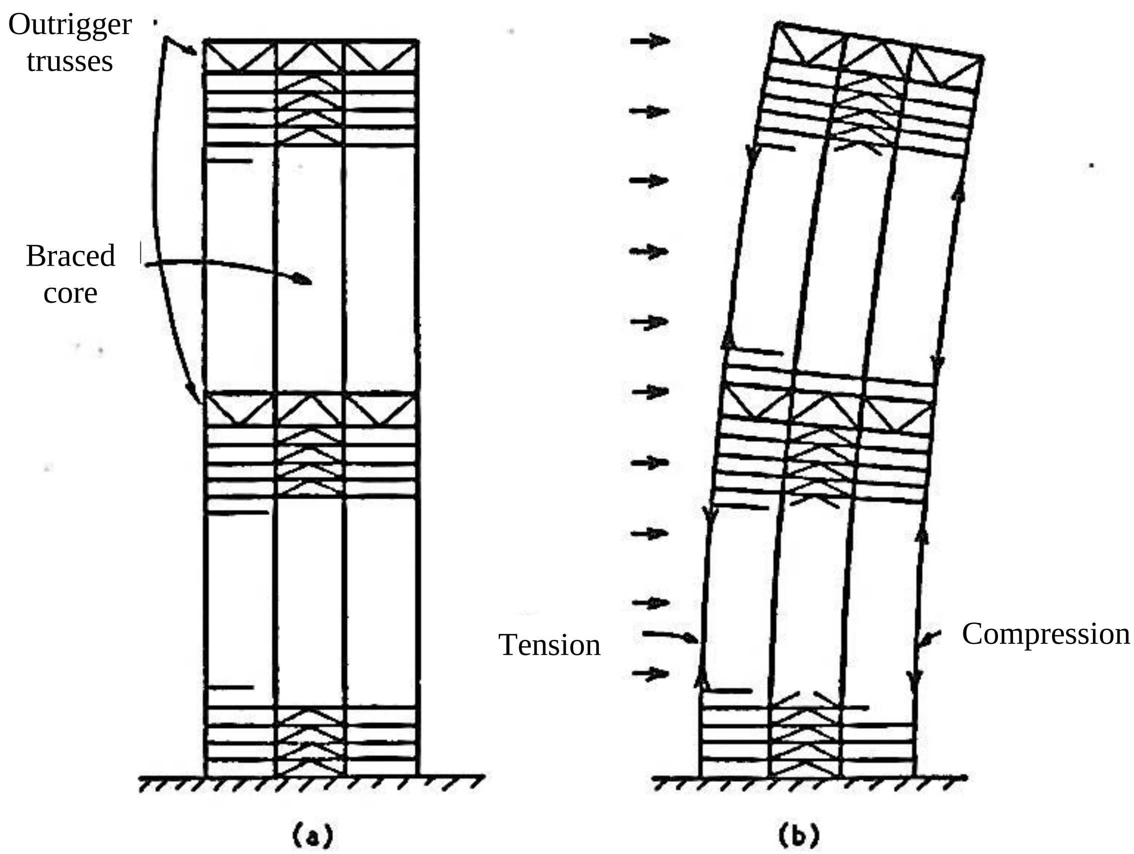


Figure 3.14. a) Outrigger-braced structure b) outrigger-braced structure under load [47]

Outrigger-braced structures have been utilized for buildings from 40 to 70 stories high, but the system should be efficient and effective for much larger heights [47].

3.8.9 Suspended Structures

The suspended structure comprises of a central core, or cores, with horizontal cantilevers at roof level, to which vertical hangers of steel cable, rod. or plate are connected. The floor slabs are suspended from the hangers.

The advantages of this structural form ate principally architectural in that, exclude for the presence of the central core; the ground story can be wholly unhampered major! vertical members, thereby providing an open confluence: also, the hangers, because they are in tension and accordingly can be of high strength steel, have a lower limit sized section and are consequently less obtrusive.

The structural disadvantages of the suspended structure are that it is ineffective in beginning transmitting the gravity loads upward to the roof-level cantilevers before returning them through the core to the ground, and that the structural width of the building at the base is confined to the comparatively specify depth of the core, which limits the system to buildings of lesser height.

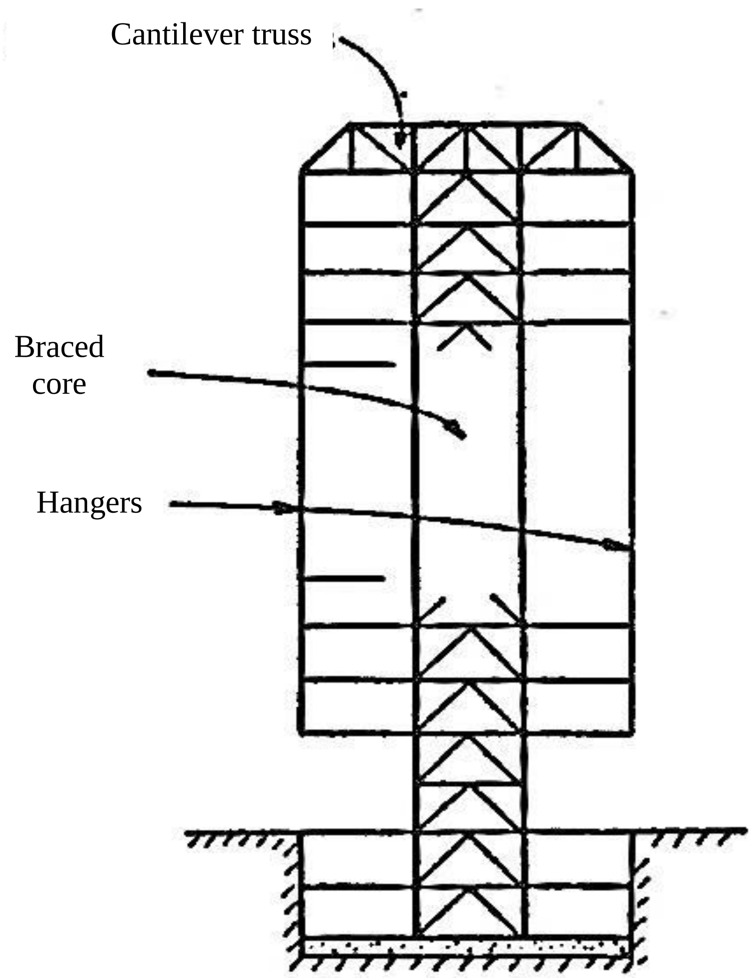


Figure 3.15. Suspended Structures [47]

The problem can be restrained by limiting the maximum number of floors confirmed by a single length of hanger to about 10 and by having multilevel cantilever systems.

The profits of such multicore hanging structures include big open floor spaces at wholly levels, and the possibility of a column-free ground story [47].

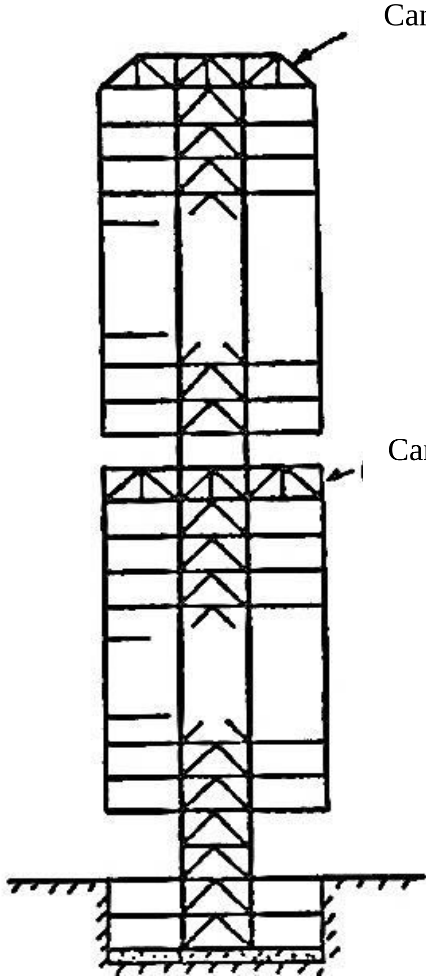


Figure 3.16. Two-tiered suspended structure [47]

3.8.10 Core Structures

In these structures, an individual core functions to carry the whole gravity and horizontal loading .In a few, the slabs are supported at each level by cantilevers from the core. In others, the slabs are confirmed between the core and perimeter columns, which end either on major cantilevers at intervals down the height, or on a individual heavy cantilever some floors above the ground. Likewise to the suspended building, the deserves of the system arc chiefly architectural, in supplying a column-free perimeter at the first floor and at other levels only under the cantilevers.

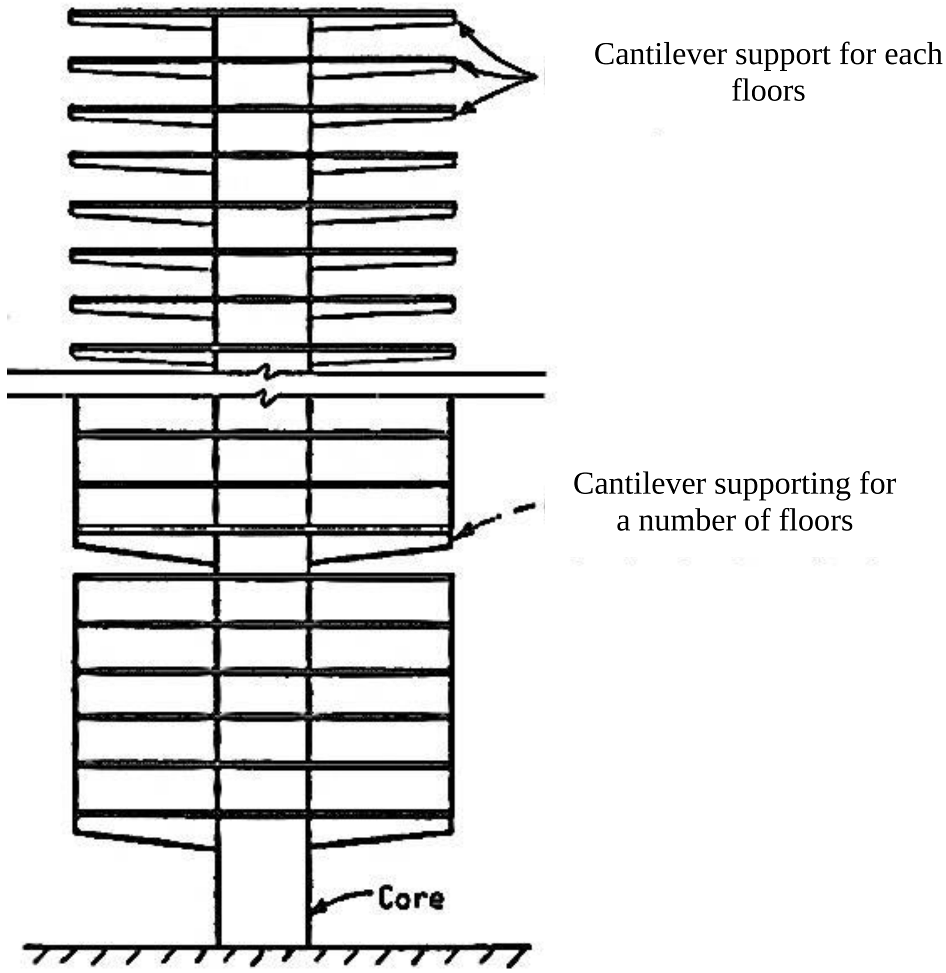


Figure 3.17. Core Structures [47]

The structural penalties are significant, however, in having just the little efficient structural depth of the core and. Consequently, being ineffective in resisting lateral loading, as well as in supporting the story loading by cantilevers an extremely ineffective structural component [47].

3.8.11 Space Structures

The basic load-resisting system of a space structure comprises basically of a three-dimensional triangulated frame as discrete from a gathering of planar bents whose members attend dually in resisting both gravity and horizontal loading. The result is an extremely effective, comparatively lightweight structure with a possible for attaining the biggest heights.

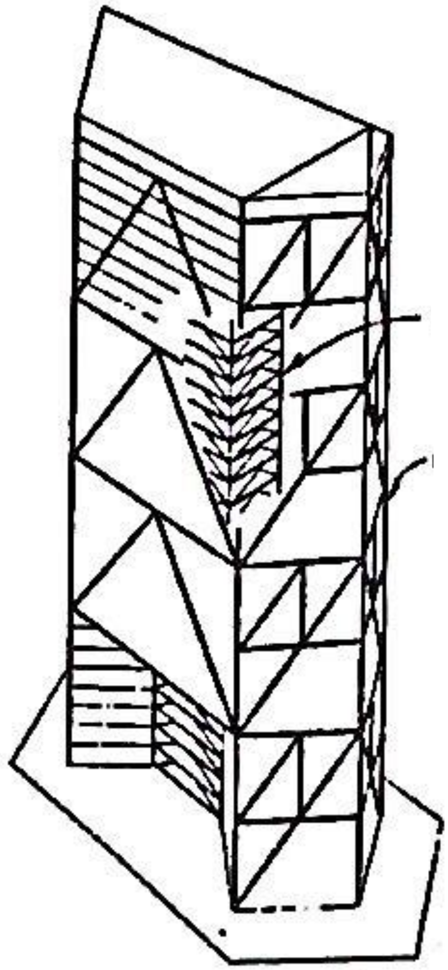


Figure 3.18. Space Structures [47]

Although simple in their overall concept, space structures are generally geometrically composite, which calls for considerable structural ingeniousness in removing both the gravity loading and the lateral loading from the stories to the chief structure? One solution is to have an inside braced core, which attends to amass the lateral loading, and the inside area gravity loading, from the slabs over a number of multistory areas. At the bottom of each area, the lateral and gravity loads are removed out to the chief joints of the space frame. Although the multidirectional sloped members of the space frame are structurally uneasy and expensive to join, as well as creating the fenestration hard, the structural form is visually concerning and aesthetically very satisfying in its seeming easiness [47].

3.8.12 Hybrid Structures

Many of the antecedently described structural systems are especially suitable for prismatically formed, tower or block, alleged “modern” buildings, which can be wholly structured by a individual recognizable system, for example, a tube or a wall frame.

Buildings of a non-prismatic shape are little compliant to an individual form of structure and. therefore, the engineer has to extemporize in modernizing an acceptable structural solution. In such situations, combining of two or even further of the primary structural forms have often been utilized in the same building, either by guide combination as. for example, in a superimposed tube and outrigger system or by taking dissimilar forms in different components of the structure as. for example, in a tube system on three faces of the building and a space frame on a faceted fourth face. Now with the ready accessibility of effective computers and extremely effective structural analysis programs, an engineer owning a sound knowledge of structural form and behavior should be capable to invent and analyze a structure to befit a building of almost any possible irregularity [47].

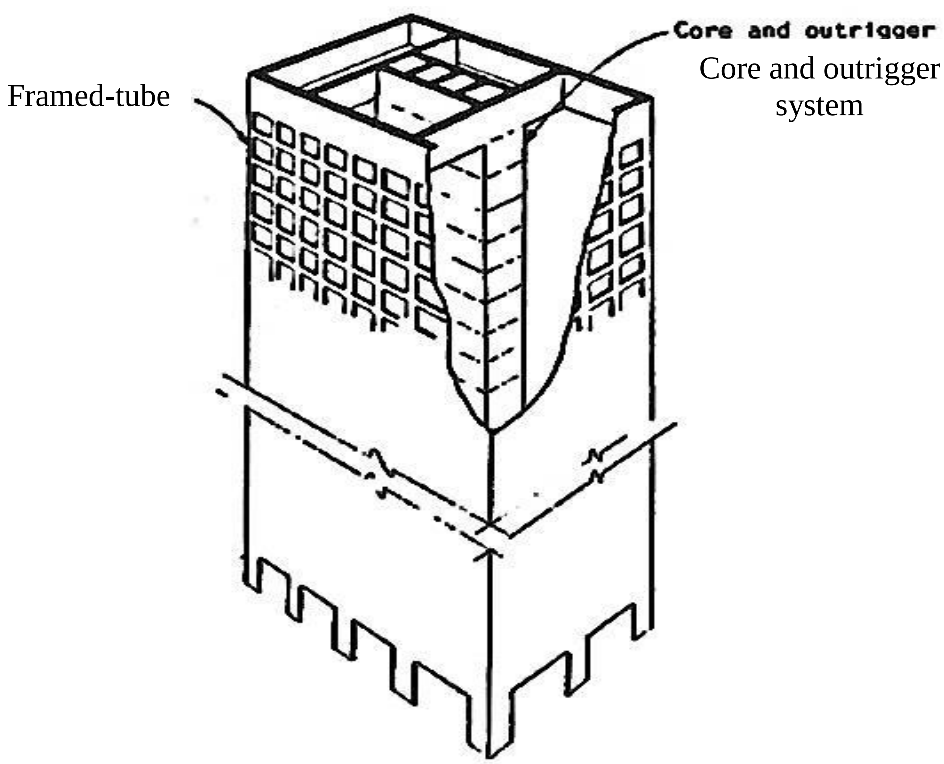


Figure 3.19. Hybrid Structures. [47]

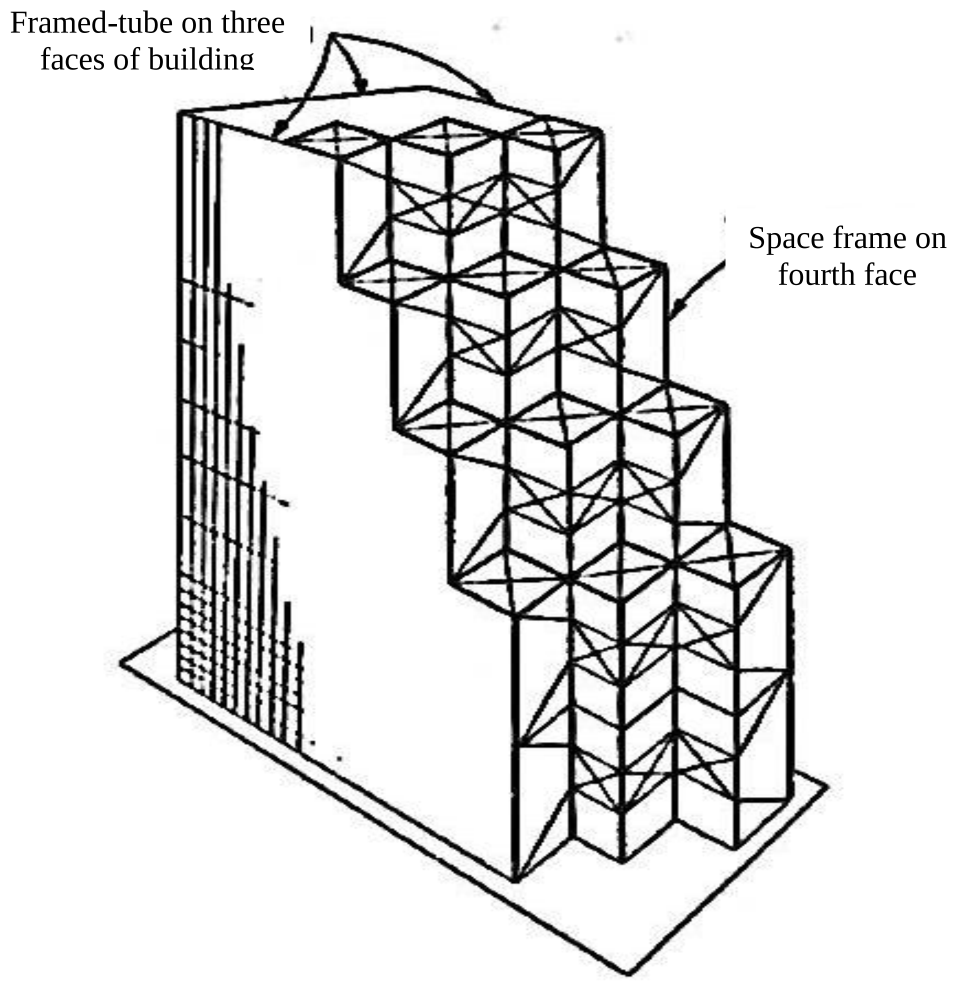


Figure 3.20. Hybrid Structures [47]

3.9 Floor Systems in Tall Buildings

Suitable floor system is fundamental element of overall cost of the building. Couple of factors affects the selection of floor systems are architectural. For instance, lower floor spans are especially preferred, because of small consistent sections of the floor space are needed. However, in commercial buildings are needed more wide, temporarily sub dividable and longer span systems. Additional factors affecting selection of floor system are associated with its structural functionality; it will take a part of the lateral load resisting systems and its construction duration. There are two different types of reinforced concrete floor systems. These are one way and two way slabs, in one way slab spans in one direction between supporting beam, walls and shear walls. In two way slab spans in two orthographic directions. In two systems, continuity over inner support is provided by reinforcement at negative moment zone in the slab [47].

3.9.1 One-Way Slabs on Beams or Walls

A solid slab of up to 8 in. (0.2 m) thick, spanning incessantly across walls or beams up to 24 ft (7.4 m) apart. Supplies a floor system demanding simple formwork. Potentially flying formwork. with simple reinforcement. The system is weighty and ineffective in its apply of both concrete and reinforcement. It is suitable for use in cross-wall and cross-frame residential high-rise construction and. when built in a number of continuous uninterrupted spans, brings itself to prestressing [47].

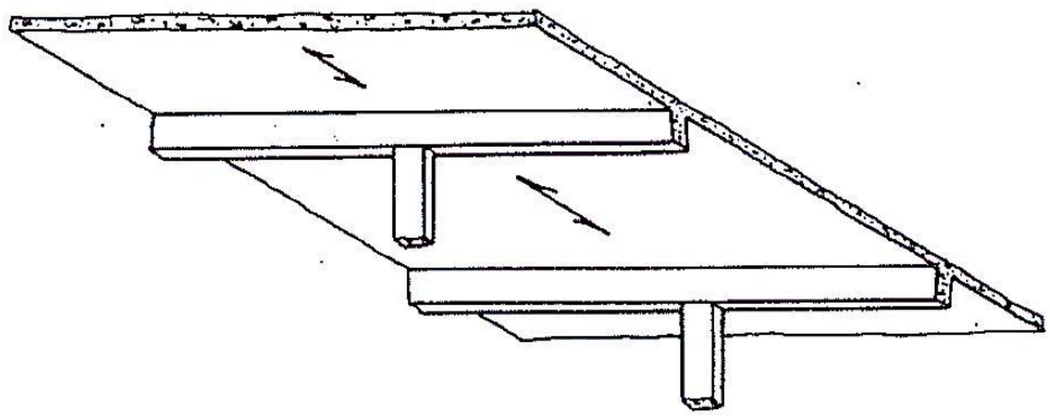


Figure 3.21. One-Way Slabs on Beams [47]

3.9.2 One-Way Pan Joists and Beams

A slim, mesh-reinforced slab models on nearly spaced cast-in-place joists spanning between major beams which carry-over the load to the columns . The slab may be as slim as 2.5 in. (6 cm) while the joists are from 6 in. (15 cm) to 20 in. (51 cm) in depth and spaced from 20 to 30 in. (76 cm) centers. The compositely acting slab and joists form effectively a adjust of nearly spaced T-beams. Competent of big, up to 40 ft (12.3 m). spans. The joists are molded between recyclable pans that are placed to adjust the uniform width of the joist, as well as any peculiar widths [47].

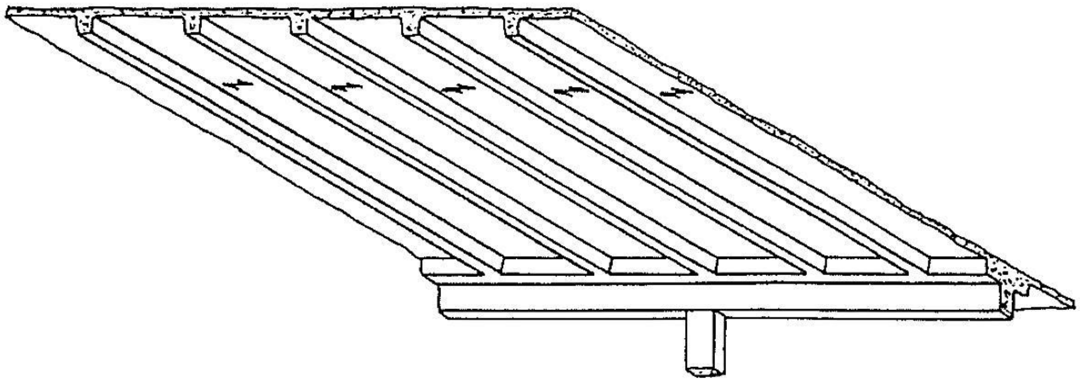


Figure 3.22. One-Way Pan Joists and Beams [47]

3.9.3 One-Way Slab on Beams and Girders

A one-way slab spans between beams at a comparatively near spacing while the beams are confirmed by girders that carry-over the load to the columns. The Figure 4.26 One-way slab on beams and girders. Short spanning slab may be slim, from 3 to 6 in. (7.6-15 cm) thick, while the system is adequate of supplying long spans of up to 46 ft (14 m). The primary merits of the system are its long span potentiality and its compatibility with a two-way lateral load resisting rigid-frame structure [47].

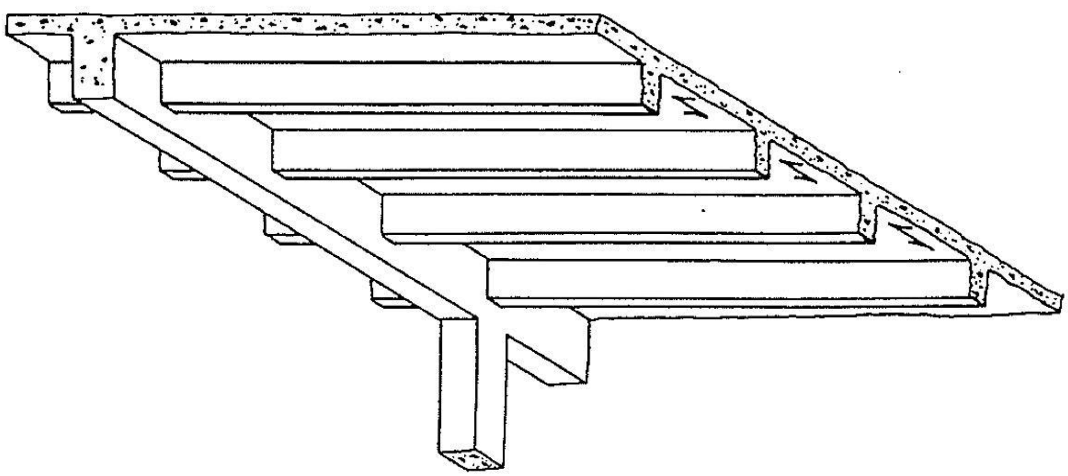


Figure 3.23. One-Way Slab on Beams and Girders [47]

3.9.4 Two-Way Flat Plate

A constant thick, two-way reinforced slab is supported directly by columns or individual short walls. It can span up to 26 ft (8 m) in the ordinary reinforced form and up to 36 ft (11 m) when posttensioned. Because of its easiness, it is the most economical floor system in terms of formwork and reinforcement. Its consistent thickness leaves extensive freedom in the location of the supporting columns and walls and. with the possibility of utilizing the dear soffit as a ceiling; it results in lower limit story height [47].

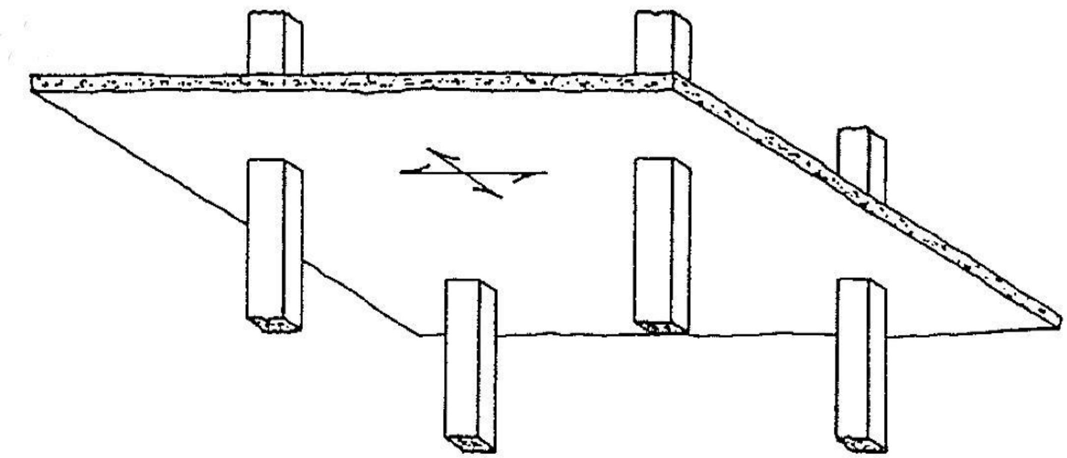


Figure 3.24. Two-Way Flat Plate [47]

3.9.5 Two-Way Flat Slab

The flat slabs vary from the flat plate in having capitals and/or drop panels at the tops of the columns. The capitals increment the shear capacity, while two-way flat plate. (The drop panels increase both the shear and negative moment capacities at the supports, where the maximum values happen. The flat slab is therefore more appropriate than the flat plate for larger loading and taller spans and. in similar positions. would necessitate lower concrete and reinforcement. It is most befittingly utilized in square, or near-to-square, arrangements [47].

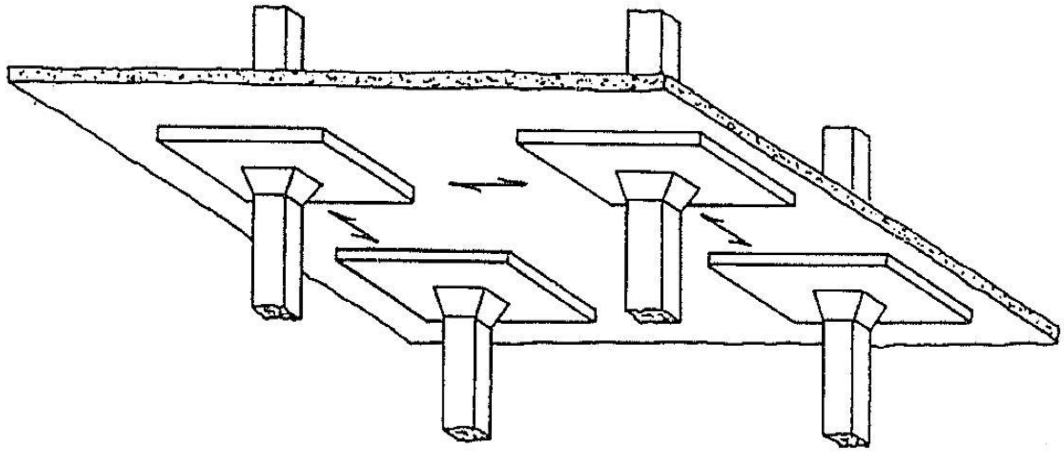


Figure 3.25. Two-Way Flat Slab [47]

3.9.6 Waffle Flat Slabs

A slab is propped by a square grid of nearly spaced joists with filler panels over the columns. The slab and joists are teemed integrally over square, domed forms that are dropped around the columns to create the filler panels. The forms, which are of sizes up to 30 in. (76 m) square and up to 20 in. (50 cm) deep, supply a geometrically occupying soffit, which is frequently left without additional finish as the ceiling [47].

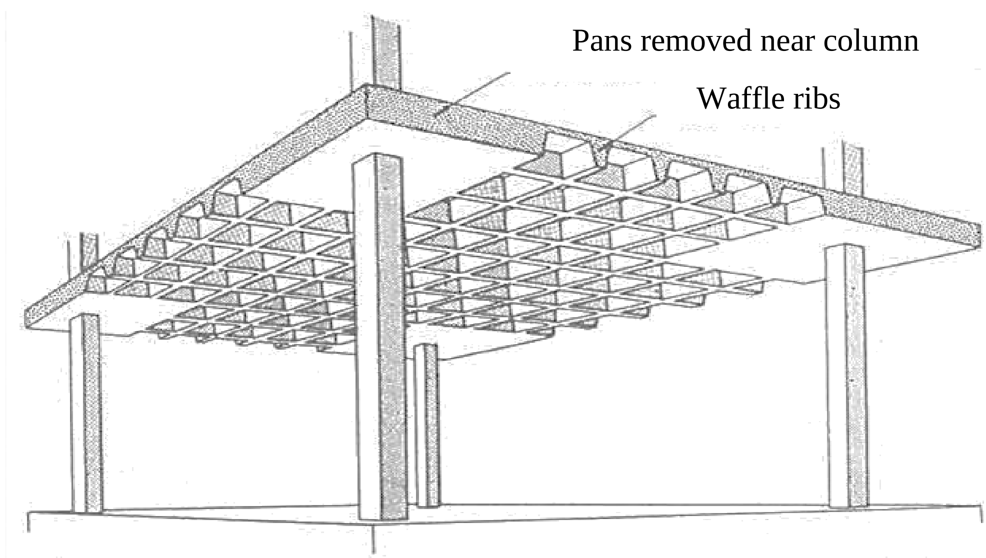


Figure 1 Figure 3.26. Waffle Flat Slabs [47]

3.9.7 Two-Way Slab and Beam

The slab spans two ways between perpendiculars adjusts of beams that carry-over the load to the columns or walls. The two-way system provides a slim slab and is economical in concrete and reinforcement. It is also agreeable with a lateral load-resisting rigid-frame structure. The upper limit of length-to-width ratio for a slab to be competent in two directions is approximately two [47].

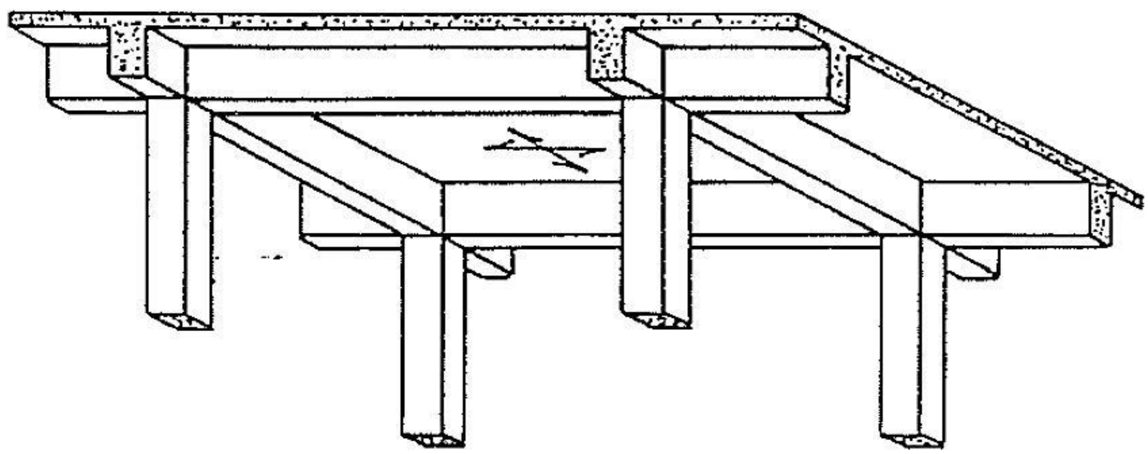


Figure 3.27. Two-Way Slab and Beam [47]

3.10. Analysis and Design of Tall Buildings

A reasonably exact appraisal of a planned tall structure's behavior is essential to form a properly representative model for analysis. A tall structure is basically a vertical cantilever that is subjected to axial loading by gravity and to transverse loading by wind or earthquake.

Gravity live loading acts on the slabs, which carry-over it horizontally to the vertical walls and columns through which it authorizes to the foundation. The magnitude of axial loading in the vertical components is calculated from the slab affluent areas, and its computation is not commonly regarded to be a hard problem. Horizontal loading exerts at each floor of a building a shear, a moment, and some of the times. a torque, which have maximum values at the base of the structure that increment quickly with the building's height. The reaction of a structure to horizontal loading, in having to carry the external shear, moment, and torque, is harder than its first-order reaction to gravity loading. The realization of the structure's behavior under horizontal loading and the constitution of the agreeing model are commonly the ascendant problems of analysis. The principal criterion of an acceptable model is that under horizontal loading it should deflect likewise to the prototype structure.

The resistance of the structure to the external moment is supplied by flexure of the vertical components, and by their axial action acting as the chords of a vertical truss. The allotment of the external moment between the flexural and axial actions of the vertical components depends upon the vertical shearing stiffness of the " web" system connecting the vertical components, that is, the girders, slabs, vertical diaphragms. and bracing. The stiffer the shear joining, the bigger the proportion of the external moment that is carried by axial forces in the vertical members, and the more rigid and more efficiently the structure behaves.

The named flexural and axial actions of the vertical components and the shear action of the connecting members are related. And their qualifying donations specify the basic characteristics of the structure. It is requisite in forming a model to valuate the nature and degree of the vertical shear stiffness between the vertical components so that the resulting flexural and axially gave resisting moments will be distributed property.

The horizontal shear at any level in a tall structure is resisted by shear in the vertical members and by the horizontal component of the axial force in any diagonal bracing at that level. If the model has been decently made with respect to its moment resistance, the external shear will mechanically be decently distributed between the components.

Torsion on a building is resisted principally by shear in the vertical components, by the horizontal components of axial force in any diagonal bracing members, and by the shear and distorting torque resistance of elevator, stair, and service shafts. If the single bents, and vertical components with specified torque constants, arc aright modeled and located in the model, and their horizontal shear connections are aright mocked up, their donation to the torsional resistance of the structure will be correctly depicted also.

A structure's resistance to bending and torsion can be importantly acted upon also by the vertical shearing action between connected perpendicular bents or walls. It is significant therefore that this is decently included in the model by insuring the vertical connections between perpendicular components.

Having evaluated a planned structure's ascendant modes of behavior, the formation of an suitable model needs next a knowledge of the uncommitted modeling elements and their methods of connection [47].

3.10.1 Tall Building Behavior during Earthquakes

The behavior of a tall building during an earthquake is a vibration problem. The seismic movements of the ground do not harm a building by impact as does a saboteurs ball, or by outwardly used pressure such as wind, but preferably by internally engendered inertial forces made by vibration of the building mass. An increment in the mass has two unsuitable effects on the earthquake design. First, it results in an increment in the force, and second, it can make buckling of vertical elements such as columns and walls when the mass downing maintains its force on a member bent or took out of perpendicular by the lateral forces. This phenomenon is called the p-Δ effect.

The larger vertical force, the larger the motion ascribable p-Δ, although buildings mostly have bigger vertical-load-carrying capacity because of gravity load necessities of the codes, the P-Δ problem is not eased. It is almost all of the time the vertical load that makes buildings to collapse; in earthquakes, buildings do not fall over they fall down.

The structure is vibrate when the seismic movements of the ground is made, and the bountifulness and distribution of dynamic deformations and their continuance are of interest to the engineer. The main aim of earth Seismic Design 135 quake design is that the building should not be a risk to life and limb in the issue of a strong shaking. During average ground shaking that has an important probability of happening during the life of the structure, the vibrations perhaps in the elastic ambit with no destructive bountifulness, but during strong ground shaking, members may undergo plastic strain and there perhaps a few cracking [46].

3.10.2 Building Deflections

Earthquake-induced movements, even when they are fiercer than those stimulated by wind are, educe a wholly dissimilar type of human response. First, because earthquakes happen a lot less frequently than windstorms, and second, because the length of movement made by earthquake is usually short and impermanent in nature. People who undergo earthquakes are thankful that they have lived on the trauma and are less bent to be supercritical of building movement. Earthquakes are, therefore, a safety besides a human uncomfortableness phenomenon. Static lateral deflections alike to those made by wind loads have a significant effect on the structural unity of the components of the buildings. These should be confined so as not to make any distress in structural frames, members, or joining, likewise as such architectural components as segmentations, claddings, and windows. Therefore, likewise valuating the dynamic characteristics of the principal structural system, it is requirement to supply for big deformations that happen between different components of a building. Prevention of outright collapse of the building under stark but rarefied earthquakes while restrictive the nonstructural damage to a lower limit during frequent but medium earth tremors forms the primary fundamental philosophy of seismic design. This is took in the following section [46].

3.11 Stability of High-Rise Buildings

The raising height and higher structural efficiency of tall buildings have led to their having littler reserves of stiffness and. Therefore, stability. A check on the effects of this decrease in stability has get an significant section of the building design technique.

In dealing stability, that of the structure in general, as well as that of members that comprise the building, must be analyzed. However, the design for stability of single columns is the equivalent for tall buildings as for low-rise structures, and this look is commonly addressed by national Design Code requirements. This treatment on stability is. Therefore, referred with the totally structure, or with all stories of the structure, rather than with separate members.

The whole gravity load on a tall structure is commonly a little proportion of the load that would be demanded to make overall buckling. Accordingly, the possibility of collapse in this path is far. The better stability consideration refers the second-order effects of gravity loading acting on transverse displacements made by horizontal loading, or acting on first vertical misalignments in the structure. The vertical eccentricity of the gravity loading makes increments in the transverse displacements and in the member moments. In an uttermost, case this alleged P-Delta effect perhaps enough to start collapse. Commonly, however, the P-Delta effects are either little and perhaps ignored, or of only average magnitude, in which case they can be suited by low increments in the sizes of the members. Nevertheless, in the design of any tall building, it is careful to evaluate whether P-Delta affects perhaps important and. if so. to calculate for them in the analysis and design. In this chapter, techniques of analysis for overall buckling and for P-Delta effects are presented [47].

CHAPTER 4

4. NUMERICAL ANALYSIS RESULTS AND DISCUSION

4.1 Introduction

Numerical analysis is the area of mathematics and computer science that produces, analyses, and applies algorithms for resolving numerically the problems of uninterrupted mathematics. Specified problems arise usually from real-world applications of algebra, geometry and calculus, and they require variables which change ceaselessly; these problems happen passim the natural sciences, social sciences, engineering, medicine, and commercial enterprise. During the ago half-century, the development in force and accessibility of digital computers has guided to an growing utilize of real mathematical patterns in science and engineering, and numerical analysis of growing sophistry has been required to resolve these more elaborated mathematical patterns of the cosmos. The conventional theoretical field of numerical analysis changes from quite academic mathematical examines to computer science issues.

With the development in importance of utilizing computers to accomplish numerical operations in resolving mathematical patterns of the world, an field called technological calculation or computational science has formed during the 1980s and 1990s. This region considers the utilize of numerical analysis from a computing linear perspective. It is worried with utilizing the heftiest tools of numerical analysis, computer graphics, emblematic mathematical calculations, and graphical user interfaces to do it simpler for a user to arrange, resolve, and construe complex mathematical patterns of the actual world.

4.2 Discription of The Problems

This study is consist of 54 models, the models analyzed under defetent types of loading according to two international building codes (american code and euro code), the models divided equally between the two codes. The models composed of the effective area to the resistance of the lateral loads with different percentage (1%, 2%

and 4%), each of this percentage consisting of three structural forms and every form formed from three different heights 10, 20 and 40 stories. Two common types of structural load bearing system are used in this study the first one is rigid frame that represent in Model 1 and the second one is wall frame that also represent in Model 2 and Model 3. The plan of models that used in this study are shown in Figures 4.1-3 below.

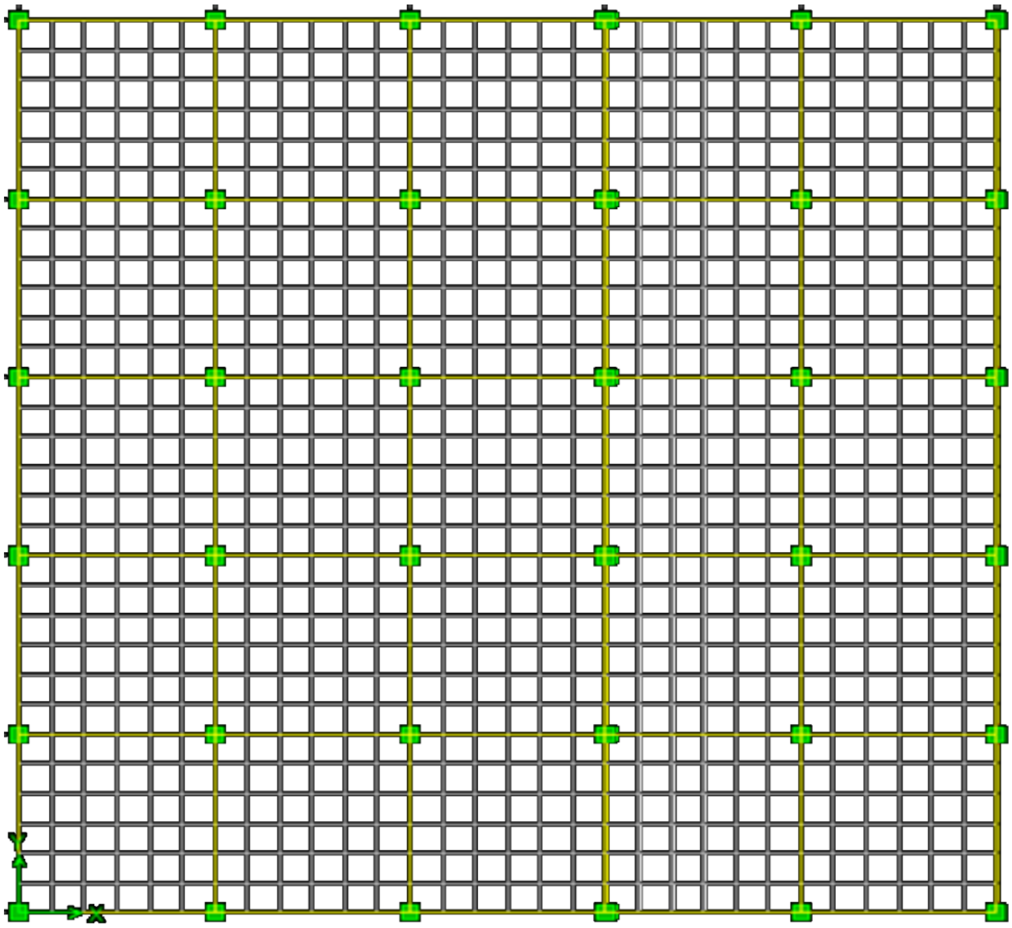


Figure 4.1. Model 1

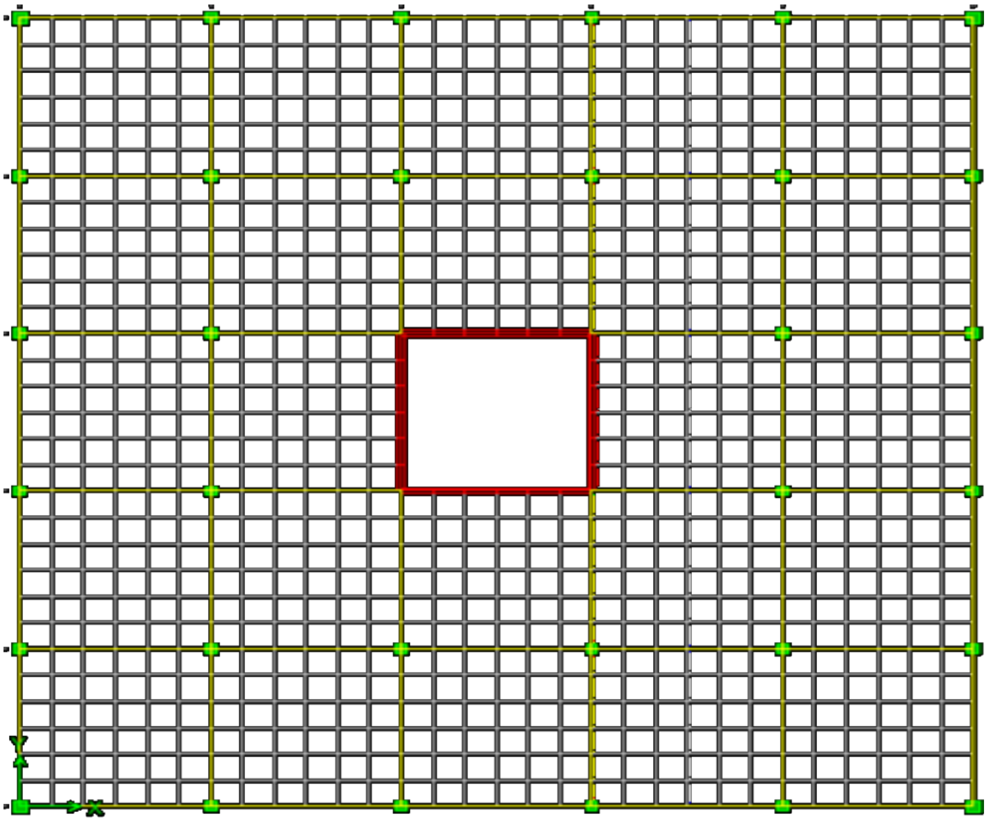


Figure 4.2. Model 2

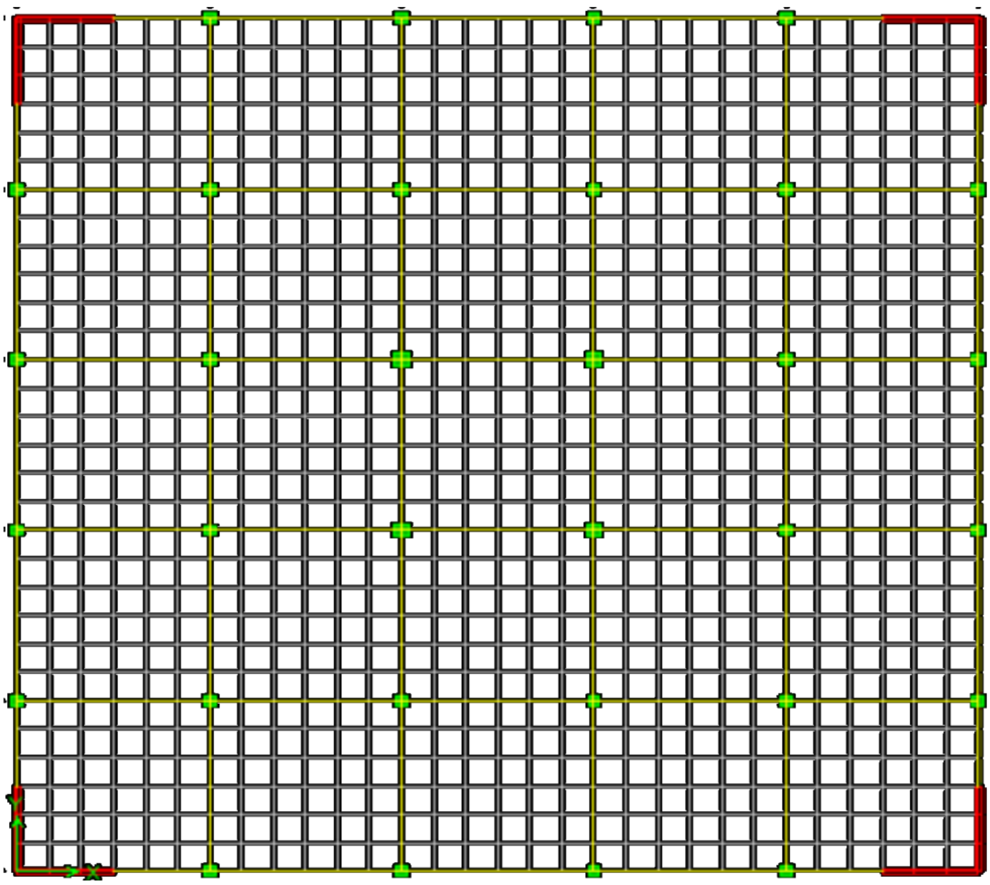


Figure 4.3. Model 3

In this study the plan of all models is symmetrical with dimension 30x30 m divided in five bays 6m in each direction. For beams, a typical section is uesd for all models 0.6 x 0.4 m, also for slabs a typical thickness is used for all models 0.15m, the height of base story is 4m and 3m for typical stories. The colums and walls have a different cross section for each structural form and percentage of effective area as shown in Tables 4.1 and 4.2.

Table 4.1. Column Geometric Data

Structural form	Effective area m^2				
	1%		2%		4%
	Column 1	Column 2	Column 1	Column 2	Column 1
Model 1	0.50x0.50	____	0.75x0.75	0.65x0.65	1.00x1.00
Model 2	0.35x0.35	0.45x0.45	0.60x0.60	0.55x0.55	0.90x0.90
Model 3	0.35x0.35	0.45x0.45	0.58x0.58	____	0.90x0.90

Tabel 4.2. Walls Geometric Data

Structural form	Effective area m^2		
	1%	2%	4%
Model 2	0.20x6.00	0.30x6.00	0.42x6.00
Model 3	0.20x3.00	0.30x3.00	0.42x3.00

The flow charts below shows the distribution of the models according to (the codes, the percentage of effective area, the structural forms and the height of building).

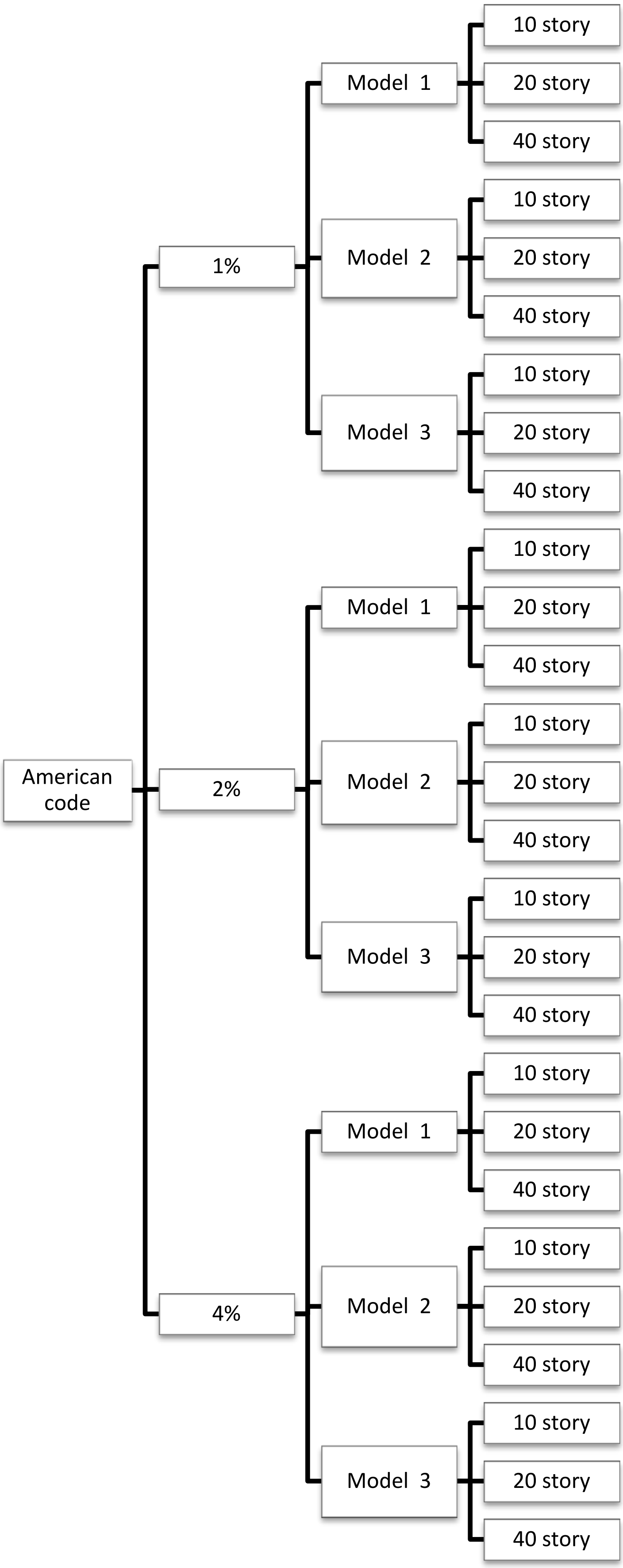


Figure 4.4 Distribution of the models

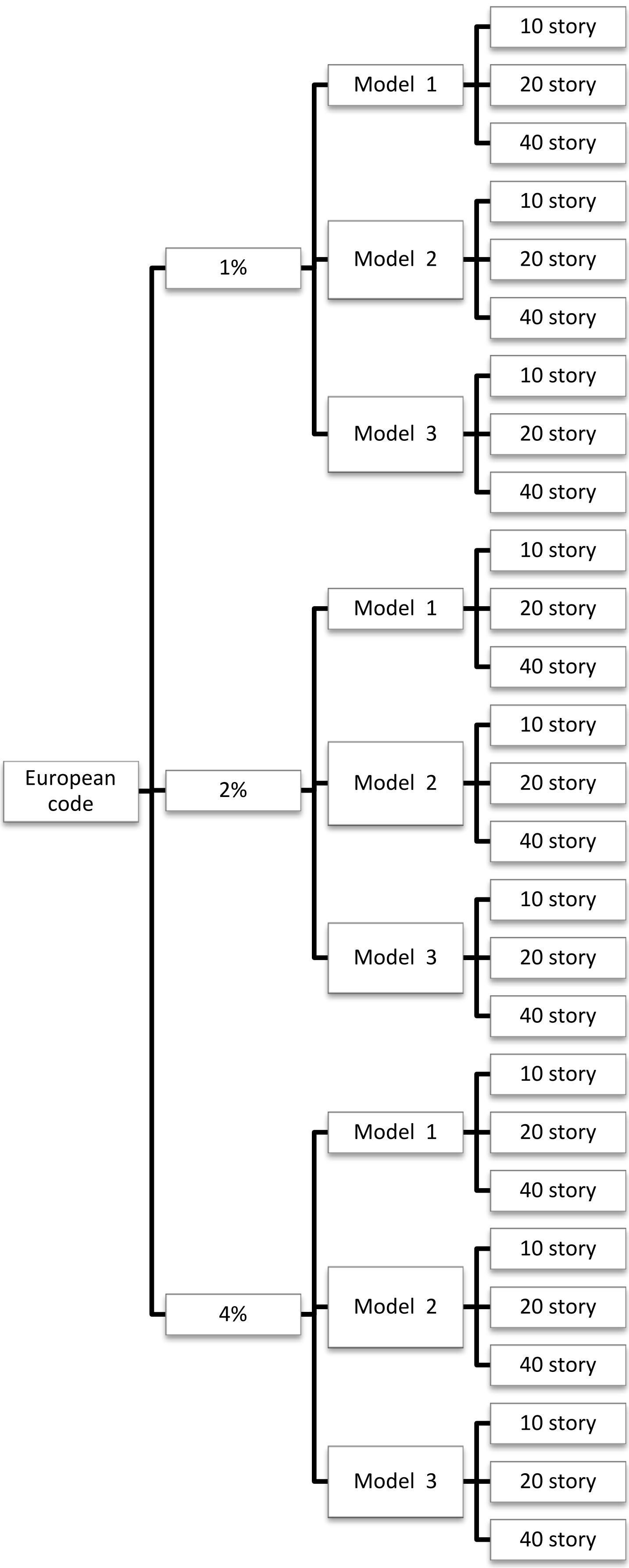


Figure 4.5 Distribution of the models

4.2.1 Boundary Conditions

The models are bounded with the following conditions:

1- The foundations supports are fixed
2- All materials have linear behavior.
3- Free sideway deformation.
4- All sections have linear geometries.

4.2.2 Material

The materials that used in this study were same for all models as shown in table

Table 4.3. Materials properties data

Concrete	Weight per unit volume	24 kN/m3
	Modulus of elasticity	24.82 GPa
	Poisson's ratio	0.2
	Specified conc. Copm. Strenght , f'_c	27.6 MPa
Steel	Bending rein. Yiled stress , f_y	413.7 MPa
	Shear rein. Yiled stress , f_{ys}	413.7 MPa

4. 3 International Codes

4.3.1 ACI 318

The American Concrete Institute (ACI) is the regulating government agency for whole concrete construction in the United States. It was built in 1904 to serve and exemplify user occupies in the area of concrete. The ACI releases a lot of dissimilar criteria, but the almost generally documented criterion utilized by designers and engineers is the ACI 318 “Building Code Requirements for Structural Concrete.” It is updated every 3 years and the latest version is ACI 318-011 updated in 2011.

Almost all Building Codes, including the IBC, refer to ACI 318 as the base for constructive design of concrete members.

4.3.1.1 IBC code

The International Building Code provisions supply many profits, amongst which is the model code growth operation that provides an international assembly for building professionals to talk about functioning and normative code necessities. This assembly supplies a superior field to argument suggested rescripts. This model code also advances international consistence in the application of victuals.

This comprehensive building code builds minimal rules for construction systems utilizing prescriptive and functioning- pertained victuals. It is established on broad-based rules that produce potential to utilize of Modern materials and new construction designs.

4.3.1.2 ASCE 7-05

The American Society of Civil Engineers (ASCE), this standard supplies minimal load necessaries for the design of constructions and additional structures that are susceptible to building code necessaries. Loads and called for load combinations, which have been evolved to be utilized unitedly, are set forth for strength design and admissible stress design. For design strengths and admissible stress bounds, design stipulations for formal structural materials utilized in buildings and adjustments comprised in this criterion shall be followed.

4.3.2 Eurocode

The Eurocode standards supply basic constructive design rules for daily apply for the design of all constructions and element productions of both conventional and advanced nature. They embracing the constructive design of most of works and productions in the structure area. Unusual, new or highly unaccustomed shapes of structure or design statuses are not specifically covered up and another adept considerateness will be demanded by the designer.

Eurocode standards realize the obligation of regulatory agency in each Member State and have safeguarded their correct to find values accompanying regulative safety matters at general stage where these go on to change from State to State. These are dealt with in the chief prescriptive text of this Eurocode Part by apply of a ambit of values, classifies or symbols with related to footnotes.

4.3.2.1 Eurocode 8

This European Standard, Eurocode 8: Design of structures for earthquake resistance: technological commission CEN/TC 250 “Structural Eurocodes”, the secretariat of which is carried by BSI, has set up universal formulas, seismic activities and formulas for buildings. CEN/TC 250 is responsible for all Structural Eurocodes.

This European criterion shall be given the condition of a National Standard, either by publishing of an identical text or by endorsement, at the current by June 2005, and conflicting national standards shall be withdrawn at latest by March 2010.

4.3.2.2 Eurocode 1 2005

This code establishes guidance on the conclusion of natural wind actions for the structural design of building and civil engineering works for each of the loaded areas under consideration. This admits the all construction or components of the construction or members attached to the construction, e.g. Elements, cladding units and their reparations, safety and noise barriers.

4.4 Loads

The models in this study is subject to different types of loads gravity load, wind load and seismic load according to different cods (American code and european code).

4.4.1 Gravity loads

Gravity loads in this study is made up of dead loads and live loads, the dead load include self weight of structural, weight of finishing on slab and Weight of wall on, the live load included load on slab only as detailed in the Table 4.4.

4.4.2 Lateral loads

The lateral loads in this study represented by wind loads and seismic loads these loads assign according to different codes as detailed below.

Table 4.4. Gravity loads

Load type	Details	Value	
Dead load	Self weight of structural members calculate automatically using self wight multipier in etabs		
	Weight of finishing on slab	1.5 KN/m^2	
	Weight of wall on enterer beam	1.5 KN/m	
	Weight of wall on outer beam	4 KN/m	
Live load	According to ACI code the value of live load on slab for office building	2.4 KN/m^2 (50psf)	Table 4-1 (ASCE 7-05)
	According to Euro code the value of live load on slab for office building	2.5 KN/m^2	RC design to Eurocode Appendix

4.4.2.1 Wind load according to (ASCE 7-05) code

The parameters that are need to define wind load in ETABS to assign the load to models is calculat by ASCE 7-05 code , Wind speed = (90 mph), Exposure type = (c) from section (C6.5.6), importance factor = (1), wind direction angle = 0 for x-axis and 90 for y-axis, topographical factor kz = (1) according to figure 6-4, gust factor= (0.85) according to section (6.5.8), directionality factor kd = (0.85) from Table 6-4, Leeward coff. C_p = 0.5, windward coff. C_p = 0.8 from Figure 6-6, Design Wind Load Cases = (all cases e_1 ratio = 0.15 e_2 ratio = 0.15) according to Figure 9-6.

4.4.2.2 Wind load according to (Eurocode 1 2005)

To assign this load to the models firstly must define the parameter that need according to Eurocode 1 2005, wind speed = 28.1m/s, terrain category = II from table 4.1, wind direction angle = 0 for x-axis and 90 for y-axis, windward coff. Cp = 0.8, Leeward coff. Cp = 0.5, orography factor, Co(z) = (1) according to section 4.3.3, turbulence factor, k1 = (1) according to section 4.4, structural factor Cs Cd = (0.85 for 10 story building 0.9 for 20 story building from Figure D.2 and 1.1 for 40 story building calculated from equation (6.1) in section 6.3.1.

4.4.2.3 Seismic load (IBC 2006)

The parameter that are need to define seismic load in ETABS to assign it on models it calculate according to IBC 2006 time period = (program calc. = 0.028; 0.8), response modification, R = (8), occupancy importance, I = (1), 0.2 sec. spectral, S_s = (0.582), 1 sec. spectral, S_1 = (0.233), Long-period transition = (4), Site class = (c) from table 1613.5.2.

4.4.2.4 Seismic load (Eurocode 8)

The parameter that are required to assign the seismic load in ETABS must define firstly, this parameter are calculat according to euro code 8. time period = program calc., Ground type = (b) from table 3.1, Spectrum type = (1), Ground acceleration, ag = (0.24), Lower bound factor, β = (0.2) according to section 3.2.2.5, Behavior factor, q = (5.85) from table 5.1, Correction factor, l = (0.85) according to section 4.3.3.2.2.

4.5 ETABS

ETABS is a sophisticated, yet easy to use, special purpose analysis and design program developed specifically for building systems. ETABS features an intuitive and powerful graphical interface coupled with unmatched modeling, analytical, design, and detailing procedures, all integrated using a common database. 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.

4.5.1 Capabilities of ETABS

ETABS offers the widest assortment of analysis and design tools available 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, buildings with curved beams, walls and floor edges, buildings with steel, concrete, composite or joist floor framing, projects with multiple towers, complex shear walls and cores 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, capacity check of beam-to-column and beam-to-beam steel connections, explicit panel-zone deformations, foundation/support settlement, large displacement analyses, buildings with base isolators and dampers, design optimization for steel and concrete frames, design capacity check of steel column base plates, floor modeling with rigid or semi-rigid diaphragms, automated vertical live load reductions**.**

4.5.2 Analysis Capabilities

- Linear static analysis
- Linear dynamic analysis
- Static and dynamic p-delta analysis
- Static non-linear analysis
- Dynamic non-linear analysis
- Pushover analysis
- Multiple response spectrum analysis
- Multiple time history analysis
- Construction sequence loading analysis

4.6 Modeling Process

In this thesis the models are formad using three stractural form, three differents hights 10, 20 and 40 stories are created foe each structural form, the forms with taken in this work are rigid frame, rigid frame with core shera wall and rigid frame with corner shear wall. Then, each form divided in three groups according to percentage of effective area of the member that resist of the affect of lateral loads (columns and shear wall).

To create these models by ETABS should be followed some steps.

Firstly, set the grid of draw window according to the dimensions of plan and spacing between columns and heights of stories.

Secondly, define the materials that will use in these models and their properties, this is done from define menu and then go to the material properties selection to difene material and their properties .

Then define the cross section, material and reinforcemt data of columns and beam that used in model, go to define menu and select frame section option to define it, after that go to define menu again and select wall/slab/deck section option to define material, thickness and type of slab and shear wall , the slab and shear wall is define as a shell element.

After define the material, cross section and reinforcement data of the beams and columns, thickness and type of slab and shear wall begin in modeling process and drawing all members, first start in drawing the columns from draw menu select draw line object then select draw line (plan, elev, 3d) and then define properties of object (type of line = fram, property = column, moment releases = continuous, plan offset normal = 0) after define all properties of object begining in drawing the colums according to locations.

For drawing the beams follow the same steps to drawing the column except need to change the property of object to beam.

To drawing the slabs go to draw menu select draw area object then select draw rectangualar areas (plan, elev) and then from this option define properties of object (property = slab).

Finaly to drawing the shear walls go to draw menu select draw area object then select draw walls (plan) from this define the peoperties of object (type of area = pier, property = wall1, plan offset normal = 0).

The option propety that available in properties of object window is refer to name of Structural members that predefined for each members.

After completing the modeling process assign the loads on model (gravity load, wind load, seismic load). First assign the gravity load that consist of dead and live load dead load represented in self weight of the structural, weight of finishing on slab and weight of walls on beams, live load consist of load on slab only,to assign the dead and live load on slab first of all select the slabs and then form assign menu select shell/area load then select uniform, in uniform serface load window chose the load case name and put value of load. And to assign the dead load on beam first select the beams and then go to assign menu select frame load line then select distributed, in frame distributed loads window chose the load case name and put value of load.

Now assigning the later load that represented in wind and seismic load from define menu select define static load cases then select define static load case names. the name of load, type of load, self weight multiplier and code that will use in lateral loads from autolateral load field, defining from define static load case names window.

After define all loads meshing the beams and slabs, to do this process first should select the members beamsor slabs, for slabs go to edit menu select mesh areas then mesh select areas will open, from this window select mesh quads/triangles into and then put the number that required to meshing the slabs, for beams also select the beams that required to divide it and then go to edit menu select divide lines then select divide rselected lines window will open from this window put number of divisions required**.**

All the steps mentioned in privouse pragraphes which have already been mentioned above was applied in base floor only, after completeing all these setps several stories were added according to the required number of storeies, from edit menu select edit story then select insert story, from insert new story window definr the number of stories that need to creat, hight of story and replicat new story from existing story, these process will done to all models in different hights.

Last setp in modeling is assigning the foundations for all models as a fixed support, select end of columns at base and then from assign menu select joint/point then select restrainta(supports) and then chose fixed support.

Now modeling process is complete and the model is ready to run analysis, from analysis menu select run analysis. 3D view for Model 3 shown in Figure 4.6

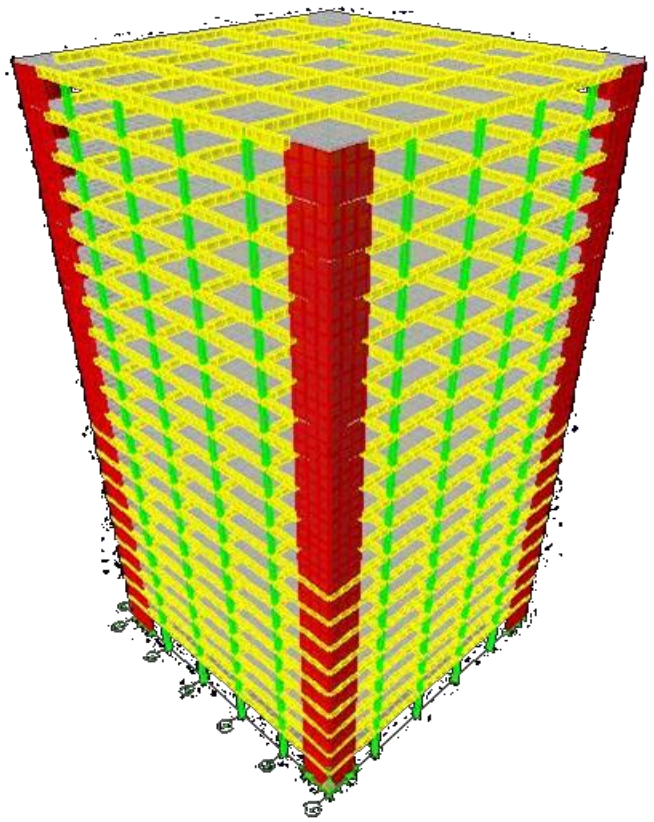


Figure 4.6. 3D view Model 3

4.6 Numerical results

After analyzing models the results of numerical analysis for all models (fundamental period results are tabulated at Tables 4.5-7. and shown in Figures 4.7-9., base shear results are tabulated at Tables 4.8-13. and shown in Figures 4.10-21., maximum displacement values are tabulated at Tables 4.14-19. and shown in Figures 4.22-33. and maximum drift values are tabulated at Tables 4.20-25. and shown in Figures 4.34-51) are presented in this section, The values of the results are varies depending on the structural form, the percentage of effective area in plan and code that used.

Table 4.5. Fundamental period for 1%

Fundamental period (sec)	Model 1	Model 2	Model 3
10 stories	1.202	0.863	1.090
20 story	2.389	2.024	2.495
40 story	5.139	5.317	5.711

Table 4.6. Fundamental period for 2%

Fundamental period (sec)	Model 1	Model 2	Model 3
10 stories	0.984	0.650	0.785
20 story	2.006	1.516	1.757
40 story	4.275	3.834	3.988

Table 4.7. Fundamental period for 4%

Fundamental period (sec)	Model 1	Model 2	Model 3
10 stories	0.900	0.576	0.707
20 story	1.915	1.394	1.605
40 story	4.099	3.432	3.641

Table 4.8. Base shear for 1% according to wind load in x-direction

Base shear (kN)	ASCE 7-05			EUROCODE 1 2005		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
10 stories	938	938	938	1218	1218	1218
20 story	2182	2182	2182	3053	3053	3053
40 story	5060	5060	5060	8708	8708	8708

Table 4.9. Base shear for 2% according to wind load in x-direction

Base shear (kN)	ASCE 7-05			EUROCODE 1 2005		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
10 stories	938	938	938	1218	1218	1218
20 story	2182	2182	2182	3053	3053	3053
40 story	5060	5060	5060	8708	8708	8708

Table 4.10. Base shear for 4% according to wind load in x-direction

Base shear (kN)	ASCE 7-05			EUROCODE 1 2005		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
10 stories	938	938	938	1218	1218	1218
20 story	2182	2182	2182	3053	3053	3053
40 story	5060	5060	5060	8708	8708	8708

Table 4.11. Base shear for 1% according to quake load in x-direction

Base shear (kN)	IBC 2006			EUROCODE 8 2004		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
10 stories	1431	2134	1590	2460	3669	2733
20 story	2258	2180	2251	4625	4465	4610
40 story	4521	4366	4483	9258	8939	9180

Table 4.12. Base shear for 2% according to quake load in x-direction

Base shear (kN)	IBC 2006			EUROCODE 8 2004		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
10 stories	1917	3003	2417	3296	5163	4156
20 story	2481	2420	2471	5081	4922	5060
40 story	4971	4816	4927	10179	9862	10089

Table 4.13. Base shear for 4% according to quake load in x-direction

Base shear (kN)	IBC 2006			EUROCODE 8 2004		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
10 stories	2477	3905	3169	4259	6713	5449
20 story	2938	3134	2930	6061	5863	6000
40 story	5894	5744	5853	12068	11761	11985

Table 4.14. Maximum displacement for 1% according to wind load in x-direction

Maximum displecement (cm)	ASCE 7-05			EUROCODE 1 2005		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
10 stories	0.726	0.355	0.649	0.985	0.488	0.891
20 story	3.502	2.920	4.099	5.123	4.315	6.403
40 story	20	23.660	25.100	35.949	42.769	45.245

Table 4.15. Maximum displacement for 2% according to wind load in x-direction

Maximum displecement (cm)	ASCE 7-05			EUROCODE 1 2005		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 2
10 stories	0.450	0.197	0.304	0.613	0.271	0.416
20 story	2.247	1.469	1.828	3.293	2.168	2.691
40 story	12.417	10.978	11.160	22.321	19.826	20.109

Table 4.16. Maximum displacement for 4% according to wind load in x-direction

Maximum displecement (cm)	ASCE 7-05			EUROCODE 1 2005		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
10 stories	0.330	0.141	0.212	0.451	0.194	0.290
20 story	1.748	1.050	1.292	2.567	1.550	1.902
40 story	9.547	7.288	7.822	17.169	13.157	14.093

Table 4.17. Maximum displacement for 1% according to quake load in x-direction

Maximum displecement (cm)	IBC 2006			EUROCODE 8 2004		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 2
10 stories	1.469	1.133	1.562	2.407	1.897	2.549
20 story	5.199	4.490	6.489	9.473	8.113	11.501
40 story	26.460	32.013	33.715	47.471	56.311	59.994

Table 4.18. Maximum displacement for 2% according to quake load in x-direction

Maximum displecement (cm)	IBC 2006			EUROCODE 8 2004		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 2
10 stories	1.225	0.864	1.067	2.030	1.470	1.787
20 story	3.627	2.393	3.005	6.714	4.456	5.575
40 story	17.985	16.202	16.388	32.318	28.601	29.200

Table 4.19. Maximum displacement for 4% according to quake load in x-direction

Maximum displecement (cm)	IBC 2006			EUROCODE 8 2004		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 2
10 stories	1.173	0.794	0.964	1.950	1.358	1.626
20 story	3.362	2.187	2.487	6.229	3.779	4.658
40 story	16.380	12.725	13.605	29.440	22.514	24.253

Table 4.20. Maximum drift ratio for 1% according to wind load in x-direction

Maximum drift ratio	ASCE 7-05			EUROCODE 1 2005		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
10 stories	0.000378	0.000133	0.000264	0.000503	0.000184	0.000362
20 story	0.000943	0.000581	0.000913	0.001339	0.000860	0.001339
40 story	0.002284	0.002453	0.002934	0.003968	0.004428	0.004988

Table 4.21. Maximum drift ratio for 2% according to wind load in x-direction

Maximum drift ratio	ASCE 7-05			EUROCODE 1 2005		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
10 stories	0.000236	0.000075	0.000130	0.000315	0.000103	0.000177
20 story	0.000606	0.000300	0.000422	0.000869	0.000443	0.000617
40 story	0.001523	0.001171	0.001286	0.002672	0.002109	0.002298

Table 4.22. Maximum drift ratio for 4% according to wind load in x-direction

Maximum drift ratio	ASCE 7-05			EUROCODE 1 2005		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
10 stories	0.000161	0.000054	0.000091	0.000212	0.000074	0.000125
20 story	0.000462	0.000216	0.000302	0.000667	0.000319	0.000441
40 story	0.001229	0.000809	0.000914	0.002170	0.001456	0.001633

Table 4.23. Maximum drift ratio for 1% according to quake load in x-direction

Maximum drift ratio	IBC 2006			EUROCODE 8 2004		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
10 stories	0.000634	0.000441	0.000617	0.001078	0.000734	0.001010
20 story	0.001032	0.000903	0.001340	0.002093	0.001621	0.002434
40 story	0.002567	0.003267	0.003554	0.004735	0.005762	0.006559

Table 4.24. Maximum drift ratio for 2% according to quake load in x-direction

Maximum drift ratio	IBC 2006			EUROCODE 8 2004		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
10 stories	0.000536	0.000333	0.000432	0.000926	0.000566	0.000726
20 story	0.000779	0.000483	0.000633	0.001546	0.000901	0.001203
40 story	0.001798	0.001664	0.001697	0.003401	0.002970	0.003131

Table 4.25. Maximum drift ratio for 4% according to quake load in x-direction

Maximum drift ratio	IBC 2006			EUROCODE 8 2004		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
10 stories	0.000523	0.000308	0.000396	0.000876	0.000527	0.000668
20 story	0.000754	0.000445	0.000533	0.001470	0.000769	0.001020
40 story	0.001708	0.001335	0.001419	0.003295	0.002410	0.002629

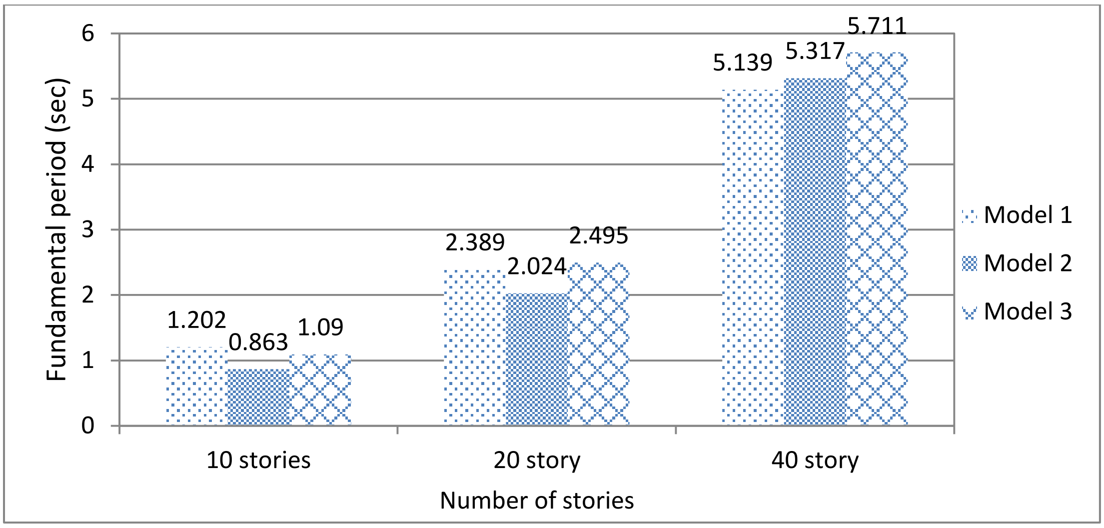


Figure 4.7. Fundamental period for 1%

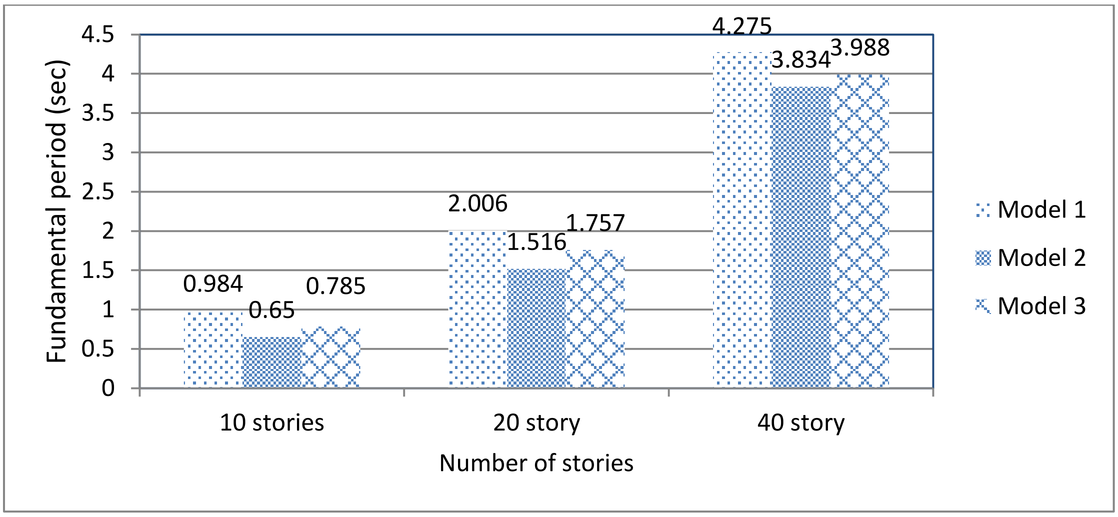


Figure 4.8. Fundamental period for 2%

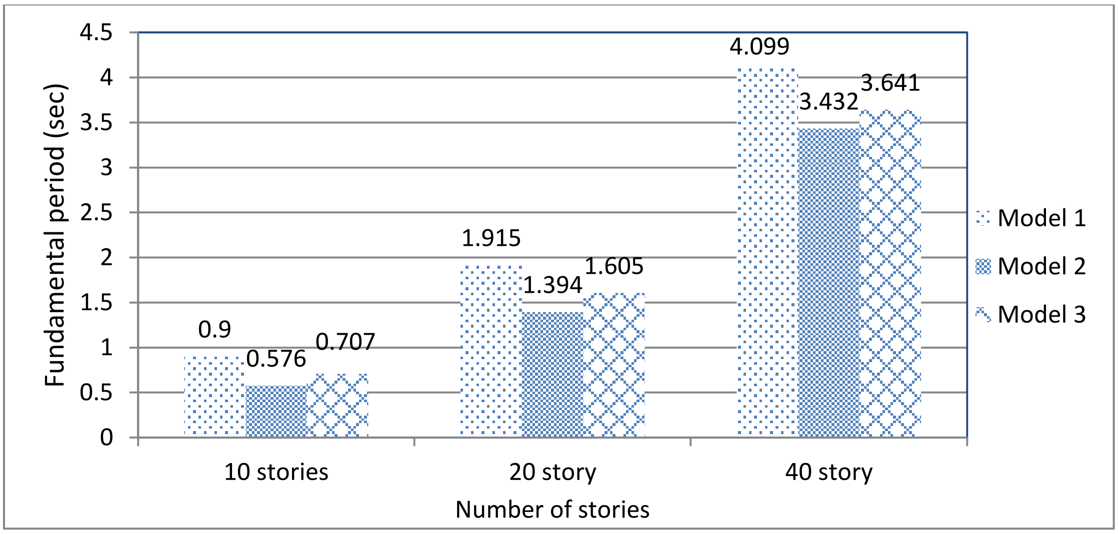


Figure 4.9. Fundamental period for 4%

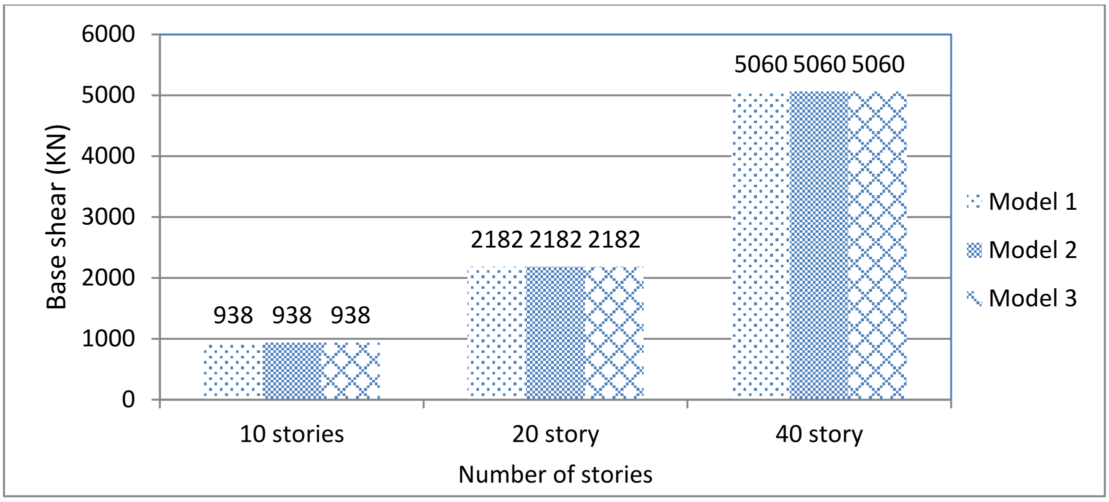


Figure 4.10. Base shear for 1% by wind load effect in x-direction according to ASCE 7-05

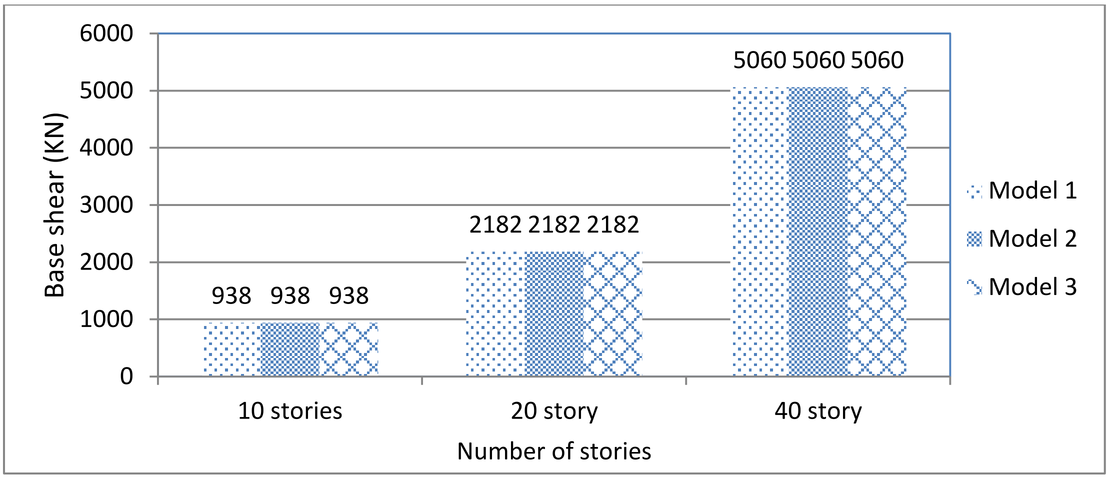


Figure 4.11. Base shear for 2% by wind load affect in x-direction according to ASCE 7-05

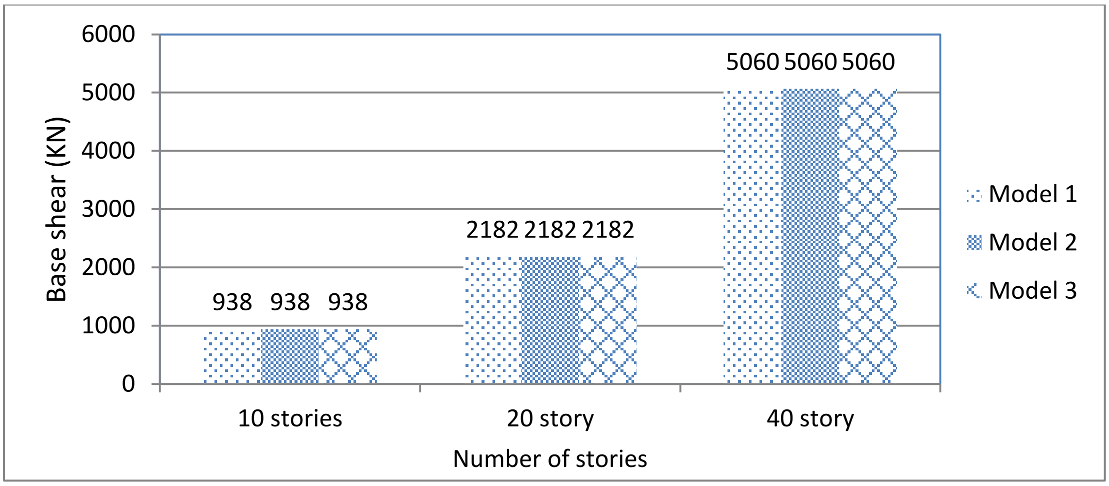


Figure 4.12. Base shear for 4% by wind load affect in x-direction according to ASCE 7-05

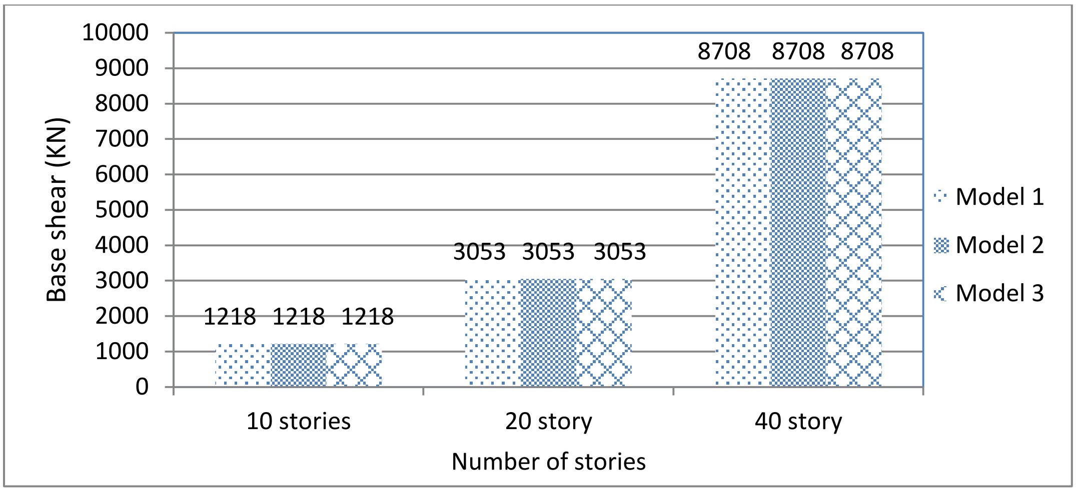


Figure 4.13. Base shear for 1%by wind load affect in x-direction according to EUROCODE 1 2005

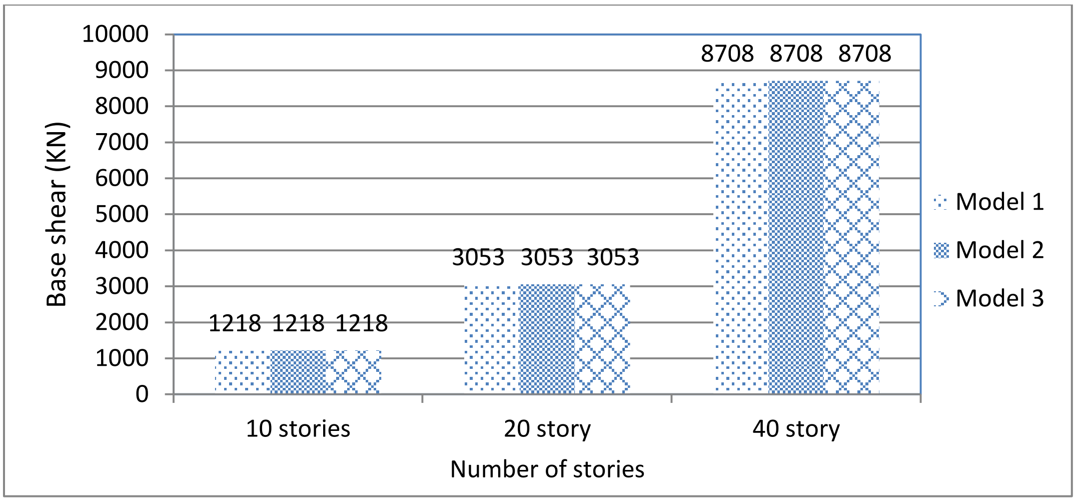


Figure 4.14. Base shear for 2%by wind load affect in x-direction according to EUROCODE 1 2005

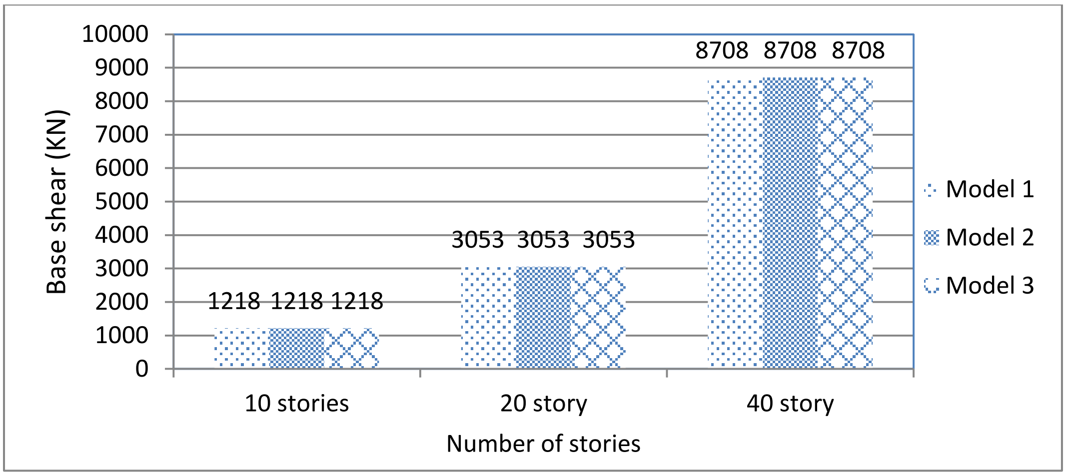


Figure 4.15. Base shear for 4%by wind load affect in x-direction according to EUROCODE 1 2005

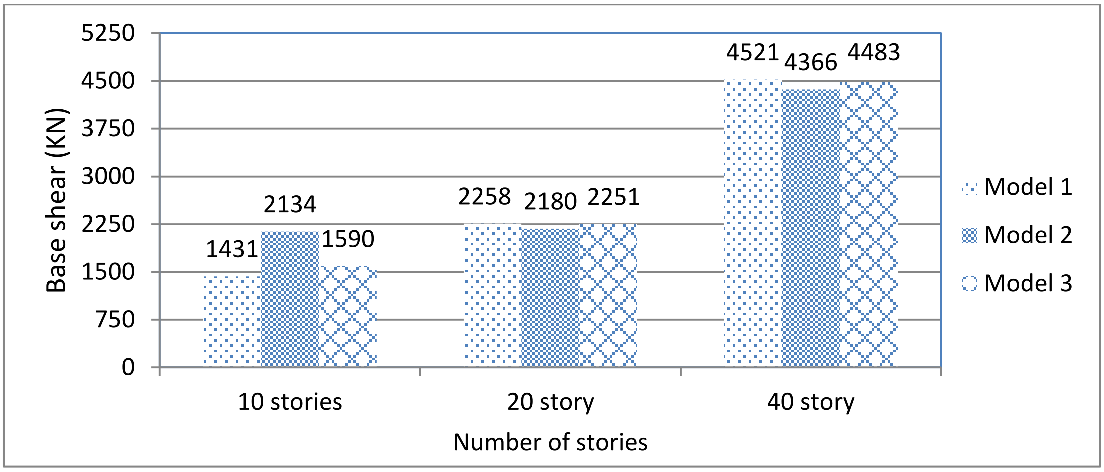


Figure 4.16. Base shear for 1% by quake load affect in x-direction according to IBC 2006

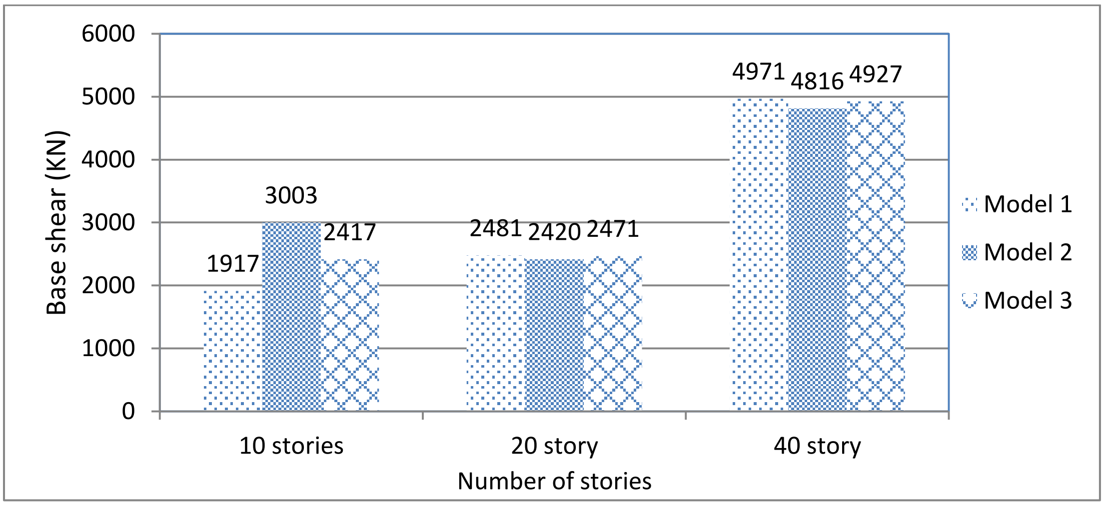


Figure 4.17. Base shear for 2% by quake load affect in x-direction according to IBC 2006

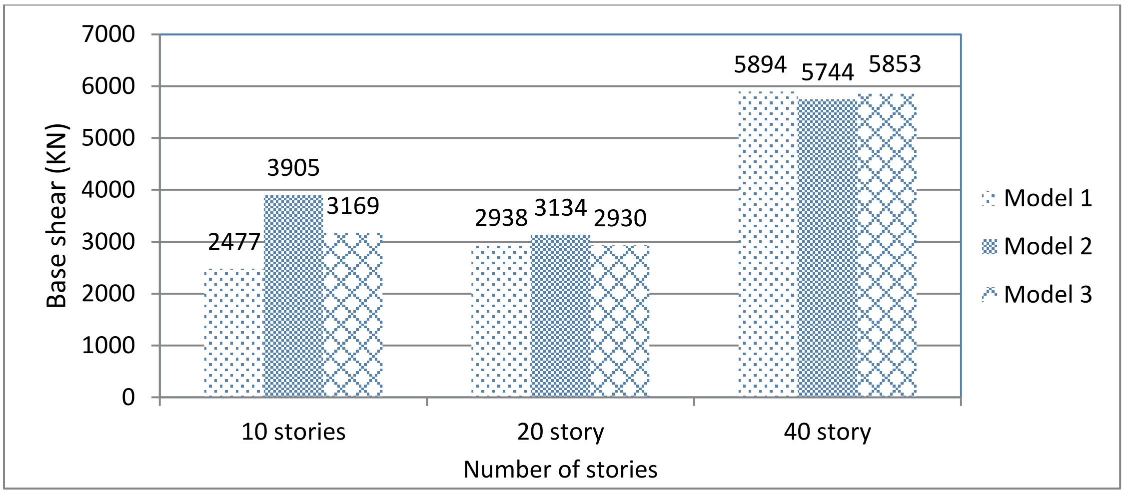


Figure 4.18. Base shear for 2% by quake load affect in x-direction according to IBC 2006

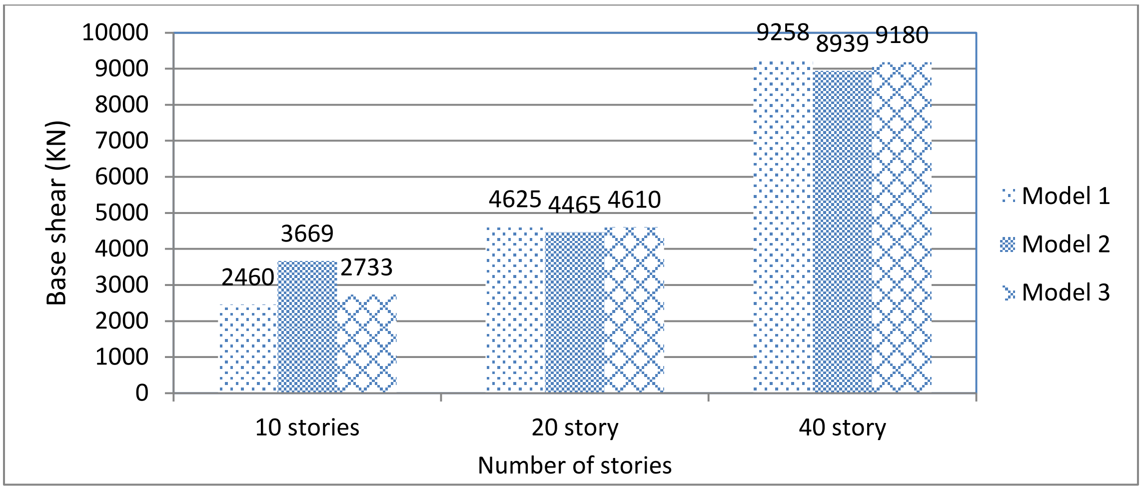


Figure 4.19. Base shear for 1% by quake load affect in x-direction according to EUROCODE 8 2004

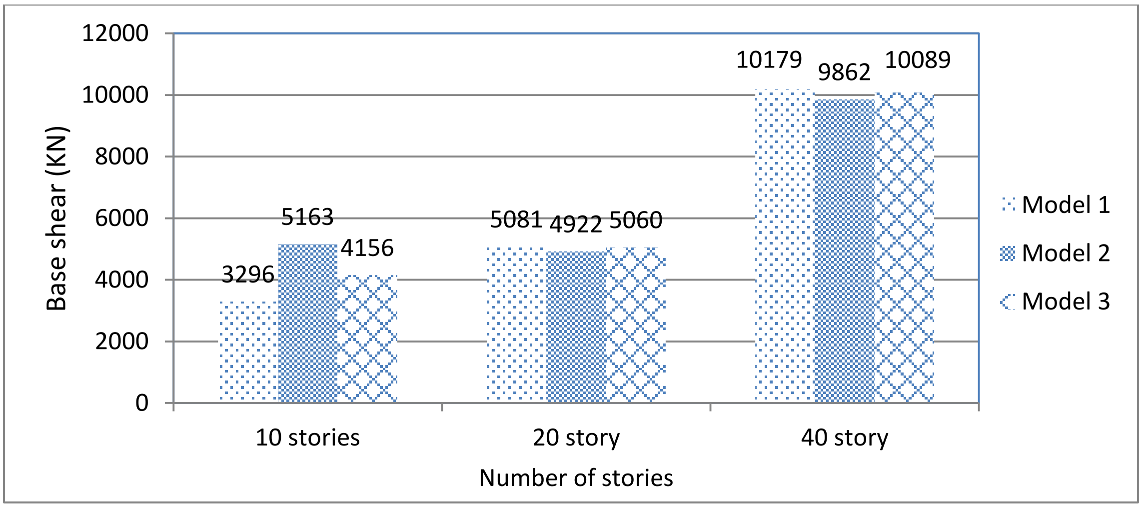


Figure 4.20. Base shear for 2% by quake load affect in x-direction according to EUROCODE 8 2004

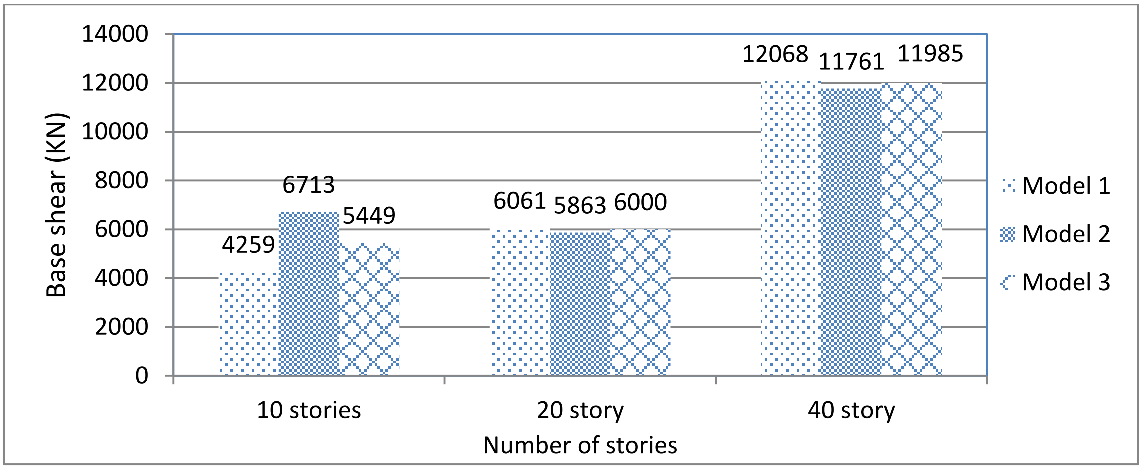


Figure 4.21. Base shear for 1% by quake load affect in x-direction according to EUROCODE 8 2004

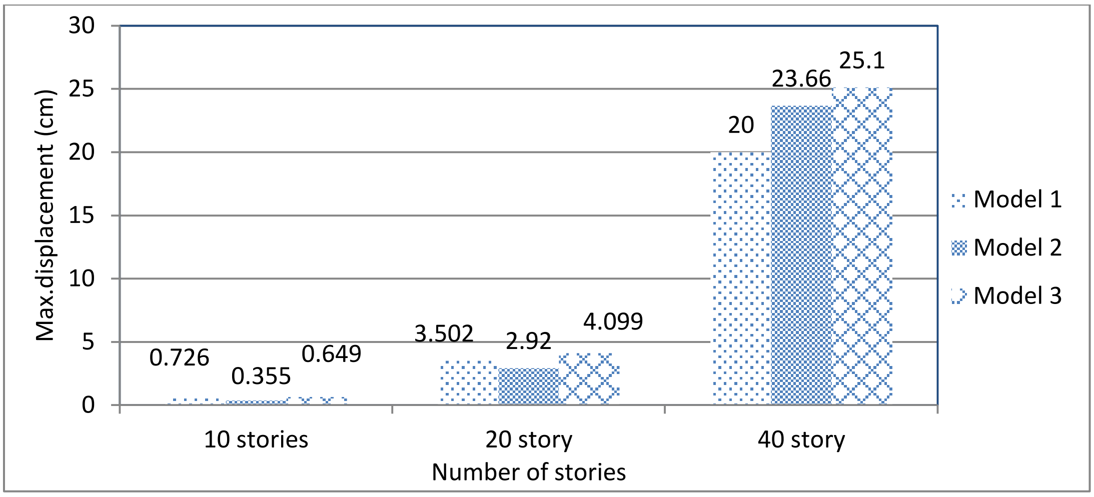


Figure 4.22. Maximum displacement for 1% by wind load affect in x-direction according to ASCE 7-05

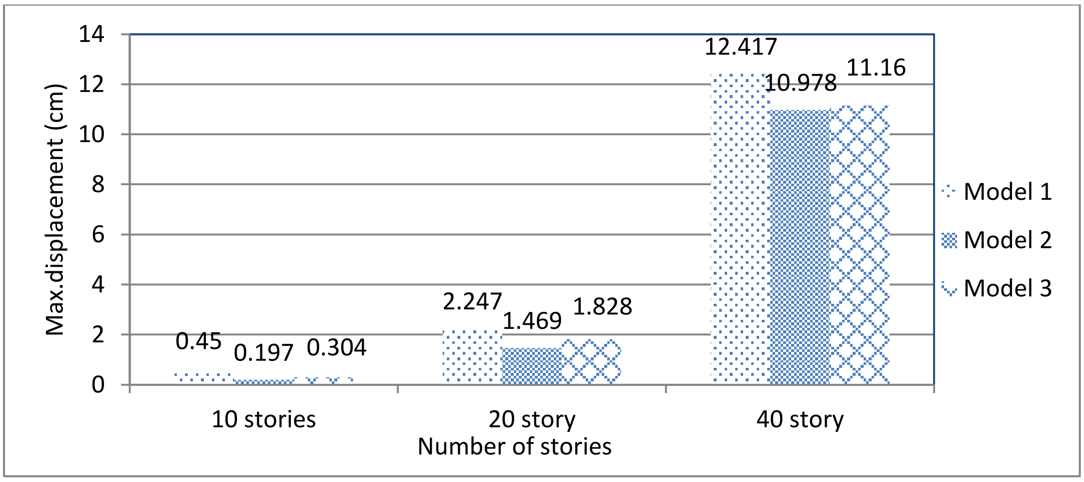


Figure 4.23. Maximum displacement for 2% by wind load affect in x-direction according to ASCE 7-05

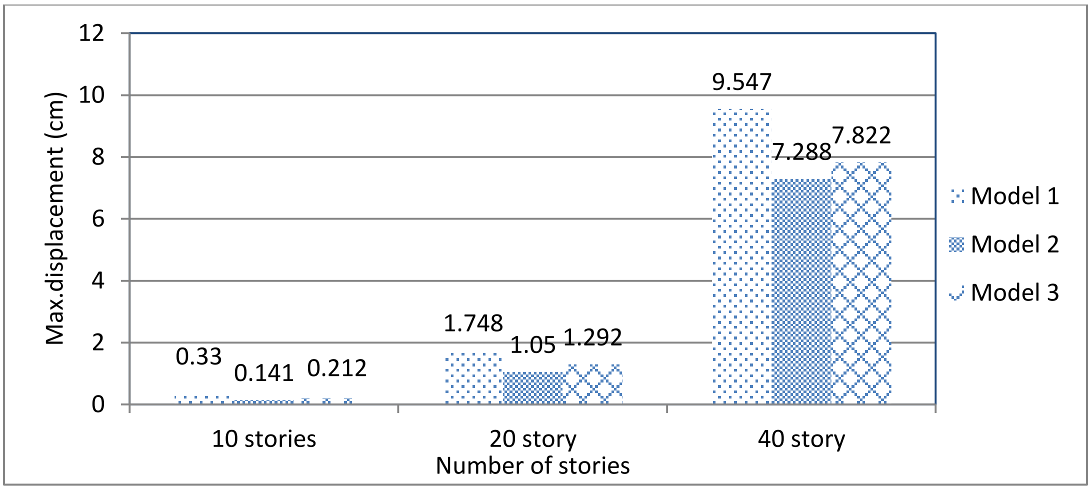


Figure 4.24. Maximum displacement for 4% by wind load affect in x-direction according to ASCE 7-05

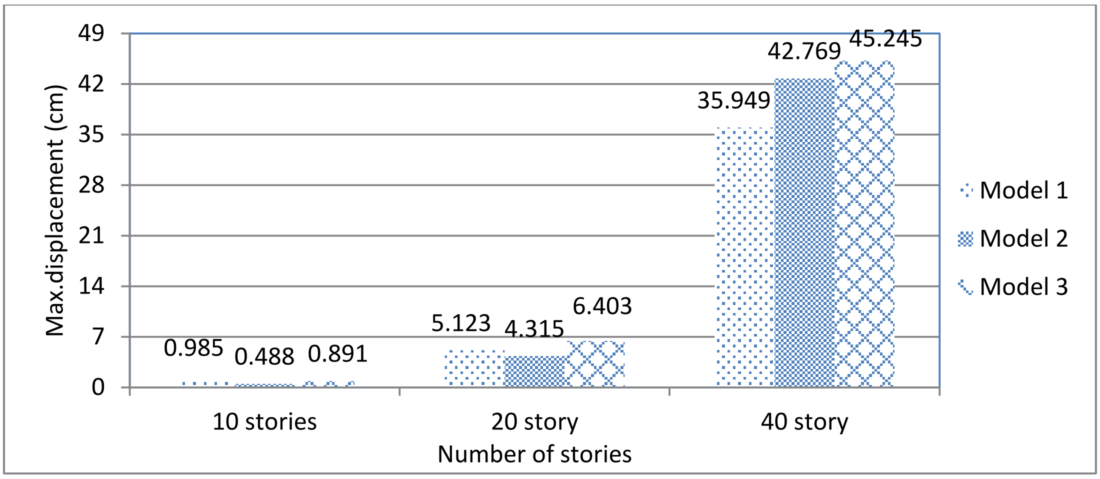


Figure 4.25. Maximum displacement for 1% by wind load affect in x-direction according to EUROCODE 1 2005

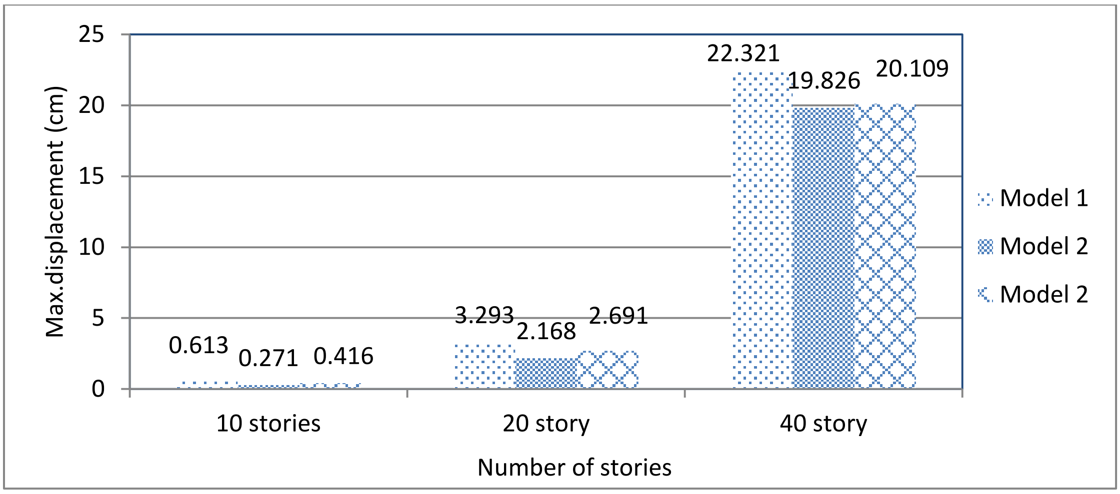


Figure 4.26. Maximum displacement for 2% by wind load affect in x-direction according to EUROCODE 1 2005

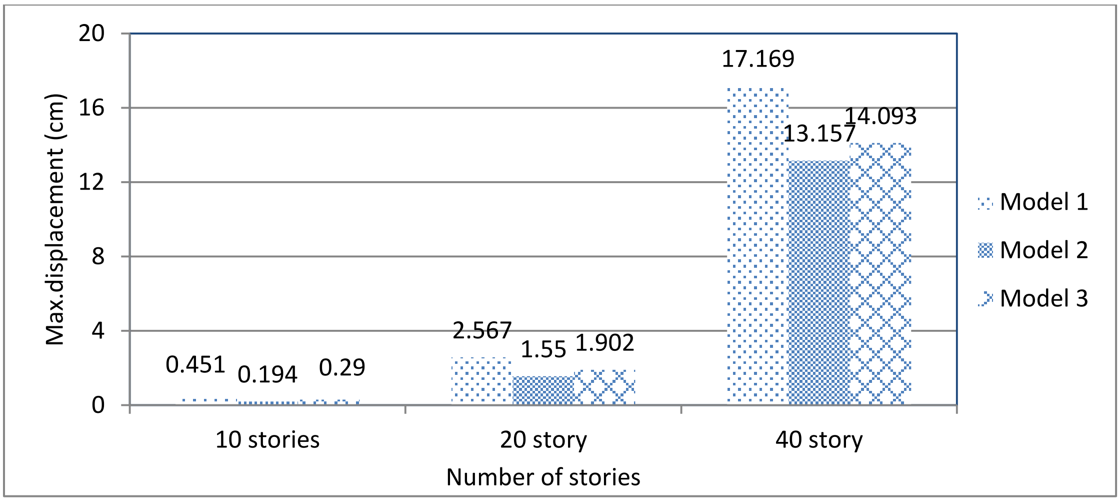


Figure 4.27. Maximum displacement for 4% by wind load affect in x-direction according to EUROCODE 1 2005

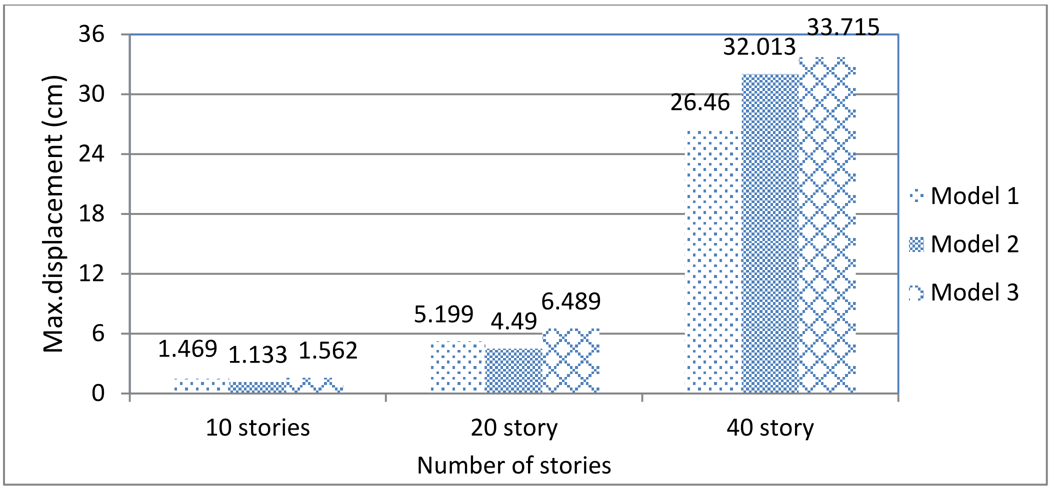


Figure 4.28. Maximum displacement for 1% by quake load affect in x-direction according to IBC 2006

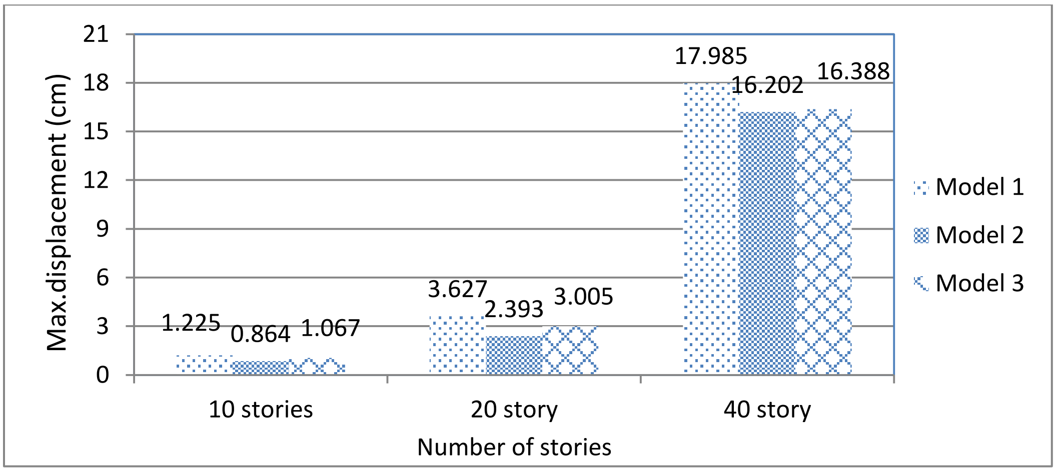


Figure 4.29. Maximum displacement for 2% by quake load affect in x-direction according to IBC 2006

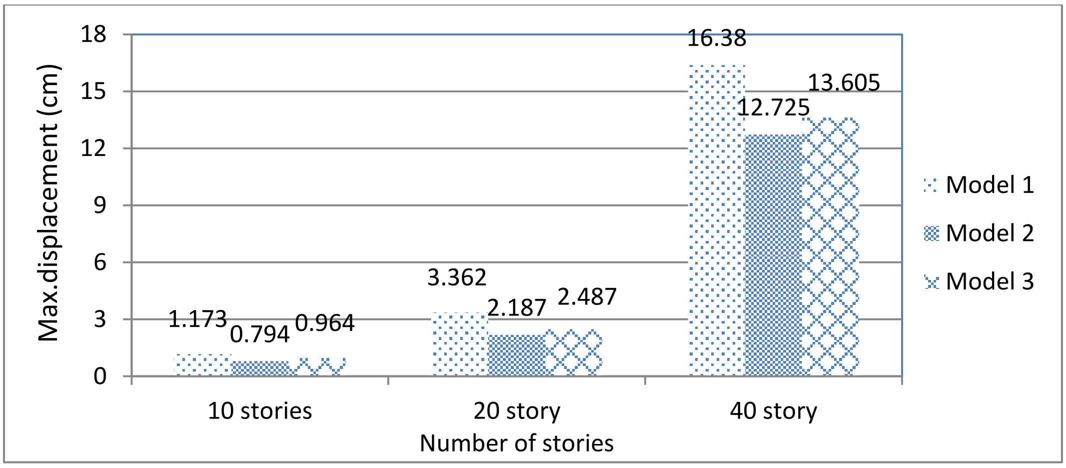


Figure 4.30. Maximum displacement for 4% by quake load affect in x-direction according to IBC 2006

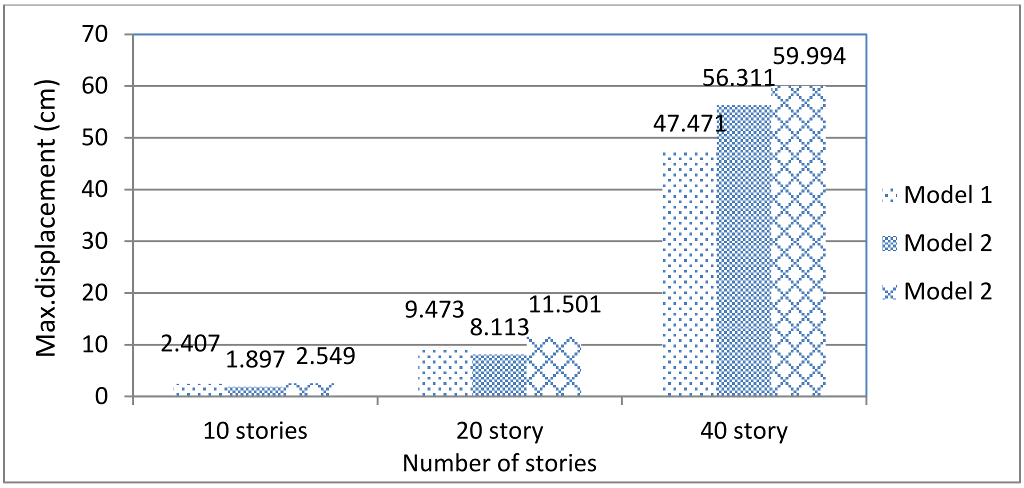


Figure 4.31. Maximum displacement for 1% by quake load affect in x-direction according to EUROCODE 8 2004

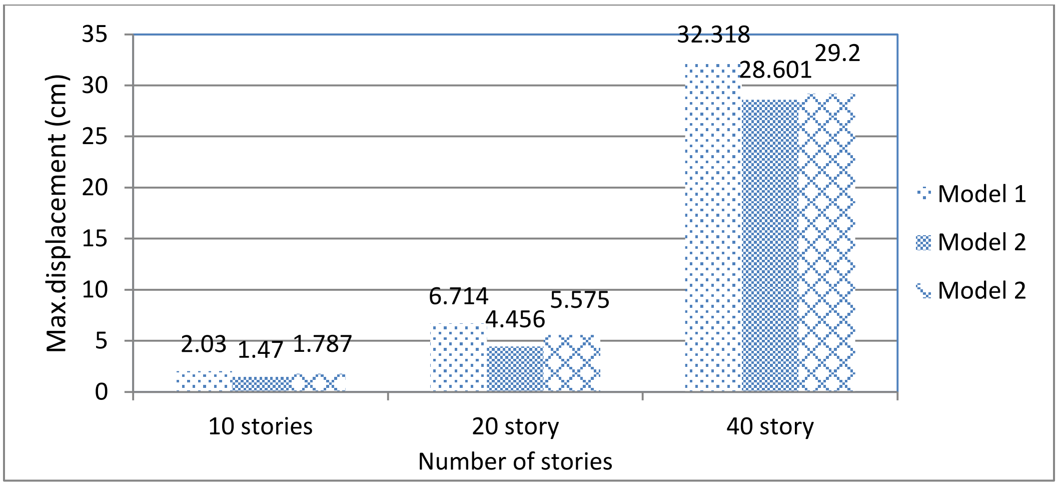


Figure 4.32. Maximum displacement for 2% by quake load affect in x-direction according to EUROCODE 8 2004

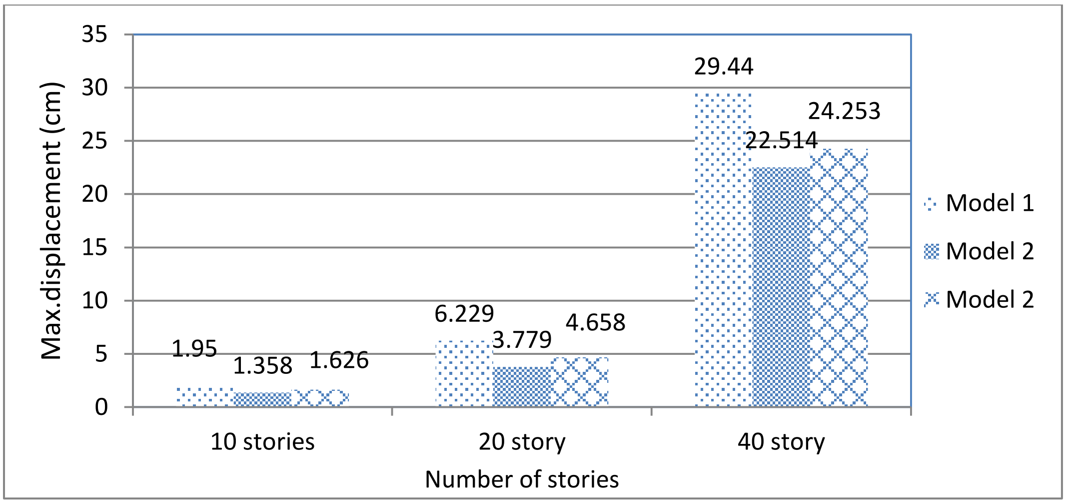


Figure 4.33. Maximum displacement for 4% by quake load affect in x-direction according to EUROCODE 8 2004

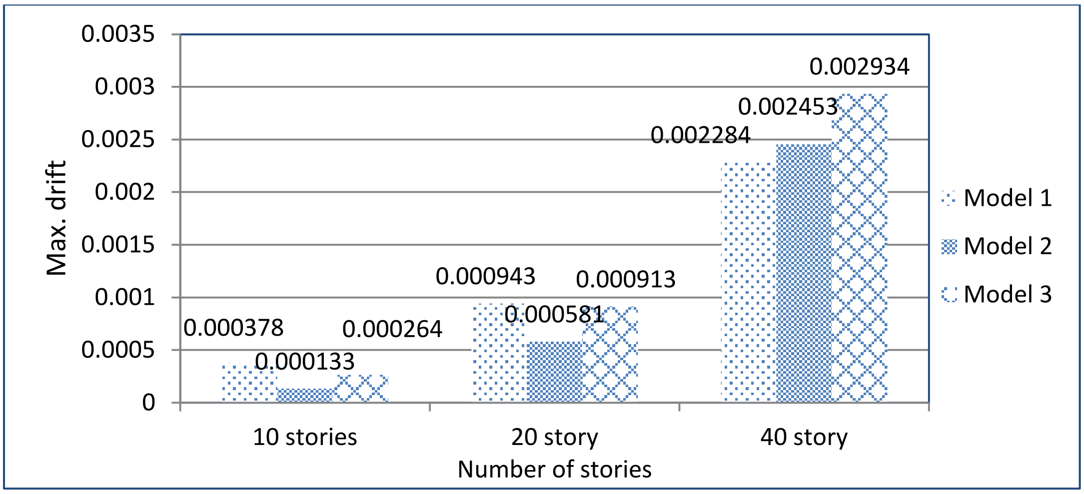


Figure 4.34. Maximum drift for 1% by wind load affect in x-direction according to ASCE 7-05

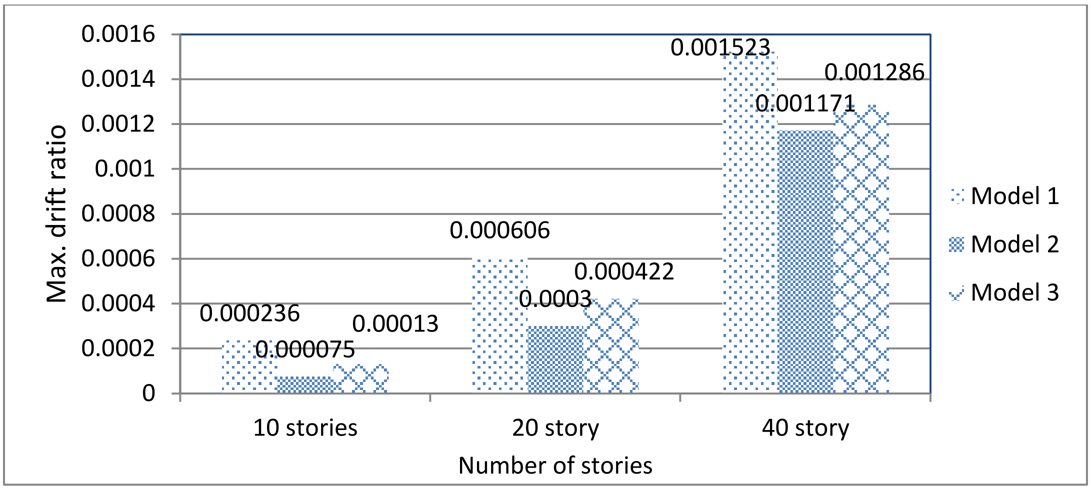


Figure 4.35. Maximum drift ratio for 2% by wind load affect in x-direction according to ASCE 7-05

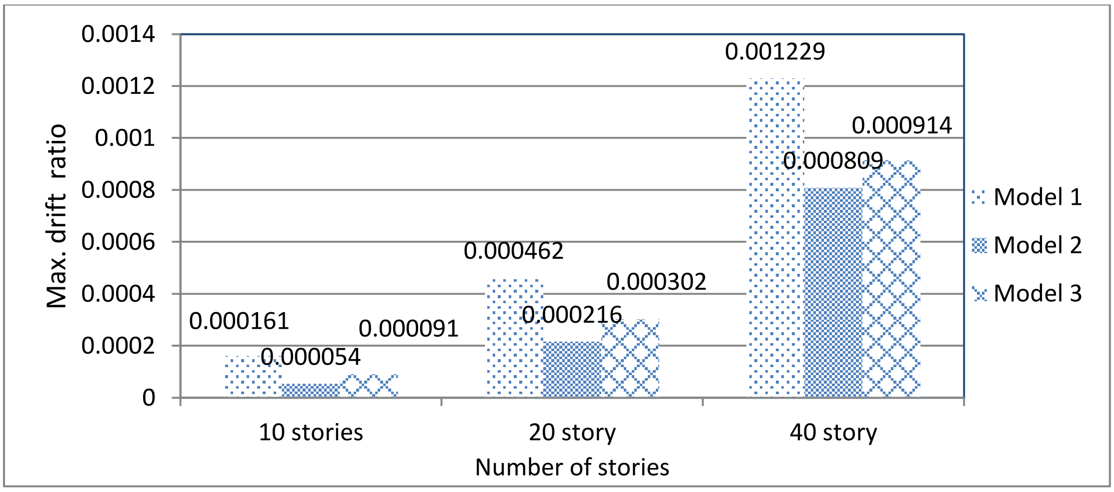


Figure 4.36. Maximum drift ratio for 4% by wind load affect in x-direction according to ASCE 7-05

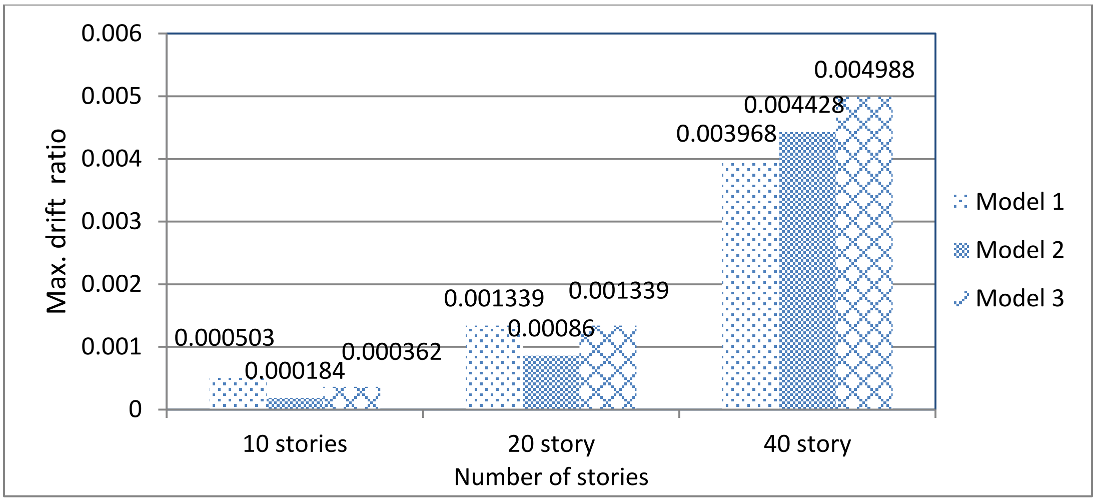


Figure 4.37. Maximum drift ratio for 1% by wind load affect in x-direction according to EUROCODE 1 2005

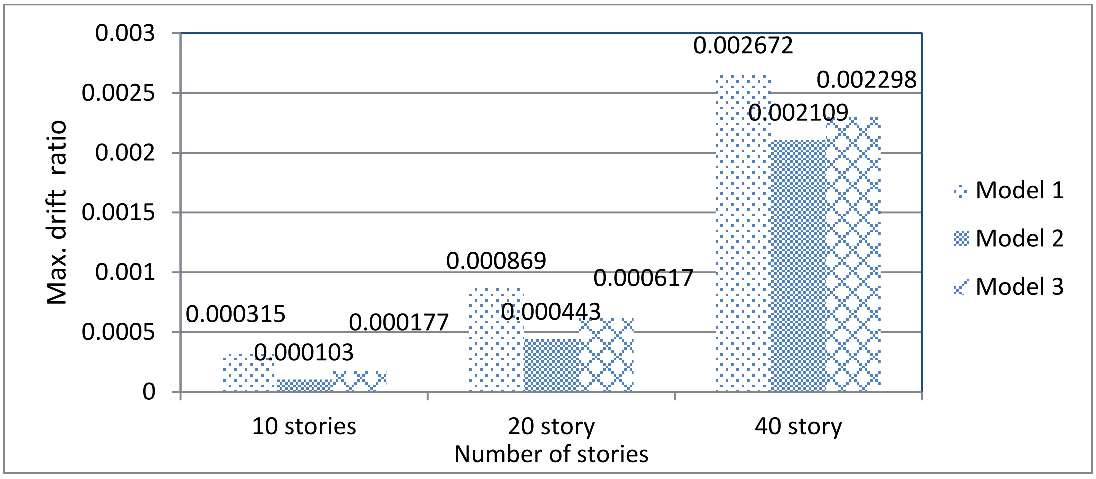


Figure 4.38. Maximum drift ratio for 2% by wind load affect in x-direction according to EUROCODE 1 2005

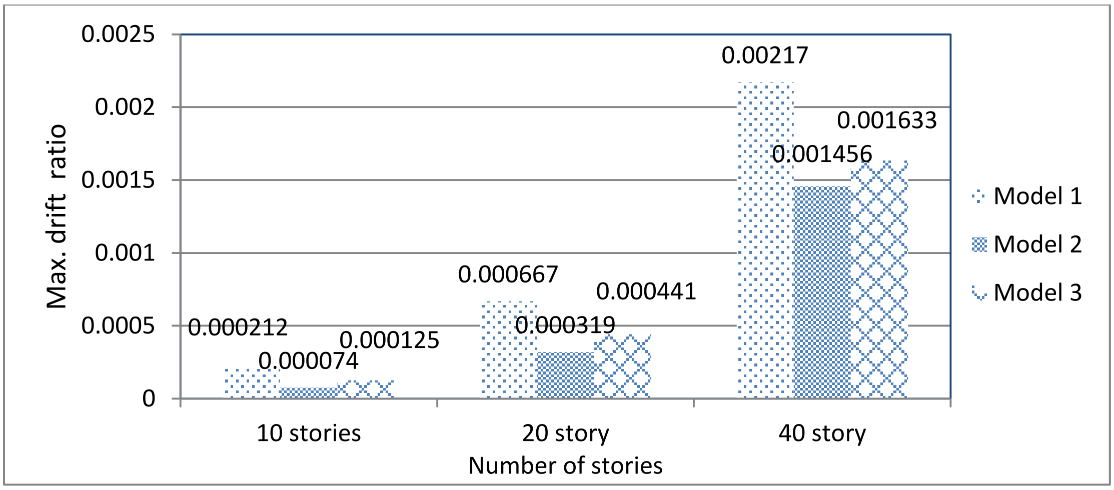


Figure 4.39. Maximum drift ratio for 4% by wind load affect in x-direction according to EUROCODE 1 2005

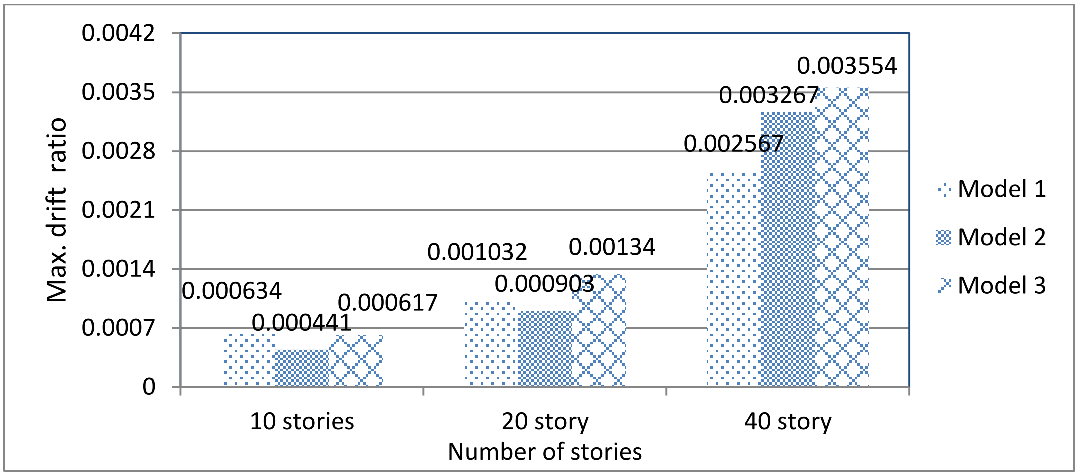


Figure 4.40. Maximum drift ratio for 1% by quake load affect in x-direction according to IBC 2006

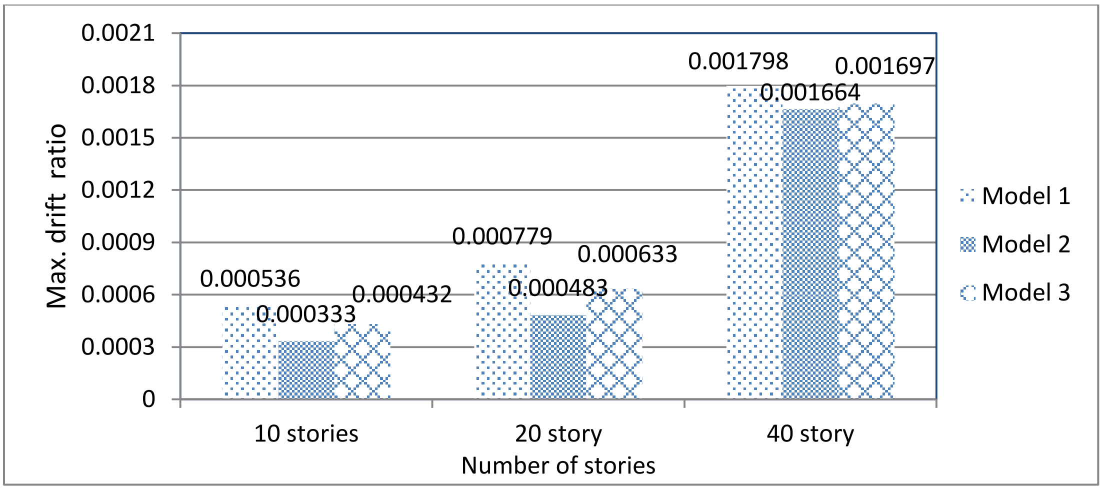


Figure 4.41. Maximum drift ratio for 2% by quake load affect in x-direction according to IBC 2006

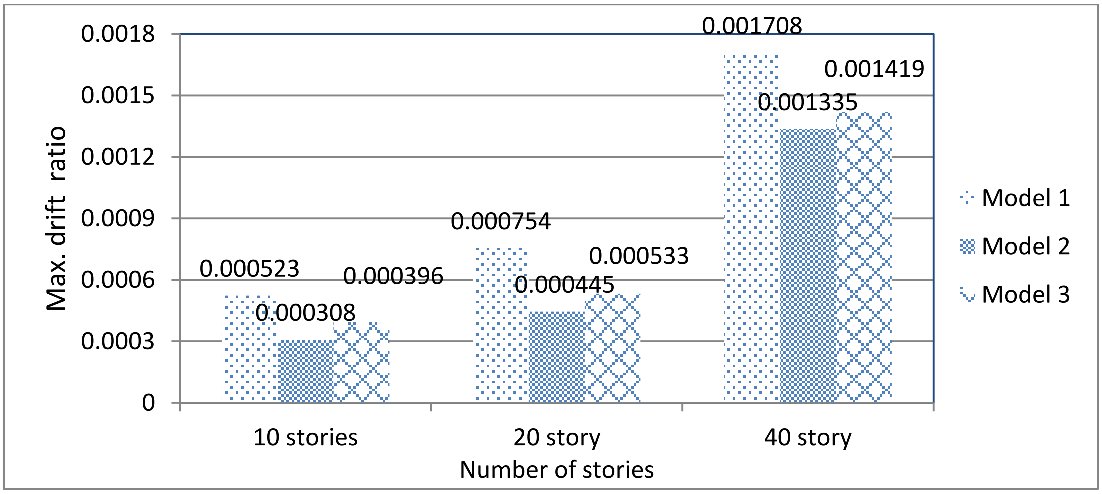


Figure 4.42. Maximum drift ratio for 4% by quake load affect in x-direction according to IBC 2006

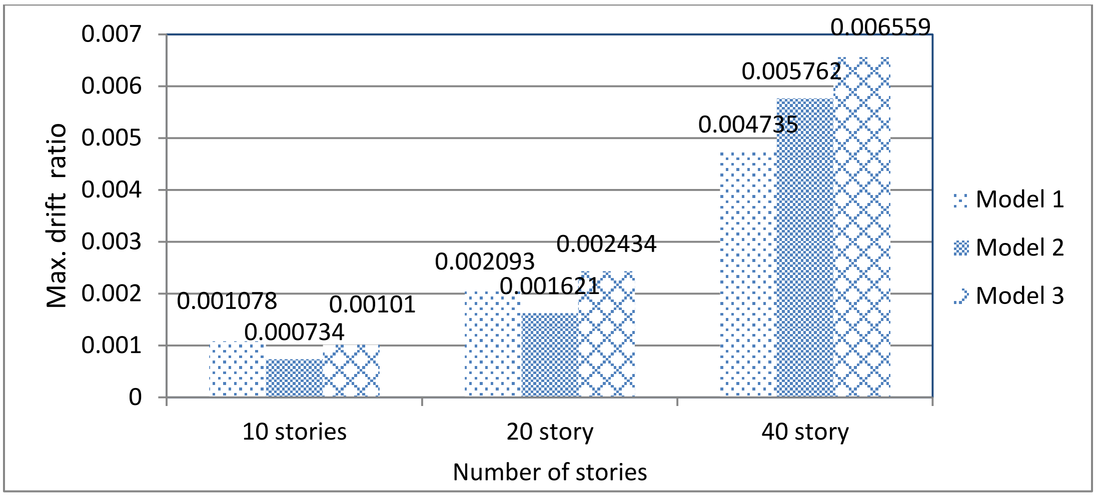


Figure 4.43. Maximum drift ratio for 1% by quake load affect in x-direction according to EUROCODE 8 2004

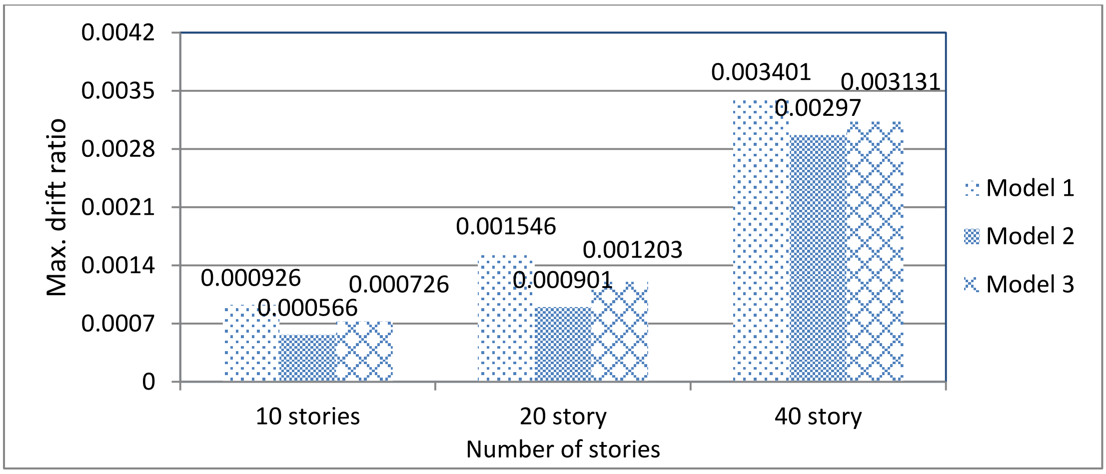


Figure 4.44. Maximum drift ratio for 2% by quake load affect in x-direction according to EUROCODE 8 2004

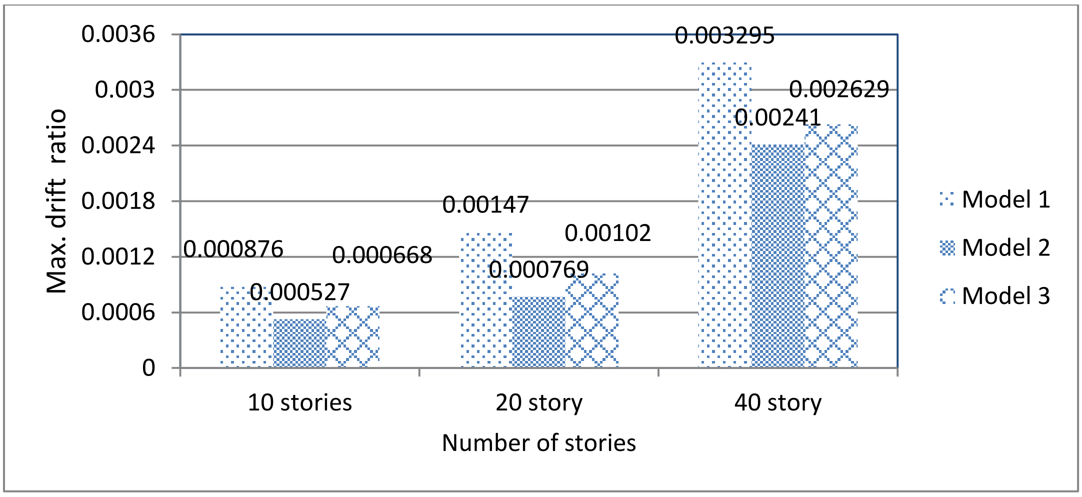


Figure 4.45. Maximum drift ratio for 4% by quake load affect in x-direction according to EUROCODE 8 2004

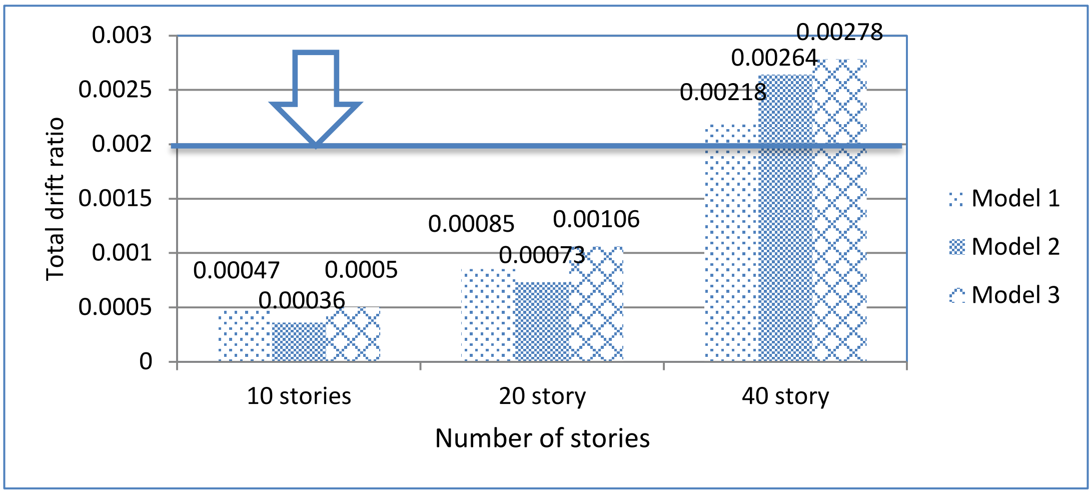


Figure 4.46. Total drift ratio for 1% by quake load affect in x-direction according to IBC 2006

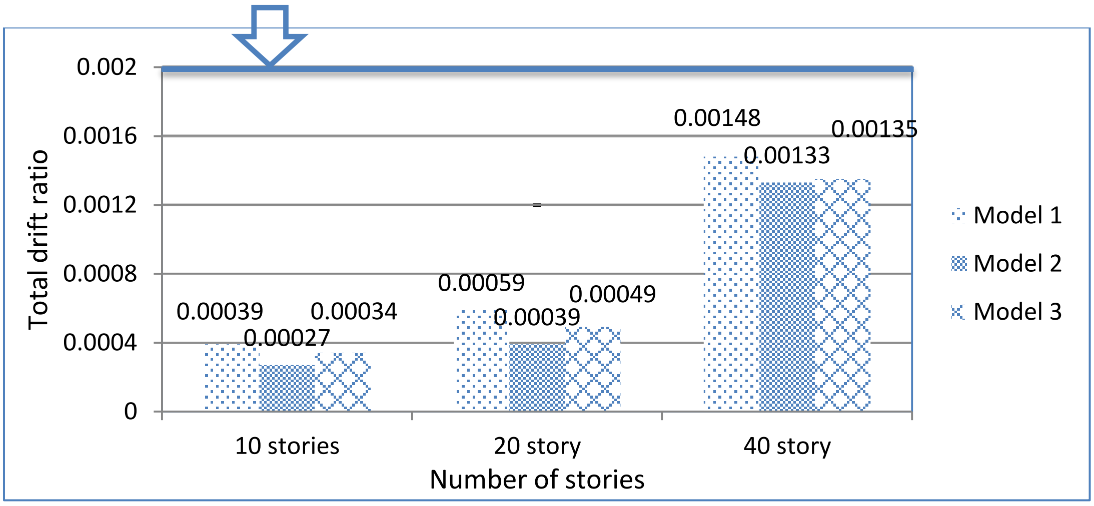
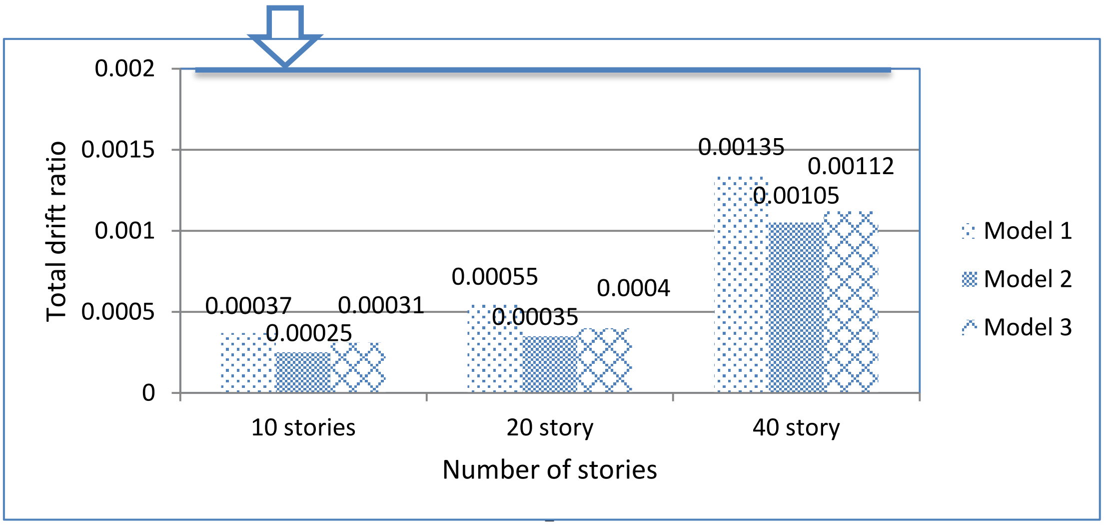


Figure 4.47. Total drift ratio for 2% by quake load affect in x-direction according to IBC 2006



igure 4.48. Total drift ratio for 4% by quake load affect in x-direction according to IBC 2006

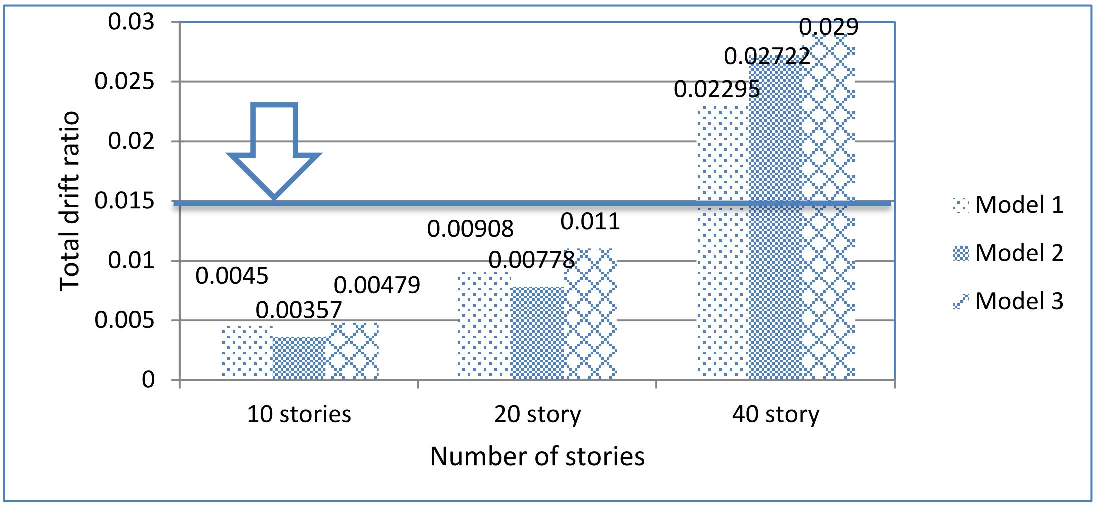


Figure 4.49. Total drift ratio for 1% by quake load affect in x-direction according to EUROCODE 8 2004

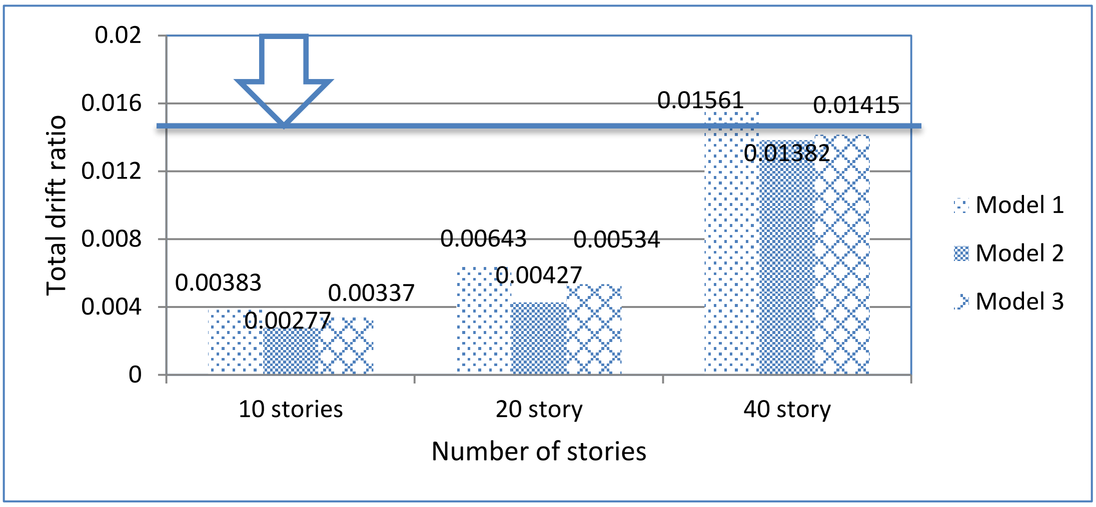


Figure 4.50. Total drift ratio for 2% by quake load affect in x-direction according to EUROCODE 8 2004

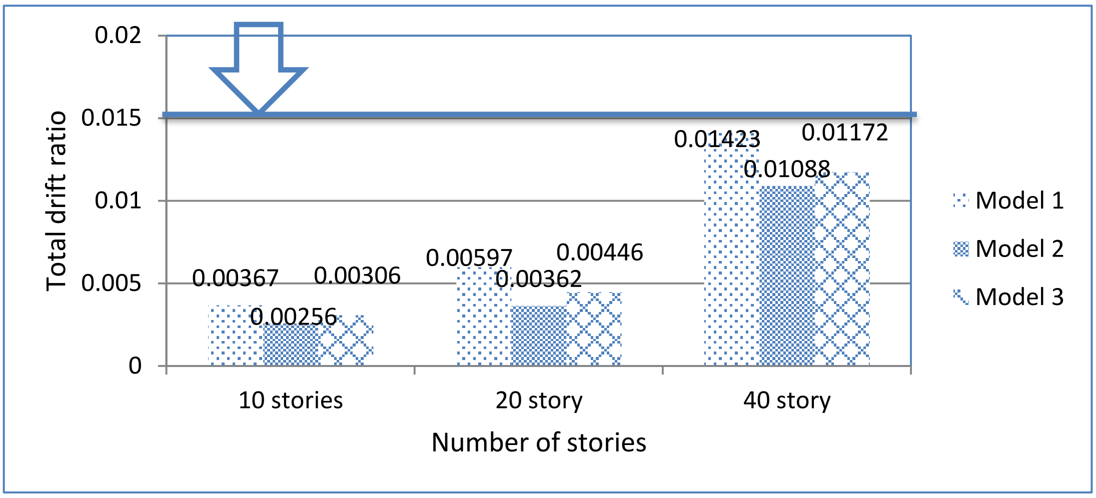


Figure 4.51. Total drift ratio for 4% by quake load affect in x-direction according to EUROCODE 8 2004

4.7 Discussion

After analyzing the models and presented the numerical results in Section 4.6 for fundamental period, base shear, maximum displacement and maximum drift values.

Figures 4.7-9 shows the values of fundamental period for all the models, from these figures realize the value of fundamental period is just affected by structural form and percentage of effective area only and does not affected by change the code or load.

The values of base shear are display in the Figures 4.10-21, from these result realize the value of base shear under the wind load affect are affected by the height of building only and does not affect by other factor like structural form, percentage of effective area and codes. However, the value of base shear under the seismic load affects is various with change factors like change the structural form, the percentage of effective area and the codes.

According to the result that represent in Figures 4.16-21, for the 10 stories the Model 1 is the best one and more effective comparing with Model 2 and Model 3 followed by Model 3 and then Model 2, where the base shear value of Model 1 less than the base shear value of Model 2 approximately in 36%. But for 20 and 40 story the Model 2 is the best one and more effective comparing with Model 1 and Model 3 followed by Model 3 and then Model 1, where the base shear value of Model 2 less than the base shear value of Model 1 approximately between 2-3.5%.

Figures 4.22-45 present the result of maximum displacement and maximum drift ratio for all models under the wind load and seismic load for two codes, from these figures shows the value of maximum displacement and maximum drift affected by type of the load, structural form, the percentage of effective area and the codes.

According to the result that presented above in Section 4.6 shows the results in European code were larger than American code about two times, efficiency of the structure is proportional directly with increase the percentage of effective area and finally the Model 2 is the best one and more efficiency to resist the lateral loads effects.

After make a comparison for the values of total drift ratio for all models with allowable limit for the drift in codes as shown in Figures 4.46-51. [49, 51].

The models with 1% are valid for 10 and 20 stories only and not valid for 40 stories according to two codes (American code and European code), the models with 2% are valid for all height 10, 20 and 40 stories according to American code and also valid for all height 10, 20 and 40 stories except Model 1 for 40 story is not valid in 2% according to European code.

Finally, all models that formed according to 4% are valid for all height 10, 20 and 40 stories according to two codes (American code and European code).

CHAPTER 5

5. CONCLUSIONS AND FUTURE WORKS

5.1 Conclusions

In the present work, analysis results of the numerical models of 54 cases with different variable parameters (structural form, percent of effective area from the plan, building height and lateral loads from different codes) are presented. The results have shown very wide range of results from the same building, that is meaning the sensitivity of these factors in the tall building design. The following points show the distinctive conclusion from the results:

- Under the lateral loads affects the lateral deflection increase with the height of the structure.
- The volume of concrete increased proportionally with the height of the structure respect to gravity loads and lateral loads.
- The most efficient procedure to limiting the lateral loads fundamental period, base shear, maximum displacement and maximum drift in a tall building is by changing the structural form of the building into something more rigid and stable to confine the deformation and increase stability.
- The stiffness (rigidity) and stability requirements become more important as the height of the structure increases, and they are commonly the main aspect for design.
- The fundamental period is affected by structural form and percentage of effective area only.
- The lateral deformation from the lateral loads effect (wind and seismic) due to the European code more than the deformation due to American code about two times.

- The efficiency of the structure to resist the lateral affect increased proportionally with increase the percentage of effective area.
- The value of base shear under wind load affect is affected by the height of the buildings only.
- Model 2 is the better structural form and most effective to resist the lateral loads affects comparing with Model 1 and Model 3.

5.2 Future works:

The following possibilities exist for extending the various aspects of the present work.

- Comparison the models under different codes, such as Turkish code, National Building Code of Canada, New Zealand/Australian Loadings Standard code .
- Use the other structural forms to design tall buildings structural.
- Increase the height of buildings.
- Include the effect of other loads such as blast Loads.
- Different loads have to be taken because of tallness.

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