Design of High Rise Reinforced Concrete Buildings

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Abstract

Design of a high-rise reinforced concrete building, like any engineering design, is a complex multidisciplinary process with the objective to discover, detail and construct a system to fulfill a given set of performance requirements. The success of this process is highly dependent upon the cooperation taking place between the members of the design team. Although present-day engineering computer technology allows for precise analysis and design of the different subsystems of the high-rise building, it does not readily provide insight for choosing among alternatives of these subsystems to arrive at the best overall design. The thesis begins with a review of the design of high rise buildings and the conceptual design of it. Then the study is carried out to investigate some special structural problems. The configuration examined in this study was a square twenty eight (28) story reinforced concrete structure, for three (3) different structures: the first one is core wall structure without bracing, the second is core wall structure with bracing system and the third is shear wall structural system. These three different structures subjected to different load combinations, the final result is analyzed. The analysis of the structural form performed using ETABS software program by two methods of analyzing, equivalent static method (static analysis) & response spectrum method (dynamic analysis) and the results of the analysis compared such as, displacement, drift, shear force and moment between the three structures in each methods. The design results presented in tabular form.

Keywords: High rise building, Structure Design, Response Spectrum Analysis, Equivalent Static Analysis, ETABS

1. Introduction

Deep Design concept is an impressive term used to describe the intrinsic essentials of design. The concept encompasses reasons for the choice of design loads, analytical techniques, design procedures, preference for particular structural systems, and of course, the desire for economic optimization of the structure. To assist engineers in tackling the design challenge by developing a feeling for the nature of loads and their effect on structural systems that paves the way to understand the structural behavior and allows the designer to match structural systems to specific types of loading (Taranath, 2009).

High-rise buildings are defined as a building of 35 meters or greater in height, which are divided at regular intervals into occupied levels constructed everywhere in the world, the height and size of high-rise buildings get larger and larger according to the development of life and shortage of free land. The structural design of high-rise buildings depends on dynamic analysis for winds and earthquakes, and today the best way to do these analysis by using computer programs for the structural design of high-rise buildings. Hence, after that the structural plan and outline of high-rise buildings are determined, the structural design of high-rise buildings which checks structural safety for the individual structural members is not necessary outstanding structural ability by the use of structural software on the market (Patil et al., 2013).

However, it is not exaggeration to say that the performance of high-rise buildings is almost determined in the preliminary design stages which work on multifaceted examinations of the structural form and outline. The structural designer is necessary to close the gap exactly of the whole picture in this stage. The static and dynamic structural behaviors of high-rise buildings are governed by the distributions of transverse shear stiffness and bending stiffness per each storey. Therefore, in the preliminary design stages of high-rise buildings a simple but accurate analytical method which reflects easily the structural stiffness on the whole situation is more suitable than an analytical method which each structural member is indispensable to calculate such as FEM. There are many simplified analytical methods which are applicable for high-rise buildings. Since high-rise buildings are composed of many structural members, the main treatment for the simplification is to be replaced with a continuous simple structural member equivalent to the original structures. This equivalently replaced continuous member is the most suitable to use the one dimensional rod theory. Since the dynamic behavior of high-rise buildings is already stated to govern by the shear stiffness and bending stiffness determined from the structural property. The deformations of high-rise buildings are composed of the axial deformation, bending deformation, transverse shear deformation, shear-lag deformation, and torsional deformation. The problem is to be how to take account of these deformations under keeping the simplification. The most challenging area of structural engineering is designing structures to resist seismic loads, Not only the magnitude of the forces generated by an earthquake, But also it is the much more destructive force, unpredictable and difficult to characterize. For these reasons earthquakes cause tremendous damage to life and infrastructure even in countries that have modern construction codes and practices (Takabatake, 2011).

Like all designs, the design of a high-rise building involves the development of the physical description of an artifact subject to a set of given constraints and specifications. There are three phases in the design of a high-rise building, first phase is the Conceptual, second is preliminary, and third is the detailed design. Conceptual design deals with the identification of different concepts and the selection of overall best subsystems and their configurations. The preliminary design stage involves the initial development of one or a few conceptual models. Finally, the detailed design stage defines a complete solution for all subsystems, and results in final drawings for architectural, structural, electrical and mechanical systems (Khajehpour, 2001).

2. Case study
2.1 Introduction
The primary purpose of all kinds of structural systems used in the building type of structures is to transfer gravity loads effectively. The most common loads resulting from the effect of gravity are dead load, live load and snow load. Besides these vertical loads, buildings are also subjected to lateral loads caused by wind, blasting or earthquake. Lateral loads can develop high stresses, produce sway movement or cause vibration. Therefore, it is very important for the structure to have sufficient strength against vertical loads together with adequate stiffness to resist lateral forces. A building must have a complete structural system capable of carrying all gravity loads to its foundation in life span of building. While dealing with lateral forces, there is a natural trend to manage these forces with same methods used for gravity loads. Conventionally designed columns of a structure cannot carry the weight of the building and tolerate the large sideways movement caused by the motions of earthquake and/or wind. Earthquake and wind gusts are idealized as equivalent static load of certain magnitude that must be resisted by the structure. The aftermath of an earthquake manifests great devastation due to unpredicted seismic motion striking extensive damage to innumerable buildings of varying degree, i.e. either full or partial. This damage to structures in turn causes irreparable loss of life with a large number of casualties. Structures are designed to resist moderate and frequently occurring earthquakes must have sufficient stiffness and strength to control deflection and to prevent any possible damage. However, it is inappropriate to design a structure to remain in the elastic region, under severe earthquakes, because of the economic constraints.
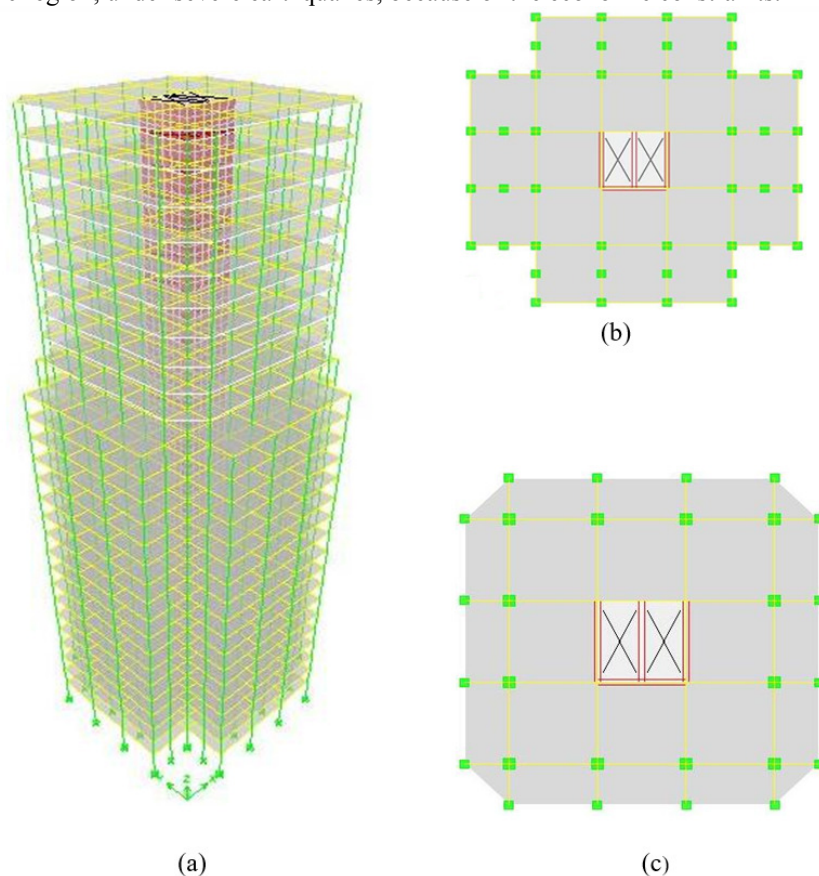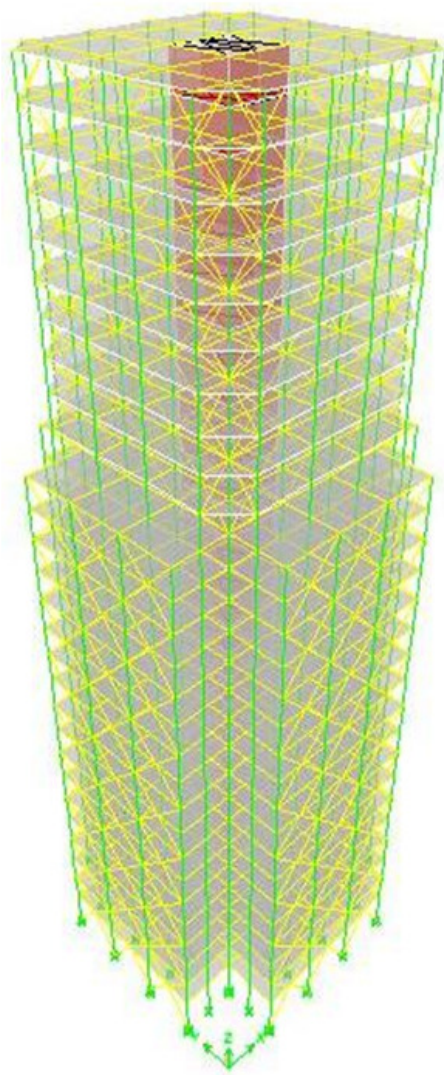

Figure 2.1 (a) building No.1 without bracing (b) plan of the building from 1-18 storey (c) plan of the building from 19-20 storey
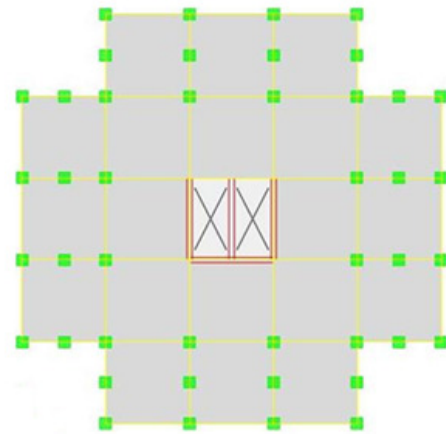
2.2 Description of the case study
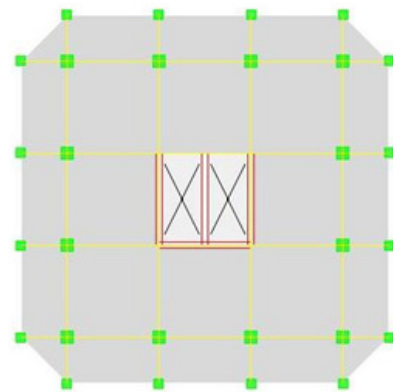Three different structural system of high rise reinforced concrete with the same dimensions are considered for

this study. Modeling, analysis and design of the structures are done on ETABS software. Plans of the buildings considered are shown in figure 2.1 , 2.2 & 2.3.

(a)

(b)

(c)

Figure 2.2 (a) building No.2 with triple layer V& Inverted-V bracing (b) plan of the building from 1-18 storey (c) plan of the building from 19-20 storey
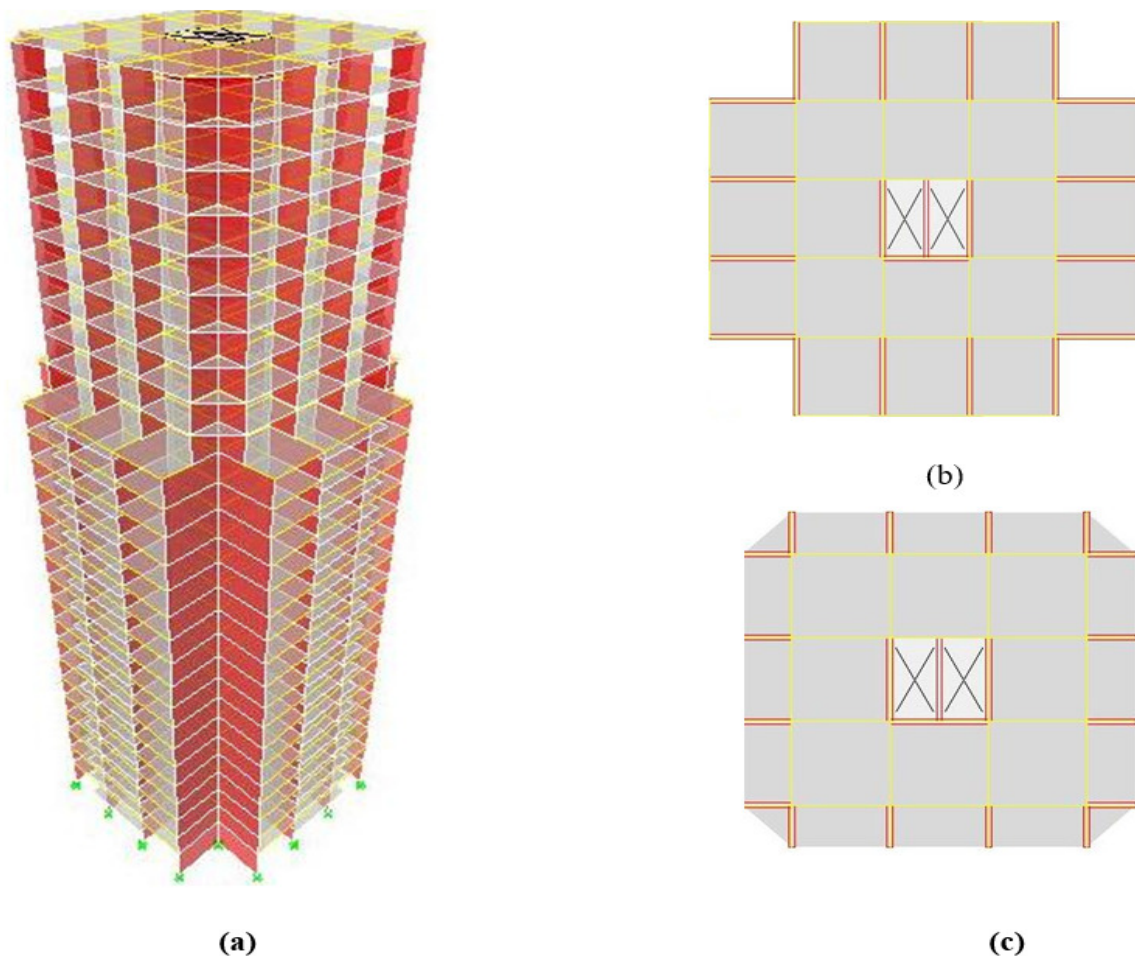
Figure 2.3 (a) building No.3 with shear wall system (b) plan of the building from 1-18 storey (c) plan of the building from 19-28 storey

2.3 Analysis by using computer programs

Computer program can do analysis but the result still depends on the input data used and formed by engineer in addition to the model created. Also analysis procedure and type with output arrangement is important to get the correct results. Because of complexity of analysis calculation especially for large buildings or 3D (three dimensions) structures that it's calculation need time and sometimes it may be impossible doing it without any errors. If hand calculations method are used, it needs more iteration to get nearly exact or reasonable value. All softwares use nearly same methods that are used for hand calculations, but concentrate on iteration method or geometric stiffness that is nearly exact. The different between hand calculations and software performing analysis are :

1. Limitation of hand computation methods:

- Applicable for small problems or small structures.
- Difficult for even medium sized problems.
- Three dimension analysis almost impossible.
- Probability of errors raises with the size of structure.
- Time needing is high for performing analysis.

2. Advantage for invention of computer:

- Matrix methods of structural analysis.
- Development of numerical techniques.
- Finite element method.
- Programming languages developed.
- Arranging input and output is easy with drawings.

2.4 Description of the structures

The structures with 28 storeys and the dimensions of 1-18 storeys are 25x25 m and from 19-28 storeys are 19x19 m in the center of structures. The thickness of slabs is 0.25m for first eighteen storeys and 0.2m for the last ten storeys. All the supports of structures are fixed. The dimensions of the beams are 0.4x0.8 m. Building No.1 consists of a central core wall structure and columns which connected by beams to form moment resisting frames in the two orthogonal directions. Building No.2 is the same building one but with bracing system and the data shown in table 4.1. Steel bracing is a highly efficient and economical method of resisting horizontal forces in a frame structure. Building No.3 is a shear wall system consists of a central core wall structure and shear walls arranged in a regular 6m grid and connected by beams to form moment resisting frames in the two orthogonal directions and the data shown in table 4.2. The concrete and reinforcement material properties used in this study that the value of f_y is 43000 ton/m^2. The value of f'c for columns and shear walls is 3500 ton/m^2 and for slabs, beams is 3000 ton/m^2.

Table 2.1 Preliminary data for building No. 1 & 2

No. of storeys	28
Typical story height	**3m**
Bottom story height	**4m**
Slab thickness 1-18 storey	**0.25 m**
Slab thickness 19-28 storey	**0.2 m**
Beam	**0.4x0.8 m**
Column 1-28 without sides19-28 storeys	**0.8x0.8 m**
Column 19-28 in the sides	**0.6x0.6 m**
Shear wall	**0.35 m**
Support conditions	**Fixed**
Bracing for building 2	**Box/tube 0.15x0.1m & thickness 0.006 m**

Table 2.2 Preliminary data for building No. 3

No. of storeys	28
Typical story height	**3 m**
Bottom story height	**4 m**
Slab thickness 1-18 storey	**0.25 m**
Slab thickness 19-28 storey	**0.2 m**
Beam	**0.4x0.8 m**
Shear wall 1-28 in the corner	**0.4 m**
Shear wall 1-28 in the center	**0.5 m**
Shear walls between the shear walls corner	**0.35 m**
Support conditions	**Fixed**
Bracing for building	**No**

2.5 Loading consideration, Input Factors and Coefficients

Loads acting on the structure are dead load (DL), live load (LL) , wind load (WL) and Earthquake Load (EQ).

- DL: Dead load, 0.3 ton/m^2 is considered
- LL: Live load, 0.4 ton/m^2 is considered
- WL: Wind load taken at wind speed of 70 mph
- Site class: C
- Response modification factor: 5 for building (1&2) & 5.5 for building (3).
- Mapped Acceleration Parameters: Ss =1.08, S$_1$= 0.43.
- Seismic group: I
- Importance factor: 1

The response modification factor, R is direction dependent. Specified in IBC 2003 code Table 1617.6.2. A typical range of values for R is 2 to 8. The seismic group can be input as I, II or III. In 2003 IBC Section 1616.2 for information about the seismic group. The programs determine the occupancy importance factor, I, from the input seismic group and 2003 IBC Table 1604.5.The seismic coefficients can be input in accordance with the code or they can be user defined. If the seismic coefficients are in accordance with code, specify a site class, Ss and S1. If seismic coefficients are user defined, specify Ss, S1, Fa and Fv. The site class can be A, B, C, D, or E. Note that site class F is not allowed for automatic 2003 IBC lateral seismic loads. See 2003 IBC Table 1615.1.1 for site class definitions.

Ss is the mapped spectral acceleration for short periods as determined in 2003 IBC Section 1615.1. A typical range of values for Ss is 0 to 3. Note that the seismic maps show Ss in % g with a typical range of 0% to

300%. The input in the programs is in g. Thus the map values should be divided by 100 when they are input. For this case the map value is 108%g, it should be input as 1.08g. S_1 is the mapped spectral acceleration for a one second period as determined in IBC 2003 code section 1615.1. A typical range of values for S_1 is 0 to 2. Note that the seismic maps show S_1 in % g with a typical range of 0% to 200%. The input in the programs is in g. Thus the map values should be divided by 100 when they are input. For this study the map value is 43%g it should be input as 0.43g. Fa is a site coefficient. If the site coefficients are determined in accordance with code, the software automatically determines Fa from the site class and Ss based on 2003 IBC Table 1615.1.2(1). If site coefficients are user defined, Fa is input directly by the user. A typical range of values for Fa is 0.8 to 2.5. Fv is a site coefficient. If the site coefficients are determined in accordance with code, the software automatically determines Fv from the site class and S1based on 2003 IBC Table 1615.1.2(2). If site coefficients are user defined, Fv is input directly by the user. A typical range of values for Fv is 0.8 to 3.5.

2.6 Analysis methods
2.6.1 Equivalent linear static analysis method
The total design lateral force or design base shear along any principal direction is given in terms of design horizontal Seismic coefficient and seismic weight of the structure. Design horizontal seismic coefficient depends on the mapped acceleration Parameters of the site, importance of the structure, response reduction factor of the lateral load resisting elements and the fundamental period of the structure. ETABS software (v. 9.6.0; Computers and Structures Inc.

(CSI), 2009) has been used for the modelling, analysis and design of this study. Several important modelling and analysis approaches used for the parametric study are summarized by using equivalent linear static analysis.

In comparison of the analysis results of the three different structural system in the study was chosen the maximum value in all load cases including load combination according to IBC 2003 code which the ETABS program calculated of each storey & each buildings in this study.

2.6.1.1 Load cases & Load combinations
Load cases & Load combination according to the IBC 2003 code were used for comparison of the analysis results in ETABS program as shown in the table 2.3

Table 2.3 The load combination for static analysis

Comb. No.	Combinations	Comb. No.	Combinations
1	1.4 DL	20	1.4 DL+1.0 LL -1.5 EQY1
2	1.2 DL+1.6 LL	21	1.4 DL+1.0 LL+1.5EQY2
3	1.2 DL+1.0LL+1.6 WLX	22	1.4 DL+1.0 LL -1.5EQY2
4	1.2 DL+1.0LL -1.6 WLX	23	1.4 DL+1.5 EQX1
5	1.2 DL+1.0LL+1.6 WLY	24	1.4 DL -1.5 EQX1
6	1.2 DL+1.0LL -1.6 WLY	25	1.4 DL+1.5 EQX2
7	1.2 DL+ 0.8 WLX	26	1.4 DL -1.5 EQX2
8	1.2 DL - 0.8 WLX	27	1.4 DL+1.5 EQY1
9	1.2 DL+ 0.8 WLY	28	1.4 DL -1.5 EQY1
10	1.2 DL - 0.8 WLY	29	1.4 DL+1.5 EQY2
11	0.9 DL+1.6 WLX	30	1.4 DL -1.5 EQY2
12	0.9 DL -1.6 WLX	31	0.7 DL+1.5 EQX1
13	0.9 DL+1.6WLY	32	0.7 DL -1.5 EQX1
14	0.9 DL -1.6WLY	33	0.7 DL+1.5 EQX2
15	1.4 DL+1.0LL+1.5 EQX1	34	0.7 DL -1.5 EQX1
16	1.4 DL+1.0LL -1.5 EQX1	35	0.7 DL+1.5 EQY1
17	1.4 DL+1.0LL+1.5 EQX2	36	0.7 DL -1.5 EQY1
18	1.4 DL+1.0LL -1.5 EQX2	37	0.7 DL+1.5 EQY2
19	1.4 DL+1.0 LL+1.5 EQY1	38	0.7 DL -1.5 EQY2

2.6.1.2 The displacement:
It is found that the displacement in different structural system cases is increasing with incrementing storeys. Maximum displacement is found in top storeys in all buildings. The maximum displacement in X-direction of the three structural system of all load cases including load combination according to IBC 2003 code which the ETABS program calculated of each storey in this study was in the combination 15 (Comb. 15), and the figure 2.4 shows the comparison of maximum displacement between the three structural system in X-direction.
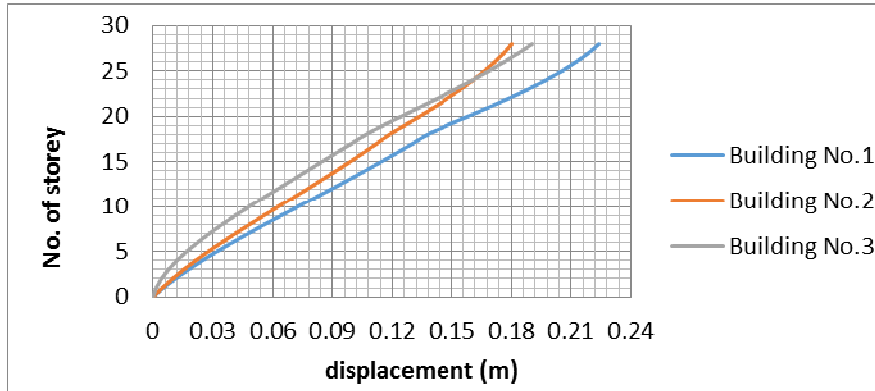
Figure 2.4 Max. displacement in X-direction (m) vs. No. of storey due to comb. 15

Figure 2.5 shows the comparison of the maximum displacement in Y-direction between the three structural system due to the combination 19 (Comb. 19) as the maximum displacement given in all load cases.
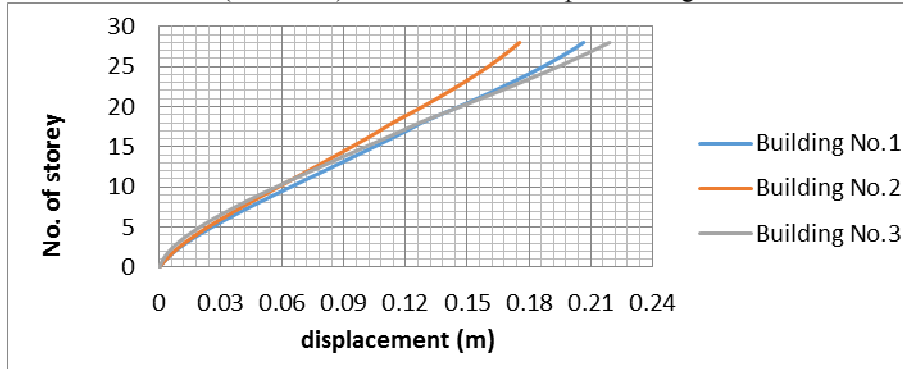

Figure 2.5 Max. displacement in Y-direction (m) vs. No. of storey due to comb. 19

2.6.1.3 The storey drifts:

Storey drift in different structural system cases is an important indicator of structural behaviour in performance-based seismic analysis. Figure 2.6 shows comparison of the maximum drift in X-direction of the three structural system in each storey at the combination 15 (Comb. 15) as the max. drift gives in all load cases.
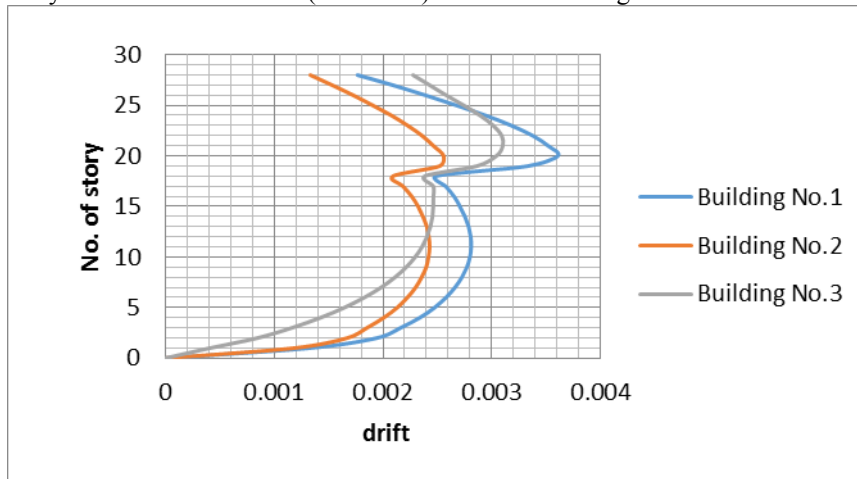
Figure 2.6 Max. drift in X-direction vs. No. of storey due to comb. 15

Figure 2.7 shows the comparison of the maximum drift in Y-direction of the three structural system due to the combination 19 (Comb.19) as the maximum drift given in all load cases.
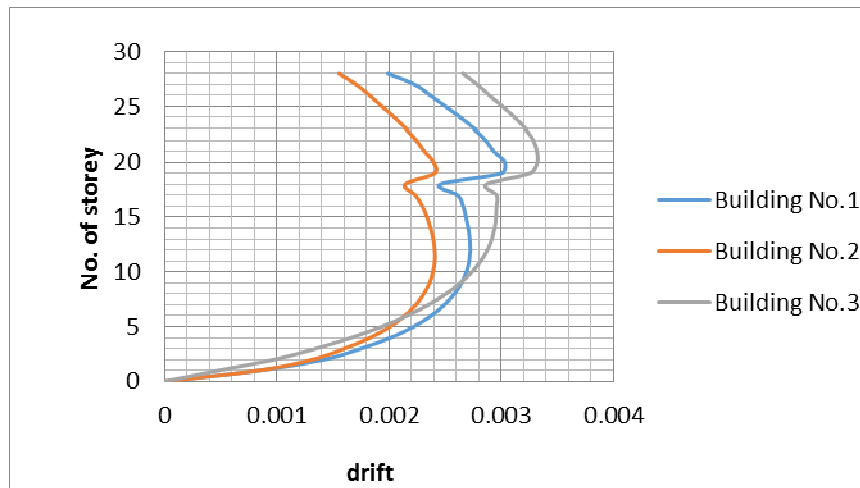
47

Figure 2.7 Max. drift in Y-direction vs. No. of storey due to comb. 19

2.6.1.4 The shear:

Maximum shear is found in bottom of the storey in all buildings. Figure 2.8 shows the comparison of the maximum shear in X-direction of the three different structural system in this study due to combination 16 (Comb. 16) as the maximum shear given in all load cases.
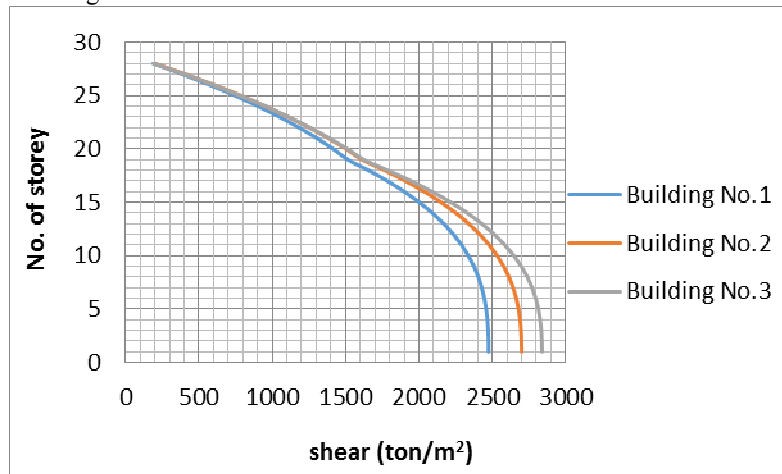

Figure 2.8 Max. shear in X-direction (ton/m^2) vs. No. of storey due to comb. 16

Figure 2.9 shows the comparison of the maximum shear in Y-direction of the three structural system due to the combination 20 (Comb. 20) as the maximum shear given in all load cases.
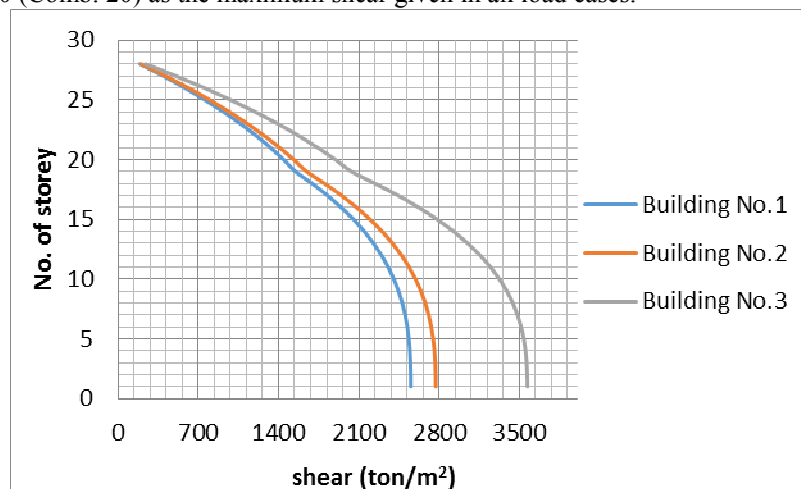

Figure 2.9 Max. shear in Y-direction (ton/m^2) vs. No. of storey due to comb. 20

2.6.1.5 The moment:

The moments are not so negligible to not count during design. The moment increases with increment of storey so slenderness has a effects to the moment. Figure 2.10 shows the comparison in the maximum moment in X-

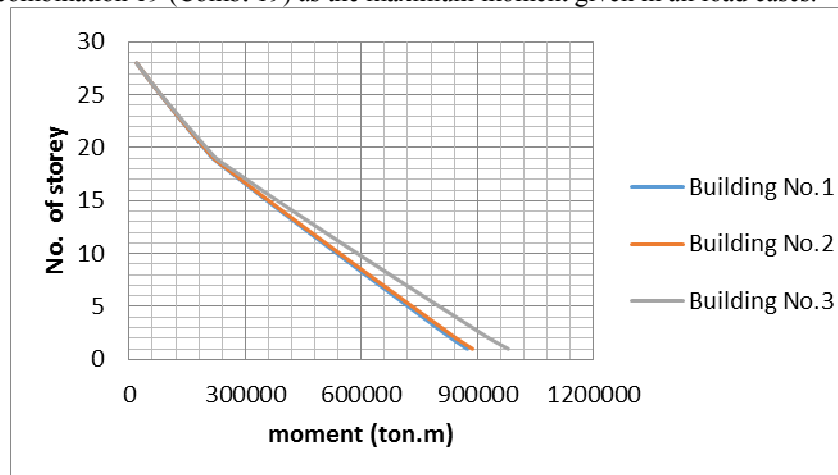direction due to combination 19 (Comb. 19) as the maximum moment given in all load cases.

Figure 2.10 Max. moment in X-direction (ton.m) vs. No. of storey due to comb. 19

Figure 2.11 shows the comparison of the maximum moment in Y-direction of the three structural system due to the combination 15 (Comb. 15) as the maximum moment given in all load cases.
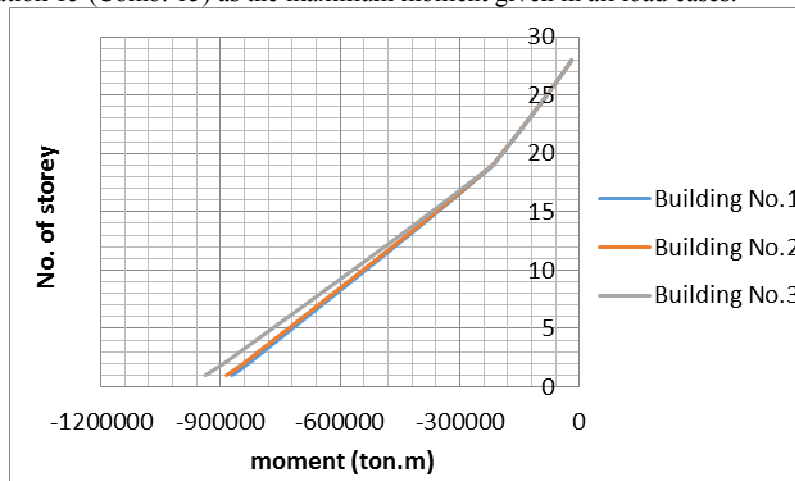

Figure 2.11 Max. moment in Y-direction (ton.m) vs. No. of storey due to comb. 15

2.6.2 Response spectrum dynamic analysis method

In order to perform the seismic analysis and design of a structure to be built at a particular location, the actual time history record is required. However, it is not possible to have such records at each and every location. Further, the seismic analysis of structures cannot be carried out simply based on the peak value of the ground acceleration as the response of the structure depend upon the frequency content of ground motion and its own dynamic properties. To overcome the above difficulties, earthquake response spectrum is the most popular tool in the seismic analysis of structures. There are computational advantages in using the response spectrum method of seismic analysis for prediction of displacements and member forces in structural systems. The method involves the calculation of only the maximum values of the displacements and member forces in each mode of vibration using smooth design spectra that are the average of several earthquake motions. Response spectrum method and its application to various types of the structures summarized. The coda provisions IBC 2003 code for response spectrum analysis of high rise building.

Response spectrum method was used in analysis for the same three structural system as in the case study explained in section 2.2 & 2.4. In comparison of the analysis results of the three structural system in the study was chosen the maximum value according to the load combination of the response spectrum as in the IBC 2003 code which the ETABS program calculated of each storey & each buildings in this study. The design spectral response acceleration at short periods, S_{DS}, to define the response spectrum functions in the ETABS by using IBC Eqns. 16-38 and 16-40.

$S_{DS} = 2/3 \ Fa \ Ss$ (IBC Eqns. 16-38 and 16-40)

And the design spectral response acceleration is calculated at a one second period, S_{D1}, using IBC Eqns.16-39 and 16-41

$S_{D1} = 2/3 \ Fv \ S_1$ (IBC Eqns. 16-39 and 16-41)

2.6.2.1 Load Combinations

The load combinations were used for static analysis add to them load combination of response spectrum analysis according to the IBC 2003 code as shown in table 2.4:

Table 2.4 Additional load combination for response spectrum analysis

Comb. No.	Combinations	Comb. No.	Combinations
1	1.4 DL+1.0 LL+1.5 SPECX	3	0.7 DL+1.5 SPECX
2	1.4 DL+1.0 LL+1.5 SPECY	4	0.7 DL+1.5 SPECY

2.6.2.2 The displacement

It is found that the displacement in different structural system cases is increasing with incrementing storey. Maximum displacement is found in top of the storey in all buildings. The maximum displacement in X-direction of the three structural system of all combination according to IBC 2003 code which the ETABS program calculated of each storey in this study was in the combination 1 (Comb. 1), and the figure 2.12 shows that comparison in response spectrum analysis method of maximum displacement between the three structural system in X-direction.
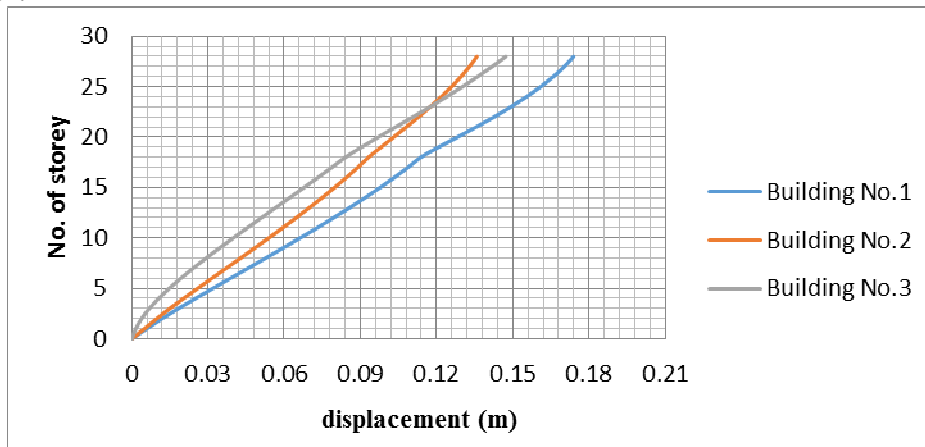

Figure 2.12 Max. displacement in X-direction (m) vs. No. of storey due to comb. 1

Figure 2.13 shows the comparison of the maximum displacement in Y-direction between the three structural system due to the combination 2 (Comb. 2) as the maximum displacement given in all load cases.
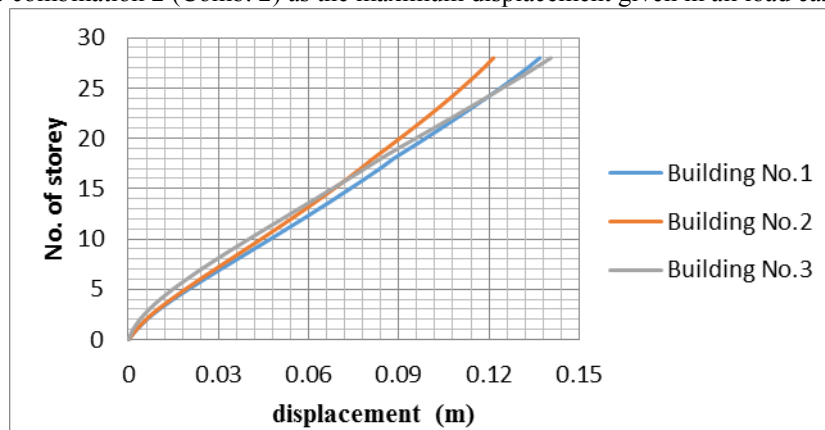

Figure 2.13 Max. displacement in Y-direction (m) vs. No. of storey due to comb. 2

2.6.2.3 The storey drifts:

Story drift in different structural system cases is an important indicator of structural behavior in performance-based seismic analysis. Figure 2.14 shows comparison of the maximum drift in X-direction of the three structural system in each storey at the combination 1 (Comb. 1) as the max. drift gives in all load cases.
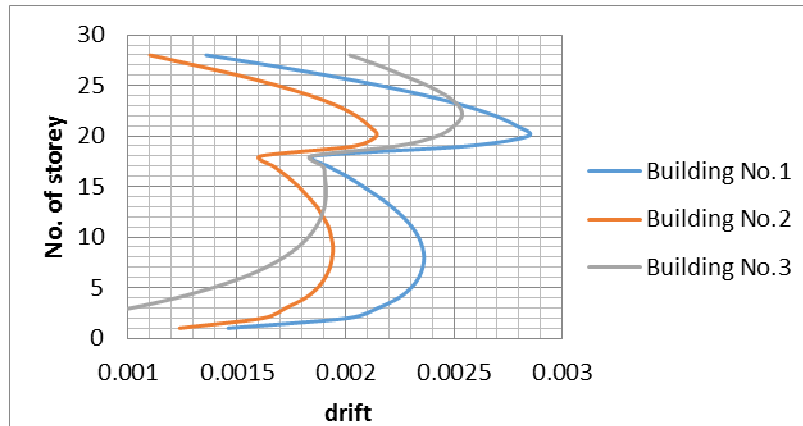
Figure 2.14 Max. drift in X-direction (m) vs. No. of storey due to comb. 1

Figure 2.15 shows the comparison of the maximum drift in Y-direction of the three structural system due to the combination 2 (Comb. 2) as the maximum drift given in all load cases.
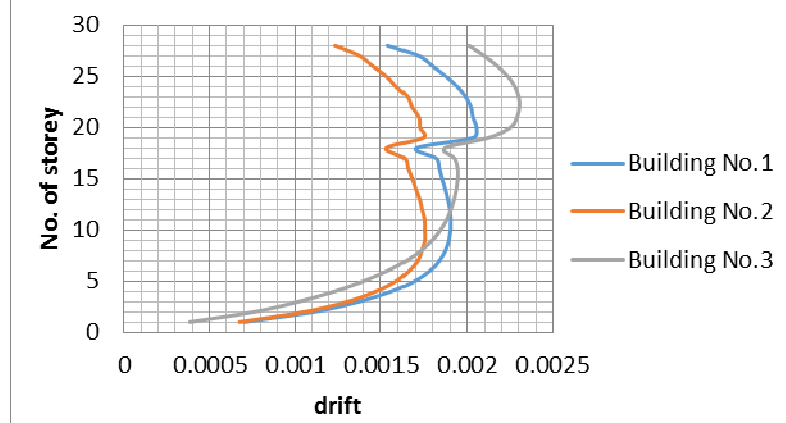
Figure 2.15 Max. drift in Y-direction vs. No. of storey due to comb. 2

2.6.2.4 The shear:

Maximum shear is found in bottom of the storey in all buildings. Figure 2.16 shows the comparison of the maximum shear in X-direction of the three different structural system in this study due to combination 1 (Comb.1) as the maximum shear given in all load cases.
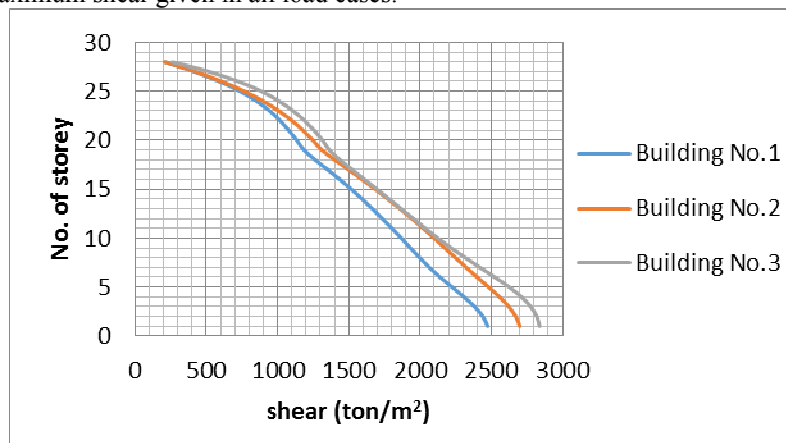
Figure 2.16 Max. shear in X-direction (ton/m^2) vs. No. of storey due to comb. 1

Figure 2.17 shows the comparison of the maximum shear in Y-direction of the three structural system due to the combination 2 (Comb. 2) as the maximum shear given in all load cases.
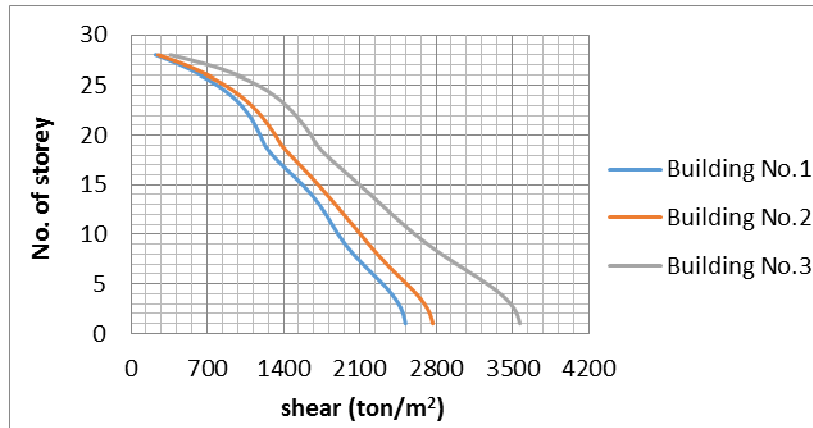
Figure 2.17 Max. shear in Y-direction (ton/m^2) vs. No. of storey due to comb. 2

2.6.2.5 The moment:

The moments are not so negligible to not count during design. The moment increases with increment of storey so slenderness has a effects to the moment. Figure 2.18 shows the comparison in the maximum moment in X-direction due to combination 2 (Comb. 2) as the maximum moment given in all load cases.
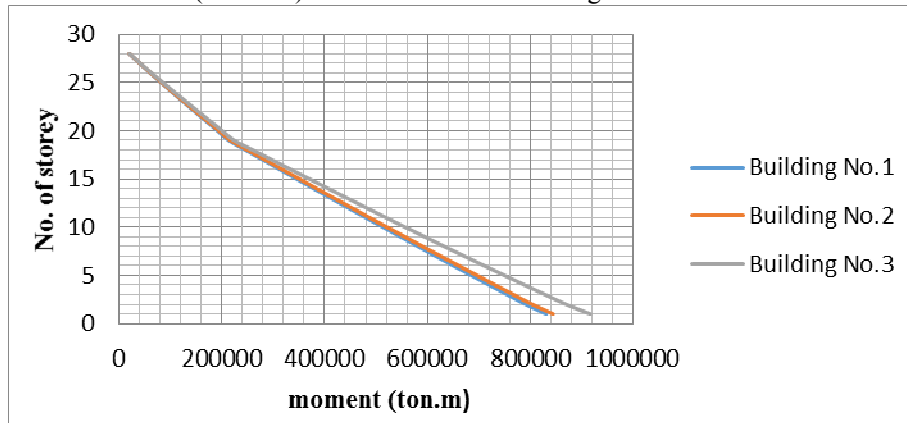

Figure 2.18 Max. moment in X-direction (ton.m) vs. No. of storey due to comb. 2

Figure 2.19 shows the comparison of the maximum moment in Y-direction of the three structural system due to the combination 1 (Comb. 1) as the maximum moment given in all load cases.
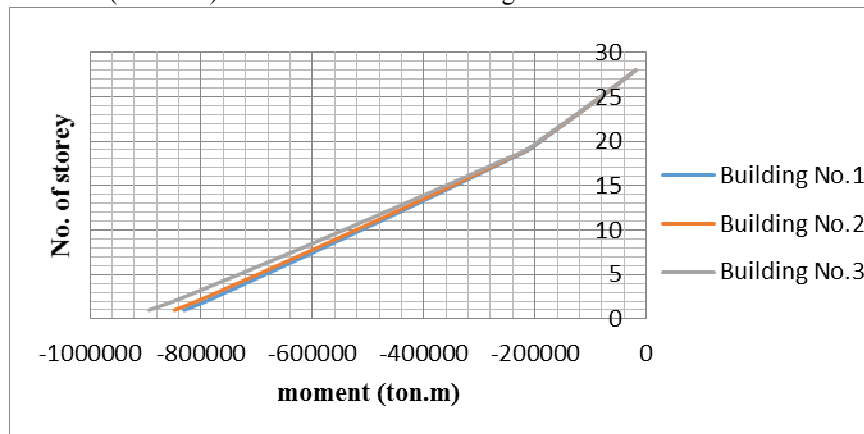

Figure 2.19 Max. moment in Y-direction (ton.m) vs. No. of storey due to comb. 1

2.7 Design results:

According to the ACI 318-5/IBC2003 code, Buildings were designed using ETABS software program and the table 2.5 shows the design results of the total required reinforcement for same sample beam, column and shear wall for each buildings in the case study.

Table 2.5 The design results of the total required reinforcement for the samples

Section	Total Required reinforcement (sq.mm)		
	Building No. 1	Building No. 2	Building No. 3
Beam	4084 mm^2/m	3555 mm^2/m	3442 mm^2/m
Column	6400 mm^2/m	6400 mm^2/m	------------
Shear wall	3904 mm^2/m	3930 mm^2/m	2500 mm^2/m

2.8 Summary Results:

Table 2.6 and 2.7 shows the summary results of equivalent static and response spectrum analysis comparison for the three different structural systems.

Table 2.6 Summary results of equivalent static analysis

Results of analysis	Building No.1	Building No.2	Building No.3
Max. dis. in X-direction	0.2240 m	0.1803 m	0.1905 m
Max. dis. in Y-direction	0.2066 m	0.1754 m	0.2192 m
Max. drift in X-direction	0.0036 m	0.0026 m	0.0031 m
Max. drift in Y-direction	0.0030 m	0.0024 m	0.0033 m
Max. shear in X-direction	2474.42 ton/m^2	2700.64 ton/m^2	2839.1 ton/m^2
Max. shear in Y-direction	2553.44 ton/m^2	2770.19 ton/m^2	3569.41 ton/m^2
Max. moment in X-direction	874092.776 ton.m	887320.30 ton.m	979391.92 ton.m
Max. moment in Y-direction	871842.913 ton.m	885434.44 ton.m	938742.19 ton.m

Table 2.7 Summary results of response spectrum dynamic analysis

Results of analysis	Building one	Building two	Building three
Max. dis. in X-direction	0.173939 m	0.135874 m	0.147269 m
Max. dis. in Y-direction	0.136876 m	0.121484 m	0.140549 m
Max. drift in X-direction	0.002843 m	0.002143 m	0.002537m
Max. drift in Y-direction	0.002053 m	0.001752 m	0.002304 m
Max. shear in X-direction	2474.04 ton/m^2	2699.75ton/m^2	2838.78ton/m^2
Max. shear in Y-direction	2518.32 ton/m^2	2769.6 ton/m^2	3569.12ton/m^2
Max. moment in X-direction	831442.1 ton.m	844731.1 ton.m	917026.5 ton.m
Max. moment in Y-direction	830561 ton.m	847900 ton.m	893785 ton.m

3.1 Conclusion

The conclusion explained in this chapter had been built on the concepts displayed in the previous chapters.

Tall buildings have been growth and developed with increasing in population and high demand of land. The problem was solved by increasing number of storeys from 10 to 20 but now the high rise buildings reached to be more than 150 storeys and may be more in near future with tower system.

The objective of this study is to review all of structural system of high rise buildings and select the important systems to make a comparison in analysis and design between them. Three structural systems have been chosen to make the comparison. The structures with 28 storeys and the dimensions of the first eighteen storeys are 25x25 m and the last ten storeys are 19x19 m in the center of structures. The thickness of slabs is 0.25 m for first eighteen storeys and 0.2 m for the last ten storeys. All the supports of structures are fixed. The dimensions of the beams are 0.4x0.8 m. Building one consists of a central core wall structure and columns which connected by beams to form moment resisting frames in the two orthogonal directions. Building two is the same building one but with bracing system. Building three is a shear wall system consists of a central core wall structure and shear walls arranged in a regular 6m grid and connected by beams to form moment resisting frames in the two orthogonal directions.

The analysis of the structures had done by two methods, static and dynamic analysis using ETABS program. In comparing the result from static analysis and dynamic analysis it has been concluded the following:

1. Displacement: From the results it is shown that building No. 2 with bracing is giving the smaller value of displacement in the top floor compared with other types of structures due to the all load cases by the two analysis methods, So that the bracing structure is better to be used in the term of displacement.

2. Storey drift: According to the results of analysis, it is shown that building No. 2 with bracing is giving the smaller value of drift compared with building No. 1 & 3 due to the all load cases by two analysis methods, So that the structure of building No. 2 is better to be used in the term of drift.

3. Base shear and moment: According to the results of analysis, it is shown that building No. 1 is giving the smaller value of shear and moment compared with building No. 2 & 3 due to the all load cases by two analysis methods, So that the structure of building No. 1 is better to be used in the term of shear & moment.

4. When comparing the results of analysis between static and dynamic analysis methods found the values of shear in three structures are too close by using the two analysis methods.

5. Design: The design made according to the results of analysis, shows that the total reinforcement needed for building No. 3 is less than other structures mentioned in the case study, So that the structure of building No. 3 is more economical in the term of reinforcement.

References

Abd Rahman, A. B., & Rais, A. Z. (2005). The Effects of Diaphragm Components in Resisting Lateral Stability of Precast Concrete Frames.

Album, P. (1991). Bank of China Tower Hong Kong. Hong Kong, Bank of China Hong Kong-Macau Regional Office.

Ali M.M. & Armstrong P.J. (1995). Architecture of tall buildings. Council on tall buildings & urban habitat committee 30, New York, p. 750.

Amit A. Sathawane and Deotale, R. S. (2011). Analysis and Design of Flat Slab and Grid Slab And Their Cost Comparison. International Journal of Engineering Research and Applications, 1, 837-848.

Bayati Z., Mahdikhani M. and Rahaei A. (2008). Optimized use of multi-outrigger system to stiffen tall buildings. The 14th World Conference on Earthquake Engineering , Beijing, China.

Bennett, D., and Steinkamp, J. R. (1995). Skyscrapers: Form & Function. Simon & Schuster.

Brazil, A., Joseph, L. M., Poon, D., and Scarangello, T. (2006). Designing High Rises for Wind Performance. In ASCE: Structures Congress.

Bungale S. Taranath (1988). Reinforced Concrete Design of Tall Buildings, McGraw-Hill Book company, USA.

Bush T. D., Jones (1991). Behavior of RC frame strengthened using structural steel bracing, Journal of Structural Engineering, Vol. 117, No. 4.