ANALYSIS OF MEDIUM RISE REINFORCED CONCRETE BUILDING SUBJECTED TO LATERAL LOADS

By

NADIA BINTI MOHAMAD NASHUKI

This dissertation is submitted to

UNIVERSITY SAINS MALAYSIA

As partial fulfilment of requirements of the degree of

BACHELOR OF ENGINEERING (CIVIL ENGINEERING)

School of Civil Engineering,
Universiti Sains Malaysia

May 2006

ACKNOWLEDGEMENT

Praise to Allah S.W.T., Lord of the Universe, the Merciful and the Gracious; for His guide and consent, my final year project; Analysis of Medium Rise Reinforced Concrete Building Subjected to Lateral Loads is completed.

First, I would like to express my million thanks to my supervisor, Mr. Shaharudin Shah Bin Zaini, for his unforgettable help, advice, guidance and encouragement in the completion of this project. Thank you so much to Associate Professor Dr. Taksiah Abdul Majid and Mr. Lau Tze Liang for their kind assistance in teaching both wind load and seismic load.

For the staff of School of Civil Engineering, thanks for the help and guidance throughout the years of learning. For my dearest friends, thank you for your help and the knowledge you gave me, and of course, thank you all for your friendship.

Lastly, I am truly thankful for my family for the understanding, consideration, sacrifice, encouragement and prayers.

Thank you all

NADIA BINTI MOHAMAD NASHUKI

SCHOOL OF CIVIL ENGINEERING

ABSTRAK

Sejak berlakunya gempa bumi dan tsunami pada 26 Disember 2004 di Sumatera, timbul kesedaran pada para jurutera di Malaysia mengenai kepentingan tentang pertimbangan beban gempa bumi terhadap struktur bangunan di sini.

Dalam projek ini, satu pelan bangunan sederhana tinggi telah diambil kira untuk dianalisa. Analisis ini adalah berkenaan dengan tindakan beban gempa bumi ataupun beban seismik, termasuk juga beban lain seperti beban angin, beban graviti atau swaberat, beban kemasan, beban hidup dan beban batu bata dengan mempertimbangkan perubahan pesongan sisi. Analisis dilakukan dengan menggunakan perisian STAAD III Release 22.3.

Daripada analisis yang telah dilakukan, didapati, beban gempa bumi memberi kesan yang lebih besar terhadap pesongan sisi struktur berbanding beban-beban lain yang diambil kira seperti beban angin, beban swaberat, dan beban mati. Pesongan akibat daripada beban seismik adalah 39.9mm manakala beban angin ialah 21.5mm.

Walaupun semakan terhadap had muktamad adalah mematuhi nilai yang dibenarkan, tetapi perbezaan pesongan yang hampir dua kali ganda akibat beban seismik berbanding beban angin memberikan peringatan awal terhadap keperluan mempertimbangkan beban seismik dalam andaian merekabentuk struktur bangunan di Malaysia.

ABSTRACT

Since the earthquake and tsunami that happened on 26th December 2004 in Sumatra, it has increased the awareness and urged engineers in Malaysia to identify the importance of considering the earthquake impact to the building structures.

In this project, a plan of a medium rise building is selected. This analysis is about the earthquake impact or seismic impact, including other forces such as wind load, gravitational load or selfweight, finishes load, life load and brick wall load with the consideration of the drift. The analysis is being done with the aid of STAAD III Release 22.3 software.

From the analysis, it shows that seismic load gave that major lateral deflection to the building structure, compared to other forces such as wind loads, selfweight and live load. The total lateral deflection due to seismic load is 39.9mm while wind load is 21.5mm. As for the inter-storey drift, the value of 3mm is due to wind and 5mm for seismic load.

Even though the drift is in the safe range for the structure, the drift difference for seismic load is nearly twice the wind loads. This gives an early notice in the importance of seismic loads consideration for designing any structure in Malaysia.

CONTENTS

LIST OF FIGURE

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.6 GENERAL

Recent earthquake tremors and tsunami that hit Indonesia in the year of 2004 gave a deep impact to Malaysia. The disaster had increased the awareness and urged engineers in Malaysia to have a better understanding on the potential hazard that may affect certain building's structures.

Medium rise reinforced concrete building of a 9 storey height is selected for this analysis. Building in Malaysia was designed and built having most of the irregularities and without incorporating the seismic loading. The behaviors of such existing structures when being re-analyzed together with seismic load may reveal the important information such as changes in deflection, mode shape, weak areas and proximity of its natural frequency to the long distance Sumatran Earthquake.

1.7 OBJECTIVES

1. To determine the deflection for a medium rise reinforced concrete building subjected to wind and seismic loads
2. To compare the difference of maximum deflection caused by seismic load and wind load for medium rise reinforced concrete building.

3. To compare the inter-storey drift of the building subjected to seismic and wind loadings.

1.8 SCOPE OF WORK

1. Obtain an acceptable structural plan of medium rise reinforced concrete building.
2. Analyze the structure combining different load factor of gravity, wind and seismic loading with the aid of STAAD-III Release 22.3.
3. Analyze the changes in deflection.

1.9 OUTCOME

1. The behavior of medium rise reinforced concrete structure experiencing combination of different load factor can be identified.
2. Effectiveness of the structural forms selected for medium rise can be identified

1.5 THE IMPORTANCE AND BENEFITS OF THE PROJECT

This project will provide useful information to the designers on the selection of efficient structural form for medium rise building when the seismic loading is considered.

Even though the seismic load are rarely being considered in Malaysia, the impact from the Sumatran Earthquake can be seen right here, and it become a concern that if the disaster occurred again, these buildings may collapsed.

CHAPTER 2

LITERATURE REVIEW

The design practice in Malaysia does not incorporate seismic load simply because the classical understanding that Malaysia is not in the seismic region. Nevertheless, an earthquake disaster that occurred in North Sumatra at Banda Aceh on 26th December 2004, killed thousands of people, including 68 people in Malaysia. Since this incidence, people realise the important for Malaysia to be prepared to confront with such disaster since this country is located near to the country that have potential for earthquake or tsunami to occurred regularly. For engineering purposes, especially the structural engineer, they start to think the important in consideration of seismic loading in their building design (Adnan and Hendiyawan, 2005).

2.1 EARTHQUAKE

In the case of earthquakes, the load source is not a force as such, but rather something that includes motion of the structure, in which case the mass of the building is actually the load source. The masses to be used in the analysis of a building should be based on known dead loads, including probable value of the live loads, applying appropriate reductions to take account that not all floors will be fully loaded at any one time. For this analysis, the loads are not been calculated in specific. The loads are considered at the critical sections, and several other sections. It is assumed that some of the sections are loaded with same impact (Ambrose and Vergun, 1995).

The seismic response of the building is depending on the dynamic property of the structure, ground motion of the foundations, and the mode of soil-structure interaction. A very stiff building’s motion will be almost identical to the ground motion but it is not for a flexible building’s (Ambrose and Vergun, 1995).

Dead load is a disadvantage in earthquakes, because the lateral force is directly proportional to it. It is useful for overturn resistance and is a requirement for the foundations that must anchor the building (Ambrose and Vergun, 1995).

A critical determination for seismic design is what is called the *base shear*, which is essentially the total lateral force assumed to be delivered to the building at its base. For structural design, the force is actually assumed to be distributed vertically in the building, but the total force thus distributed is visualized as the base shear (Ambrose and Vergun, 1995).

Although it is of major importance, the determination of the base shear is only the first step in the process of structural design or investigation for seismic effects. The total horizontal force computed as the base shear must be distributed both vertically and horizontally to the elements of the lateral load-resisting system. It begins with a consideration of the actual distribution of the building mass, developing actual inertial forces (Ambrose and Vergun, 1995).

Earthquakes are essentially vibrations of the earth's crust caused by subterranean ground faults. Major earthquakes occur most frequently in particular areas of the earth's surface that are called zones of high probability cause significant damage to buildings (Ambrose and Vergun, 1987).

During an earthquake, the ground surface moves in all directions and the most damaging effects on structures are generally the movements in a parallel direction to the ground surface. This is because the fact that the structures are routinely designed for vertical gravity loads (Ambrose and Vergun, 1987). Table 2.1 showed the list of major earthquakes detected since 1990, while Figure 2.1 showed the world map of earthquakes with magnitude 8.0 and greater since 1990.

Table 2.1: List of Major Earthquakes since 1990

Location	Date	Magnitude
Chile	22 05 1960	9.5
Prince William Sound, Alaska	28 03 1964	9.2
Off the West Coast of Northern Sumatra	26 12 2004	9.0
Kamchatka	04 11 1952	9.0
Off the Coast of Ecuador	31 01 1906	8.8
Northern Sumatra, Indonesia	28 03 2005	8.7
Rat Islands, Alaska	04 02 1965	8.7
Andreanof Islands, Alaska	09 03 1957	8.6
Assam - Tibet	15 08 1950	8.6
Kuril Islands	13 10 1963	8.5
Banda Sea, Indonesia	01 02 1938	8.5
Chile-Argentina Border	11 11 1922	8.5

Source: http://neic.usgs.gov/neis/eqlists/10maps_world.html

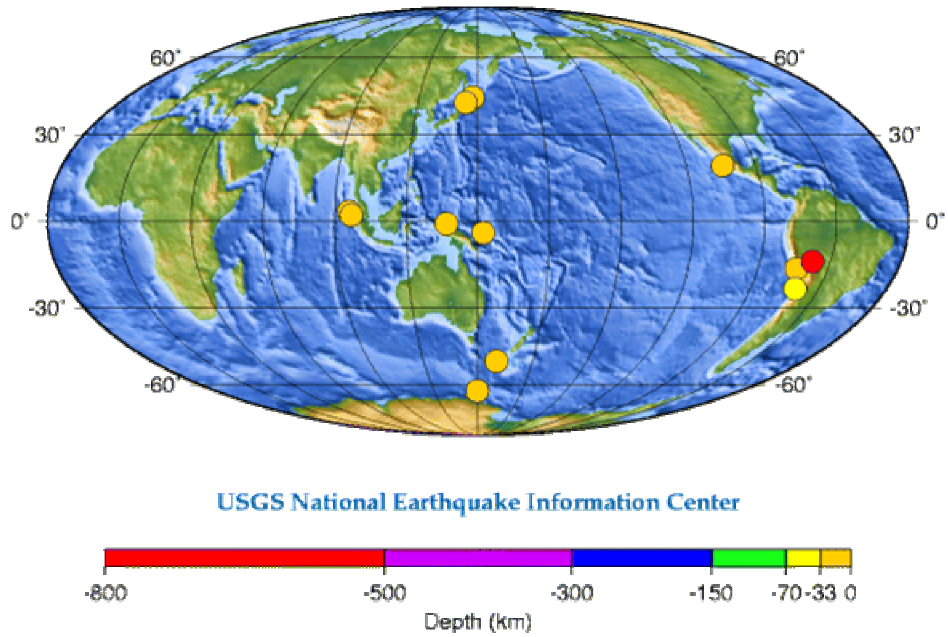

Figure 2.1: World map of earthquakes with Magnitude 8.0 and greater since 1990

Source: http://neic.usgs.gov/neis/eqlists

Table 2.2 showed the death occurrence due to large magnitude earthquake.

Table 2.2: Deaths from Magnitude 8 and Greater Earthquakes since 1990

Date UTC	Region	Magnitude	Number Killed
1994 06 09	Northern Bolivia	8.2	10
1994 10 04	Kuril Islands	8.3	11
1995 07 30	Near Coast of Northern Chile	8.0	3
1995 10 09	Near Coast of Jalisco, Mexico	8.0	49
1996 02 17	Irian Jaya Region, Indonesia	8.2	166
1998 03 25	Balleny Islands Region	8.1	0

2000 11 16	New Ireland Region, P.N.G.	8.0	2
2001 06 23	Near Coast of Peru	8.4	138
2003 09 25	Hokkaido, Japan Region	8.3	0
2004 12 23	North of Macquarie Island	8.1	0
2004 12 26	Off West Coast of Northern Sumatra	9.0	275950
2005 03 28	Northern Sumatra, Indonesia	8.7	1313
Total			277642

Source: http://neic.usgs.gov/neis/eqlists

Table 2.3 showed the frequency of earthquake occurrence detected since 1990.

Table 2.3: Frequency of Occurrence of Earthquakes

Descriptor	Magnitude	Average Annually
Great	8 and higher	1 [1]
Major	7 - 7.9	17 [2]
Strong	6 - 6.9	134 [2]
Moderate	5 - 5.9	1319 [2]
Light	4 - 4.9	13,000 (estimated)
Minor	3 - 3.9	130,000 (estimated)
Very Minor	2 - 2.9	1,300,000 (estimated)
[1] Based on observations since 1900. [2] Based on observations since 1990.		

Source: http://neic.usgs.gov/neis/eqlists

Table 2.4: Damage Caused by the Earthquake

BACKGROUND AND THE DAMAGE
Location: **Pakistan** Magnitude: **7.6** Date: **8 October 2005**
At least 30,000 people killed, 43,000 injured and many towns and villages destroyed or badly damaged in northern Pakistan. At least 800 people were killed in India and four people in Afghanistan. An estimated 2.5 million people in the area have been left homeless. Landslides have damaged roads and bridges blocking access to many of the worst-hit areas.
Location: **Northern Sumatra** Magnitude: **8.7** Date: **28 March 2005**
At least 1000 people killed, 300 injured and 300 buildings destroyed on Nias; 100 people killed, many injured and several buildings damaged on Simeulue; 200 people killed in Kepulauan Banyak; 3 people killed, 40 injured and some damage in the Meulaboh area, Sumatra. A 3-meter tsunami damaged the port and airport on Simeulue. At least 10 people were killed during evacuation of the coast of Sri Lanka. Felt along the west coast of Malaysia; at Bangkok and at Phuket, Thailand; at Singapore; at Male, Maldives. The quake was also felt in the Andaman and Nicobar Islands, India and in Sri Lanka.

Table 2.4 continued

Location: **Sumatra-Andaman Island** Magnitude: **9.0** Date: **26 December 2004**
The fourth largest earthquake in the world since 1900 and is the largest since the 1964 Prince William Sound, Alaska earthquake. In total, more than 283,100 people were killed, 14,100 are still listed as missing, and 1,126,900 were displaced by the earthquake and subsequent tsunami in 10 countries in South Asia and East Africa. The earthquake itself caused severe damage and casualties in northern Sumatra, Indonesia and in the Nicobar Islands, India. It was felt at Banda Aceh, at Meulaboh and at Medan, Sumatra; at Port Blair, Andaman Islands, India; in parts of Bangladesh, mainland India, Malaysia, Maldives, Myanmar, Singapore, Sri Lanka and Thailand. The tsunami caused more casualties than any other in recorded history and was recorded nearly world-wide on tide gauges in the Indian, Pacific and Atlantic Oceans. At least 108,100 people were killed and 127,700 are missing and presumed killed by the earthquake and tsunami in Indonesia. Tsunamis killed at least 30,900 people in Sri Lanka, 10,700 in India, 5,300 in Thailand, 150 in Somalia, 90 in Myanmar, 82 in Maldives, 68 in Malaysia, 10 in Tanzania, 3 in Seychelles, 2 in Bangladesh and 1 in Kenya. Tsunamis caused damage in Madagascar and Mauritius and caused minor damage at two places on the west coast of Australia. Seiches were observed in India and the United States and water level fluctuations occurred in wells in various parts of the United States. Subsidence and landslides were observed in Sumatra. A mud volcano near Baratang, Andaman Islands became active on December 28 and gas emissions were reported in Arakan, Myanmar

Source: http://earthquake.usgs.gov

2.2 SEISMIC LOAD

Seismic codes have long relied upon the concept of *inelastic spectrum* for specifying design actions (forces) to be used for elastic analysis of structures which are expected to respond inelastically to the design earthquake (Hyo Seon Park et al., 2005).

Seismic load is a load that caused by the earthquake includes building's inertia force produce by the basic shake of a seismic disturbance. An earthquake resistance design more on inertia force where the impact on the building is more significant than the lateral shaking components (Coull and Smith, 1991).

Earthquake produces disastrous effects, including tidal wave, tsunami, and vibratory motions. This activity cannot be fully understood in terms of static force alone, however, as dynamic aspects of both the ground motion and building response must be considered in the design (Ambrose and Vergun, 1995).

In the area where an earthquake occurred, the intensity is non proportional with frequency. A design of an earthquake resistance for building should (Englekirk, 2003):

1. Resists a minor earthquake without damage
2. Resists a moderate earthquake without structural damage but accepted the possibility of non-structural damage.
3. Resists a major earthquake with the possibility of structural and non-structural damage, but without collapsing.

The magnitude of seismic force is a resultant of the dynamic reaction because of the earth movement. To estimate the seismic load, the method that is used is by considering the structure's characteristic and the history of earthquake event in the stated area (Englekirk, 2003).

Seismic loads are actually generated by the dead weight of the building itself. Each part of the building's weight is considered as a horizontal force. To determine a seismic load, all the elements that permanently attached to the structure will be considered as total dead weight (Englekirk, 2003).

2.3 WIND LOAD

A complete description of wind loads relies on proper definition of the wind climate from meteorological records, together with an understanding of atmospheric boundary layers, turbulence properties and the variation of wind speed with height, the aerodynamic forces produced by the interaction of the building with the turbulent boundary layer, and the dynamic response of the structure to the wind forces (Coull and Smith, 1991).

The critical condition of individual parts or surface of an object may be caused by one or the combination of wind effects. Damage can occur with regard of the object. If it resting on the ground, it may be collapsed or slid, rolled over or lift from the position. For the horizontal surface, it is subjected to either inward or suction pressure because of the wind. Horizontal force is calculated as a horizontal pressure on the building figure with adjustments made for height (Coull and Smith, 1991).

Dead load is an advantage in wind design, because it can resist uplift, overturn and sliding. But, if the load is too big, it will cause the stress to offset (Ambrose and Vergun, 1995).

Interstorey drift refer to as a horizontal deflection that caused by the lateral loads. The Uniform Building Codes (UBC) does not provide limits for wind drift, but a common one being a limit of interstorey drift to 0.005 times the interstorey height while for masonry structure is 0.0025 times the interstorey height (Ambrose and Vergun, 1995). Another limit that can be adopted is 0.0015H (H is the height of the building) as recommended by Coull and Smith (1991)

2.4 SHEAR WALL

Shear wall usually used for giving a lateral support to a building, and it can changes over its elasticity limit. Shear wall's strength must exceed its seismic load or the foundation is designed for absorbing the energy from earthquake (Ambrose and Vergun, 1995).

Ductile shear wall design is based on the post-yield deformation through the flange. When the ductile capacity less than the shear strength, the shear wall characteristic will changes like beam characteristic. When the shear strength less than wall's bending strength, a ductile path will be formed. When opening occurred at shear wall, seismic load path will flow to the tension. When the tension parallel, the un-parallel part will cause a major deformation at the beam that connect two stiffer members.

The used of pre-cast will be increase if it is connected effectively. Test has been done and the result proves that the pre-cast element that is connected carefully not only stiff upon earthquake, but also less damage.

Shear wall functions as a large vertical cantilever to resists seismic forces, is an essential element in tall reinforced concrete structures and a valuable element in those of medium and low rise structure. Shear wall provides strength more economically than a frame and control displacements to a degree that cannot be achieve by a frame (Waleed et al., 2005).

Seismic design for a shear wall building support usually is formed by decreasing the building to a single-degree-of-freedom model that consists mass that act effectively. Stiffness and post-yield for a shear wall can be signified from the test with the choice of stiffness and effective ductility. When the shear walls that support the building is the same, the design work is easy with the ductile component and systems are the same (Ambrose and Vergun, 1995).

2.5 DUCTILITY

Ductility is important for structure that response to the major movement from the ground. It acts like a shake absorber in the building, whereas it decreases the flow of the force to the firm structure (Coull and Smith, 1991).

The resultant of force usually used in designing the hypothesis elastic for a building. This simple design is not true because it involves an imaginative structure and ductility is a result from that design. There are efforts to apply the design process to the real structure (Coull and Smith, 1991).

The principal concern in structural design for earthquake forces is for the laterally resistive system of the building. Most building consists of combination of horizontally distributing elements and vertical bracing elements. Failure of any part of this system, or of connections between the parts, can result in major damage to the building, including the possibility of total collapse.

An earthquake shakes the whole building and if the building is to remain completely intact, the potential movement of all its parts must be considered in the design. The survival of the structure system is limited accomplishment if suspended ceiling fall, windows shatters, plumbing pipes burst and elevators are derailed.

2.6 SHEAR

Shear strength and effective development shear transfer is important in designing a concrete structure and it is critical in pre-cast effective used as a seismic load path. The complex mechanism in shear transfer that exists in an in-situ concrete has been decrease to the beam characteristic mechanism and it's not always right, especially in pre-cast concrete structure. The understanding in shear transfer and the limit is important in developing the force path in a pre-cast concrete system.

2.7 RIGID FRAME STRUCTURE

A rigid frame building usually have a parallel bending arrangement consists from column and purlin with a bending resistance connection. Lateral forces are resisted by column bending moment, purlin and connecter. Frame connections also help in resisting the gravity load by decreasing purlin's moment.

The advantage of rigid frame is the rectangular shape. The arrangement is free from support member and structure wall, giving an internal and external freedom for windows. Rigid frame building is considered economical for building to the height of 25. But if the rigid frame is combined with shear wall, the structure is stiffer and the height can reached to 50 floors. Plate structure is the same as rigid frame, but the purlin is replaced by slab. For rigid frame structure, the horizontal and vertical force in a plane plate caused by bending will continuously occurred between vertical and horizontal components.

The horizontal stiffness for a rigid frame depends on the bending resistance of the purlin, column and the connection. The collection of horizontal shear in every rigid frame floor is resisted by shear column in that floor.

Shear that caused the tall column bend in a twin curve with the contraflexular point is exactly in the middle of the floor. Moment that is forced to the bond from upper and below floor is resisted by purlin link, where it also bend in the twin curve, with a contraflexular point is right in the middle of member.

The changes of column and purlin shape allowed the frame movement and horizontal deformation in every floor. The whole deformation rigid frame structures caused by the shear arrangement with extension towards wind, maximum bend at below and minimum displacement at upper as shown is Figure 2.2.

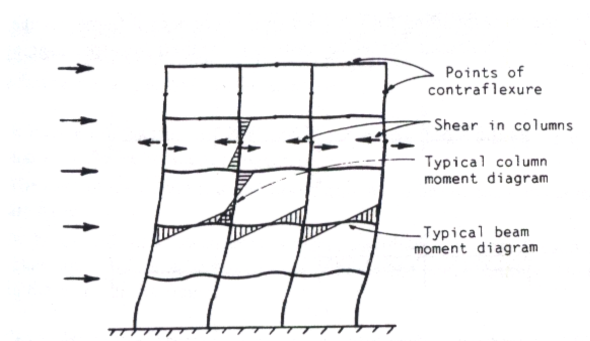

Figure 2.2 Forces and Deformation Caused by External Shear

(Coull and Smith, 1991)

The whole moment for external horizontal load is resisted by every floor with the combination of axial tension and compression force in a column in against structural condition (Figure 2.3). Because of the total rotation is increasing with the floor, the floor swing due to the increasing of bending and decreasing of movement. Results of all bending to the sway will increase than movement will not exceed 10% movement, except for a really tall and slender rigid frame.

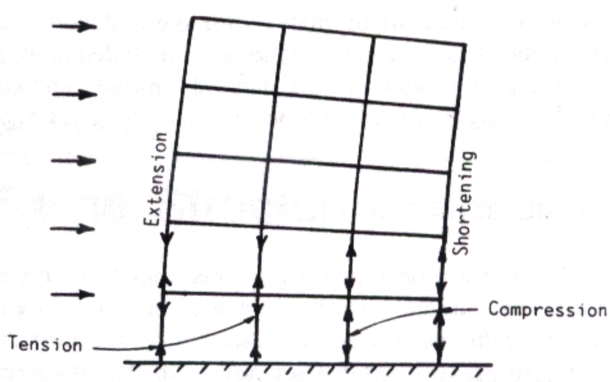

Figure 2.3: Forces and Deformation Caused by External Moment

(Coull and Smith, 1991)

2.8 STAAD III

STAAD III is and engineering software equipped with powerful analysis, design, graphics and visualization capabilities. It is owned by Research Engineering Inc, a company in United State of America. User can build model, verify it graphically, perform analysis and design, review the results, sort and search the data to create a report, all within the same graphics based environment.

Following are the main options available from the Concurrent Graphics Environment:

STAAD-III Analysis and Design

STAAD-PRE Graphical Input Generation

STAAD-POST Graphical Post-Processing

STAAD-INTDES interactive Design of Structural Components

The advantage of STAAD III

i. Input can be done in text or graphic method

ii. Powerful icon-based graphics tools provide extremely user-friendly navigation and manipulation capabilities.

iii. Checking can be done in text or graphic method

iv. 'REPEAT' is an easy command for define a repeating joint, member or element.

v. Output can be in text or graphic method

2.8.1 STAAD-III ANALYSIS AND DESIGN

The process of analyzing and designing can be performed in the same run. This software uses a command language that can be created through an editor. Output generated by STAAD-III consists of detailed numerical results for analysis or design and sharp presentation quality printer plots as part of the run document. Figure 2.4 gives the STAAD-III Rel 22.3W basic environment mode.

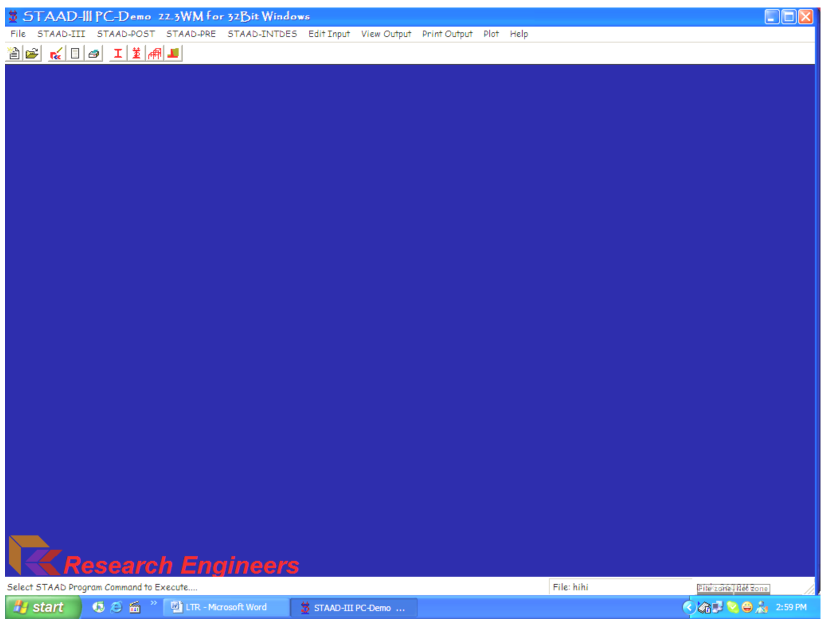

Figure 2.4 STAAD-III Rel 22.3W Environments

2.8.2 STAAD-PRE GRAPHICAL INPUT GENERATION

It's allowed powerful geometry generation of structural models graphically with algorithm facilities generation and viewing the models in 2D and 3D situations. The specification like section properties, support, loads, analysis and design requirements are available. As the output, it'll generate command based on the input file. Figure 2.5

and 2.6 show the STAAD-PRE environments and STAAD-PRE environment with the text editor.

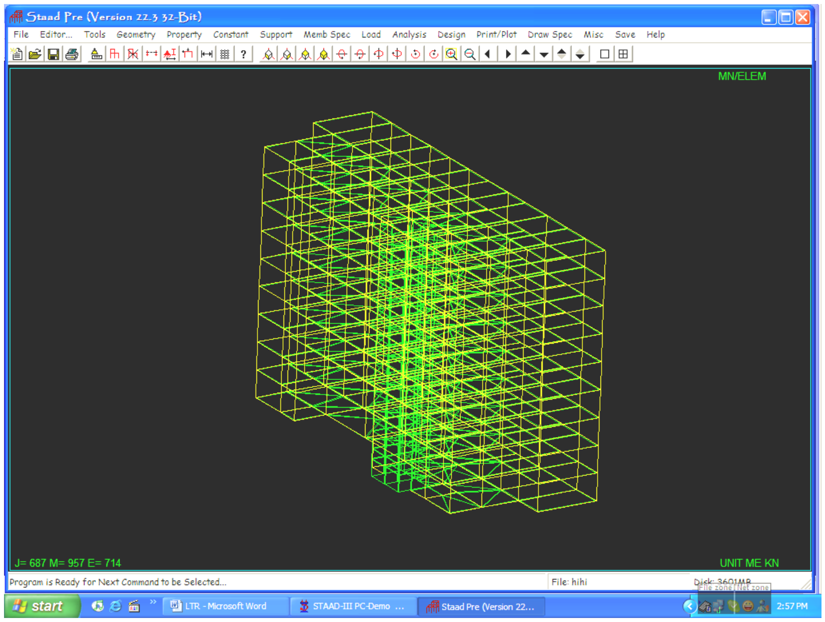

Figure 2.5 STAAD-PRE environments

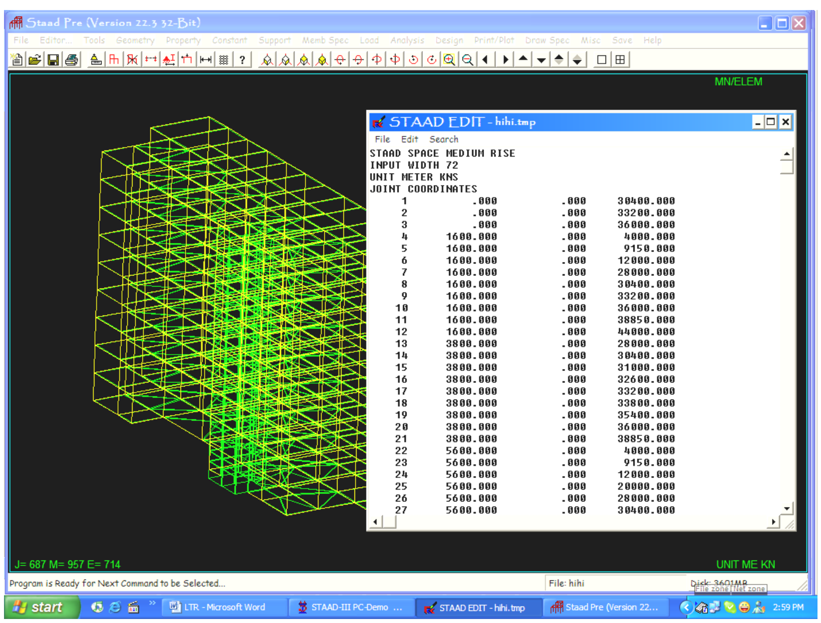

Figure 2.6 STAAD-PRE environment and Text Editor

The text editor is available in the STAAD-PRE facility. Its access as an independent application and can be used for creating a new input file, viewing and editing the existing input file.

2.8.3 STAAD-POST GRAPHICAL POST-PROCESSING

STAAD-POST is a graphics facility for verification of the model and display of the results. The model verification capabilities include complete graphics verification and visualization for all items, while the results display the plotting structure, deflection, mode shape, bending moment and shear forces diagrams. Figure 2.7 shows the STAAD-POST environment.

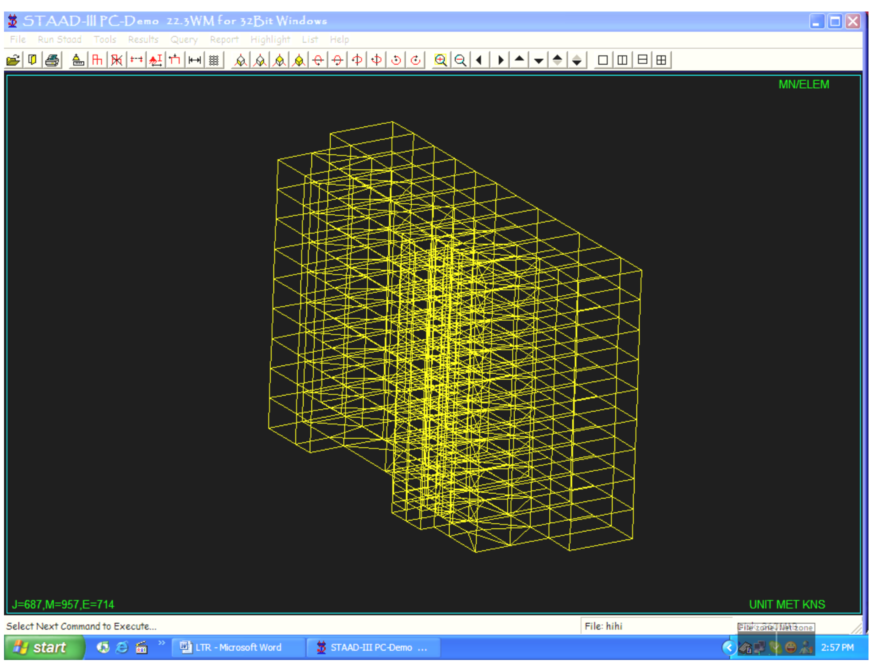

Figure 2.7 STAAD-POST Environments

CHAPTER 3

METHODOLOGY

Nowadays, there are so many softwares that have been designed for helping the engineers to follow up their design work. These softwares are used to analyze and design the concrete and steel structures.

These sofwares are important to make the engineers work easy and they can predict the structural behaviour. They can check the design so that the design will not face a failure. The examples of softwares are STAAD III, ESTEEM, ROBOT97 and ADS

STAAD-III is used to analyze the medium-rise building. This software has the capabilities of analyzing, designing, graphical and visual. Figure 3.1 showed the flow chart of the overall studies.

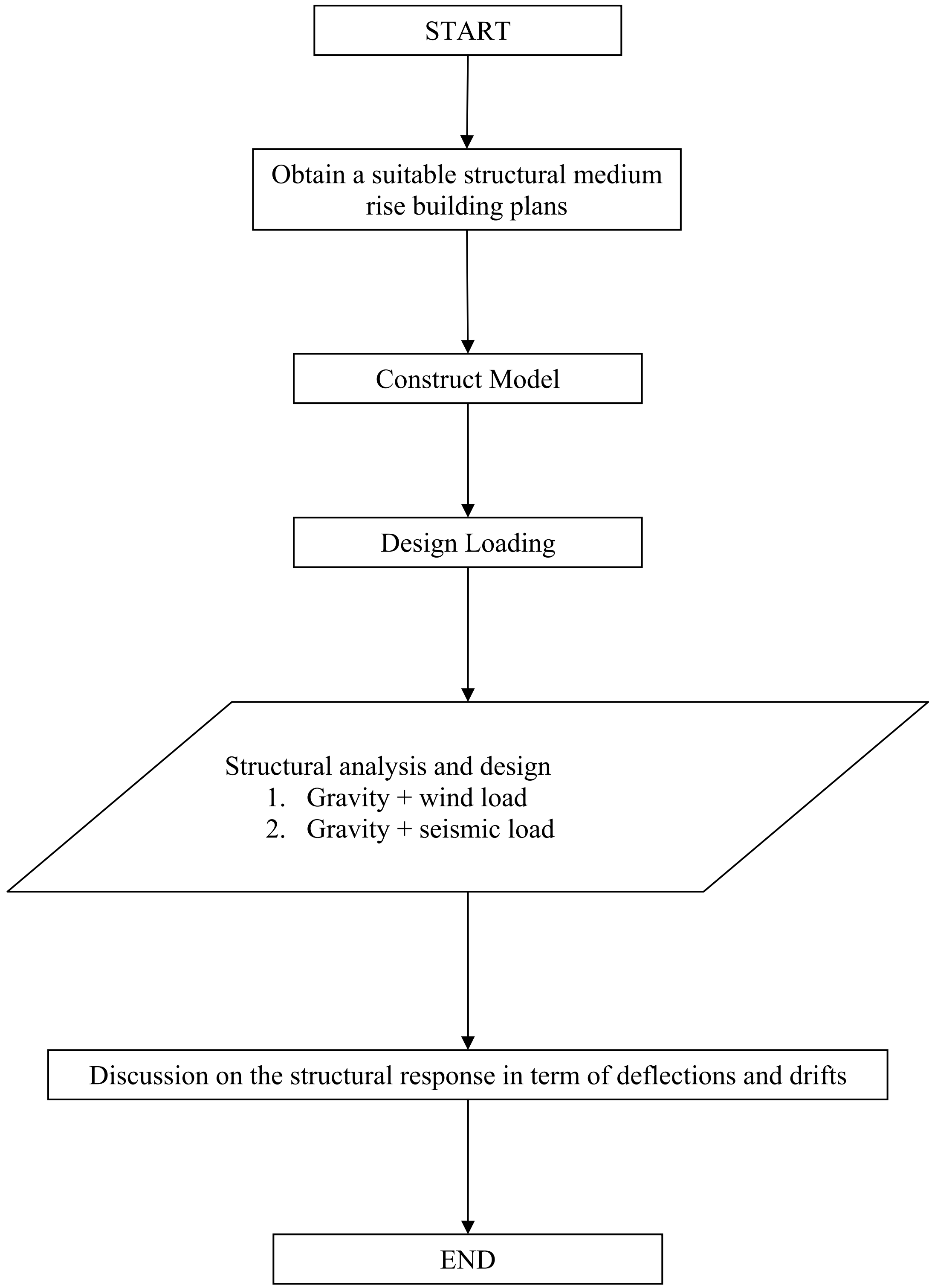

Figure 3.1 Project Methodology