Effect of Roof Top Towers On Lateral Load Analysis of the Buildings

A Dissertation Submitted in Partial Fulfillment
for the Award of the Degree of

Master of Engineering
in
Civil Engineering (Structures)

Submitted by

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Candidate's Declaration Certificate

This is to declare that the minor project titled **Effect of Roof Top Towers on Lateral Load Analysis of the Buildings** is the bonafide record of work done by me (Jatin Narula) for the partial fulfillment of the requirements for the degree of Master of Engineering in Civil Engineering (Structural Engineering), Delhi College of Engineering.

This project has been carried out under the supervision of Dr. (Mrs.) P.R.Bose and Shri Alok Verma.

I have not submitted the matter embodied in this report for the award any other degree or diploma.

July 28, 2005 Name & Roll Number

Jatin Narula
01/str/03

This is to certify that the above statements made by the candidate are correct to the best of our knowledge.

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Abstract

Towers are important structural components used for various purposes in today's life. Communication and transmission line towers are widely used to transmit data and electricity respectively over long distances. Transmission line towers essentially rest on ground due to their large dimensions. Communication towers either rest on ground or are installed on the roof top of the buildings depending on the size of the tower and also on the availability of the space. The roof top communication towers are mainly used in metropolitan cities like Delhi where the space is available at a premium and the rapid expansion of the telecom network has necessitated their installation in large number. The advantage of a roof top tower is the utilization of the height of the building in covering a greater area. The close proximity of such towers permits them to be of small height up to 20 metres.

The common practice for analyzing roof top towers is to first analyze the tower as a separate structure and then transfer the forces generated in this tower to the building where it is to be installed. The wind forces in the tower are calculated by assuming it to be standing on the roof top. This report tries to differ in this approach by modeling the tower as a part of a three and a six storey building located in Delhi and compares the results with that of traditional methodology.

The position of a tower on the plan of the building is likely to affect the forces generated in the tower as well as in the building. This aspect can be studied by modeling the tower at different positions on the plan of the building and comparing various parameters like the time period of the combined system, forces and moments generated in the building and in the tower and the displacements at the locations where the tower is supported on to the building. Similarly the effect of the tower on the building will vary with increasing building height. This report analyzes this effect by repeating the numerical study for a six storey building.

Objectives of the Project

The various objectives of this project report are listed below.

- To study the present state of art and state of practice for roof top communication towers by literature survey and by carrying out visits to various roof top tower locations.

- To study the Codes and guidelines applicable to such towers.

- To carry out a numerical analysis of roof top towers and study the following:

    - Effect of roof top towers on building forces when considered as a part of the building.

    - Effect of the position of the tower in the building plan on the forces in the building.

    - The effect of the roof top tower on building forces with increase in building height.

- Comparing the results obtained from the two approaches of roof top tower design – one in which the tower reactions are applied on to supports in the buildings and the other one in which the tower is considered as a part of the building

- To suggest the scope of further study.

Chapter One

Literature Survey

Introduction

A tower can be defined as a vertical structure, which is generally more vertical than linear. In communications, the term refers to a structure, which supports antennae. In other words, it is a tall skeleton structure with relatively small cross-section, which has a large ratio between height and maximum width. It is a freely standing self supporting structure fixed to the base or foundation. Following paragraphs deal with the theoretical part of the various literature including types of towers, various types of bracing configurations, loadings on the towers and discusses the wind load calculations for towers as per Indian Code in detail.

Classification

Towers (short, medium, tall) are mostly used for bridges, communications systems, electric power transmission, distribution networks, overhead tanks etc.
Towers are mainly of two types:

1. guyed towers
2. self-supporting towers

The towers have vertical or inclined trusses for the sides while the cross-section of the tower in the plan is either a triangle, rectangle a regular polygon. Such towers are also called lattice towers. Free-standing towers act as cantilever trusses in carrying the wind and seismic loads. These towers demand more steel but less base area and are suitable in many situations. Most of the TV, MW, power transmission, flood light towers are free standing towers.
The guyed towers are supported by guy wires which transmit the wind loads to the ground. These towers are much lighter than the free standing type but require a large free space to anchor guywires.
Moments due to wind loads is quite large in self-supporting towers which behaved as cantilever whereas the moments are small in guyed towers whose behaviour is like a continuous beam on elastic supports.

The characteristics of tower types can be summarized as below.

Characteristics of Self Supporting (SS) Towers, Guyed Towers and Monopoles

A. Self-Supporting Lattice Towers
- Three or four sided (mostly three)
- Requires less land area compared to guyed towers
- Moderate cost to build, excluding real estate
- Can be built as high as ~ 1,000 feet
- Can be modified after construction
- Aesthetically, considered less pleasing

B. Guyed Towers
- Slender column supported by guy cables
- Requires a relatively large land area to place guys and anchors (guy radius ~ 40-80% of tower height)
- Least costly tower to build, excluding real estate
- Can be built as high as ~2,000 feet
- Tend to be used primarily by Broadcast industry (radio and TV)
- Most easily modified

C. Monopoles
- Tubular, free-standing, tapered (stepped or continuous) structure
- Requires less land area compared to other towers
- Foundation is significant
- Most costly, excluding real estate
- Tend to be deployed in urban areas
- Can be built as high as ~ 250 feet
- Nearly impossible to modify
- Not as rigid -- top deflection may be a problem

Based on the placement of tower, communication towers can be classified in to the following two groups:

• Green Field Tower
• Roof Top Tower

If the tower is erected on the natural ground after excavation of soil and provided with suitable foundation system then this tower is called Green Field Tower. Similarly if the tower is erected on the existing building by raising the existing columns and provided with tie beams as foundation in between the columns, it is called Roof Top Tower.

The height of roof top tower varies generally from 9m to 30m where as the height of green field communication tower varies from 30m to 200m depending on the line of sight required. Green field towers are preferable in rural areas where land is available and in urban areas most of the towers are of roof top as it is difficult to acquire open land for green field towers. Roof top towers are more economical as compared to Green field towers as the height of building is utilized in reducing the height of tower required.

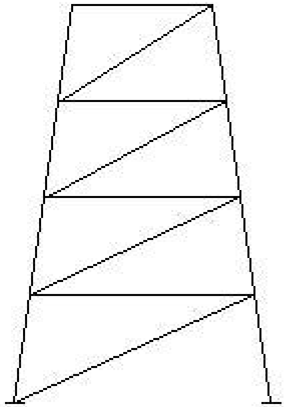
This report deals with the self-supporting lattice towers only. Before discussing the design methodology, it is necessary to mention the configurations of lattice towers, various loads acting on the towers and the Codes to be followed for their design.

Lattice Tower Configurations and Bracings

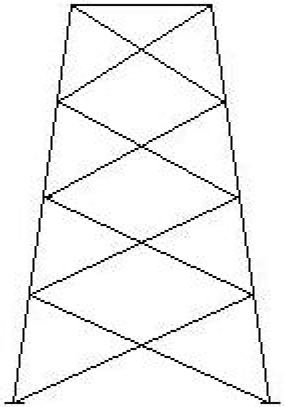
The corner vertical or nearly vertical members of the towers are called legs or column members and they are the main load bearing elements. The leg members are interconnected by bracings with or without horizontals with carry a nominal force. The leg and bracing members will be under compression in some load conditions therefore the slenderness ratio of the members' plays important role.

The various types of bracings used in towers are as mentioned below.

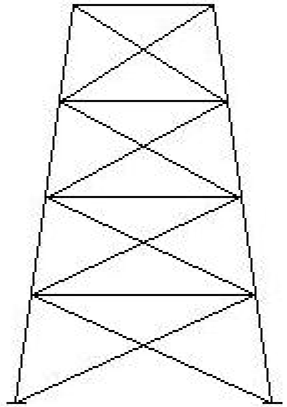
1. Single diagonal bracings: This is the simplest form of bracing. The wind shear at any level is shared by the single diagonal of the panel. Such bracing is used for towers up to 30 m height.
2. X-X bracing: This is a double diagonal system without horizontal bracing, and used for towers up to 50 m height. It is a statically determinate structure.
3. X-B bracing: This is a double diagonal system with horizontal bracings. Such bracings are quite rigid, and may be used for towers up to 50 m height. The structure is statically indeterminate. The horizontal members are redundant members and carry only nominal stresses.
4. K-bracing: Such a bracing gives large head room, and hence K-bracing can be used in lower panels where large head room is required. The structure is statically determinate. Such bracing can be used for towers of 50 to 200 m height.
5. X B X bracing: This is a combination of XX and XB bracing where horizontal members are provided only at the level of crossing of diagonals. The structure is statically indeterminate. However, the length of the diagonal is reduced. Such bracing can be used for towers of 50 to 200 m height.
6. W-bracing: This system uses a number of overlapping diagonals. The system is statically indeterminate. However, the effective length of diagonals is reduced and the system is quite rigid.
7. Y-bracing: This system gives larger headroom and can be used for lower panels. It is statically determinate.
8. Arch bracing: Such a bracing can be adopted for wider panels. This system also provides greater headroom and is statically determinate.



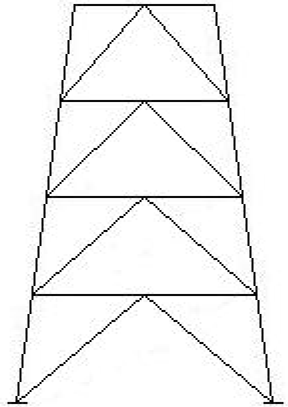
Single Diagonal Bracing



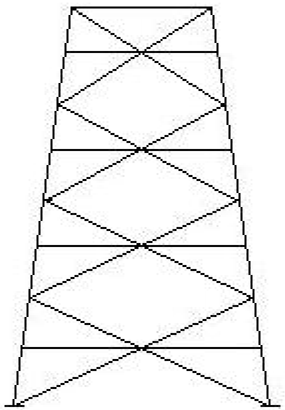
Double Diagonal X-X Bracing



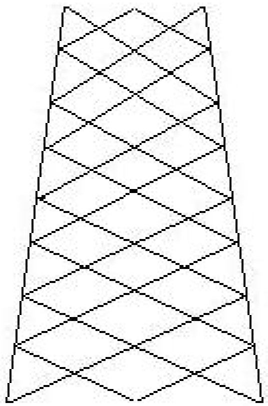
X-B Bracing



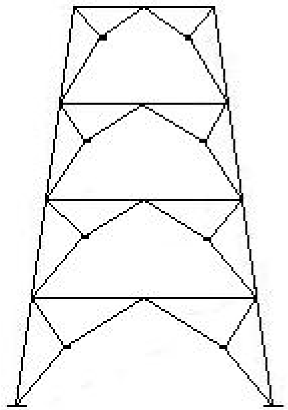
K - Bracing



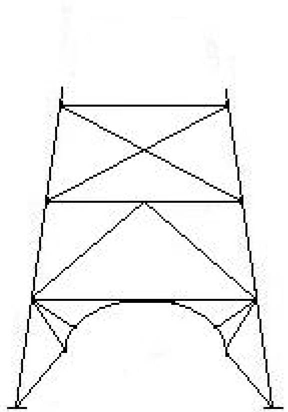
XBX Bracing



W Bracing



Y Bracing



Arch Bracing

Lattice Tower Loading

The towers are invariably analysed as trusses, the loads are applied at joints and members are designed as either ties or as struts. The loads on the tower consist of the following:

1. Member weights.
2. Platform and railing weights.
3. Antennae weights.
4. Ladder and lift loads.
5. Gusset and secondary bracings.
6. Wind load.
7. Seismic loads.
8. Lifting or hoisting loads.
9. Dynamic effects.
10. Erection loads.
11. Live loads.

The first five sets of loads are fixed type of which member weights are structural design dependents while the rest are based on functional aspect. Wind and seismic loads are the most important of all and often control the design. The seismic load may not be critical as the mass of the structure is not heavy and near the ground. The criticality of the wind or seismic effects has to be examined. Dynamic effects due to wind become critical in slender and tall towers. In most cases of towers up to 100 m height, the dynamic effect may not control the design. Live loads on towers are negligible when compared with the other loads.
Since wind loads affect the tower design the most, hence it is necessary to cover them in detail. In case of roof top towers, seismic loads are also crucial as the collapse of towers during earthquake can cause severe damages to the surroundings. The discussion on seismic loads is done after the wind loads.

Wind Loads

Wind is the air in motion relative to the surface of the earth. Since the vertical components of atmospheric motion are relatively small, especially near the surface of the earth, the term ‘wind’ denotes almost exclusively to horizontal wind. *Wind pressure*, therefore, acts horizontally on the exposed vertical surfaces of walls, columns, chimneys, towers etc. and inclined roof surfaces.
All exposed structures are affected to some degree by wind forces. The liability of a structure to high wind pressures depends not only upon the geographical location and proximity of the obstructions to air flow but also upon the characteristics of the structure itself.

Design Wind Speed as per IS: 875 -1987

The design wind speed V_z is obtained by multiplying the basic wind speed (V_b) by the factors k_1, k_2 and k_3.

$$V_z = V_b * k_1 * k_2 * k_3$$

Where
V_b = the basic wind speed in m/s at 10 m height
k_1 = probability factor (or risk coefficient)
k_2 = terrain, height and structure size factor
k_3 = topography factor

Basic Wind Speed
For basic wind speed, India has been divided into six zones. The map given in the Code gives the basic wind speed for some important cities/towns.

Probability factor k_1
Basic wind speeds given in the map have been worked out for 50 years return period. The *design life* of structure is based on the functional aspect as well as the importance of the structure. The factor k_1 is based on statistical concepts which take account of the degree of reliability required and period of time in years during which there will be exposure to wind, that is life of the structure. The Code has tabulated the values of k_1 on the basis of class of structure and the basic wind speed.

Terrain, height and structure size factor k_2
This factor takes into account terrain roughness, height and size of structure.
Terrain categories: Selection of terrain categories is made with due regard to the effect of obstructions which constitute the ground surface roughness. The terrain on which specific structure stands is grouped under *four* categories.
Category 1: This represents exposed open terrain with few or no obstructions and in which the average height of any object surrounding the structure is less than 1.5 m. This includes open sea coasts and flat treeless plains.

Category 2: This represents open terrain with well scattered obstructions having height generally between 1.5 to 10 m. This includes air fields, open park lands and underdeveloped sparsely built-up outskirts of towns and suburbs.

Category 3: This represents terrain with numerous closely spaced obstructions having size of building structures up to 10 m in height with or without a few isolated tall structures. This category includes well wooded areas, shrubs, towns and industrial areas fully or partially developed.

Category 4: This represents terrain with numerous large high closely spaced obstructions. This category includes large city centres, generally with obstructions above 25 m and well developed industrial areas.

Structure Size: Buildings or structures are classified into the following three different classes depending upon on their size (that is, greater horizontal or vertical dimension).

Class A: Structures having maximum dimension less than 20 m.
Class B: Structures having maximum dimension between 20 m and 50 m.
Class C: Structures having maximum dimension more than 50 m.

Height: The design wind speed is a function of height at which the design wind speed is being computed. It should be noted that for a given structure, out of the three factors k_1 , k_2 and k_3 , factors k_1 and k_3 are fixed depending on the zone, life of structure, terrain category and class of structure while factor k_2 varies with the *height of the element* (of the structure) at which the design wind speed is being computed.

Topography factor k_3

The basic wind speed takes into account the general level of site above sea level. This does not allow for allow for local topographic features such as hills, valleys, cliffs, or ridges which can significantly affect wind speed in their vicinity. The effect of topography is to accelerate wind near the summits of hills or crests of cliffs and decelerate the wind in valleys or near the foot of cliffs, steep escarpments or ridges.

The effect of topography will be significant at a site when the upwind slope is greater than about 3^0 and below that, the value of k_3 may be taken equal to 1.0.

Design Wind Pressure

The design wind pressure at any height above mean ground level is given by:

$$p_z = 0.6 * V_z^2$$

where p_z = design wind pressure in N/m^2 at height z.

The total wind load on the structure is given by:

$$F = C_f * A_e * p_z$$

Where F = wind force acting in a direction specified.
A_e = effective frontal area of the structure.
p_z = design wind pressure
C_f = force coefficient for the structure.
In case of towers, it depends upon the solidity ratio φ of the tower.
Φ = solidity ratio = obstruction area of front face/gross area of front face

For towers, φ varies from 0.15 to 0.3, and is to be assumed in the beginning of the design. After designing the members, the assumed solidity ratio is compared with the actual solidity ratio to test the adequacy of the structure.

Tower Appurtenances: The wind load on Tower Appurtenances such as ladders, conduits, lights, elevators etc. shall be calculated using appropriate net pressure coefficients for these elements. Allowance may be made for shielding effect from other elements.

Tower mountings: The pressure on antennae mountings can be computed by suitably selecting pressure coefficients.

Seismic Loads

The seismic load analysis in our country is done in accordance with IS: 1893-2002. The Part I of the code deals with the criteria for design of earthquake resistant buildings. The seismic load analysis of towers is done on the basis of this Code by treating the tower as an appendage to the building. Since the collapse of tower due to an earthquake can be of severe damage to the surroundings, the code stipulates stringent provisions in this regard.
For vertical projections such as towers, the horizontal seismic coefficient has to be the five times the basic seismic factor specified for that zone. However, this increased coefficient is only for designing the projection part and for designing their connection with the main structure.

The horizontal base shear V_B as per IS 1893-2002 is given by

$$V_B = A_h * W$$

where,
A_h = design horizontal seismic coefficient
W = effective weight of the structure
The design horizontal seismic coefficient A_h for a structure shall be determined by the following expression:

$$A_h = \frac{Z\ I\ S_a}{2\ R\ g} \qquad (1)$$

where,
Z = zone factor as given in table below.
I = importance factor
R = Response Reduction factor
S_a / g = Average response acceleration coefficient for rock or soil sites as given by the figure below.

Seismic Zone	II	III	IV	V
Intensity	Low	Moderate	Severe	Very Severe
Z	0.1	0.16	0.24	0.36

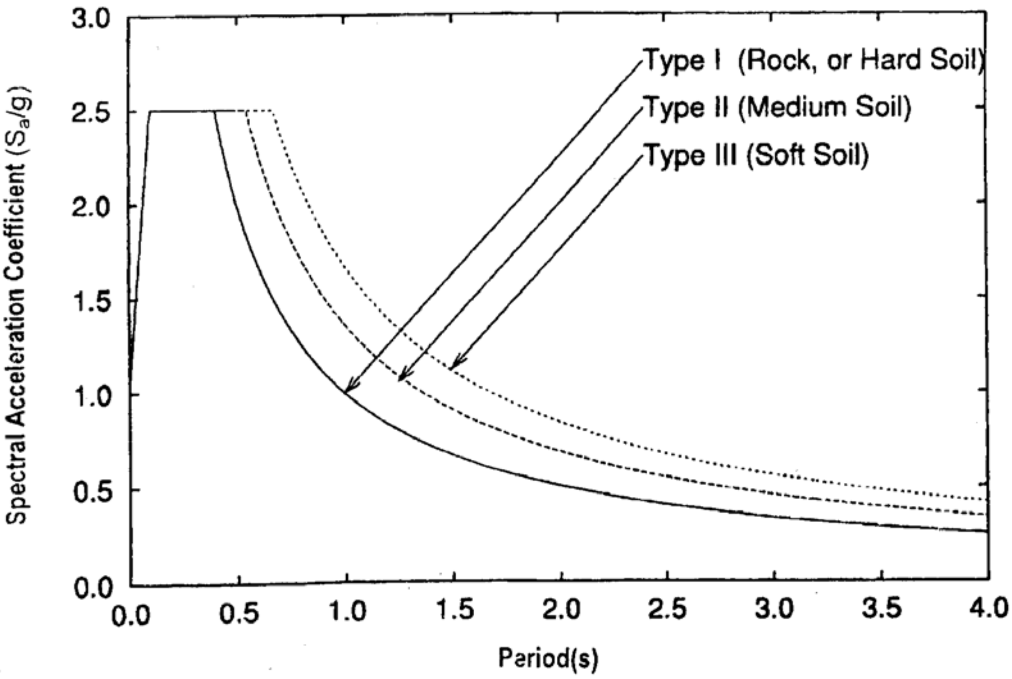


Figure giving Response Spectra for 5% damping

The code specifies two methods for calculating design seismic force and its distribution to different levels along the height of the structure. These methods are namely static and dynamic analysis. Since this report does the dynamic analysis by the response spectrum method, this method is discussed below.
According to this method,
Design lateral force at each floor in each mode is given by

$$Q_{ik} = A_K * \Phi_{ik} * P_K * W_i$$

where,
A_k = Design horizontal acceleration spectrum value as per (1) using the natural period of vibration (T_K) of mode k.
Φ_{ik} = Mode shape coefficient at floor I in mode k.
W_i = seismic weight of floor i.
P_K = modal participation factor of mode k.

The base shear is obtained by adding the design lateral force at each floor starting from the top storey. The peak storey shear force in storey i due to all modes considered is obtained by combining those due to each mode as per Complete Quadratic Combination method.

Codes for Tower Design

The following Codes are generally used for analysing & designing of towers globally.

1. **ANSI/TIA/EIA-222-F-1996**: is a set of American standards published by the Telecommunications Industry Association Standards and Technology Department.

2. **IS 802:** Use of structural steel in overhead transmission line towers – code of practice (Part 1 – Material Loads and Permissible stresses).

3. **BS 8100:** British design code for Lattice Towers and Masts.

4. **IS 875 -1987:** Code of Practice for Design Loads (other than earthquake) for Buildings and structures (Part 3) Wind Loads.

5. **IS 1893 -1984:** Criteria for Earthquake Resistant Design of Structures (Part 1) General Provisions And Buildings

6. **IS 800-1984:** of Practice for General Construction in Steel.

Planning a tower project

The planning of a tower project is a challenging task. The structural engineer's skills are tested to provide an economical configuration. The process can be divided into the following two categories for convenience.

1. Site Considerations

- Detailed topography analysis
- Soil surface and sub-surface analysis
- Site and foundation engineering
- Wind and weather conditions analysis
- Structural analysis and integrity
- Long-range viability and maintenance
- Materials requirements

2. Tower Considerations

- Height of the tower
- Space available for installation of tower
- Type of building available
- Type of tower & facilities required
  - a) Ladder or step bolts
  - b) Cable tray for supporting cables
  - c) Safety Cage for the ladder
  - d) Levels of platforms required
  - e) Size of platform required at each level
  - f) Finish of tower- hot dip galvanized with painting or without painting
  - g) Aviation Obstruction Light

Information Required

1. Height of the tower: The cost of a tower varies exponentially with the height of the tower, that is, when the tower height is doubled, the cost of the tower is much more than 2 times. Moreover, if the height of the tower is less than what is required by "Line Of Sight" considerations, then the communication will be erratic and very purpose of installing a tower is defeated.

2. Space available for installation of tower: In highly populated cities, the real estate is at a very high premium. The space available may be able to take a narrow base tower only. If high rise buildings exist adjacent to tower installation site, then foundation design will need special considerations.

3. Type of building available: If it is desired that the tower be installed on roof top, then complete details of building structure, i.e. spacing of columns, beam sizes, reinforcements, slab details, height of each floor, etc are required to ascertain, whether building is structurally suitable to take the load of the tower & the load generated due to wind on tower. If tower is to be installed on ground, then information about the soil i.e. soil condition, water table height etc will be required.

4. Type of tower & facilities required: what is required-triangular tower or a square tower? You may need a circular or octagonal platform at top. If your antenna system has space diversity requirement, then that must be specified. The tower is normally constructed from angles or pipes & plates with bolted construction. If welded or any other type of construction is required, then that should be specified.

5. Wind Speed, which the tower will be required to withstand.

6. Loads on the tower: information like the number of antennae, physical sizes thereof and the height of installation, future requirement of antennae and other equipment load likely to be put on tower is required

7.Permissible limits of twist & sway in tower in operational wind
The performance of a communication antenna in wind conditions depends on the twist and sway of the antenna, directivity of the antenna, and the spare capacity of signal strength in the system design. Typically a value of 1 degree is acceptable. If lesser value is desired, then that should be specified.

Chapter Two

General Methodology for Roof Top Tower Analysis

The following paragraph discusses the general method followed for the analysis of the roof top towers, that is, the steps to be followed for calculating the forces in the given tower configuration for the loads as applicable.

Analysis of Roof top Lattice Towers

1. **Wind Load Analysis**

The following steps are generally involved:

1. The wind pressure is calculated at the top horizontal member of each panel. While designing the roof top tower, the height of building should be considered in calculating Gust Response Factors (GRF).
2. The force thus calculated (explained below) is applied at the nodes (joints) by equally dividing the force calculated.
3. The wind forces on the ladder, cable racks, antennae and its mountings should be calculated and applied to the respective nodes.
4. Since wind can change its direction, hence the loads are to be applied in the opposite direction also.
5. In case of square towers, the diagonal wind is to be resolved in two mutually perpendicular directions and then applied to the nodes.
6. The combinations of dead load and the wind loads give the forces in each member and the maximum of the force obtained is used to check the adequacy of that member.
7. A factor of safety of 1.2 is usually considered sufficient.

The calculation of force coefficient forms the most important part of analysis. This requires the calculation of solidity ratio, which is the ratio of net effective area of a panel to the total area of the panel.
The force coefficient used for wind load calculations depends on the solidity ratio. The table below shows the variation of force coefficient on solidity ratio.

Solidity Ratio	Tower Base		$DV_z < 6$ m/s		$DV_z > 6$ m/s	
Φ	Square	Triangular	Face	Corner	Face	Corner
0.05	4.0	3.3	2.4	2.5	1.1	1.2
0.1	3.8	3.1	2.2	2.3	1.2	1.3
0.2	3.3	2.7	1.9	2.1	1.3	1.6
0.3	2.8	2.3	1.7	1.9	1.4	1.6
0.4	2.3	1.9	1.6	1.9	1.4	1.6
0.5	2.1	1.5	1.4	1.9	1.4	1.6

The coefficients are to be multiplied by 1.2 for square sided towers for wind blowing on corners.

D = diameter of rounded members in meters
V_z = wind velocity in m/s

After the calculation of solidity ratio, the force coefficient is calculated by interpolation if required so. Thus the force on the panel is calculated and distributed to the nodes as explained earlier.

2. **Seismic Load Analysis**

The effect of seismic forces on the towers can be analyzed either by the static method or by the dynamic analysis. The fundamental difference between the two methods lies in their approach of calculation of the design seismic force and its distribution to different levels along the height of the structure.
The numerical problem in this report has been analyzed using the Response Spectrum Method. The design spectrum, as given by clause 6.4.2 of IS: 1893-2002, has been used to calculate the design horizontal acceleration spectrum value i.e. $A_{h.}$
Since towers are like appendages to the building on which they are installed, they are subjected to larger motions than the building itself. Therefore the Code stipulates stringent provisions for their design. For vertical projections such as towers, the horizontal seismic coefficient has to be the five times the basic seismic factor specified for that zone. However, this increased coefficient is only for designing the projection part and for designing their connection with the main structure.

The horizontal base shear V_B as per IS 1893-2002 is given by

$$V_B = A_h * W$$

where,
A_h = design horizontal seismic coefficient
W = effective weight of the structure

In practice, the roof top towers can be analyzed for seismic forces in two ways. First, they can be assumed to be rested on ground and are analyzed for the seismic loads. The support reactions so obtained are then transferred to the roof of the building where the tower is supposed to be installed. The building is then analyzed with this increased load to check any possible failure. Second method of analyzing the roof top towers for seismic loads is to model the tower along with the building and analyze the whole structure as one unit. This report tries to study the differences in the time period, forces generated in the building due these to approaches.

The forces and reactions obtained by the STAAD analysis are used for designing the individual members, connections, base plate and anchor bolts.

Using STAAD

The analysis and design of tower members has been carried out using the structural analysis and design software (STAAD 2004). The methodology used by the software in analysis is discussed below.

Stiffness Analysis

The stiffness analysis implemented in STAAD is based on the matrix displacement method. In the matrix analysis of structures by the displacement method, the structure is first idealized into an assembly of discrete structural components (frame members or finite elements). Each component has an assumed form of displacement in a manner which satisfies the force equilibrium and displacement compatibility at the joints.

Assumptions of the Analysis

For a complete analysis of the structure, the necessary matrices are generated on the basis of the following assumptions:

1. The structure is idealized into an assembly of beam, plate and solid type elements joined together at their vertices (nodes). The assemblage is loaded and reacted by concentrated loads acting at the nodes. These loads may be both forces and moments which may act in any specified direction.
2. A beam member is a longitudinal structural member having a constant, doubly symmetric or near-doubly symmetric cross section along its length. Beam members always carry axial forces. They may also be subjected to shear and bending in two arbitrary perpendicular planes, and they may also be subjected to torsion.
3. Internal and external loads acting on each node are in equilibrium. If torsional or bending properties are defined for any member, six degrees of freedom are considered at each node (i.e. three translational and three rotational) in the generation of relevant matrices. If the member is defined as truss member (i.e. carrying only axial forces) then only the three degrees (translational) of freedom are considered at each node.
4. Two types of coordinate systems are used in the generation of the required matrices and are referred to as local and global systems.

Seismic Load Input in STAAD

The seismic load analysis of the structures can be done using STAAD by employing the response spectrum method of dynamic analysis. The following steps are involved in this process.

1. User provides the value for Z*I/2R as factors for input spectrum.

2. Program calculates time periods for first six modes or as specified by the user.

3. Program calculates Sa/g for each mode utilizing time period and damping for each mode.

4. The program calculates design horizontal acceleration spectrum A_k for different modes.

5. The program then calculates mode participation factor for different modes.

6. The peak lateral seismic force at each floor in each mode is calculated.

7. All response quantities for each mode are calculated.

8. The peak response quantities are then combined as per method (CQC or SRSS or ABS or TEN or CSM) as defined by the user to get the final results.

Chapter Three

Numerical Study

In this report, 8 roof top communication towers have been analysed – in a set of four each located at a different position on plan of a three storey building (9 metres high) and a six storey building (18 metres high). All the towers are of 15 m height and loaded with same number and type of antennae (4 GSM Antennae 0.262m X 1.58m). They are located in same wind zone having basic wind speed of 47 m/s and in seismic zone IV. The bracing configuration of the towers is same for all of them. All the towers are of square plan are fabricated using standard steel angles available in the market.
The towers are first analyzed as separate structures and the reactions so obtained are transferred to the building. As a second approach, they are analyzed as a part of the building itself for the wind as well as the seismic loads. The results obtained from two approaches have been compared. The data used in the numerical study is given below.

Tower Data

Height of Tower	=	**15 m**
Base width of tower	=	**2.5 m**
Top width of tower	=	**1 m**
Panel heights	=	**1 panel of 5 m height. 4 panels each of 2.5 m height.**
Plan Shape of tower	=	**Square.**
Structural Steel type	=	**Angles.**
Antenna particulars	=	**4 no. GSM Antenna at top. 0.262 m X 1.58 m**

Building Data

Number of Storeys	=	**3 and 6**
Height of the building	=	**9 m and 18 m**
Length of the building	=	**11.7 m**
Width of the building	=	**18.2 m**
Column size	=	**0.45 m X 0.45 m**
Beam size	=	**0.23 m X 0.5 m**

Concrete Grade used = M30

Steel Grade used = Fe 415

Wind Data

Basic wind speed = 47 m/s (City: Delhi)

Terrain Category = 2 (as per IS: 875-1987)

Class of structure = B

Seismic Data

Seismic Zone = IV

Soil type = Medium Soil

The towers have been analysed for the following load combinations.

- **Dead load + wind load with wind blowing normal to the face of tower.**
- **Dead load + wind load with wind blowing diagonal to the face of tower.**
- **Dead Load + seismic load in X direction**
- **Dead Load + seismic load in Z direction**

Note: Suitable factors have been used in all cases as given in the Code.

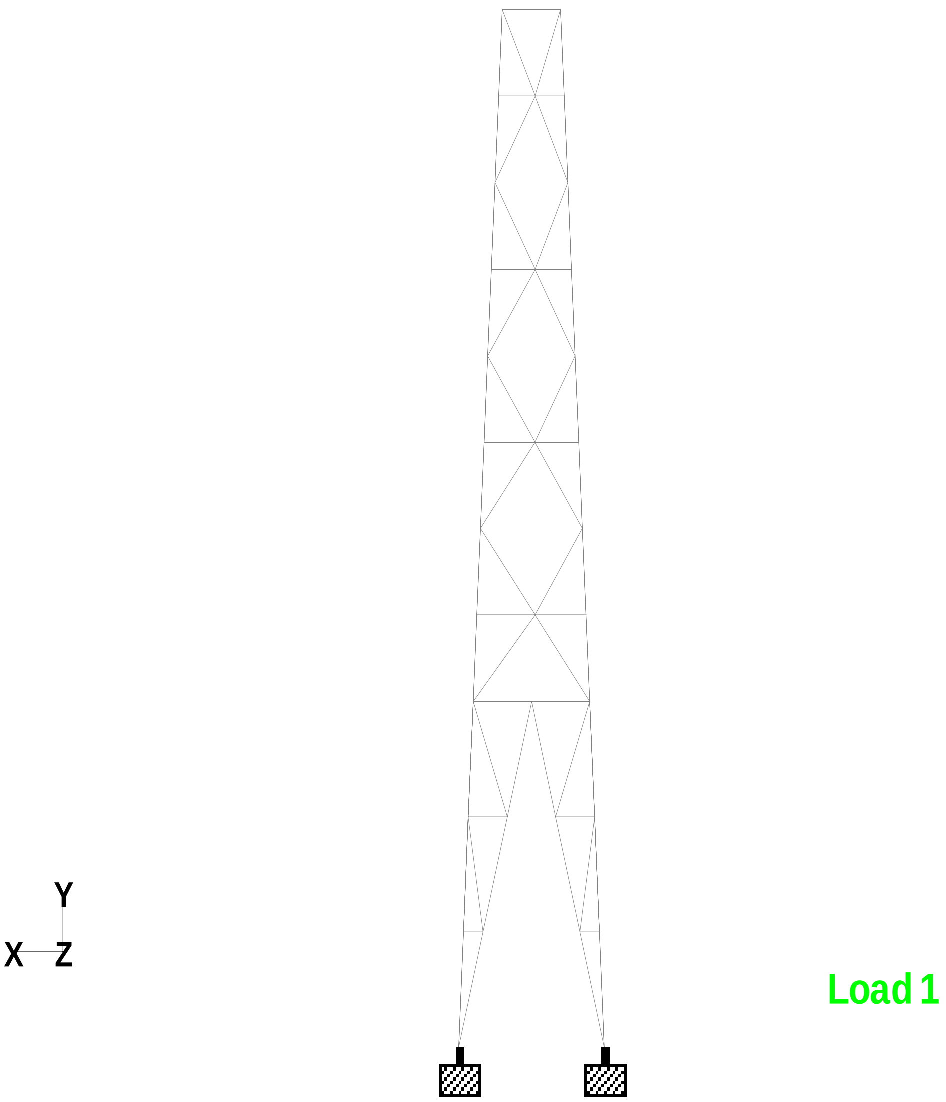
The building along with the tower has been analysed for the following load combinations.

- **Dead Load + Imposed Load.**
- **Dead Load + Imposed Load ± Earthquake Load.**
- **Dead Load ± Earthquake Load.**
- **Dead Load + Imposed Load ± Wind Load.**
- **Dead Load ± Wind Load.**

The characteristics of wind mentioned in IS: 875 (Part-3)-1987 are taken for computing wind loads whereas the seismic analysis has been carried in accordance to the IS: 1893 (Part-1)-2002.

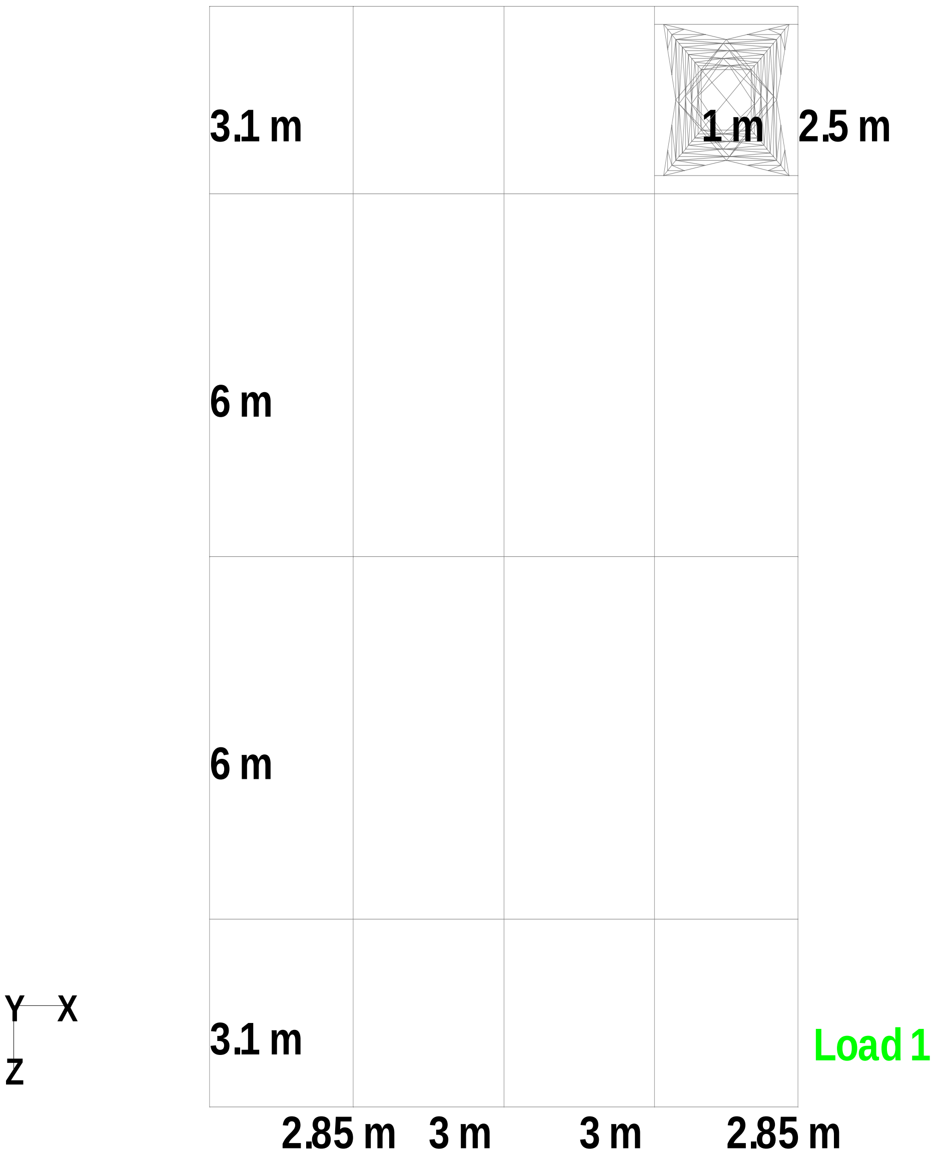
The building plan and the four locations of towers on the building plan are given below.
The calculation of wind load on the buildings and on various tower panels follows the plan drawing.
The different results obtained are tabulated and discussed after the tabulation.

Plan of the building

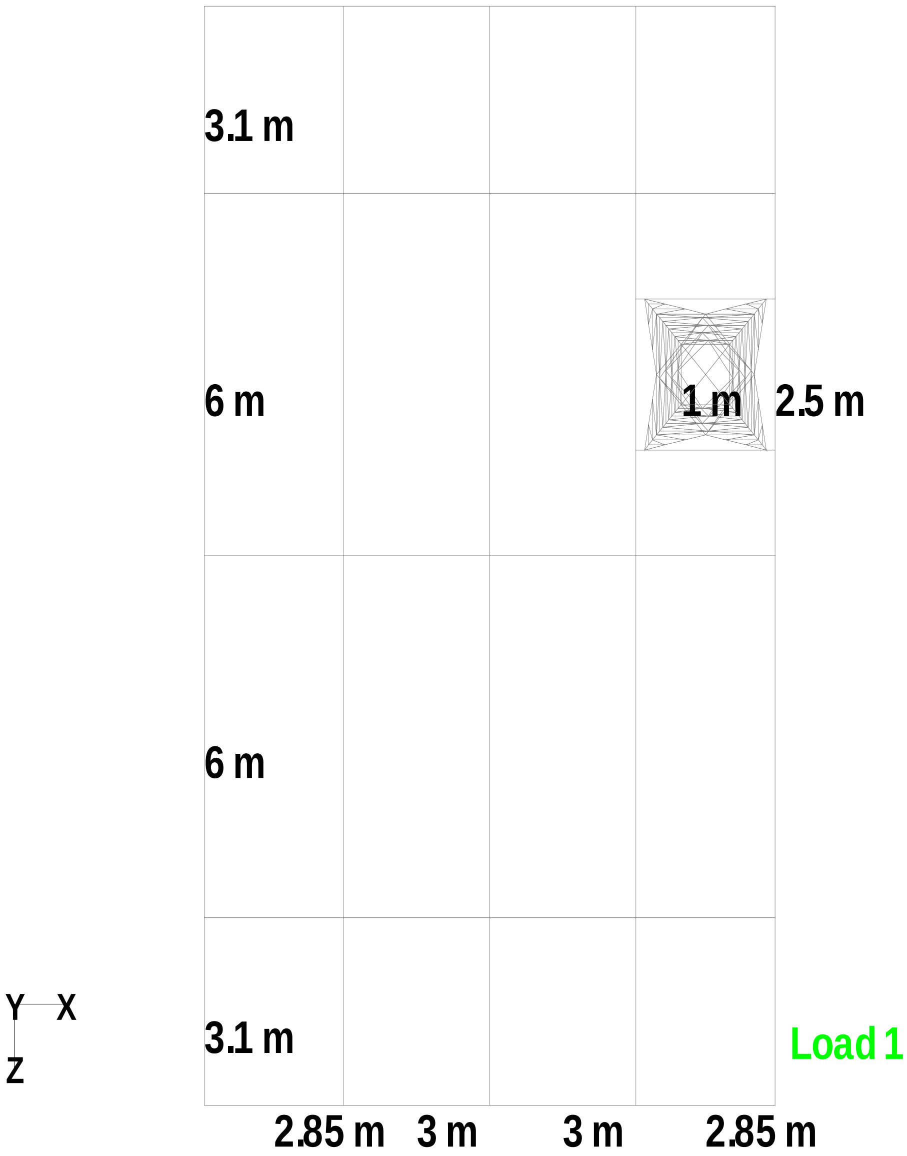


Elevation of 15 m high tower

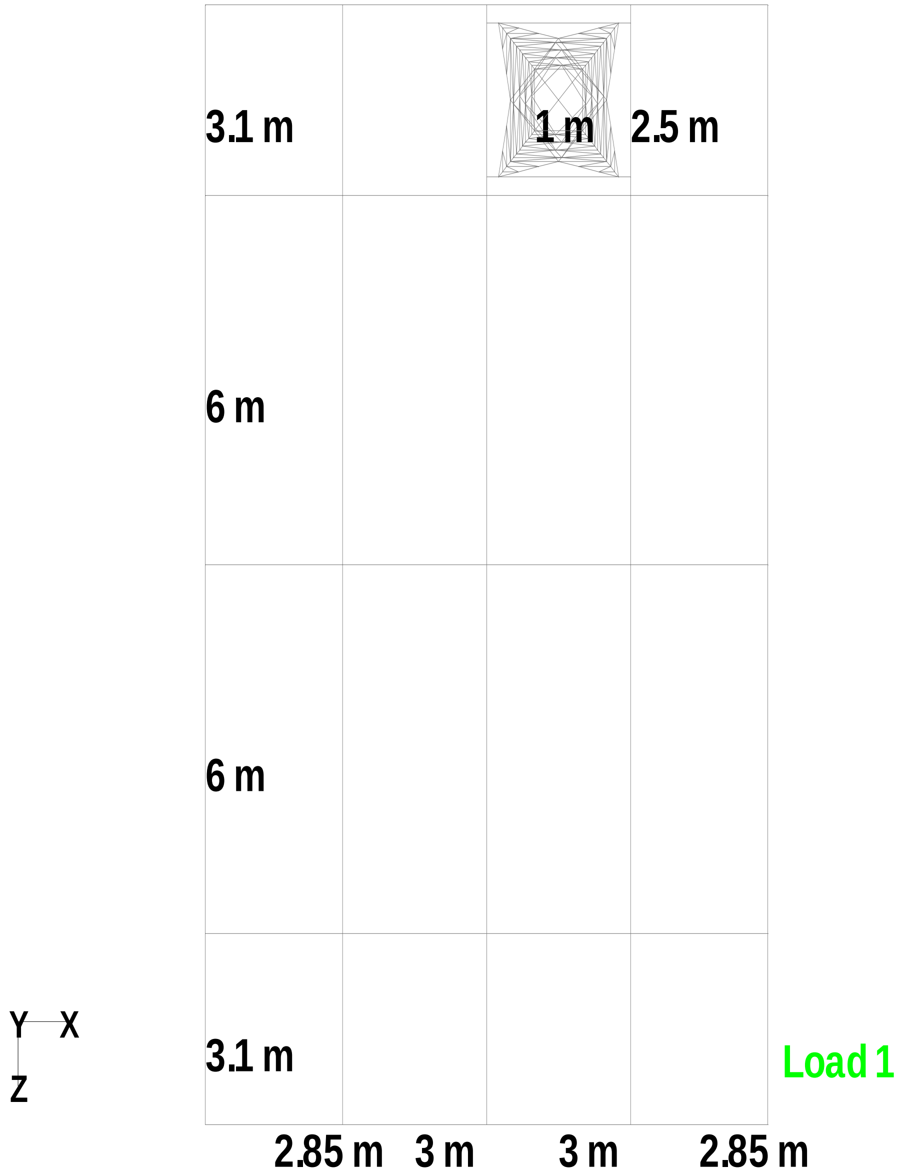
Tower at Location 1



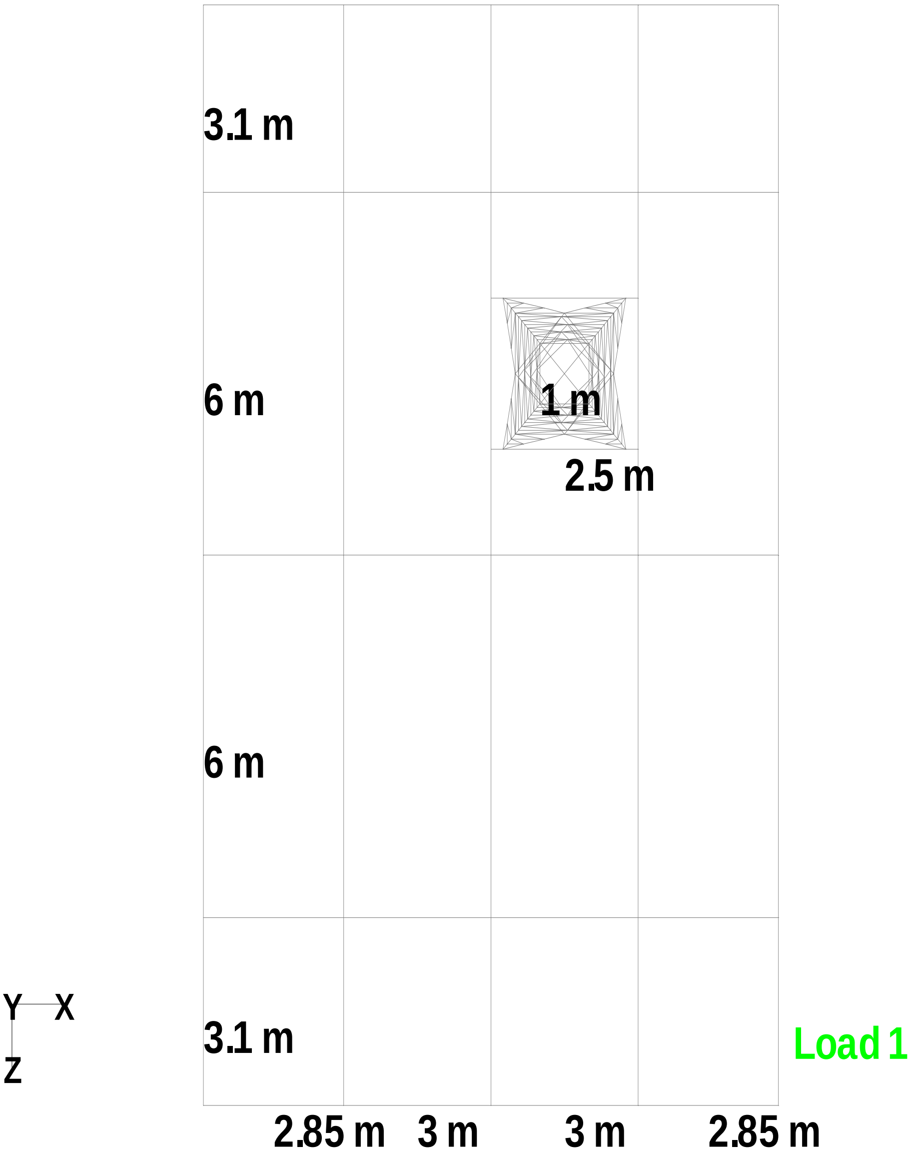
Tower at Location 2



Tower at Location 3



Tower at Location 4



WIND LOAD CALCULATIONS FOR THREE STOREY BUILDING

The design wind speed V_z is obtained by multiplying the basic wind speed (V_b) by the factors k_1, k_2 and k_3.

$V_z = V_b * k_1 * k_2 * k_3$

Where
V_b = the basic wind speed in m/s at 10 m height
k_1 = probability factor (or risk coefficient)
k_2 = terrain, height and structure size factor
k_3 = topography factor

V_b = 47 m/s for Delhi
k_1 = 1.0
k_2 = varies with the height as given in the table below
k_3 = 1.0

Therefore, $V_z = 47 * k_2$

Since, $p_z = 0.6 * V_z^2$
$= 1325.4 * k_2^2$ N/m^2

Now, as per IS 875 Part III Table 2 for terrain category 2, the factor k_2 varies with height as follows.

	k_2	
Height (m)	Class A	Class B
10	1	0.98
15	1.05	1.02
20	1.07	1.05
30	1.12	1.1
50	1.17	1.15

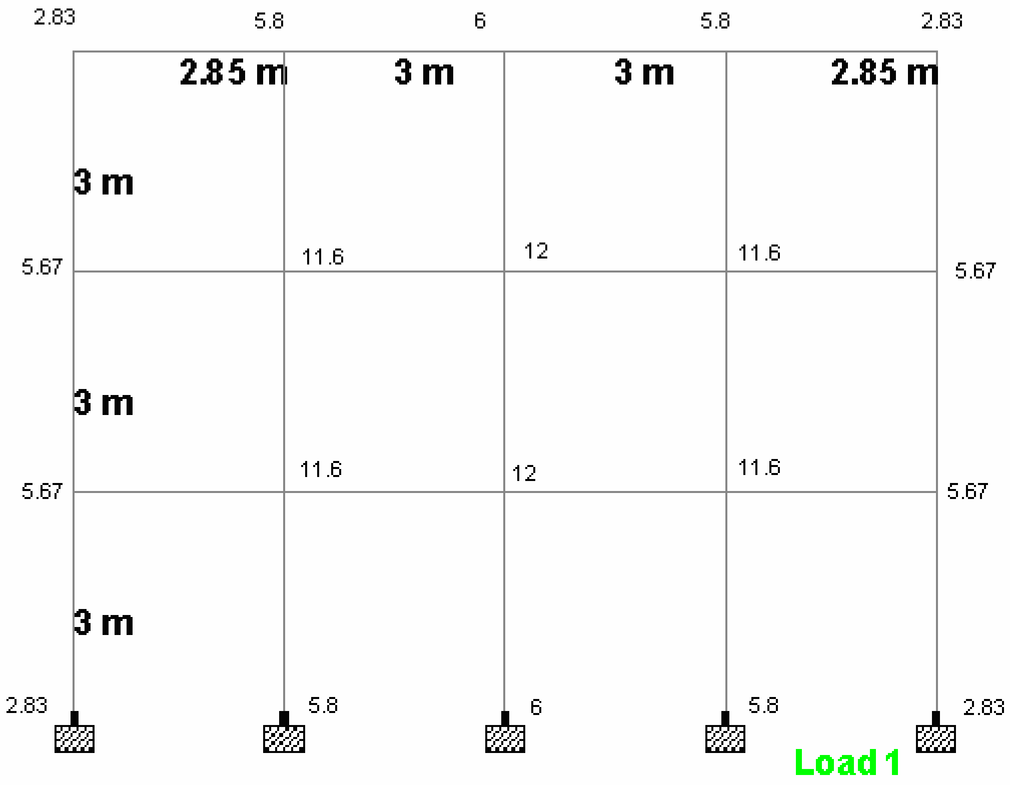
For wind in z direction, (see figure)

C_f = 1.0 (from Figure 4A of IS: 875 Part III – 1987)

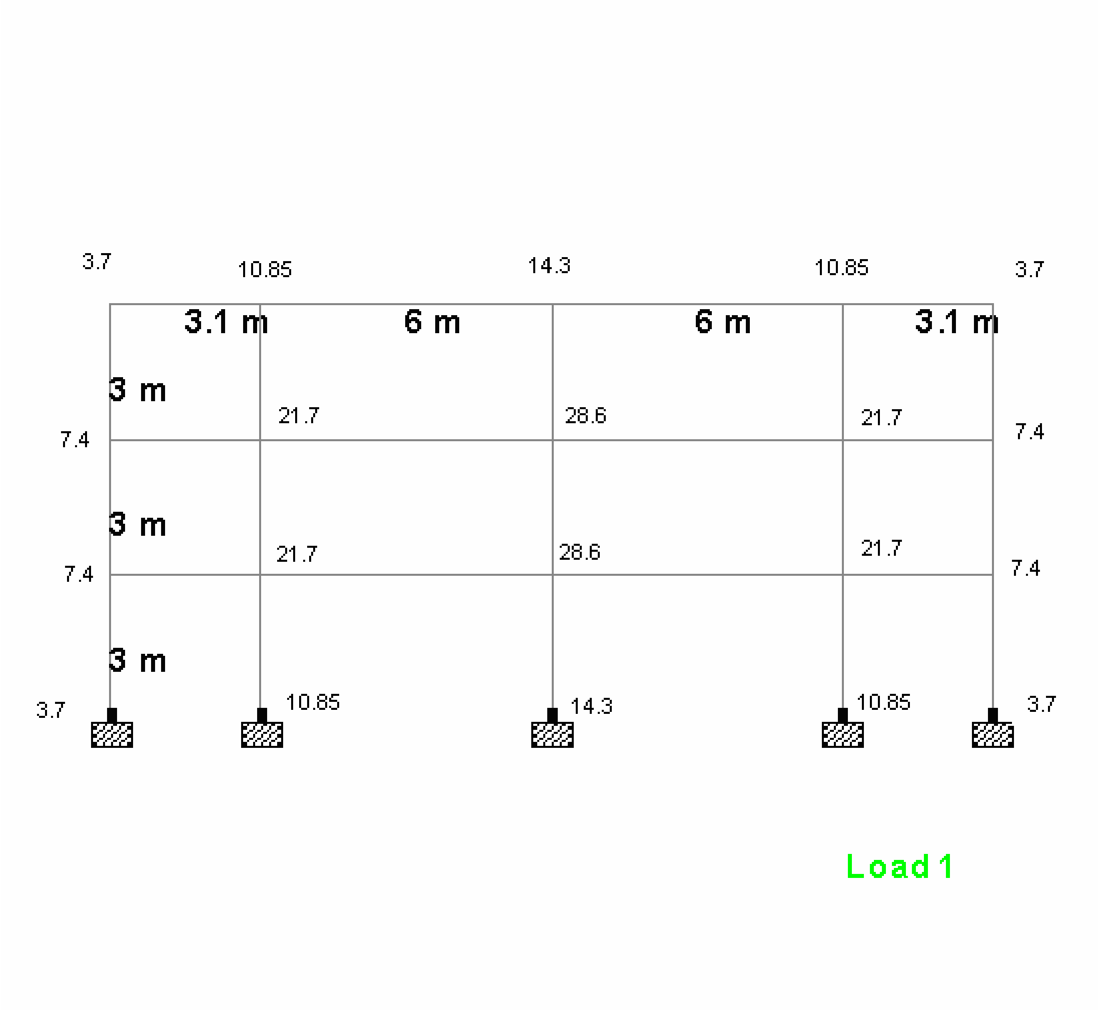
Now,
$F = C_f * A_e * p_z$
$F = 1.0 * 1325.4 * A_e$ N
Therefore,
F = 11.33 kN for panels having A_e = 8.55 sq.mt, &
F = 11.93 kN for panels having A_e = 9 sq.mt.

The nodal forces so calculated have been marked in the figure.

In Z Direction,
All nodal loads are in kN



In X Direction,
All nodal loads are in kN



For wind in x direction, (see figure)

C_f = 1.2 (from Figure 4B of IS: 875 Part III – 1987)

Now,

$F = C_f * A_e * p_z$

$F = 1.2 * 1325.4 * A_e$ N

Therefore,

F = 14.80 kN for panels having A_e = 9.3 sq.mt, &

F = 28.63 kN for panels having A_e = 18 sq.mt.

The nodal forces so calculated have been marked in the figure.

WIND LOAD CALCULATIONS FOR SIX STOREY BUILDING

The expression for the design pressure remains same as above.

$p_z = 0.6 * V_z^2$

$= 1325.4 * k_2^2$ N/m^2

For wind in z direction, (see figure)

C_f = 1.1 (from Figure 4A of IS: 875 Part III – 1987)

Now,

$F = C_f * A_e * p_z$

$F = 1.1 * 1325.4 * A_e$ N

Therefore,

F = 12.48 kN for panels having A_e = 8.55 sq.mt, &

F = 13.12 kN for panels having A_e = 9 sq.mt.

The nodal forces so calculated have been marked in the figure.

For wind in x direction, (see figure)

C_f = 1.2 (from Figure 4B of IS: 875 Part III – 1987)

Now,

$F = C_f * A_e * p_z$

$F = 1.2 * 1325.4 * A_e$ N

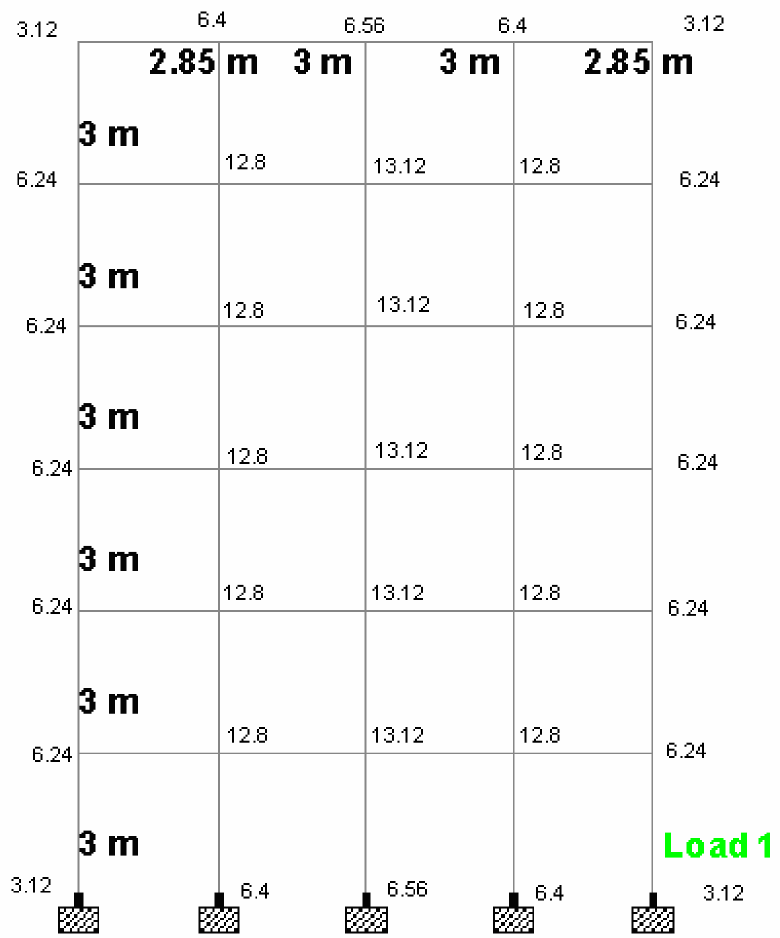
Therefore,

F = 14.80 kN for panels having A_e = 9.3 sq.mt, &

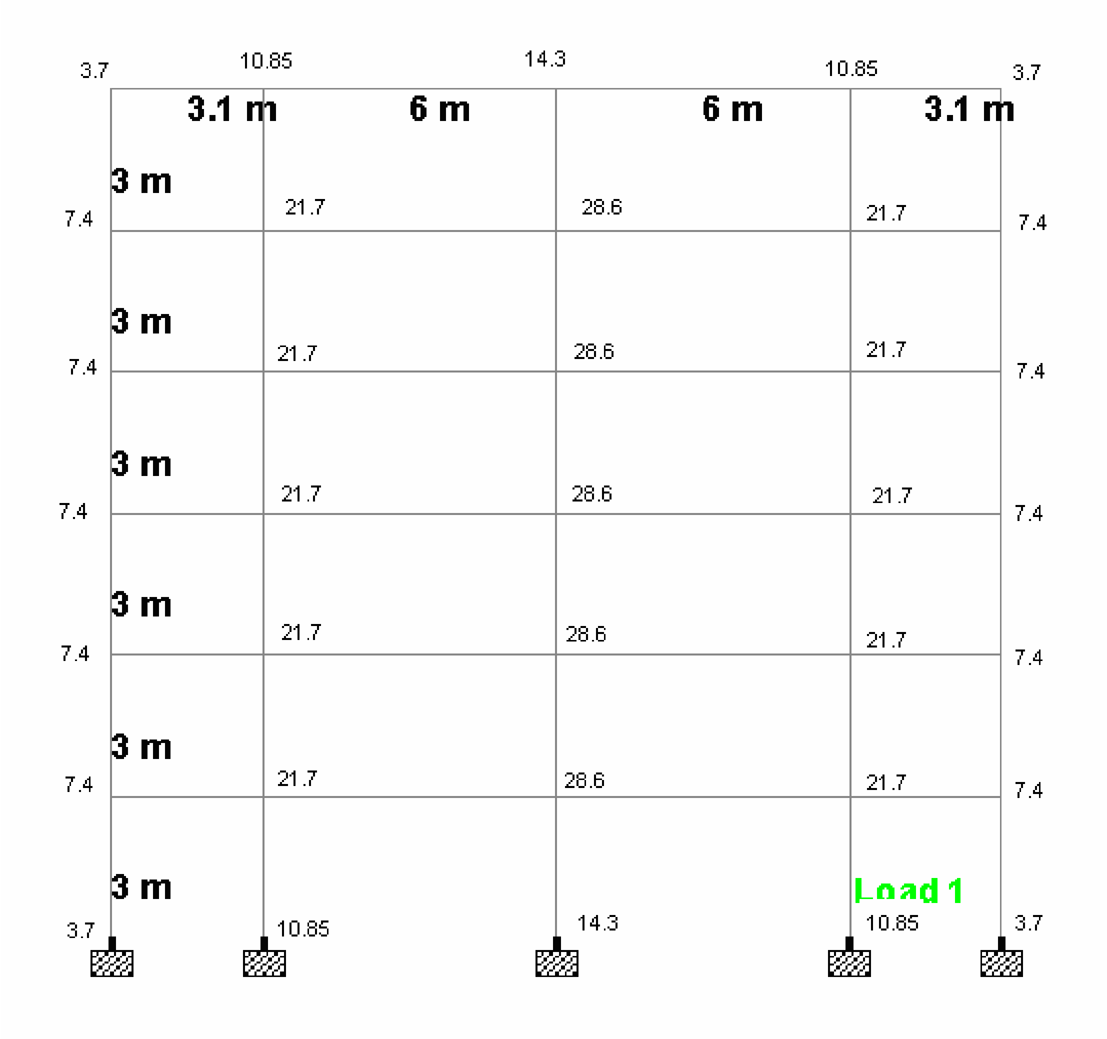
F = 28.63 kN for panels having A_e = 18 sq.mt.

The nodal forces so calculated have been marked in the figure.

In Z Direction,
All nodal loads are in kN



In X Direction,
All nodal loads are in kN



CALCULATION OF WIND LOAD ALONG HEIGHT OF 15 M SQUARE BASE TOWER ON 9 M HIGH BUILDING

WIND LOAD DIRECTIONS

1. WIND LOAD ALONG X OR Z DIRECTION
2. WIND LOAD ALONG DIAGONAL

CALCULATION OF DESIGN WIND LOADS AS PER IS 875

Basic wind speed = 50 m/s

Design wind speed Vz = k1*k2*k3*Vb

Terrain Category 2 Class of Structure B

$F = C_f * A_e * p_d$

Solidity Ratio φ	C_f
0.05	4
0.1	3.8
0.2	3.3
0.3	2.8
0.4	2.3
0.5	2.1

Panel No.	Height	k2
1	14.75	0.98
2	17.25	1.02
3	19.75	1.05
4	22.25	1.05
5	24.75	1.07

Member	Height(m)	Section B	Section L	Exposed Area	Nos	Total Area	Top Width	Bottom Width	Panel Height	Panel Area	Solidity Ratio	Cf	Vb m/s	k1	k2	k3	Vz (m/s)	pd(N/m2)	F(kN)
Antenna		0.262	1.58	0.41	4	1.64						1	50	1	1.07	1	53.5	1983.75	3.25
Panel No.5	24.75																		
Main Leg		0.05	2.5	0.13	2	0.26													
Horizontal		0.05	2.125	0.11	1	0.11													
Diagonal		0.05	2.75	0.14	2	0.28													
Cage Flat		0.045	2.5	0.11	3	0.33													
Ladder		0.045	2.5	0.11	1	0.11													
Rungs		0.016	0.4	0.01	8	0.08													
Total						1.17	1	1.25	2.5	2.81	0.42	2.26	50	1	1.07	1	53.5	1717.35	4.54

Member	Height(m)	Section B	Section L	Exposed Area	Nos	Total Area	Top Width	Bottom Width	Panel Height	Panel Area	Solidity Ratio	Cf	Vb m/s	k1	k2	k3	Vz (m/s)	pd(N/m2)	F(kN)
Panel No.4	22.25																		
Main Leg		0.05	2.5	0.13	2	0.26													
Horizontal		0.05	1.375	0.07	1	0.07													
Diagonal		0.05	2.86	0.14	2	0.28													
Cage Flat		0.03	2.5	0.08	3	0.24													
Ladder		0.045	2.5	0.11	1	0.11													
Rungs		0.016	0.4	0.01	8	0.08													
Total						1.04	1.25	1.5	2.5	3.44	0.3	2.8	50	1	1.05	1	52.5	1653.75	4.82
Panel No.3	19.75																		
Main Leg		0.05	2.5	0.13	2	0.26													

Horizontal		0.05	1.625	0.08	1	0.08													
Diagonal		0.05	2.97	0.15	2	0.3													
Cage Flat		0.03	2.5	0.08	3	0.24													
Ladder		0.045	2.5	0.11	1	0.11													
Rungs		0.016	0.4	0.01	8	0.08													
Total						1.07	1.5	1.75	2.5	4.06	0.26	3	50	1	1.05	1	52.5	1653.75	5.31
Panel No.2	17.25																		
Main Leg		0.05	2.5	0.13	2	0.26													
Horizontal		0.05	1.875	0.09	1	0.09													
Diagonal		0.05	3.13	0.16	2	0.32													
Cage Flat		0.03	2.5	0.08	3	0.24													
Ladder		0.045	2.5	0.11	1	0.11													
Rungs		0.016	0.4	0.01	8	0.08													
Total						1.1	1.75	2	2.5	4.69	0.23	3.15	50	1	1.02	1	51	1560.6	5.41
Panel No.1	14.75																		
Main Leg		0.075	5	0.38	2	0.76													
Horizontal		0.05	2	0.1	1	0.1													
Diagonal		0.05	5.155	0.26	2	0.52													
Inclined		0.05	4.452	0.22	2	0.44													
Cage Flat		0.03	5	0.15	3	0.45													
Ladder		0.045	5	0.23	1	0.23													
Rungs		0.016	0.4	0.01	15	0.15													
Total						2.65	2	2.5	5	11.25	0.24	3.1	50	1	0.98	1	49	1440.6	11.83

LOAD DISTRIBUTION ON NODAL POINTS OF 15 M TOWER ON 9 M HIGH BUILDING

Panel No.	F (kN)	Load Distribution	Load on Nodes	Total load on nodes	Normal Load on each node	Total Diagonal Load	X & Z Components on L&R Node	Middle Node
		Top	1.27	1.27	0.635	1.524	0.27	0.54
5	2.54	Bottom	1.27					
		Top	1.4	2.67	1.335	3.204	0.57	1.13
4	2.8	Bottom	1.4					
		Top	1.54	2.94	1.47	3.528	0.62	1.25
3	3.08	Bottom	1.54					
		Top	1.665	3.205	1.6025	3.846	0.68	1.36
2	3.33	Bottom	1.665					
		Top	3.945	5.61	2.805	6.732	1.19	2.38
1	7.89	Bottom	3.945					
				3.945	1.9725	4.734	0.84	1.67

CALCULATION OF WIND LOAD ALONG HEIGHT OF 15 M TOWER ON SIX STOREY BUILDING

WIND LOAD DIRECTIONS

1. WIND LOAD ALONG X OR Z DIRECTION
2. WIND LOAD ALONG DIAGONAL

CALCULATION OF DESIGN WIND LOADS AS PER IS 875

Basic wind speed = 47 m/s

Design wind speed   Vz = k1*k2*k3*Vb

Terrain Category   2   Class of Structure   B

$F = C_f * A_e * p_d$

Solidity Ratio φ	C_f
0.05	4
0.1	3.8
0.2	3.3
0.3	2.8
0.4	2.3
0.5	2.1

Panel No.	Height	k2
1	23.75	1.06
2	26.25	1.07
3	28.75	1.10
4	31.25	1.10
5	33.75	1.10

Member	Height(m)	Section B	Section L	Exposed Area	Nos	Total Area	Top Width	Bottom Width	Panel Height	Panel Area	Solidity Ratio	Cf	Vb m/s	k1	k2	k3	Vz (m/s)	pd(N/m2)	F(kN)
Antenna		0.262	1.58	0.41	4	1.64						1	47	1	1.10	1	51.7	1603.73	2.63
Panel No.5	33.75																		
Main Leg		0.05	2.5	0.13	2	0.26													
Horizontal		0.05	2.125	0.11	1	0.11													
Diagonal		0.05	2.75	0.14	2	0.28													
Cage Flat		0.045	2.5	0.11	3	0.33													
Ladder		0.045	2.5	0.11	1	0.11													
Rungs		0.016	0.4	0.01	8	0.08													
Total						1.17	1	1.25	2.5	2.81	0.42	2.3	47	1	1.10	1	51.7	1603.73	4.24

Member	Height(m)	Section B	Section L	Exposed Area	Nos	Total Area	Top Width	Bottom Width	Panel Height	Panel Area	Solidity Ratio	Cf	Vb m/s	k1	k2	k3	Vz (m/s)	pd(N/m2)	F(kN)
Panel No.4	31.25																		
Main Leg		0.05	2.5	0.13	2	0.26													
Horizontal		0.05	1.375	0.07	1	0.07													
Diagonal		0.05	2.86	0.14	2	0.28													
Cage Flat		0.03	2.5	0.08	3	0.24													
Ladder		0.045	2.5	0.11	1	0.11													
Rungs		0.016	0.4	0.01	8	0.08													
Total						1.04	1.25	1.5	2.5	3.44	0.3	2.8	47	1	1.10	1	51.7	1603.73	4.67

PanelNo.3	28.75																		
Main Leg		0.05	2.5	0.13	2	0.26													
Horizontal		0.05	1.625	0.08	1	0.08													
Diagonal		0.05	2.97	0.15	2	0.3													
Cage Flat		0.03	2.5	0.08	3	0.24													
Ladder		0.045	2.5	0.11	1	0.11													
Rungs		0.016	0.4	0.01	8	0.08													
Total						1.07	1.5	1.75	2.5	4.06	0.26	3	47	1	1.10	1	51.7	1603.73	5.15
Panel No.2	26.25																		
Main Leg		0.06	2.5	0.15	2	0.3													
Horizontal		0.05	1.875	0.09	1	0.09													
Diagonal		0.05	3.13	0.16	2	0.32													
Cage Flat		0.03	2.5	0.08	3	0.24													
Ladder		0.045	2.5	0.11	1	0.11													
Rungs		0.016	0.4	0.01	8	0.08													
Total						1.14	1.75	2	2.5	4.69	0.24	3.1	47	1	1.07	1	50.3	1517.45	5.36
Panel No.1	23.75																		
Main Leg		0.08	5	0.4	2	0.8													
Horizontal		0.05	2	0.1	1	0.1													
Diagonal		0.05	5.155	0.26	2	0.52													
Inclined		0.05	4.452	0.22	2	0.44													
Cage Flat		0.03	5	0.15	3	0.45													
Ladder		0.045	5	0.23	1	0.23													
Rungs		0.016	0.4	0.01	15	0.15													
Total						2.69	2	2.5	5	11.25	0.24	3.1	47	1	1.06	1	49.8	1489.22	12.42

LOAD DISTRIBUTION ON NODAL POINTS OF 15 m TOWER ON SIX STOREY BUILDING

Panel No.	F (kN)	Load Distribution	Load on Nodes	Total load on nodes	Normal Load on each node	Total Diagonal Load	X & Z Components on L&R Node	Middle Node
		Top	2.12	2.12	1.06	2.544	0.45	0.9
5	4.24	Bottom	2.12					
		Top	2.335	4.455	2.2275	5.346	0.95	1.89
4	4.67	Bottom	2.335					
		Top	2.575	4.91	2.455	5.892	1.04	2.08
3	5.15	Bottom	2.575					
		Top	2.68	5.255	2.6275	6.306	1.11	2.23
2	5.36	Bottom	2.68					
		Top	6.21	8.89	4.445	10.668	1.89	3.77
1	12.42	Bottom	6.21	6.21	3.105	7.452	1.32	2.63

CALCULATION OF WEIGHT FOR CABLE TRAY AND LADDER

Panel	Member	Wt/m	H	Nos.	Load of Ladder	Tray Wt/m	Cable Wt/m	Load of Tray	Total Load	Load per Joint (kN)
5	ISA45X45X5	4.97	2.5	2	24.85	12	6.9	47.25	72.1	0.35
4	ISA45X45X5	4.97	2.5	2	24.85	12	6.9	47.25	72.1	0.35
3	ISA45X45X5	4.97	2.5	2	24.85	12	6.9	47.25	72.1	0.35
2	ISA45X45X5	4.97	2.5	2	24.85	12	6.9	47.25	72.1	0.35
1	ISA45X45X5	4.97	5	2	49.7	12	6.9	94.5	144.2	0.71

Wt of 16 mm diameter round bar	=	1.57
Wt of ISA45X45X5	=	3.4
Total	=	4.97

CALCULATION OF WEIGHT OF PLATFORM

Panel	B	H	A	Load/sqm Kg/m^2	Total Load	Load at a joint
5	1.125	1.125	1.27	50	63.5	15.875

LOAD DISTRIBUTION ON NODAL POINTS FOR CABLE TRAY+LADDER+PLATFORM

Panel	Height	Load of Ladder	Platform Load	Tray Load	Total Load	Total Load at each joint	Load Distribution	Load per joint (kN)	Load on Each Leg(kN)
5	2.5	24.85	50	47.25	122.1	61.05	Top	0.3	0.3
							Bottom	0.3	
4	2.5	24.85		47.25	72.1	36.05	Top	0.18	0.48
							Bottom	0.18	
3	2.5	24.85		47.25	72.1	36.05	Top	0.18	0.36
							Bottom	0.18	
2	2.5	24.85		47.25	72.1	36.05	Top	0.18	0.36
							Bottom	0.18	
1	5	49.7		94.5	144.2	72.1	Top	0.35	0.53
							Bottom	0.35	0.35

Time Periods Of the Three Storey Building with 15 metre high Tower at 4 different locations

TIME PERIOD OF THE BUILDING WITHOUT TOWER		
MODE	FREQUENCY(CYCLES/SEC)	PERIOD(SEC)
1	3.065	0.32627
2	3.441	0.29059
3	4.079	0.24515

TIME PERIOD OF THE BUILDING WITH TOWER AT LOCATION 1		
MODE	FREQUENCY(CYCLES/SEC)	PERIOD(SEC)
1	3.056	0.32719
2	3.362	0.29742
3	3.862	0.25896

TIME PERIOD OF THE BUILDING WITH TOWER LOAD AT LOCATION 1		
MODE	FREQUENCY(CYCLES/SEC)	PERIOD(SEC)
1	3.053	0.32752
2	3.399	0.29419
3	4.012	0.24927

TIME PERIOD OF THE BUILDING WITH TOWER AT LOCATION 2		
MODE	FREQUENCY(CYCLES/SEC)	PERIOD(SEC)
1	2.895	0.34547
2	3.345	0.29896
3	3.402	0.29395

TIME PERIOD OF THE BUILDING WITH TOWER LOAD AT LOCATION 2		
MODE	FREQUENCY(CYCLES/SEC)	PERIOD(SEC)
1	3.006	0.33269
2	3.399	0.29419
3	4.031	0.24805

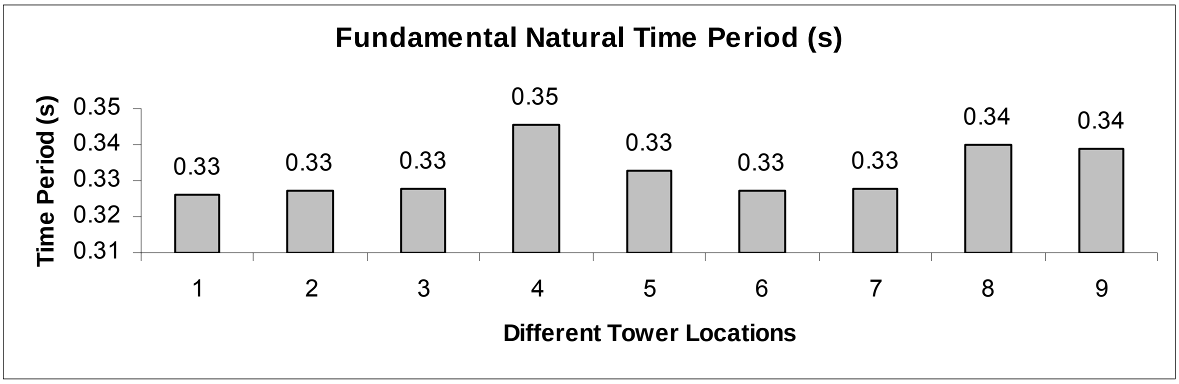
TIME PERIOD OF THE BUILDING WITH TOWER AT LOCATION 3		
MODE	FREQUENCY(CYCLES/SEC)	PERIOD(SEC)
1	3.058	0.32703
2	3.341	0.29928
3	3.897	0.25663

TIME PERIOD OF THE BUILDING WITH TOWER LOAD AT LOCATION 3		
MODE	FREQUENCY(CYCLES/SEC)	PERIOD(SEC)
1	3.053	0.32751
2	3.391	0.29492
3	4.012	0.24926

TIME PERIOD OF THE BUILDING WITH TOWER AT LOCATION 4		
MODE	FREQUENCY(CYCLES/SEC)	PERIOD(SEC)
1	2.941	0.34003
2	3.367	0.29698
3	3.382	0.29566

TIME PERIOD OF THE BUILDING WITH TOWER LOAD AT LOCATION 4				
MODE	FREQUENCY(CYCLES/SEC)	PERIOD(SEC)		
1	3.006	0.33268		
2	3.391	0.29493		
3	4.032	0.24804		

S.No.	Location Of Tower or Tower Load	Fundamental Natural Time Period (s)
1	Without Tower	0.33
2	Tower at Location 1	0.33
3	Tower Load at Location 1	0.33
4	Tower at Location 2	0.35
5	Tower Load at Location 2	0.33
6	Tower at Location 3	0.33
7	Tower Load at Location 3	0.33
8	Tower at Location 4	0.34
9	Tower Load at Location 4	0.34



Legend	
1	Building without Tower
2	Tower at Location 1
3	Tower Load at Location 1
4	Tower at Location 2
5	Tower Load at Location 2
6	Tower at Location 3
7	Tower Load at Location 3
8	Tower at Location 4
9	Tower Load at Location 4

Time Periods Of the Six Storey Building with 15 metre high Tower at 4 different locations

TIME PERIOD OF THE BUILDING WITHOUT TOWER		
MODE	FREQUENCY(CYCLES/SEC)	PERIOD(SEC)
1	1.588	0.62974
2	1.597	0.62604
3	2.042	0.48981

TIME PERIOD OF THE BUILDING WITH TOWER AT LOCATION 1		
MODE	FREQUENCY(CYCLES/SEC)	PERIOD(SEC)
1	1.580	0.63296
2	1.584	0.63116
3	2.019	0.49524

TIME PERIOD OF THE BUILDING WITH TOWER LOAD AT LOCATION 1		
MODE	FREQUENCY(CYCLES/SEC)	PERIOD(SEC)
1	1.581	0.63255
2	1.588	0.62988
3	2.025	0.49395

TIME PERIOD OF THE BUILDING WITH TOWER AT LOCATION 2		
MODE	FREQUENCY(CYCLES/SEC)	PERIOD(SEC)
1	1.576	0.63467
2	1.586	0.63047
3	2.037	0.49096

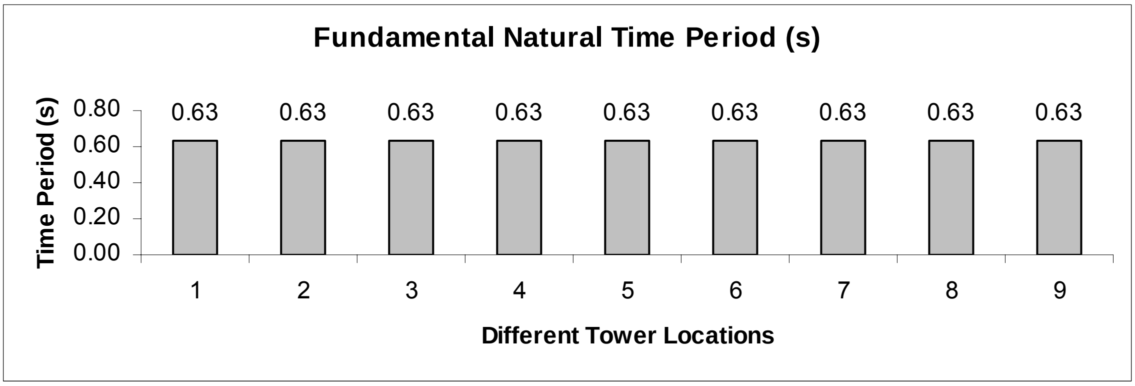
TIME PERIOD OF THE BUILDING WITH TOWER LOAD AT LOCATION 2		
MODE	FREQUENCY(CYCLES/SEC)	PERIOD(SEC)
1	1.576	0.63434
2	1.588	0.62988
3	2.033	0.49200

TIME PERIOD OF THE BUILDING WITH TOWER AT LOCATION 3		
MODE	FREQUENCY(CYCLES/SEC)	PERIOD(SEC)
1	1.581	0.63266
2	1.583	0.63165
3	2.025	0.49394

TIME PERIOD OF THE BUILDING WITH TOWER LOAD AT LOCATION 3		
MODE	FREQUENCY(CYCLES/SEC)	PERIOD(SEC)
1	1.581	0.63255
2	1.587	0.63011
3	2.027	0.49331

TIME PERIOD OF THE BUILDING WITH TOWER AT LOCATION 4		
MODE	FREQUENCY(CYCLES/SEC)	PERIOD(SEC)
1	1.579	0.63341
2	1.586	0.63040
3	2.040	0.49030

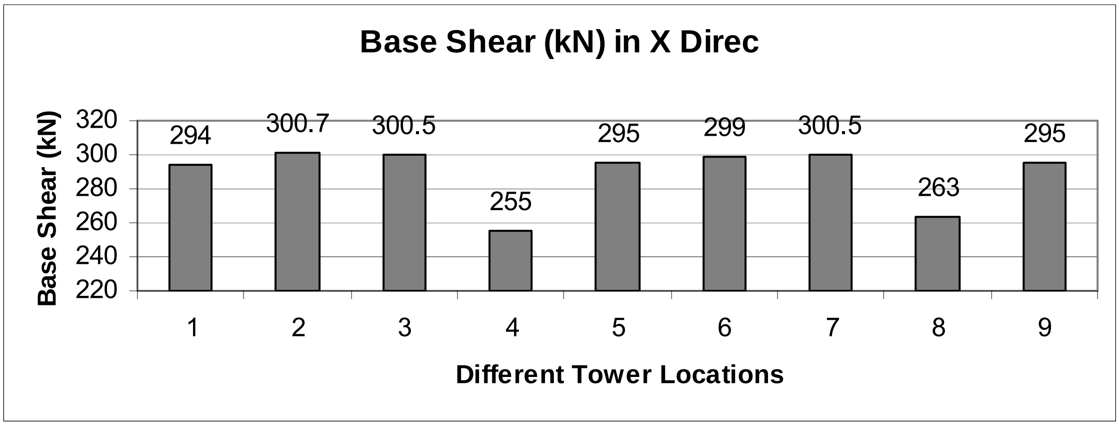
TIME PERIOD OF THE BUILDING WITH TOWER LOAD AT LOCATION 4		
MODE	FREQUENCY(CYCLES/SEC)	PERIOD(SEC)
1	1.576	0.63434
2	1.587	0.63011
3	2.035	0.49136

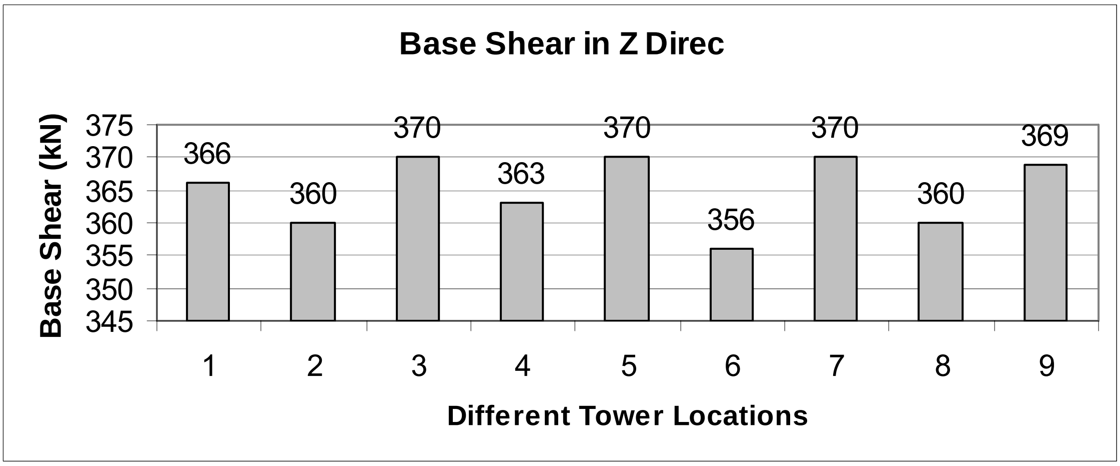


S.No.	Location Of Tower or Tower Load	Fundamental Natural Time Period (s)
1	Without Tower	0.63
2	Tower at Location 1	0.63
3	Tower Load at Location 1	0.63
4	Tower at Location 2	0.63
5	Tower Load at Location 2	0.63
6	Tower at Location 3	0.63
7	Tower Load at Location 3	0.63
8	Tower at Location 4	0.63
9	Tower Load at Location 4	0.63

Base Shear In the Three Storey Building for Different Locations of the Towers

S.No.	Location Of Tower or Tower Load	Base Shear (kN)	
		X Direction	Z Direction
1	Without Tower	294	366
2	Tower at Location 1	300.7	360
3	Tower Load at Location 1	300.5	370
4	Tower at Location 2	255	363
5	Tower Load at Location 2	295	370
6	Tower at Location 3	299	356
7	Tower Load at Location 3	300.5	370
8	Tower at Location 4	263	360
9	Tower Load at Location 4	295	369

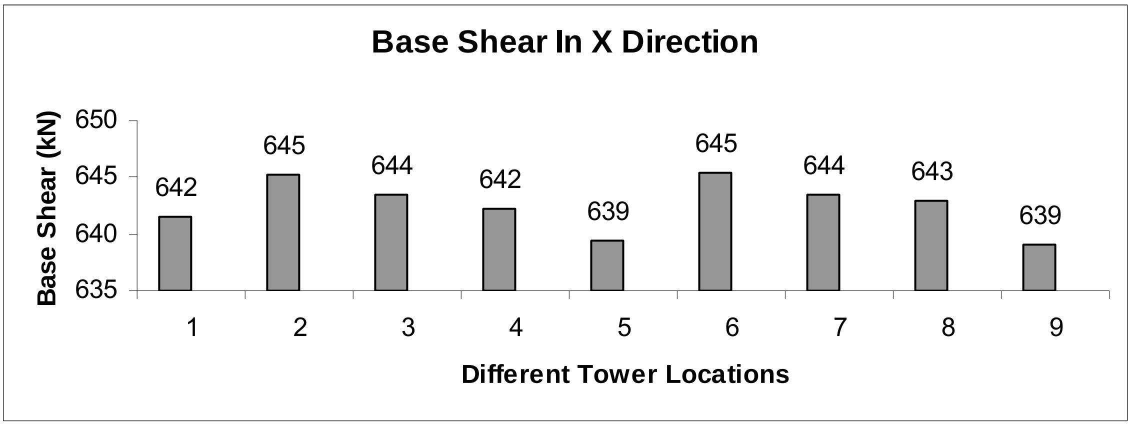


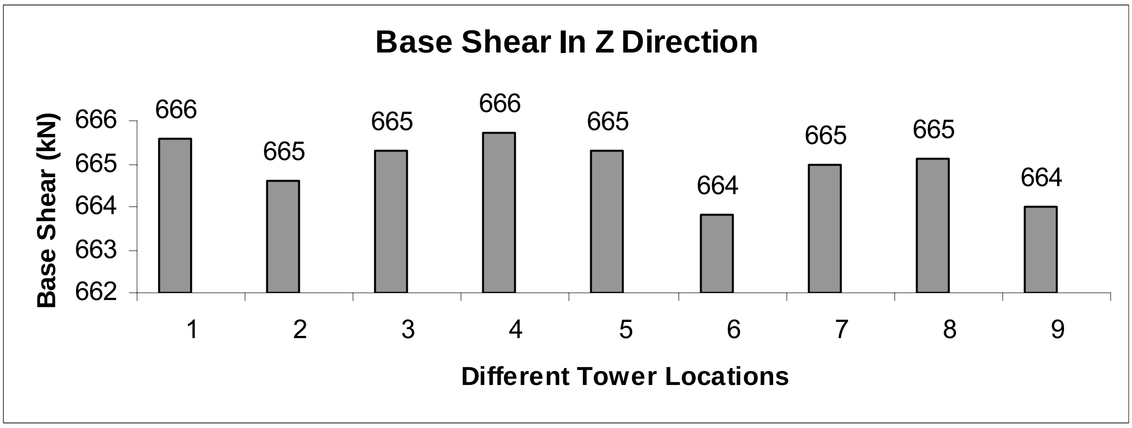


Legend	
1	Building without Tower
2	Tower at Location 1
3	Tower Load at Location 1
4	Tower at Location 2
5	Tower Load at Location 2
6	Tower at Location 3
7	Tower Load at Location 3
8	Tower at Location 4
9	Tower Load at Location 4

Base Shear In the Six Storey Building for Different Locations of the Towers

S.No.	Location Of Tower or Tower Load	Base Shear (kN)	
		X Direction	Z Direction
1	Without Tower	642	666
2	Tower at Location 1	645	665
3	Tower Load at Location 1	644	665
4	Tower at Location 2	642	666
5	Tower Load at Location 2	639	665
6	Tower at Location 3	645	664
7	Tower Load at Location 3	644	665
8	Tower at Location 4	643	665
9	Tower Load at Location 4	639	664





Legend	
1	Building without Tower
2	Tower at Location 1
3	Tower Load at Location 1
4	Tower at Location 2
5	Tower Load at Location 2
6	Tower at Location 3
7	Tower Load at Location 3
8	Tower at Location 4
9	Tower Load at Location 4

The following are the load cases as considered in the analysis of the building and towers

Load Case Number	Description
1	Seismic Load (EQ) in X Dir
2	Seismic Load (EQ) in Z Dir
3	Dead Load (DL)
4	Live Load (LL)
5	Wind Load (WL) in X Dir
6	Wind Load (WL) in Z Dir
7	Dead Load + Live Load
8	DL + LL + EQ in X Dir
9	DL + LL + EQ in -X Dir
10	DL + LL + EQ in Z Dir
11	DL + LL + EQ in -Z Dir
12	DL + EQ in X Dir
13	DL + EQ in -X Dir
14	DL + EQ in Z Dir
15	DL + EQ in -Z Dir
16	DL + LL + WL in X Dir
17	DL + LL + WL in -X Dir
18	DL + LL + WL in Z Dir
19	DL + LL + WL in -Z Dir
20	DL + WL in X Dir
21	DL + WL in -X Dir
22	DL + WL in Z Dir
23	DL + WL in -Z Dir

SUPPORT REACTIONS OF THE TOWER TO BE INSTALLED ON THREE STOREY BUILDING

Node	Load Case	Fx	Fy	Fz	Mx	My	Mz
1	Seismic X + DL	0.474	12.711	0.133	0.172	0.022	0.019
	Seismic Z + DL	0.081	12.483	0.493	0.16	0.025	0.044
	DL + Wind Normal	2.027	-42.241	8.684	0.284	0.061	0.542
	DL + Wind Diagonal	9.713	-79.119	9.403	-0.333	-0.004	0.272
2	Seismic X + DL	1.007	12.734	0.135	0.172	0.024	0.16
	Seismic Z + DL	0.614	12.505	0.493	0.161	0.026	0.185
	DL + Wind Normal	-2.026	-42.208	8.683	0.284	-0.061	-0.541
	DL + Wind Diagonal	5.052	5.092	4.455	0.804	-0.109	-0.677
3	Seismic X + DL	1.193	14.343	0.635	0.032	0.025	0.186
	Seismic Z + DL	0.678	14.146	1.09	0.001	0.026	0.204
	DL + Wind Normal	2.623	53.986	6.661	0.121	-0.061	0.7
	DL + Wind Diagonal	7.776	90.862	8.023	-0.447	-0.003	0.494
4	Seismic X + DL	0.535	14.366	0.635	0.032	0.024	0.007
	Seismic Z + DL	0.02	14.167	1.09	0.001	0.025	0.025
	DL + Wind Normal	-2.624	54.019	6.662	0.12	0.061	-0.701
	DL + Wind Diagonal	4.145	6.721	4.805	0.597	0.102	-0.776

SUPPORT REACTIONS OF THE TOWER TO BE INSTALLED ON SIX STOREY BUILDING

Node	Load Case	Fx	Fy	Fz	Mx	My	Mz
1	Seismic X + DL	0.494	12.808	0.132	0.167	0.025	0.029
	Seismic Z + DL	0.072	12.507	0.502	0.163	0.025	0.036
	DL + Wind Normal	2.617	-54.252	11.278	0.342	0.075	0.621
	DL + Wind Diagonal	12.163	-95.635	11.853	-0.305	-0.004	0.249
2	Seismic X + DL	1.037	12.829	0.131	0.167	0.026	0.167
	Seismic Z + DL	0.616	12.531	0.502	0.163	0.027	0.174
	DL + Wind Normal	-2.616	-54.209	11.277	0.342	-0.075	-0.62
	DL + Wind Diagonal	6.315	5.197	5.695	0.901	-0.131	-0.78
3	Seismic X + DL	1.206	14.439	0.642	0.025	0.026	0.183
	Seismic Z + DL	0.679	14.167	1.109	0.008	0.027	0.192
	DL + Wind Normal	3.223	66.214	8.367	0.182	-0.074	0.775
	DL + Wind Diagonal	9.463	107.623	9.71	-0.425	-0.003	0.467
4	Seismic X + DL	0.537	14.46	0.644	0.024	0.024	0.009
	Seismic Z + DL	0.011	14.189	1.11	0.007	0.025	0.018
	DL + Wind Normal	-3.224	66.256	8.368	0.181	0.074	-0.776
	DL + Wind Diagonal	5.385	6.824	6.068	0.706	0.124	-0.876

These reactions are transferred to the roof of the building when the tower is considered as lumped mass on the building.

Comparison of Forces in Beams of Three Storey Building With Tower at 4 Different Locations

MAXIMUM & MINIMUM FORCES IN THE BUILDING WITHOUT TOWER									
	Beam	**L/C**	**Node**	**Fx kN**	**Fy kN**	**Fz kN**	**Mx kNm**	**My kNm**	**Mz kNm**
Max Fx	10	7 1.5(DL+LL)	10	**829**	0	0	0	0	0
Min Fx	11	1 SEISMIC X	30	**-52**	-46	0	0	0	-34
Max Fy	65	8 1.2(DL+LL+ELX)	29	-11	**106**	0	0	0	180
Min Fy	106	8 1.2(DL+LL+ELX)	29	-15	**-106**	0	0	0	20
Max Fz	7	14 1.5(DL+ELZ)	7	344	0	**51**	0	90	0
Min Fz	13	14 1.5(DL+ELZ)	32	104	0	**-51**	0	-60	0
Max Mx	66	10 1.2(DL+LL+ELZ)	31	-7	60	2	**7**	2	66
Min Mx	62	10 1.2(DL+LL+ELZ)	77	-10	16	-2	**-7**	-2	-62
Max My	13	14 1.5(DL+ELZ)	13	345	0	47	0	**94**	0
Min My	7	11 1.2(DL+LL-ELZ)	7	387	0	-32	0	**-81**	0
Max Mz	65	8 1.2(DL+LL+ELX)	29	-11	106	0	0	0	**180**
Min Mz	10	13 1.5(DL-ELX)	10	296	-90	0	0	0	**-178**

MAXIMUM & MINIMUM FORCES IN THE BUILDING WITH TOWER AT LOCATION 1									
	Beam	**L/C**	**Node**	**Fx kN**	**Fy kN**	**Fz kN**	**Mx kNm**	**My kNm**	**Mz kNm**
Max Fx	10	7 1.5(DL+LL)	10	**829**	0	0	0	0	0
Min Fx	189	21 1.5(DL-WLX)	104	**-95**	-13	-7	0	-1	0
Max Fy	182	21 1.5(DL-WLX)	96	22	**121**	11	7	-5	2
Min Fy	179	21 1.5(DL-WLX)	61	16	**-138**	-26	1	-7	42
Max Fz	26	10 1.2(DL+LL+ELZ)	26	329	1	**41**	1	21	2
Min Fz	32	10 1.2(DL+LL+ELZ)	51	237	-1	**-41**	-1	-63	-1
Max Mx	185	22 1.5(DL+WLZ)	100	-11	82	17	**14**	0	10
Min Mx	185	23 1.5(DL-WLZ)	100	9	-96	-16	**-11**	-1	-9
Max My	13	14 1.5(DL+ELZ)	13	322	1	36	1	**74**	2
Min My	7	11 1.2(DL+LL-ELZ)	7	401	-1	-23	-1	**-65**	-2
Max Mz	106	9 1.2(DL+LL-ELX)	29	-12	-59	0	0	0	**152**
Min Mz	10	13 1.5(DL-ELX)	10	295	-58	-1	0	-2	**-116**

MAXIMUM & MINIMUM FORCES IN THE BUILDING WITH TOWER LOAD AT LOCATION 1									
	Beam	**L/C**	**Node**	**Fx kN**	**Fy kN**	**Fz kN**	**Mx kNm**	**My kNm**	**Mz kNm**
Max Fx	10	7 1.5(DL+LL)	10	**830**	0	0	0	0	0
Min Fx	46	5 WIND X	46	**-69**	-5	0	0	0	-2
Max Fy	65	8 1.2(DL+LL+ELX)	29	-11	**106**	0	0	0	180
Min Fy	106	8 1.2(DL+LL+ELX)	29	-15	**-106**	0	0	0	20
Max Fz	7	14 1.5(DL+ELZ)	7	359	1	**52**	1	91	1
Min Fz	13	14 1.5(DL+ELZ)	32	100	-1	**-52**	-1	-60	-1
Max Mx	115	10 1.2(DL+LL+ELZ)	80	-6	-16	1	**7**	2	-39
Min Mx	117	10 1.2(DL+LL+ELZ)	33	-10	-60	-2	**-7**	-2	47
Max My	13	14 1.5(DL+ELZ)	13	348	1	48	1	**95**	1
Min My	7	11 1.2(DL+LL-ELZ)	7	392	-1	-33	-1	**-82**	-1
Max Mz	106	9 1.2(DL+LL-ELX)	29	-11	-49	0	0	0	**180**
Min Mz	10	13 1.5(DL-ELX)	10	297	-89	0	0	0	**-177**

MAXIMUM & MINIMUM FORCES IN THE BUILDING WITH TOWER AT LOCATION 2									
	Beam	**L/C**	**Node**	**Fx kN**	**Fy kN**	**Fz kN**	**Mx kNm**	**My kNm**	**Mz kNm**
Max Fx	10	7 1.5(DL+LL)	10	**838**	0	0	0	0	0
Min Fx	190	23 1.5(DL-WLZ)	106	**-77**	-5	11	0	0	1
Max Fy	65	7 1.5(DL+LL)	29	-15	**97**	0	0	0	125
Min Fy	185	23 1.5(DL-WLZ)	95	3	**-107**	-16	-13	-3	7
Max Fz	26	10 1.2(DL+LL+ELZ)	26	331	3	**41**	1	20	4
Min Fz	32	10 1.2(DL+LL+ELZ)	51	237	-2	**-41**	-1	-63	-3
Max Mx	181	21 1.5(DL-WLX)	98	0	-79	9	**20**	-9	-76
Min Mx	170	21 1.5(DL-WLX)	92	9	88	-16	**-20**	14	62
Max My	13	14 1.5(DL+ELZ)	13	320	2	36	1	**74**	4
Min My	7	11 1.2(DL+LL-ELZ)	7	416	-2	-23	0	**-64**	-5
Max Mz	106	9 1.2(DL+LL-ELX)	29	-12	-60	1	0	1	**150**
Min Mz	10	13 1.5(DL-ELX)	10	273	-56	-2	-1	-5	**-111**

MAXIMUM & MINIMUM FORCES IN THE BUILDING WITH TOWER LOAD AT LOCATION 2									
	Beam	**L/C**	**Node**	**Fx kN**	**Fy kN**	**Fz kN**	**Mx kNm**	**My kNm**	**Mz kNm**
Max Fx	10	7 1.5(DL+LL)	10	**842**	0	0	0	0	0
Min Fx	49	6 WIND Z	49	**-75**	-10	-6	-1	7	-5
Max Fy	65	8 1.2(DL+LL+ELX)	29	-9	**108**	0	0	0	184
Min Fy	106	8 1.2(DL+LL+ELX)	29	-16	**-108**	0	0	0	16
Max Fz	7	14 1.5(DL+ELZ)	7	360	1	**52**	1	91	1
Min Fz	13	14 1.5(DL+ELZ)	32	101	-1	**-52**	-1	-60	-1
Max Mx	115	10 1.2(DL+LL+ELZ)	80	-6	-16	1	**7**	2	-39
Min Mx	117	10 1.2(DL+LL+ELZ)	33	-10	-60	-2	**-7**	-2	47
Max My	13	14 1.5(DL+ELZ)	13	349	1	48	1	**95**	1
Min My	7	11 1.2(DL+LL-ELZ)	7	393	-1	-33	-1	**-82**	-1
Max Mz	106	9 1.2(DL+LL-ELX)	29	-11	-48	0	0	0	**184**
Min Mz	10	13 1.5(DL-ELX)	10	309	-92	0	0	0	**-184**

MAXIMUM & MINIMUM FORCES IN THE BUILDING WITH TOWER AT LOCATION 3									
	Beam	**L/C**	**Node**	**Fx kN**	**Fy kN**	**Fz kN**	**Mx kNm**	**My kNm**	**Mz kNm**
Max Fx	10	7 1.5(DL+LL)	10	**829**	0	0	0	0	0
Min Fx	188	20 1.5(DL+WLX)	103	**-93**	17	-7	0	-1	0
Max Fy	183	22 1.5(DL+WLZ)	96	17	**125**	-13	-12	3	24
Min Fy	181	20 1.5(DL+WLX)	61	16	**-132**	20	-5	6	41
Max Fz	26	10 1.2(DL+LL+ELZ)	26	379	1	**42**	0	22	1
Min Fz	32	10 1.2(DL+LL+ELZ)	51	234	-1	**-42**	0	-64	-1
Max Mx	182	23 1.5(DL-WLZ)	95	14	96	15	**11**	-4	11
Min Mx	179	22 1.5(DL+WLZ)	96	37	-127	17	**-20**	-3	-17
Max My	13	14 1.5(DL+ELZ)	13	325	1	37	0	**76**	2
Min My	7	11 1.2(DL+LL-ELZ)	7	405	-2	-24	0	**-66**	-3
Max Mz	65	8 1.2(DL+LL+ELX)	29	-12	96	0	0	0	**152**
Min Mz	10	13 1.5(DL-ELX)	10	295	-58	-1	0	-1	**-116**

MAXIMUM & MINIMUM FORCES IN THE BUILDING WITH TOWER LOAD AT LOCATION 3									
	Beam	**L/C**	**Node**	**Fx kN**	**Fy kN**	**Fz kN**	**Mx kNm**	**My kNm**	**Mz kNm**
Max Fx	10	7 1.5(DL+LL)	10	**830**	0	0	0	0	0
Min Fx	45	5 WIND X	45	**-73**	16	0	-1	0	14
Max Fy	65	8 1.2(DL+LL+ELX)	29	-11	**106**	0	0	0	180
Min Fy	106	8 1.2(DL+LL+ELX)	29	-15	**-106**	0	0	0	20
Max Fz	7	14 1.5(DL+ELZ)	7	386	0	**53**	0	93	0
Min Fz	13	14 1.5(DL+ELZ)	32	97	0	**-53**	0	-61	-1
Max Mx	115	10 1.2(DL+LL+ELZ)	80	-6	-16	2	**7**	3	-40
Min Mx	117	10 1.2(DL+LL+ELZ)	33	-10	-60	-2	**-7**	-2	47
Max My	13	14 1.5(DL+ELZ)	13	351	0	49	0	**97**	1
Min My	7	11 1.2(DL+LL-ELZ)	7	408	0	-34	0	**-83**	-1
Max Mz	106	9 1.2(DL+LL-ELX)	29	-11	-49	0	0	0	**180**
Min Mz	10	13 1.5(DL-ELX)	10	297	-89	0	0	0	**-178**

MAXIMUM & MINIMUM FORCES IN THE BUILDING WITH TOWER AT LOCATION 4									
	Beam	**L/C**	**Node**	**Fx kN**	**Fy kN**	**Fz kN**	**Mx kNm**	**My kNm**	**Mz kNm**
Max Fx	10	7 1.5(DL+LL)	10	**859**	0	0	0	0	0
Min Fx	191	23 1.5(DL-WLZ)	105	**-77**	5	11	0	0	-1
Max Fy	182	23 1.5(DL-WLZ)	95	3	**106**	15	13	-3	11
Min Fy	106	7 1.5(DL+LL)	29	-17	**-97**	0	0	0	125
Max Fz	7	14 1.5(DL+ELZ)	7	339	1	**42**	0	71	1
Min Fz	32	10 1.2(DL+LL+ELZ)	51	234	-1	**-42**	0	-65	-1
Max Mx	170	20 1.5(DL+WLX)	92	12	86	15	**17**	-13	61
Min Mx	181	20 1.5(DL+WLX)	98	5	-78	-8	**-17**	9	-74
Max My	13	14 1.5(DL+ELZ)	13	321	1	37	0	**76**	1
Min My	7	11 1.2(DL+LL-ELZ)	7	443	-1	-24	0	**-66**	-1
Max Mz	106	9 1.2(DL+LL-ELX)	29	-11	-60	1	0	1	**150**
Min Mz	10	13 1.5(DL-ELX)	10	305	-56	-1	-1	-2	**-111**

MAXIMUM & MINIMUM FORCES IN THE BUILDING WITH TOWER LOAD AT LOCATION 4									
	Beam	**L/C**	**Node**	**Fx kN**	**Fy kN**	**Fz kN**	**Mx kNm**	**My kNm**	**Mz kNm**
Max Fx	10	7 1.5(DL+LL)	10	**866**	0	0	0	0	0
Min Fx	48	5 WIND X	48	**-77**	21	-1	0	1	19
Max Fy	65	8 1.2(DL+LL+ELX)	29	-10	**108**	0	0	0	184
Min Fy	106	8 1.2(DL+LL+ELX)	29	-16	**-108**	0	0	0	16
Max Fz	7	14 1.5(DL+ELZ)	7	389	0	**53**	0	93	0
Min Fz	13	14 1.5(DL+ELZ)	32	98	0	**-53**	0	-61	0
Max Mx	115	10 1.2(DL+LL+ELZ)	80	-6	-16	2	**7**	3	-40
Min Mx	117	10 1.2(DL+LL+ELZ)	33	-10	-60	-2	**-7**	-2	47
Max My	13	14 1.5(DL+ELZ)	13	352	0	49	0	**98**	1
Min My	7	11 1.2(DL+LL-ELZ)	7	410	0	-34	0	**-84**	-1
Max Mz	106	9 1.2(DL+LL-ELX)	29	-11	-47	0	0	0	**184**
Min Mz	10	13 1.5(DL-ELX)	10	333	-92	0	0	0	**-184**

Comparison of Forces in Beams of Six Storey Building With Tower at 4 Different Locations

MAXIMUM & MINIMUM FORCES IN THE BUILDING WITHOUT TOWER									
	Beam	**L/C**	**Node**	**Fx kN**	**Fy kN**	**Fz kN**	**Mx kNm**	**My kNm**	**Mz kNm**
Max Fx	10	7 1.5(DL+LL)	10	**1744**	0	0	0	0	0
Min Fx	5	1 SEISMIC X	24	**-195**	-37	0	-1	-1	-33
Max Fy	161	8 1.2(DL+LL+ELX)	47	5	**113**	0	0	0	200
Min Fy	185	8 1.2(DL+LL+ELX)	49	-3	**-113**	0	0	0	-13
Max Fz	26	14 1.5(DL+ELZ)	26	607	0	**89**	0	125	0
Min Fz	32	14 1.5(DL+ELZ)	51	105	0	**-89**	0	-129	0
Max Mx	184	10 1.2(DL+LL+ELZ)	143	1	-11	2	**11**	3	-30
Min Mx	186	10 1.2(DL+LL+ELZ)	52	0	-65	-2	**-11**	-3	42
Max My	13	14 1.5(DL+ELZ)	13	773	0	76	0	**154**	0
Min My	7	11 1.2(DL+LL-ELZ)	7	688	0	-55	0	**-130**	0
Max Mz	185	9 1.2(DL+LL-ELX)	49	5	-41	0	0	0	**200**
Min Mz	10	13 1.5(DL-ELX)	10	579	-88	0	0	0	**-182**

MAXIMUM & MINIMUM FORCES IN THE BUILDING WITH TOWER AT LOCATION 1									
	Beam	**L/C**	**Node**	**Fx kN**	**Fy kN**	**Fz kN**	**Mx kNm**	**My kNm**	**Mz kNm**
Max Fx	10	7 1.5(DL+LL)	10	**1744**	0	0	0	0	0
Min Fx	5	1 SEISMIC X	24	**-172**	-31	-1	-1	-1	-27
Max Fy	351	21 1.5(DL-WLX)	118	19	**160**	-35	-2	10	50
Min Fy	364	22 1.5(DL+WLZ)	173	16	**-149**	17	15	4	19
Max Fz	26	14 1.5(DL+ELZ)	26	574	1	**75**	0	104	1
Min Fz	32	14 1.5(DL+ELZ)	51	143	-1	**-75**	0	-109	-1
Max Mx	362	22 1.5(DL+WLZ)	175	-14	102	22	**18**	0	13
Min Mx	362	23 1.5(DL-WLZ)	175	13	-116	-20	**-15**	-1	-12
Max My	13	14 1.5(DL+ELZ)	13	722	1	64	0	**130**	2
Min My	26	11 1.2(DL+LL-ELZ)	26	606	-1	-42	0	**-110**	-1
Max Mz	185	9 1.2(DL+LL-ELX)	49	5	-48	0	0	0	**180**
Min Mz	10	13 1.5(DL-ELX)	10	579	-71	0	0	-1	**-147**

MAXIMUM & MINIMUM FORCES IN THE BUILDING WITH TOWER LOAD AT LOCATION 1									
	Beam	**L/C**	**Node**	**Fx kN**	**Fy kN**	**Fz kN**	**Mx kNm**	**My kNm**	**Mz kNm**
Max Fx	10	7 1.5(DL+LL)	10	**1745**	0	0	0	0	0
Min Fx	5	1 SEISMIC X	24	**-201**	-38	-1	-1	-1	-33
Max Fy	161	8 1.2(DL+LL+ELX)	47	5	**113**	0	0	0	200
Min Fy	185	8 1.2(DL+LL+ELX)	49	-3	**-113**	0	0	0	-13
Max Fz	26	14 1.5(DL+ELZ)	26	615	1	**89**	0	125	1
Min Fz	32	14 1.5(DL+ELZ)	51	102	-1	**-89**	0	-130	-1
Max Mx	184	10 1.2(DL+LL+ELZ)	143	1	-11	2	**11**	3	-30
Min Mx	186	10 1.2(DL+LL+ELZ)	52	0	-66	-2	**-11**	-3	42
Max My	13	14 1.5(DL+ELZ)	13	776	1	77	0	**155**	1
Min My	7	11 1.2(DL+LL-ELZ)	7	689	0	-55	0	**-130**	-1
Max Mz	185	9 1.2(DL+LL-ELX)	49	5	-41	0	0	0	**200**
Min Mz	10	13 1.5(DL-ELX)	10	580	-88	0	0	0	**-182**

MAXIMUM & MINIMUM FORCES IN THE BUILDING WITH TOWER AT LOCATION 2									
	Beam	**L/C**	**Node**	**Fx kN**	**Fy kN**	**Fz kN**	**Mx kNm**	**My kNm**	**Mz kNm**
Max Fx	10	7 1.5(DL+LL)	10	**1753**	0	0	0	0	0
Min Fx	5	1 SEISMIC X	24	**-170**	-31	-1	-1	-1	-27
Max Fy	338	20 1.5(DL+WLX)	122	20	**112**	19	10	-17	116
Min Fy	362	23 1.5(DL-WLZ)	172	3	**-128**	-20	-16	-4	9
Max Fz	26	14 1.5(DL+ELZ)	26	579	1	**75**	0	104	2
Min Fz	32	14 1.5(DL+ELZ)	51	143	-1	**-75**	0	-110	-1
Max Mx	356	21 1.5(DL-WLX)	171	-3	-94	9	**23**	-11	-91
Min Mx	352	21 1.5(DL-WLX)	167	12	105	-22	**-24**	21	73
Max My	13	14 1.5(DL+ELZ)	13	720	1	64	0	**130**	2
Min My	26	11 1.2(DL+LL-ELZ)	26	614	-1	-42	0	**-111**	-1
Max Mz	161	8 1.2(DL+LL+ELX)	47	4	105	0	0	1	**179**
Min Mz	10	13 1.5(DL-ELX)	10	578	-70	-1	0	-2	**-145**

MAXIMUM & MINIMUM FORCES IN THE BUILDING WITH TOWER LOAD AT LOCATION 2									
	Beam	**L/C**	**Node**	**Fx kN**	**Fy kN**	**Fz kN**	**Mx kNm**	**My kNm**	**Mz kNm**
Max Fx	10	7 1.5(DL+LL)	10	**1750**	0	0	0	0	0
Min Fx	5	1 SEISMIC X	24	**-199**	-37	0	-1	-1	-33
Max Fy	161	8 1.2(DL+LL+ELX)	47	5	**113**	0	0	0	201
Min Fy	185	8 1.2(DL+LL+ELX)	49	-3	**-113**	0	0	0	-14
Max Fz	26	14 1.5(DL+ELZ)	26	616	1	**89**	0	125	1
Min Fz	32	14 1.5(DL+ELZ)	51	103	-1	**-89**	0	-130	-1
Max Mx	184	10 1.2(DL+LL+ELZ)	143	1	-11	2	**11**	3	-30
Min Mx	186	10 1.2(DL+LL+ELZ)	52	0	-66	-2	**-11**	-3	42
Max My	13	14 1.5(DL+ELZ)	13	777	1	77	0	**155**	1
Min My	7	11 1.2(DL+LL-ELZ)	7	689	0	-55	0	**-130**	-1
Max Mz	161	8 1.2(DL+LL+ELX)	47	5	113	0	0	0	**201**
Min Mz	10	13 1.5(DL-ELX)	10	585	-88	0	0	0	**-183**

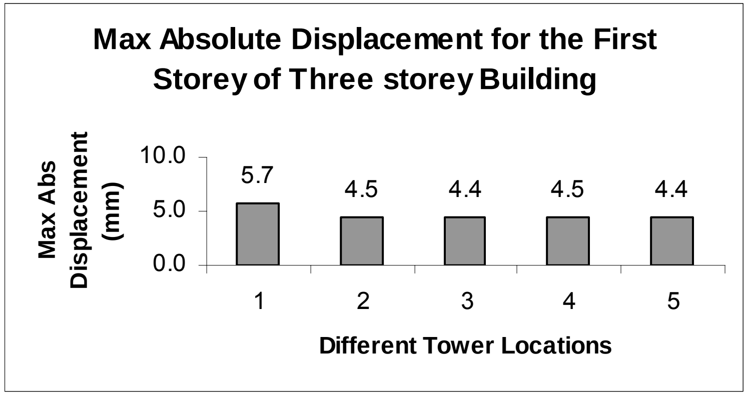
MAXIMUM & MINIMUM FORCES IN THE BUILDING WITH TOWER AT LOCATION 3									
	Beam	**L/C**	**Node**	**Fx kN**	**Fy kN**	**Fz kN**	**Mx kNm**	**My kNm**	**Mz kNm**
Max Fx	10	7 1.5(DL+LL)	10	**1745**	0	0	0	0	0
Min Fx	5	1 SEISMIC X	24	**-167**	-31	-1	-1	-1	-27
Max Fy	351	20 1.5(DL+WLX)	118	21	**156**	26	-5	-8	49
Min Fy	356	22 1.5(DL+WLZ)	121	49	**-141**	21	-21	3	11
Max Fz	26	14 1.5(DL+ELZ)	26	606	0	**75**	0	104	0
Min Fz	32	14 1.5(DL+ELZ)	51	140	0	**-75**	0	-109	0
Max Mx	359	23 1.5(DL-WLZ)	170	20	118	19	**15**	-4	13
Min Mx	356	22 1.5(DL+WLZ)	171	49	-139	21	**-21**	-4	-31
Max My	13	14 1.5(DL+ELZ)	13	723	0	64	0	**130**	1
Min My	26	11 1.2(DL+LL-ELZ)	26	620	0	-41	0	**-110**	0
Max Mz	161	8 1.2(DL+LL+ELX)	47	5	106	0	0	0	**180**
Min Mz	10	13 1.5(DL-ELX)	10	580	-71	0	0	0	**-147**

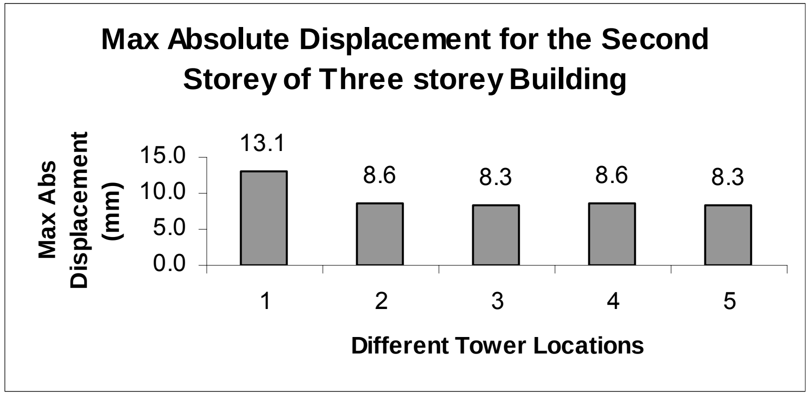
MAXIMUM & MINIMUM FORCES IN THE BUILDING WITH TOWER LOAD AT LOCATION 3									
	Beam	**L/C**	**Node**	**Fx kN**	**Fy kN**	**Fz kN**	**Mx kNm**	**My kNm**	**Mz kNm**
Max Fx	10	7 1.5(DL+LL)	10	**1745**	0	0	0	0	0
Min Fx	5	1 SEISMIC X	24	**-201**	-38	-1	-1	-1	-33
Max Fy	161	8 1.2(DL+LL+ELX)	47	5	**113**	0	0	0	200
Min Fy	185	8 1.2(DL+LL+ELX)	49	-3	**-113**	0	0	0	-13
Max Fz	26	14 1.5(DL+ELZ)	26	627	0	**89**	0	126	0
Min Fz	32	14 1.5(DL+ELZ)	51	101	0	**-89**	0	-130	0
Max Mx	184	10 1.2(DL+LL+ELZ)	143	1	-11	2	**11**	3	-30
Min Mx	186	10 1.2(DL+LL+ELZ)	52	0	-66	-2	**-11**	-3	42
Max My	13	14 1.5(DL+ELZ)	13	777	0	77	0	**155**	0
Min My	7	11 1.2(DL+LL-ELZ)	7	696	0	-55	0	**-130**	0
Max Mz	161	8 1.2(DL+LL+ELX)	47	5	113	0	0	0	**200**
Min Mz	10	13 1.5(DL-ELX)	10	580	-88	0	0	0	**-182**

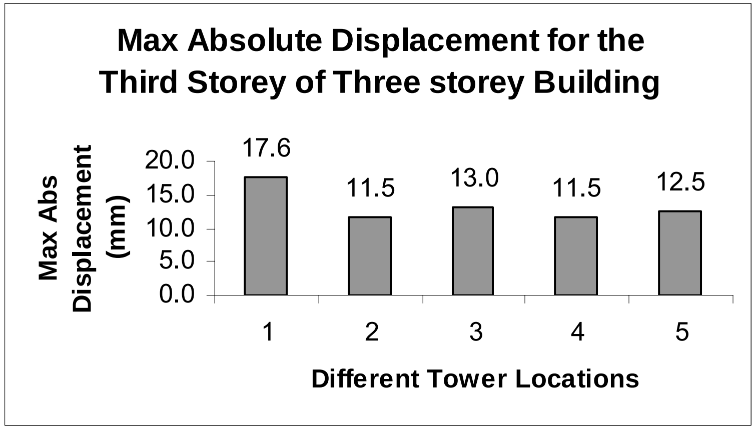
MAXIMUM & MINIMUM FORCES IN THE BUILDING WITH TOWER AT LOCATION 4									
	Beam	**L/C**	**Node**	**Fx kN**	**Fy kN**	**Fz kN**	**Mx kNm**	**My kNm**	**Mz kNm**
Max Fx	10	7 1.5(DL+LL)	10	**1763**	0	0	0	0	0
Min Fx	5	1 SEISMIC X	24	**-170**	-31	-1	-1	-1	-27
Max Fy	359	23 1.5(DL-WLZ)	170	4	**128**	20	16	-4	12
Min Fy	185	8 1.2(DL+LL+ELX)	49	-2	**-105**	-1	0	-1	8
Max Fz	26	14 1.5(DL+ELZ)	26	593	0	**76**	0	104	0
Min Fz	32	14 1.5(DL+ELZ)	51	141	0	**-75**	0	-110	0
Max Mx	352	20 1.5(DL+WLX)	167	19	102	21	**20**	-20	72
Min Mx	358	20 1.5(DL+WLX)	173	4	-91	-9	**-20**	10	-88
Max My	13	14 1.5(DL+ELZ)	13	721	0	64	0	**130**	0
Min My	26	11 1.2(DL+LL-ELZ)	26	628	0	-42	0	**-111**	0
Max Mz	161	8 1.2(DL+LL+ELX)	47	4	106	1	0	1	**179**
Min Mz	10	13 1.5(DL-ELX)	10	601	-70	0	0	0	**-145**

MAXIMUM & MINIMUM FORCES IN THE BUILDING WITH TOWER LOAD AT LOCATION 4									
	Beam	**L/C**	**Node**	**Fx kN**	**Fy kN**	**Fz kN**	**Mx kNm**	**My kNm**	**Mz kNm**
Max Fx	10	7 1.5(DL+LL)	10	**1761**	0	0	0	0	0
Min Fx	5	1 SEISMIC X	24	**-199**	-37	0	-1	-1	-33
Max Fy	161	8 1.2(DL+LL+ELX)	47	5	**113**	0	0	0	201
Min Fy	185	8 1.2(DL+LL+ELX)	49	-3	**-113**	0	0	0	-14
Max Fz	26	14 1.5(DL+ELZ)	26	628	0	**89**	0	125	0
Min Fz	32	14 1.5(DL+ELZ)	51	102	0	**-89**	0	-130	0
Max Mx	184	10 1.2(DL+LL+ELZ)	143	1	-11	2	**11**	3	-30
Min Mx	186	10 1.2(DL+LL+ELZ)	52	0	-66	-2	**-11**	-3	42
Max My	13	14 1.5(DL+ELZ)	13	778	0	77	0	**155**	0
Min My	7	11 1.2(DL+LL-ELZ)	7	697	0	-55	0	**-130**	0
Max Mz	161	8 1.2(DL+LL+ELX)	47	5	113	0	0	0	**201**
Min Mz	10	13 1.5(DL-ELX)	10	596	-88	0	0	0	**-183**

Different tower locations	Maximum absolute displacement in Three Storey Building(mm)		
	First Storey	Second Storey	Third Storey
without tower	5.7	13.1	17.6
with tower at location 1	4.5	8.6	11.5
with tower load at location 1	5.7	13.1	17.6
with tower at location 2	4.4	8.3	13.0
with tower load at location 2	5.9	13.8	19.0
with tower at location 3	4.5	8.6	11.5
with tower load at location 3	5.7	13.1	17.6
with tower at location 4	4.4	8.3	12.5
with tower load at location 4	5.9	13.8	19.0

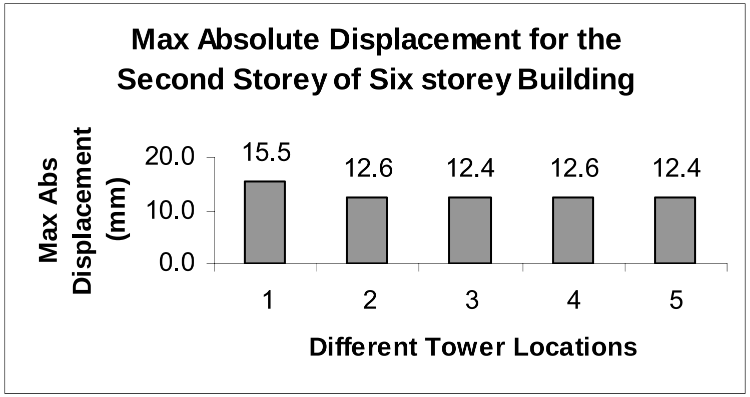


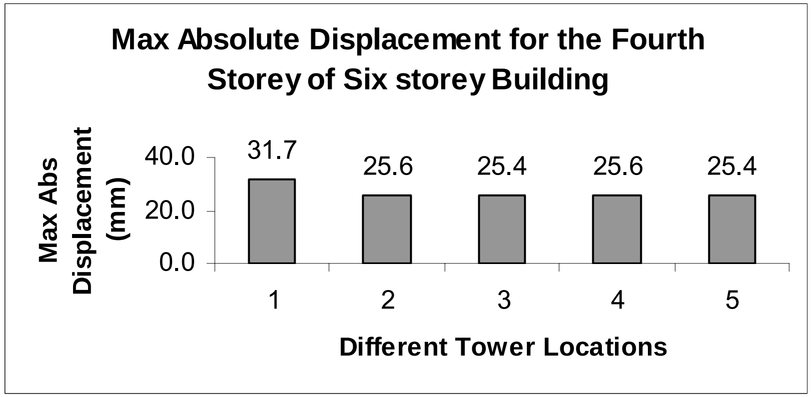


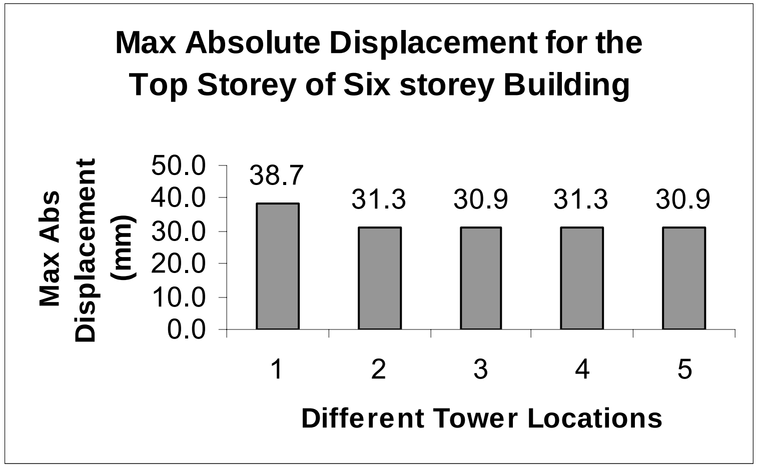


Legend	
1	Building without Tower
2	Tower at Location 1
3	Tower at Location 2
4	Tower at Location 3
5	Tower at Location 4

Different tower locations	Maximum absolute displacement in Six Storey Building(mm)		
	Second Storey	Fourth Storey	Top Storey
without tower	15.5	31.7	38.7
with tower at location 1	12.6	25.6	31.3
with tower at location 2	12.4	25.4	30.9
with tower at location 3	12.6	25.6	31.3
with tower at location 4	12.4	25.4	30.9







Legend	
1	Building without Tower
2	Tower at Location 1
3	Tower at Location 2
4	Tower at Location 3
5	Tower at Location 4

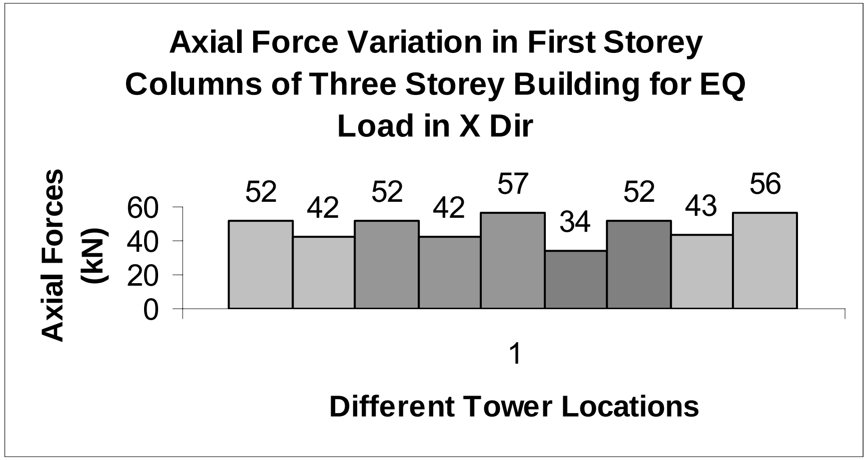
Axial Forces in Columns of the Three Storey building without and with tower at location 1

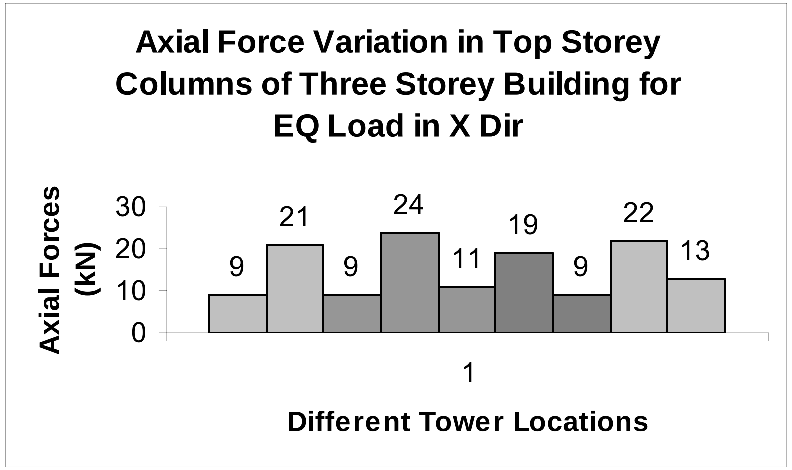
First Storey Columns										
Without Tower				With Tower at Location 1				With Tower Load at Location 1		
Earthquake Load Cases										
Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)
10	10	663		10	10	664		10	10	664
10	8	663		10	8	663		10	8	664
10	9	663		10	9	662		10	9	664
10	11	663		10	11	662		10	11	664
13	2	73		5	2	71		7	2	76
11	1	52		5	1	42		9	1	52
Wind Load Cases										
10	17	663		10	18	664		10	17	667
10	19	663		10	17	664		10	19	667
10	18	663		10	16	662		10	18	661
10	16	663		10	19	662		10	16	661
15	5	17		8	6	82		5	5	66
7	6	14		5	5	82		8	6	48
Top Storey Columns										
Without Tower				With tower at Location 1				With Tower Load at Location 1		
Earthquake Load Cases										
Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)
48	10	148		48	10	149		48	10	149
48	8	148		48	8	148		48	8	149
48	9	148		48	9	148		48	9	149
48	11	148		48	11	147		48	11	149
51	2	12		43	2	34		45	2	13
49	1	9		43	1	21		47	1	9
Wind Load Cases										
48	17	148		48	18	177		46	17	174
48	19	148		48	17	149		46	19	173
48	18	148		48	16	147		48	18	146
48	16	148		48	19	147		48	16	146
43	5	2		46	6	70		46	5	69
51	6	2		43	5	61		46	6	68

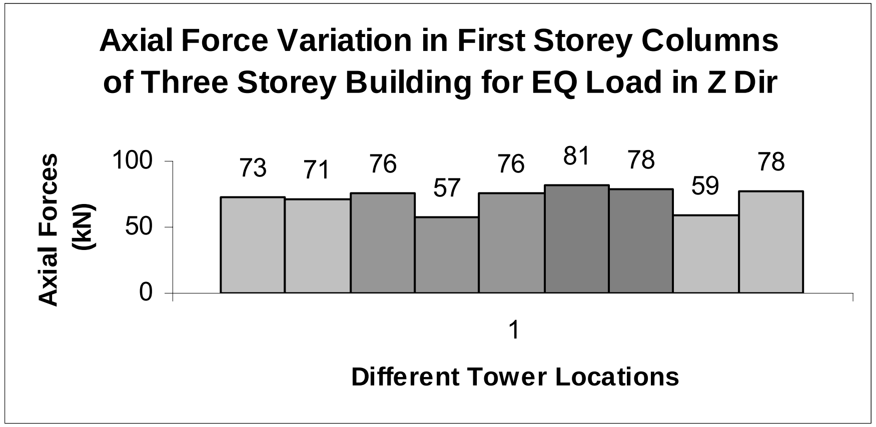
Axial Forces in Columns of the Three Storey building without and with tower at location 2										
First Storey Columns										
Without Tower				With Tower at Location 2				With Tower Load at Location 2		
Earthquake Load Cases										
Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)
10	10	663		10	8	697		10	8	674
10	8	663		10	10	675		10	10	674
10	9	663		10	11	666		10	11	674
10	11	663		10	9	645		10	9	674
13	2	73		13	2	57		7	2	76
11	1	52		11	1	42		11	1	57
Wind Load Cases										
10	17	663		10	17	700		10	17	702
10	19	663		10	18	681		10	19	702
10	18	663		10	19	660		10	18	645
10	16	663		10	16	641		10	16	645
15	5	17		11	6	43		11	6	74
7	6	14		11	5	42		8	5	54
Top Storey Columns										
Without Tower				With tower at Location 2				With Tower Load at Location 2		
Earthquake Load Cases										
Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)
48	10	148		48	8	183		48	8	159
48	8	148		48	10	160		48	10	159
48	9	148		48	11	151		48	11	159
48	11	148		48	9	129		48	9	159
51	2	12		46	1	24		45	2	13
49	1	9		49	2	15		49	1	11
Wind Load Cases										
48	17	148		48	17	187		49	19	210
48	19	148		48	18	167		49	17	206
48	18	148		48	19	145		46	18	165
48	16	148		48	16	145		46	16	164
43	5	2		49	6	43		49	6	75
51	6	2		46	5	30		49	5	71

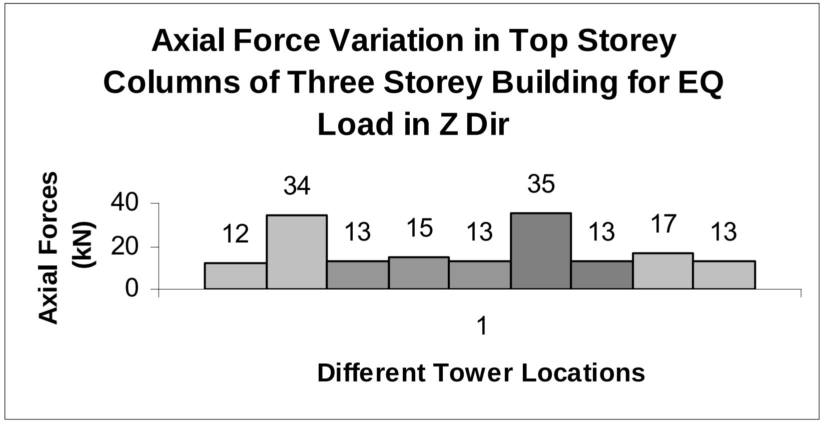
Axial Forces in Columns of the Three Storey building without and with tower at location 3										
First Storey Columns										
Without Tower				With Tower at Location 3				With Tower Load at Location 3		
Earthquake Load Cases										
Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)
10	10	663		10	10	664		10	10	664
10	8	663		10	8	664		10	8	664
10	9	663		10	9	663		10	9	664
10	11	663		10	11	662		10	11	664
13	2	73		7	2	81		7	2	78
11	1	52		11	1	34		9	1	52
Wind Load Cases										
10	17	663		10	18	665		10	17	668
10	19	663		10	16	664		10	19	668
10	18	663		10	17	662		10	18	661
10	16	663		10	19	661		10	16	661
15	5	17		7	6	85		7	5	68
7	6	14		3	5	45		7	6	45
Top Storey Columns										
Without Tower				With tower at Location 3				With Tower Load at Location 3		
Earthquake Load Cases										
Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)
48	10	148		45	10	176		45	10	150
48	8	148		45	8	151		48	8	149
48	9	148		48	9	148		48	9	149
48	11	148		48	11	147		48	11	149
51	2	12		45	2	35		45	2	13
49	1	9		42	1	19		47	1	9
Wind Load Cases										
48	17	148		45	18	218		45	17	222
48	19	148		45	17	157		45	19	217
48	18	148		48	16	150		48	18	146
48	16	148		48	19	147		48	16	146
43	5	2		45	6	70		45	5	73
51	6	2		42	5	55		45	6	69

Axial Forces in Columns of the Three Storey building without and with tower at location 4										
First Storey Columns										
Without Tower				With Tower at Location 4				With Tower Load at Location 4		
Earthquake Load Cases										
Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)
10	10	663		10	10	707		10	8	693
10	8	663		10	8	704		10	10	693
10	9	663		10	9	670		10	11	693
10	11	663		10	11	667		10	9	693
13	2	73		13	2	59		7	2	78
11	1	52		11	1	43		9	1	56
Wind Load Cases										
10	17	663		10	18	737		10	17	782
10	19	663		10	17	710		10	19	782
10	18	663		10	16	665		10	18	604
10	16	663		10	19	637		10	16	604
15	5	17		11	5	42		7	6	74
7	6	14		10	6	42		10	5	74
Top Storey Columns										
Without Tower				With tower at Location 4				With Tower Load at Location 4		
Earthquake Load Cases										
Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)
48	10	148		48	10	193		48	8	179
48	8	148		48	8	189		48	10	179
48	9	148		48	9	156		48	11	179
48	11	148		48	11	152		48	9	179
51	2	12		46	1	22		45	2	13
49	1	9		48	2	17		47	1	11
Wind Load Cases										
48	17	148		48	18	225		48	17	271
48	19	148		48	17	196		48	19	271
48	18	148		45	19	183		45	18	208
48	16	148		48	16	150		45	16	204
43	5	2		48	6	43		48	5	77
51	6	2		46	5	27		48	6	77

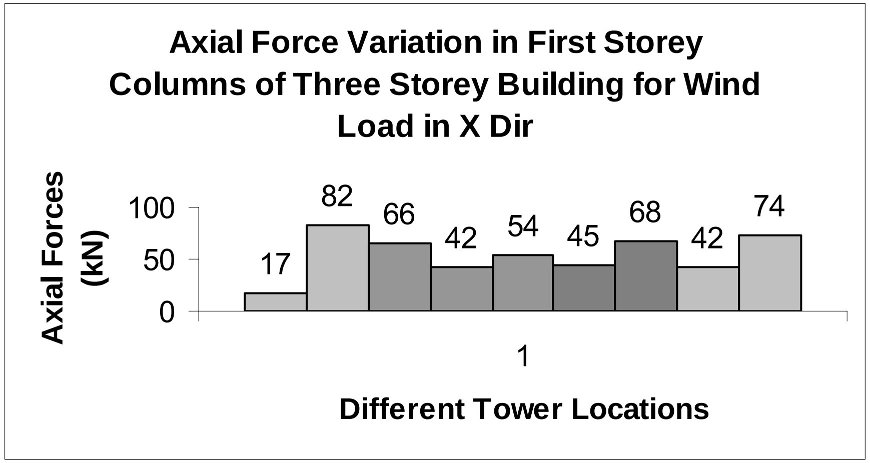


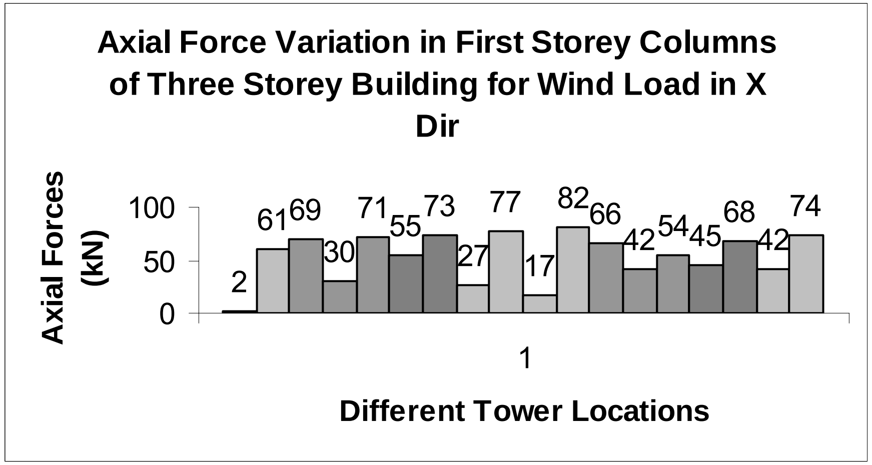


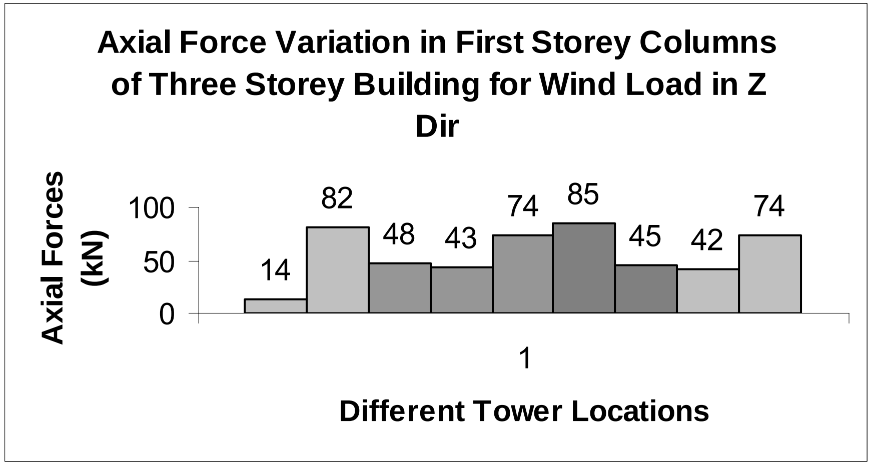


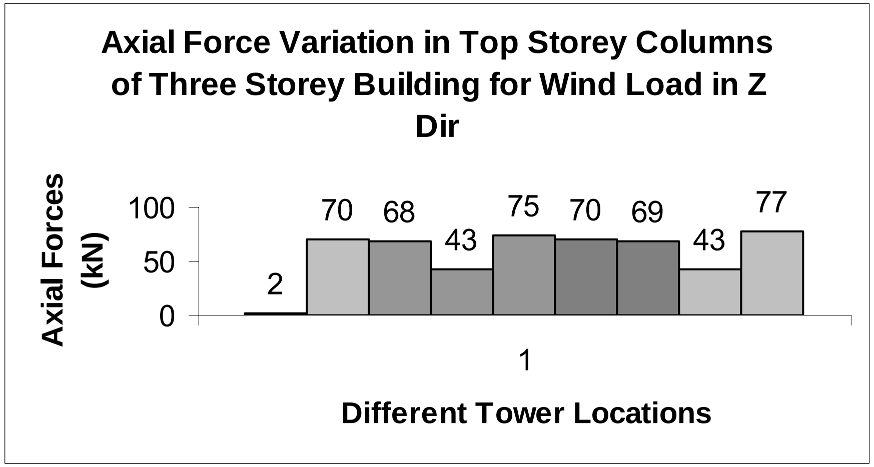


Legend							
1	Building without Tower			6	Tower at Location 3		
2	Tower at Location 1			7	Tower Load at Location 3		
3	Tower Load at Location 1			8	Tower at Location 4		
4	Tower at Location 2			9	Tower Load at Location 4		
5	Tower Load at Location 2						

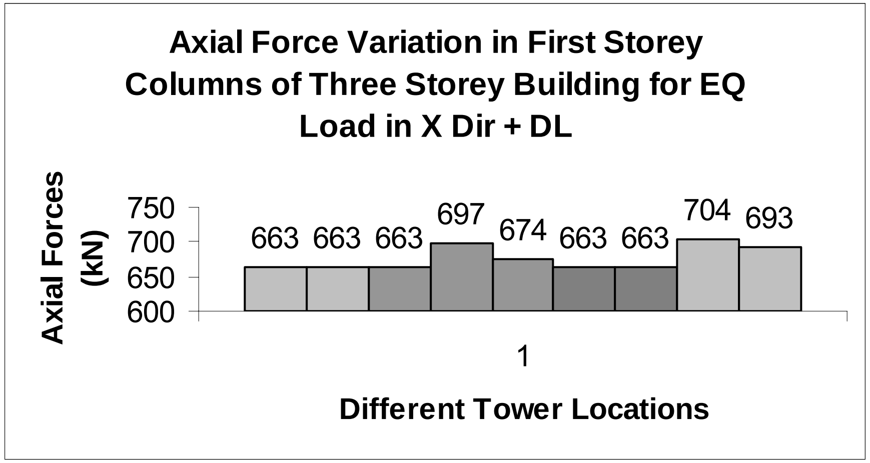


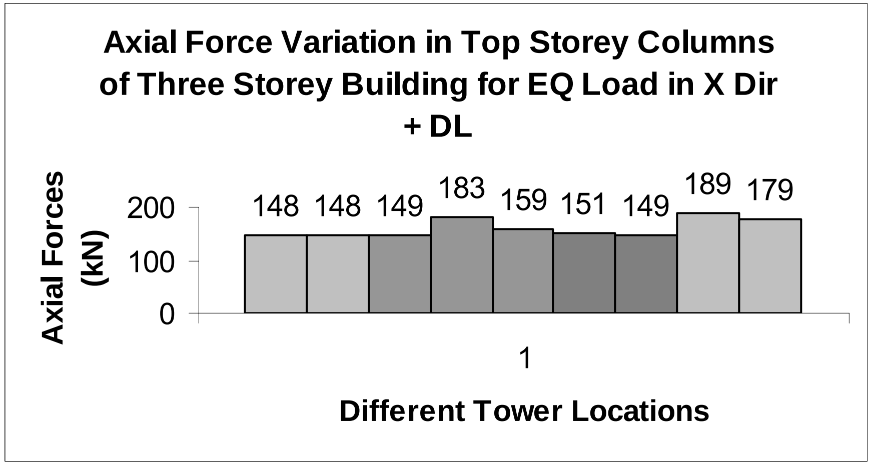


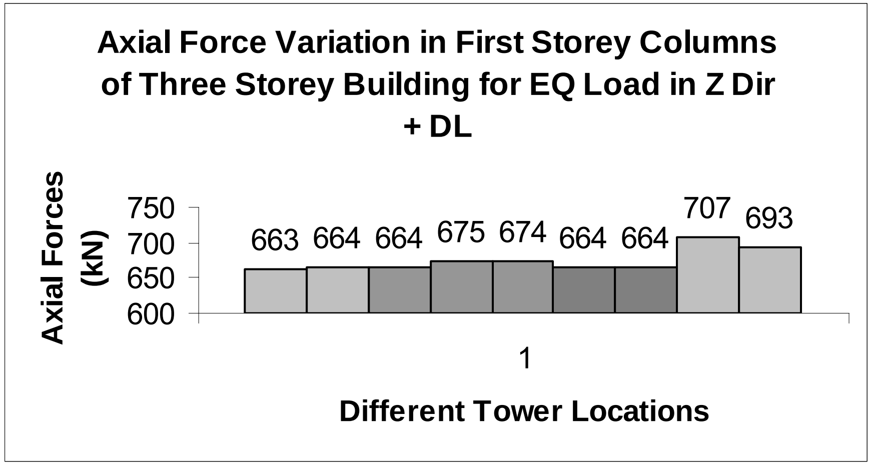


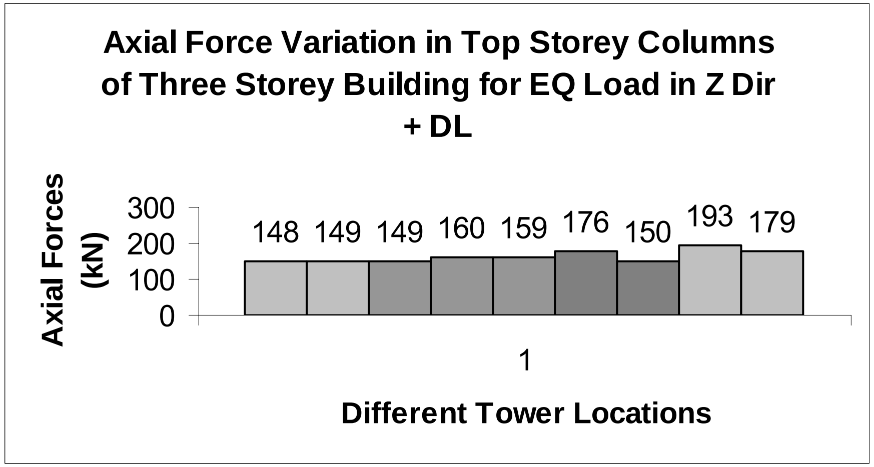


Legend							
1	Building without Tower			6	Tower at Location 3		
2	Tower at Location 1			7	Tower Load at Location 3		
3	Tower Load at Location 1			8	Tower at Location 4		
4	Tower at Location 2			9	Tower Load at Location 4		
5	Tower Load at Location 2						

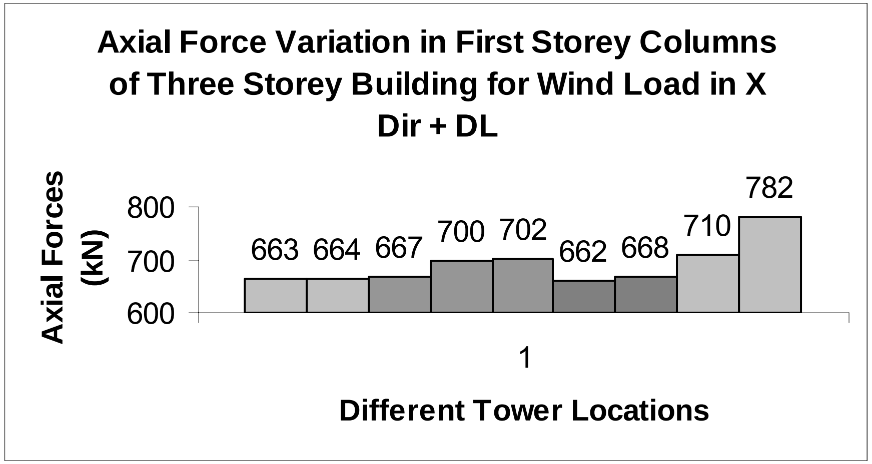


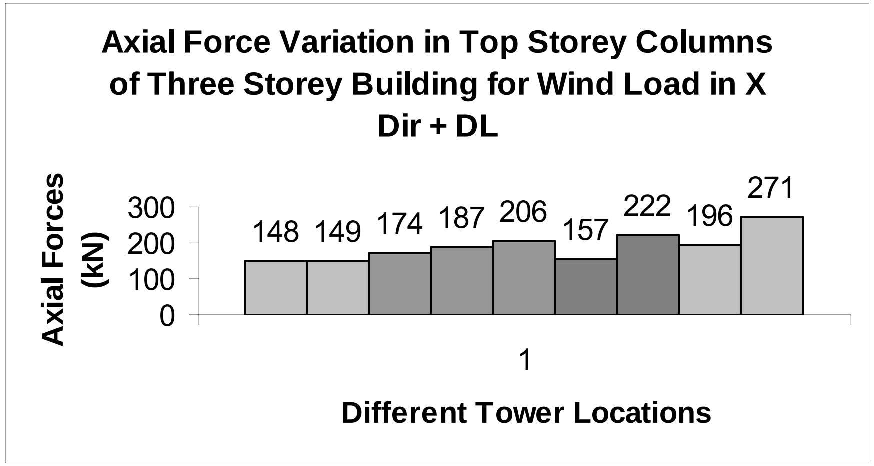


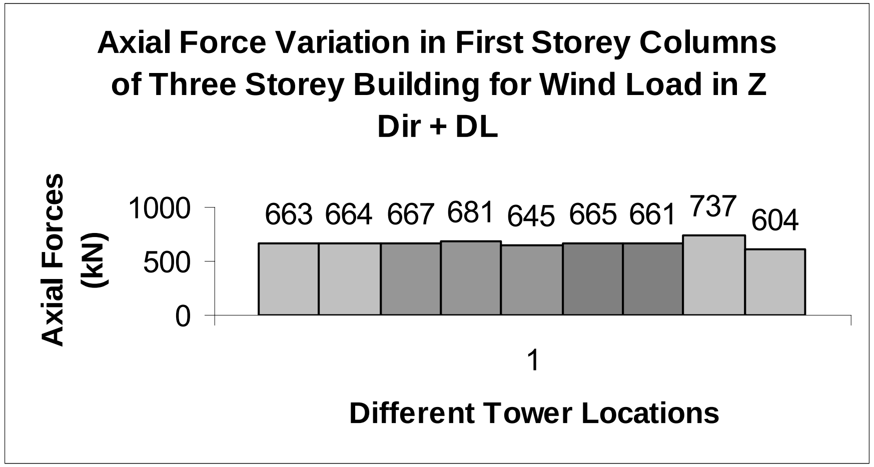


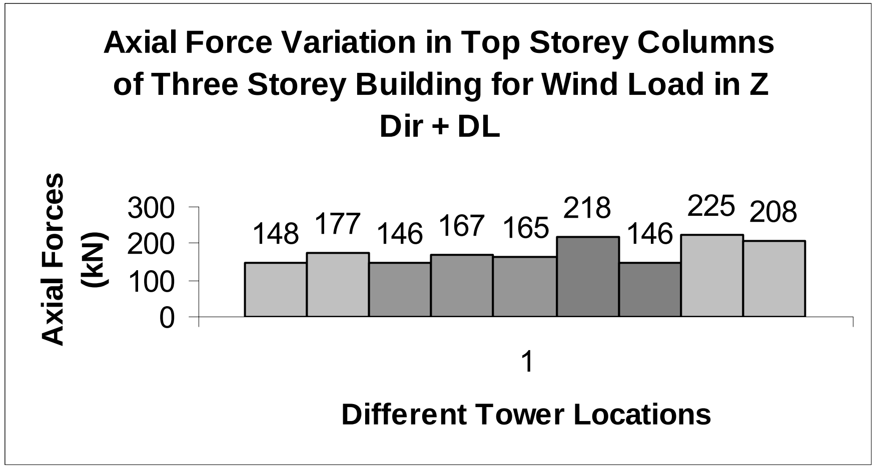


Legend							
1	Building without Tower			6	Tower at Location 3		
2	Tower at Location 1			7	Tower Load at Location 3		
3	Tower Load at Location 1			8	Tower at Location 4		
4	Tower at Location 2			9	Tower Load at Location 4		
5	Tower Load at Location 2						









Legend							
1	Building without Tower			6	Tower at Location 3		
2	Tower at Location 1			7	Tower Load at Location 3		
3	Tower Load at Location 1			8	Tower at Location 4		
4	Tower at Location 2			9	Tower Load at Location 4		
5	Tower Load at Location 2						

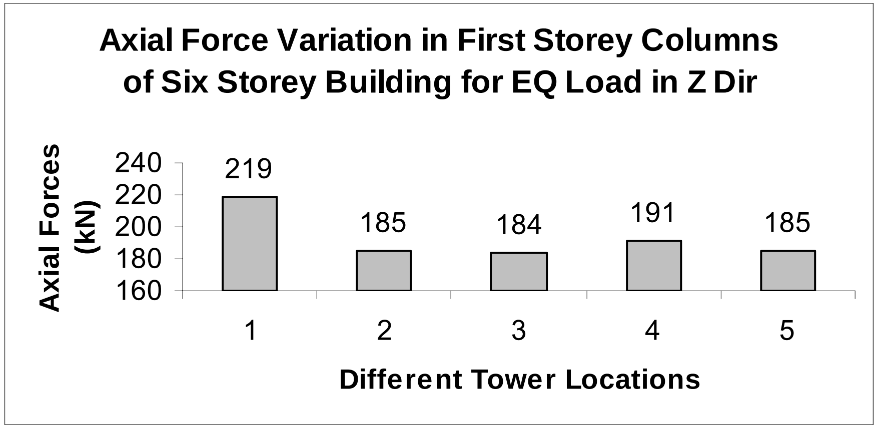
Axial Forces in Columns of the Six Storey building without and with tower at location 1

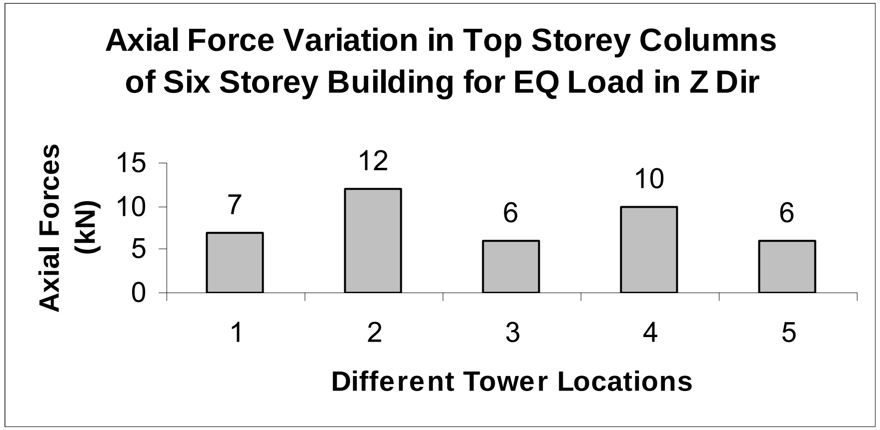
First Storey Columns										
Without Tower				With Tower at Location 1				With Tower Load at Location 1		
Earthquake Load Cases										
Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)
10	8	1395		10	10	1395		10	10	1396
10	11	1395		10	8	1395		10	8	1396
10	10	1395		10	9	1395		10	9	1396
10	9	1395		10	11	1395		10	11	1396
13	2	219		7	2	185		7	2	223
5	1	195		5	1	172		5	1	207
Wind Load Cases										
10	19	1395		10	18	1398		10	17	1402
10	16	1395		10	17	1396		10	19	1402
10	17	1395		10	16	1393		10	18	1391
10	18	1395		10	19	1392		10	16	1391
1	5	92		5	5	169		5	5	159
7	6	61		8	6	129		13	6	72
Top Storey Columns										
Without Tower				With tower at Location 1				With Tower Load at Location 1		
Earthquake Load Cases										
Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)
105	8	140		105	10	140		105	10	141
105	10	140		105	8	140		105	8	141
105	11	140		105	9	140		105	9	141
105	9	140		105	11	140		105	11	141
99	2	7		100	1	13		99	2	8
103	1	5		100	2	12		103	1	6
Wind Load Cases										
105	17	140		103	18	192		103	19	193
105	19	140		99	17	154		103	17	191
105	18	140		105	16	138		105	18	137
105	16	140		105	19	138		105	16	137
97	5	2		103	6	81		103	6	84
113	6	1		100	5	70		103	5	83

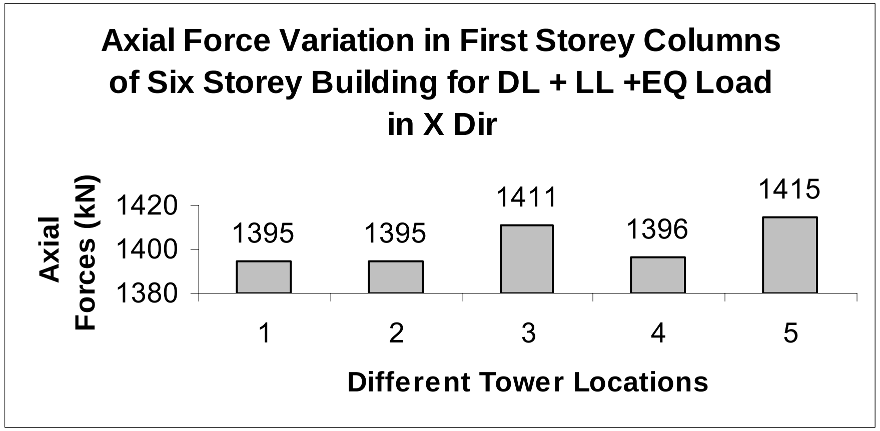
Axial Forces in Columns of the Six Storey building without and with tower at location 2										
First Storey Columns										
Without Tower				With Tower at Location 2				With Tower Load at Location 2		
Earthquake Load Cases										
Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)
10	8	1395		10	8	1411		10	8	1406
10	11	1395		10	10	1403		10	10	1406
10	10	1395		10	11	1402		10	11	1406
10	9	1395		10	9	1394		10	9	1406
13	2	219		7	2	184		7	2	223
5	1	195		5	1	170		5	1	202
Wind Load Cases										
10	19	1395		10	17	1436		10	17	1439
10	16	1395		10	18	1416		10	19	1438
10	17	1395		10	19	1390		10	18	1373
10	18	1395		10	16	1370		10	16	1373
1	5	92		5	5	115		8	6	119
7	6	61		5	6	80		5	5	114
Top Storey Columns										
Without Tower				With tower at Location 2				With Tower Load at Location 2		
Earthquake Load Cases										
Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)
105	8	140		105	8	157		105	8	151
105	10	140		105	10	148		105	10	151
105	11	140		105	11	148		105	11	151
105	9	140		105	9	139		105	9	151
99	2	7		103	1	13		99	2	8
103	1	5		99	2	6		103	1	6
Wind Load Cases										
105	17	140		105	17	185		106	19	232
105	19	140		106	18	179		106	17	229
105	18	140		103	19	152		103	16	183
105	16	140		106	16	151		103	18	182
97	5	2		106	6	53		106	6	93
113	6	1		103	5	37		106	5	91

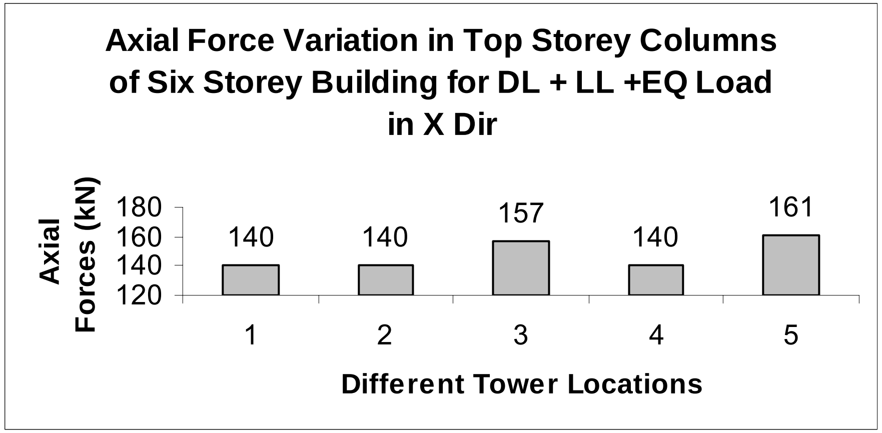
Axial Forces in Columns of the Six Storey building without and with tower at location 3										
First Storey Columns										
Without Tower				With Tower at Location 3				With Tower Load at Location 3		
Earthquake Load Cases										
Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)
10	8	1395		10	10	1397		10	10	1397
10	11	1395		10	8	1396		10	8	1397
10	10	1395		10	9	1396		10	9	1397
10	9	1395		10	11	1395		10	11	1397
13	2	219		7	2	191		7	2	225
5	1	195		5	1	167		5	1	206
Wind Load Cases										
10	19	1395		10	18	1402		10	17	1406
10	16	1395		10	16	1396		10	19	1406
10	17	1395		10	17	1396		10	18	1389
10	18	1395		10	19	1390		10	16	1388
1	5	92		7	6	135		5	5	116
7	6	61		5	5	134		13	6	69
Top Storey Columns										
Without Tower				With tower at Location 3				With Tower Load at Location 3		
Earthquake Load Cases										
Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)
105	8	140		105	10	140		105	10	141
105	10	140		105	8	140		105	8	141
105	11	140		105	9	140		105	9	141
105	9	140		105	11	140		105	11	141
99	2	7		99	1	13		99	2	8
103	1	5		99	2	10		103	1	6
Wind Load Cases										
105	17	140		102	18	216		102	17	228
105	19	140		99	16	149		102	19	226
105	18	140		102	17	146		105	18	136
105	16	140		105	19	137		105	16	136
97	5	2		102	6	81		102	5	88
113	6	1		99	5	69		102	6	87

Axial Forces in Columns of the Six Storey building without and with tower at location 4										
First Storey Columns										
Without Tower				With Tower at Location 4				With Tower Load at Location 4		
Earthquake Load Cases										
Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)
10	8	1395		10	10	1416		10	10	1423
10	11	1395		10	8	1415		10	8	1423
10	10	1395		10	9	1406		10	9	1423
10	9	1395		10	11	1405		10	11	1423
13	2	219		13	2	185		7	2	225
5	1	195		5	1	170		5	1	202
Wind Load Cases										
10	19	1395		10	18	1465		10	17	1520
10	16	1395		10	17	1435		10	19	1520
10	17	1395		10	16	1386		10	18	1326
10	18	1395		10	19	1356		10	16	1326
1	5	92		5	5	116		7	6	126
7	6	61		13	6	75		5	5	107
Top Storey Columns										
Without Tower				With tower at Location 4				With Tower Load at Location 4		
Earthquake Load Cases										
Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)		Column	Load Case	Axial (kN)
105	8	140		105	10	163		105	8	171
105	10	140		105	8	161		105	10	171
105	11	140		105	9	152		105	11	171
105	9	140		105	11	151		105	9	171
99	2	7		103	1	11		99	2	8
103	1	5		99	2	6		103	1	6
Wind Load Cases										
105	17	140		105	18	220		105	17	284
105	19	140		105	17	184		105	19	283
105	18	140		102	19	181		102	18	212
105	16	140		106	16	131		102	16	211
97	5	2		105	6	53		105	5	94
113	6	1		106	5	30		105	6	94

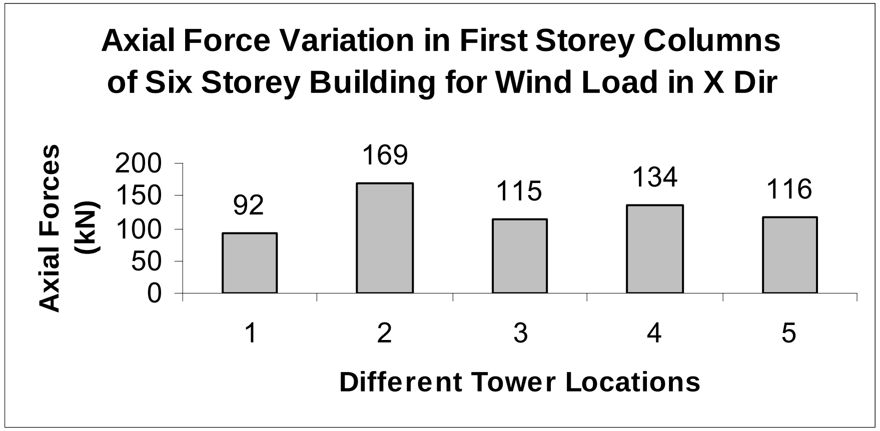


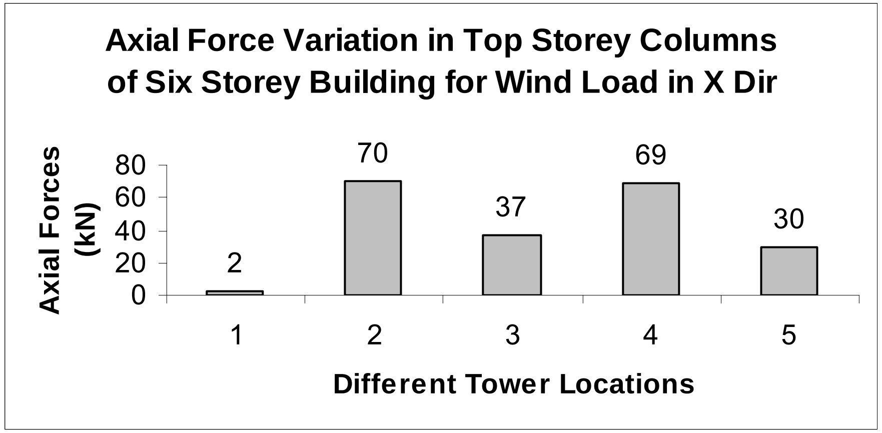


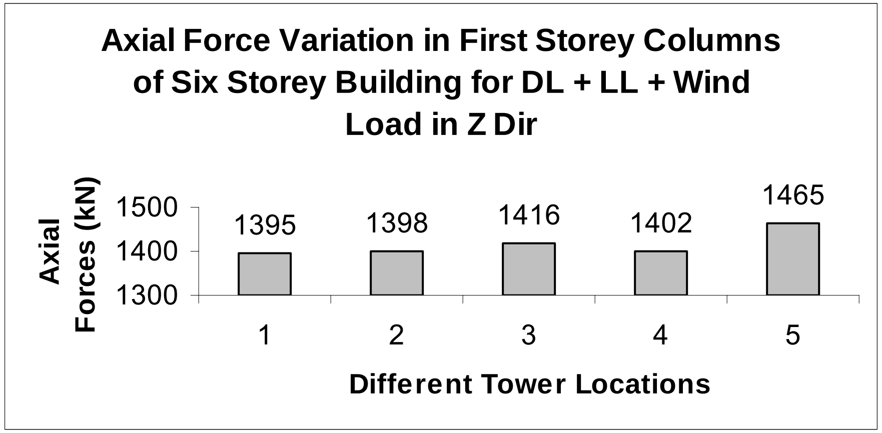


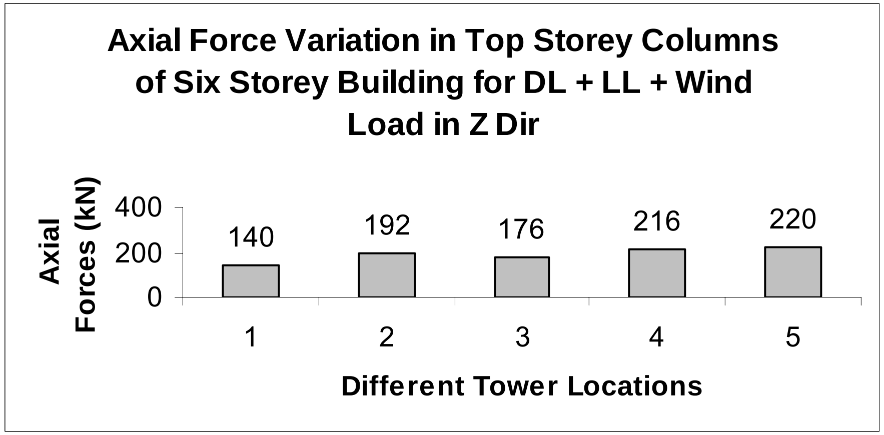


Legend			
1	Building without Tower		
2	Tower at Location 1		
3	Tower at Location 2		
4	Tower at Location 3		
5	Tower at Location 4		









Legend			
1	Building without Tower		
2	Tower at Location 1		
3	Tower at Location 2		
4	Tower at Location 3		
5	Tower at Location 4		

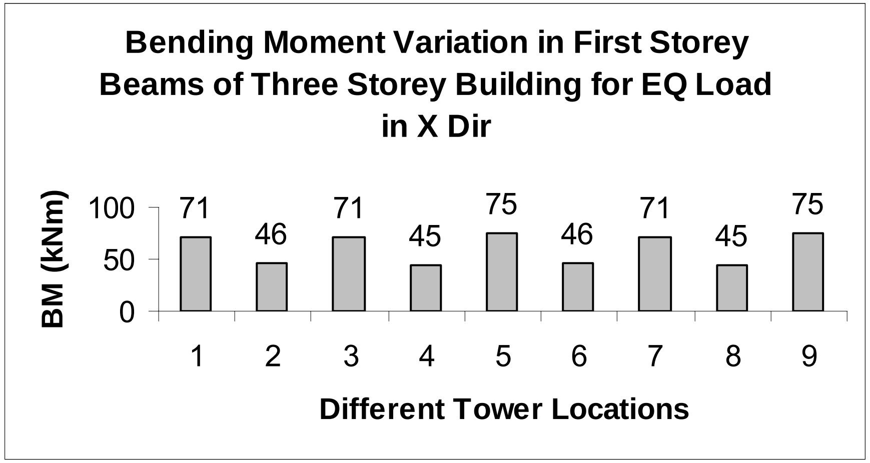
Bending Moments in Beams of the Three Storey building without and with tower at location 1

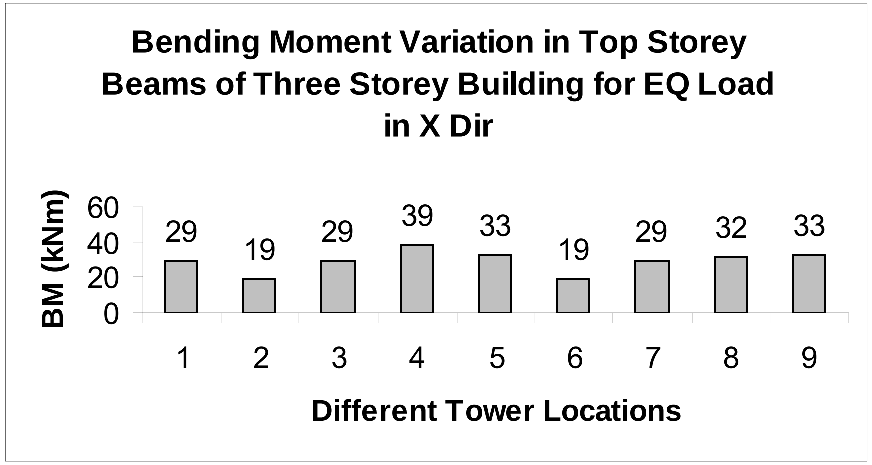
First Storey Beams										
Without Tower				With Tower at Location 1				With Tower Load at Location 1		
Earthquake Load Cases										
Beam	Load Case	BM		Beam	Load Case	BM		Beam	Load Case	BM
65	8	180		65	8	152		65	8	180
65	10	100		65	10	101		65	10	100
65	11	100		65	11	99		65	11	100
64	9	81		64	9	83		64	9	81
64	1	71		116	1	46		116	1	71
111	2	51		111	2	40		111	2	52
Wind Load Cases										
65	17	126		65	17	127		65	17	128
65	19	100		65	19	100		65	19	100
65	18	100		65	18	100		65	18	100
64	16	87		64	16	88		64	16	88
62	6	2		117	6	3		63	6	3
64	5	1		64	5	1		64	5	1
Top Storey Beams										
Without Tower				With tower at Location 1				With Tower Load at Location 1		
Earthquake Load Cases										
Beam	Load Case	BM		Beam	Load Case	BM		Beam	Load Case	BM
93	8	86		93	8	74		93	8	87
93	10	54		93	10	55		93	10	55
93	11	54		93	11	53		93	11	55
92	9	45		92	9	46		93	9	46
160	1	29		92	1	19		92	1	29
166	2	18		176	2	15		166	2	19
Wind Load Cases										
93	17	61		93	17	63		91	17	85
93	18	54		93	18	56		91	19	76
93	19	54		93	19	52		93	18	52
92	16	48		92	16	48		92	16	48
177	6	1		91	6	21		159	5	33
160	5	0		179	5	17		159	6	32

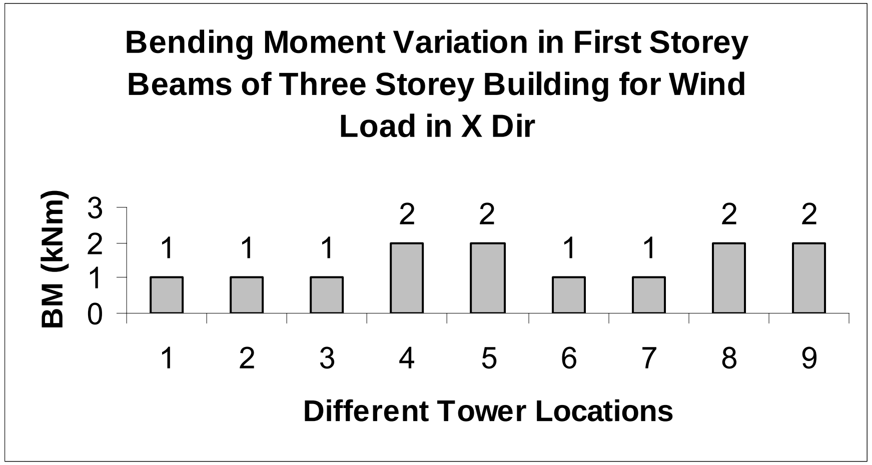
Bending Moments in Beams of the Three Storey building without and with tower at location 2										
First Storey Beams										
Without Tower				With Tower at Location 2				With Tower Load at Location 2		
Earthquake Load Cases										
Beam	Load Case	BM		Beam	Load Case	BM		Beam	Load Case	BM
65	8	180		65	8	150		65	8	184
65	10	100		65	10	103		65	10	100
65	11	100		65	11	97		65	11	100
64	9	81		64	9	83		64	9	81
64	1	71		64	1	45		64	1	75
111	2	51		111	2	40		111	2	52
Wind Load Cases										
65	17	126		65	17	131		65	17	132
65	19	100		65	19	101		65	18	100
65	18	100		65	18	100		65	19	100
64	16	87		64	16	88		64	16	88
62	6	2		63	6	3		117	6	3
64	5	1		64	5	2		64	5	2
Top Storey Beams										
Without Tower				With tower at Location 2				With Tower Load at Location 2		
Earthquake Load Cases										
Beam	Load Case	BM		Beam	Load Case	BM		Beam	Load Case	BM
93	8	86		93	8	107		93	8	104
93	10	54		93	10	68		93	10	68
93	11	54		93	11	59		93	11	68
92	9	45		92	9	43		93	9	60
160	1	29		91	1	39		160	1	33
166	2	18		173	2	15		166	2	19
Wind Load Cases										
93	17	61		93	17	111		93	17	117
93	18	54		173	16	85		93	19	110
93	19	54		93	18	78		91	18	70
92	16	48		170	19	64		91	16	67
177	6	1		173	5	43		160	5	39
160	5	0		178	6	29		160	6	38

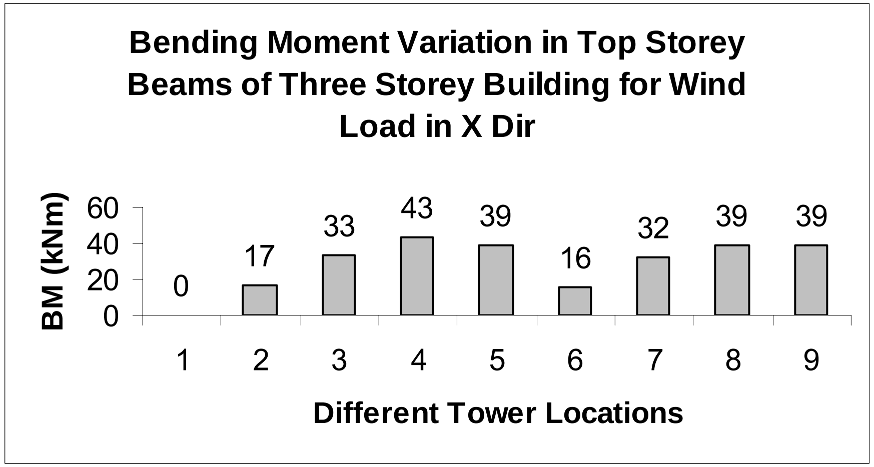
Bending Moments in Beams of the Three Storey building without and with tower at location 3										
First Storey Beams										
Without Tower				With Tower at Location 3				With Tower Load at Location 3		
Earthquake Load Cases										
Beam	Load Case	BM		Beam	Load Case	BM		Beam	Load Case	BM
65	8	180		65	8	152		65	8	180
65	10	100		65	10	101		65	10	100
65	11	100		65	11	100		65	11	100
64	9	81		64	9	83		64	9	81
64	1	71		64	1	46		116	1	71
111	2	51		111	2	41		111	2	54
Wind Load Cases										
65	17	126		65	17	127		65	17	128
65	19	100		65	18	101		65	19	100
65	18	100		65	19	100		65	18	100
64	16	87		64	16	88		64	16	88
62	6	2		117	6	3		63	6	4
64	5	1		64	5	1		64	5	1
Top Storey Beams										
Without Tower				With tower at Location 3				With Tower Load at Location 3		
Earthquake Load Cases										
Beam	Load Case	BM		Beam	Load Case	BM		Beam	Load Case	BM
93	8	86		93	8	75		93	8	87
93	10	54		93	10	55		93	10	56
93	11	54		93	11	53		93	11	55
92	9	45		92	9	46		93	9	46
160	1	29		160	1	19		92	1	29
166	2	18		166	2	16		166	2	21
Wind Load Cases										
93	17	61		93	17	61		91	17	82
93	18	54		93	18	56		91	19	76
93	19	54		93	19	52		93	18	52
92	16	48		93	16	48		92	16	48
177	6	1		91	6	19		159	5	34
160	5	0		91	5	16		159	6	32

Bending Moments in Beams of the Three Storey building without and with tower at location 4										
First Storey Beams										
Without Tower				With Tower at Location 4				With Tower Load at Location 4		
Earthquake Load Cases										
Beam	Load Case	BM		Beam	Load Case	BM		Beam	Load Case	BM
65	8	180		65	8	150		65	8	184
65	10	100		65	10	101		65	10	100
65	11	100		65	11	99		65	11	100
64	9	81		64	9	83		64	9	81
64	1	71		64	1	45		64	1	75
111	2	51		111	2	42		111	2	54
Wind Load Cases										
65	17	126		65	17	132		65	17	131
65	19	100		65	19	100		65	18	101
65	18	100		65	18	100		65	19	99
64	16	87		64	16	88		64	16	88
62	6	2		63	6	3		117	6	3
64	5	1		64	5	2		64	5	2
Top Storey Beams										
Without Tower				With tower at Location 4				With Tower Load at Location 4		
Earthquake Load Cases										
Beam	Load Case	BM		Beam	Load Case	BM		Beam	Load Case	BM
93	8	86		93	8	83		93	8	103
93	10	54		93	10	65		93	10	67
93	11	54		93	11	55		93	11	67
92	9	45		92	9	44		95	8	52
160	1	29		160	1	32		160	1	33
166	2	18		167	2	16		166	2	20
Wind Load Cases										
93	17	61		93	16	90		93	17	115
93	18	54		167	17	89		93	19	109
93	19	54		93	18	74		91	18	69
92	16	48		167	19	66		91	16	67
177	6	1		170	5	39		160	5	39
160	5	0		178	6	29		160	6	38

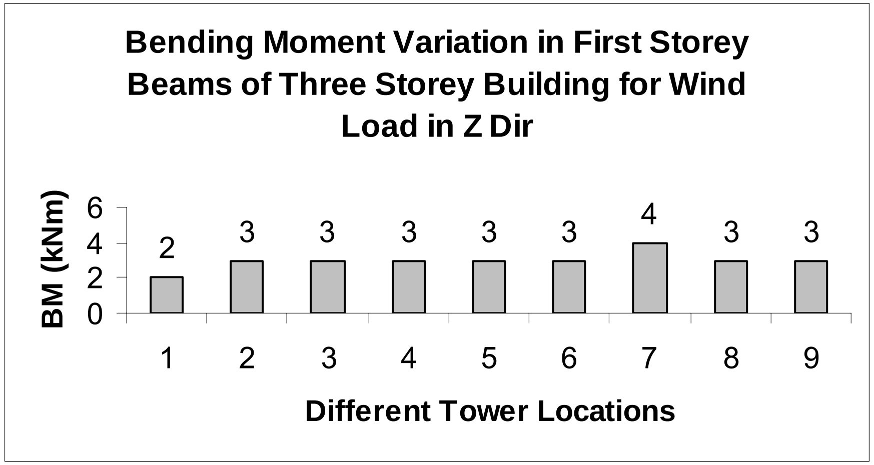


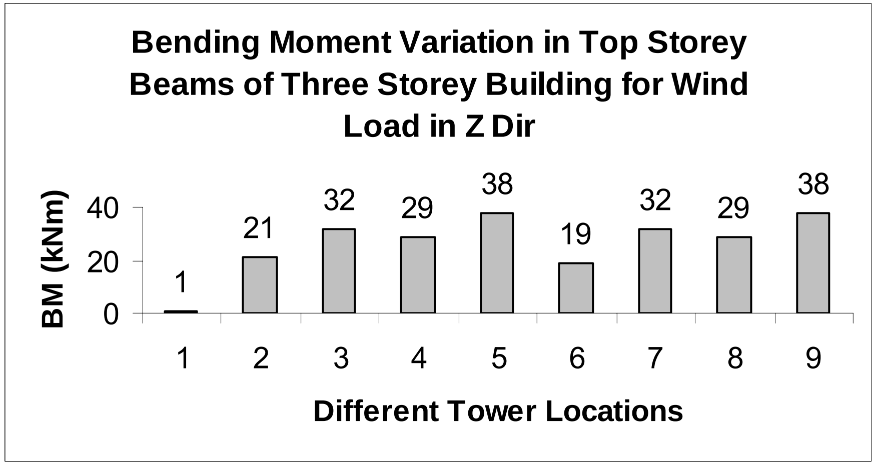


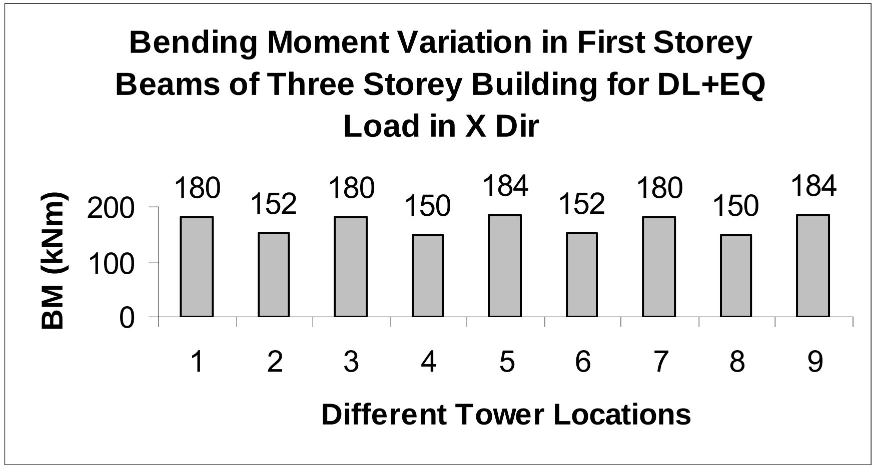


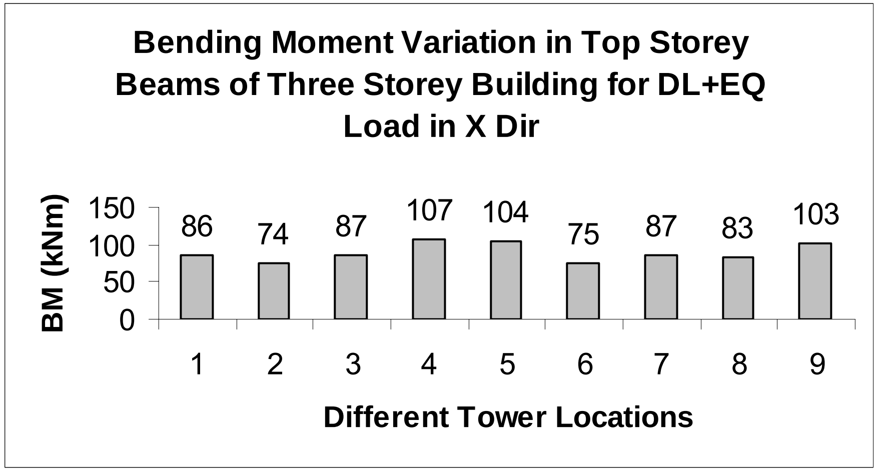


Legend							
1	Building without Tower			6	Tower at Location 3		
2	Tower at Location 1			7	Tower Load at Location 3		
3	Tower Load at Location 1			8	Tower at Location 4		
4	Tower at Location 2			9	Tower Load at Location 4		
5	Tower Load at Location 2						

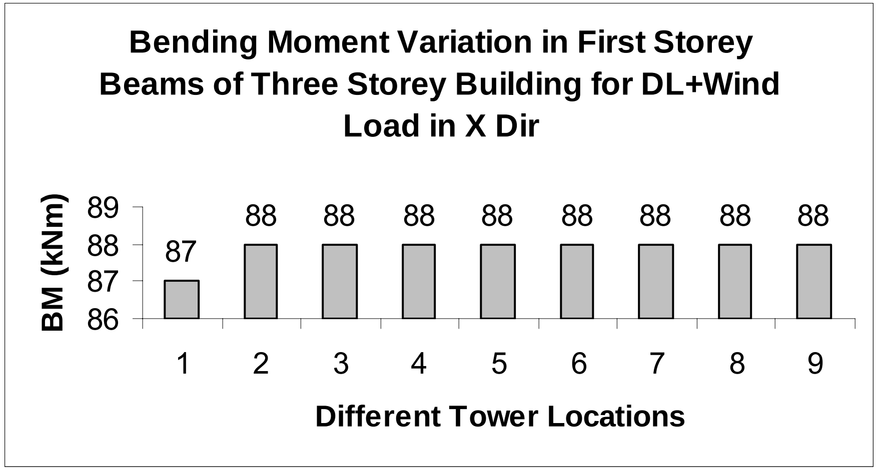


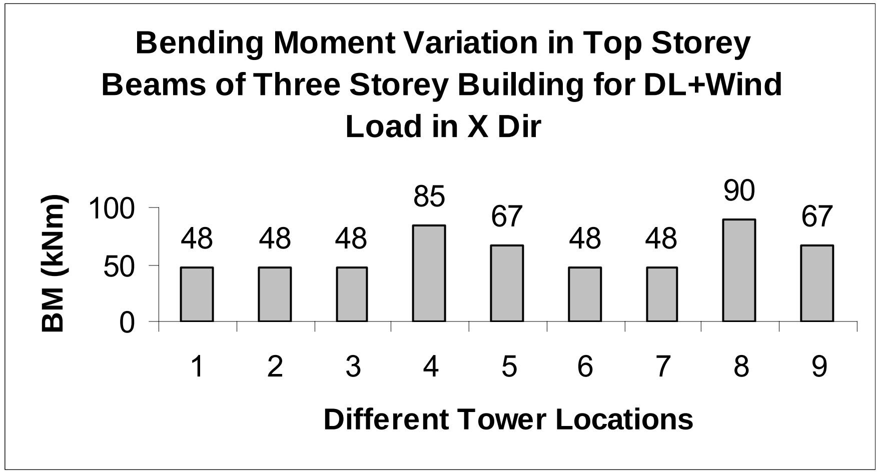






Legend								
1	Building without Tower			6	Tower at Location 3			
2	Tower at Location 1			7	Tower Load at Location 3			
3	Tower Load at Location 1			8	Tower at Location 4			
4	Tower at Location 2			9	Tower Load at Location 4			
5	Tower Load at Location 2							





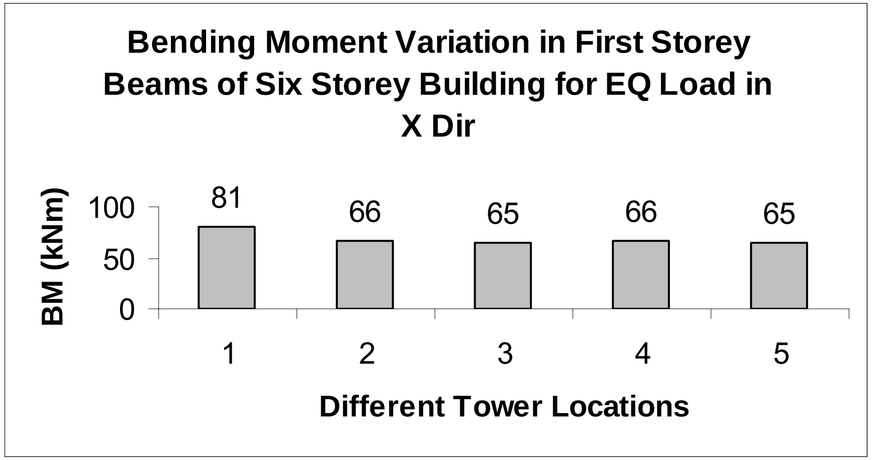
Legend								
1	Building without Tower			6	Tower at Location 3		
2	Tower at Location 1			7	Tower Load at Location 3		
3	Tower Load at Location 1			8	Tower at Location 4		
4	Tower at Location 2			9	Tower Load at Location 4		
5	Tower Load at Location 2						

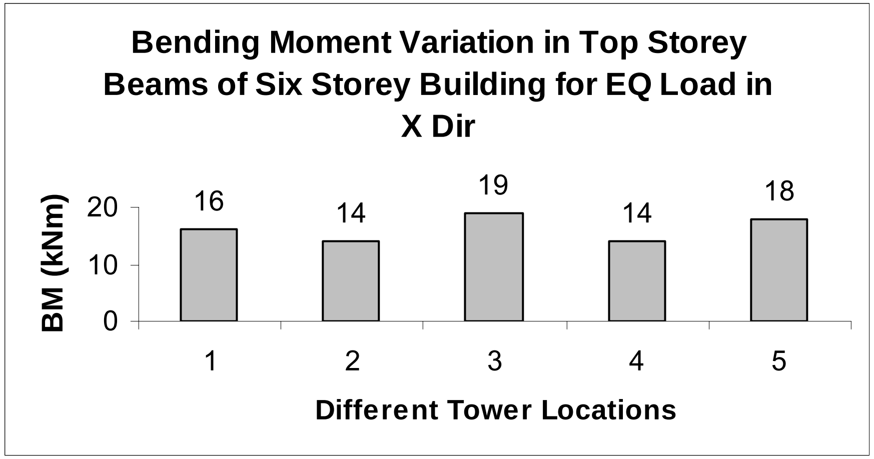
Bending Moments in Beams of the Six Storey building without and with tower at location 1										
First Storey Beams										
Without Tower				With Tower at Location 1				With Tower Load at Location 1		
Earthquake Load Cases										
Beam	Load Case	BM		Beam	Load Case	BM		Beam	Load Case	BM
122	8	190		122	8	172		122	8	190
133	10	122		133	10	105		133	10	124
122	11	98		122	11	98		122	11	98
133	2	91		121	9	81		133	2	92
121	1	81		133	2	77		115	1	83
121	9	80		115	1	66		121	9	80
Wind Load Cases										
122	17	151		122	17	154		122	17	154
122	19	98		122	18	98		122	19	99
122	18	98		122	19	98		122	18	98
121	16	89		121	16	89		121	16	89
119	6	5		146	6	6		120	6	6
121	5	3		121	5	3		121	5	3
Top Storey Beams										
Without Tower				With tower at Location 1				With Tower Load at Location 1		
Earthquake Load Cases										
Beam	Load Case	BM		Beam	Load Case	BM		Beam	Load Case	BM
321	8	69		321	8	66		321	8	70
321	10	50		321	10	51		321	10	50
321	11	50		321	11	50		321	11	50
321	9	46		321	9	46		322	9	47
345	1	16		317	1	14		317	1	17
334	2	15		338	2	14		338	2	16
Wind Load Cases										
321	17	53		320	17	63		320	17	90
321	19	50		320	18	56		320	19	87
321	18	50		321	19	51		321	18	51
321	16	48		321	16	48		321	16	48
329	5	1		320	6	26		344	5	41
328	6	1		344	5	22		344	6	40

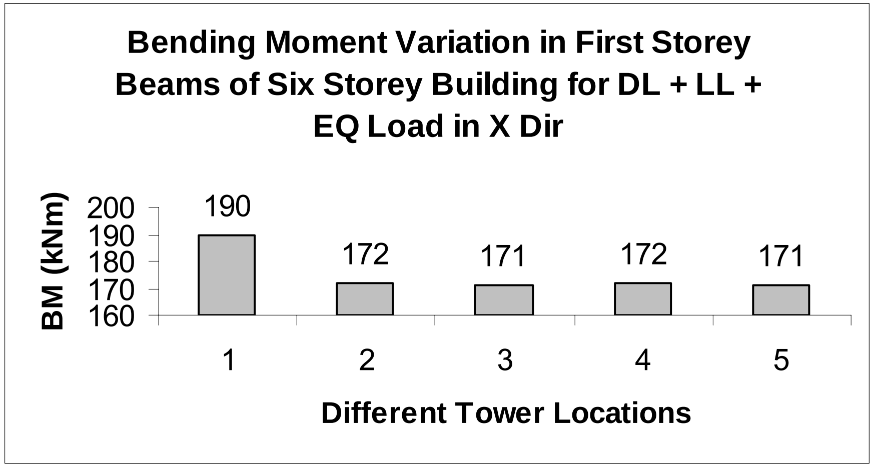
Bending Moments in Beams of the Six Storey building without and with tower at location 2										
First Storey Beams										
Without Tower				With Tower at Location 2				With Tower Load at Location 2		
Earthquake Load Cases										
Beam	Load Case	BM		Beam	Load Case	BM		Beam	Load Case	BM
122	8	190		122	8	171		122	8	191
133	10	122		133	10	105		133	10	124
122	11	98		122	11	97		122	11	98
133	2	91		121	9	82		133	2	92
121	1	81		133	2	77		121	1	82
121	9	80		115	1	65		121	9	80
Wind Load Cases										
122	17	151		122	17	154		122	17	154
122	19	98		122	18	99		122	19	99
122	18	98		122	19	98		122	18	98
121	16	89		121	16	89		121	16	89
119	6	5		120	6	6		146	6	6
121	5	3		121	5	3		121	5	3
Top Storey Beams										
Without Tower				With tower at Location 2				With Tower Load at Location 2		
Earthquake Load Cases										
Beam	Load Case	BM		Beam	Load Case	BM		Beam	Load Case	BM
321	8	69		322	8	76		322	8	80
321	10	50		322	10	59		322	10	64
321	11	50		322	11	59		322	11	64
321	9	46		321	9	45		322	9	62
345	1	16		320	1	19		345	1	19
334	2	15		338	2	17		334	2	16
Wind Load Cases										
321	17	53		322	17	122		322	17	121
321	19	50		338	16	100		322	19	120
321	18	50		322	18	81		320	18	78
321	16	48		352	19	75		320	16	76
329	5	1		338	5	55		345	5	47
328	6	1		357	6	37		345	6	47

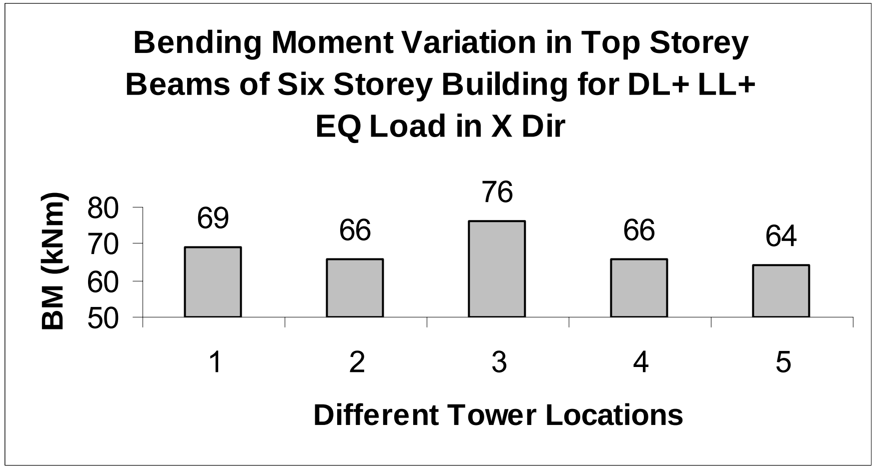
Bending Moments in Beams of the Six Storey building without and with tower at location 3										
First Storey Beams										
Without Tower				With Tower at Location 3				With Tower Load at Location 3		
Earthquake Load Cases										
Beam	Load Case	BM		Beam	Load Case	BM		Beam	Load Case	BM
122	8	190		122	8	172		122	8	190
133	10	122		133	10	105		133	10	124
122	11	98		122	11	98		122	11	98
133	2	91		121	9	81		133	2	92
121	1	81		133	2	77		115	1	83
121	9	80		118	1	66		121	9	80
Wind Load Cases										
122	17	151		122	17	154		122	17	153
122	19	98		122	18	99		122	19	98
122	18	98		122	19	98		122	18	98
121	16	89		121	16	89		121	16	89
119	6	5		146	6	6		120	6	6
121	5	3		121	5	3		121	5	3
Top Storey Beams										
Without Tower				With tower at Location 3				With Tower Load at Location 3		
Earthquake Load Cases										
Beam	Load Case	BM		Beam	Load Case	BM		Beam	Load Case	BM
321	8	69		321	8	66		321	8	70
321	10	50		321	10	50		321	10	50
321	11	50		321	11	50		321	11	50
321	9	46		321	9	46		322	9	47
345	1	16		316	1	14		317	1	17
334	2	15		334	2	14		334	2	17
Wind Load Cases										
321	17	53		321	17	55		320	17	89
321	19	50		351	16	52		320	19	87
321	18	50		320	18	51		321	18	51
321	16	48		321	19	51		321	16	48
329	5	1		320	6	23		344	5	42
328	6	1		320	5	21		344	6	41

Bending Moments in Beams of the Six Storey building without and with tower at location 4										
First Storey Beams										
Without Tower				With Tower at Location 4				With Tower Load at Location 4		
Earthquake Load Cases										
Beam	Load Case	BM		Beam	Load Case	BM		Beam	Load Case	BM
122	8	190		122	8	171		122	8	191
133	10	122		133	10	105		133	10	124
122	11	98		122	11	98		122	11	98
133	2	91		121	9	82		133	2	92
121	1	81		133	2	77		121	1	82
121	9	80		115	1	65		121	9	80
Wind Load Cases										
122	17	151		122	17	154		122	17	153
122	19	98		122	19	99		122	18	99
122	18	98		122	18	98		122	19	98
121	16	89		121	16	89		121	16	89
119	6	5		120	6	6		146	6	6
121	5	3		121	5	3		121	5	3
Top Storey Beams										
Without Tower				With tower at Location 4				With Tower Load at Location 4		
Earthquake Load Cases										
Beam	Load Case	BM		Beam	Load Case	BM		Beam	Load Case	BM
321	8	69		321	8	64		322	8	79
321	10	50		334	10	57		322	10	64
321	11	50		321	11	50		322	11	64
321	9	46		321	9	46		322	9	62
345	1	16		344	1	18		345	1	19
334	2	15		334	2	16		334	2	17
Wind Load Cases										
321	17	53		334	17	101		322	17	121
321	19	50		322	16	95		322	19	120
321	18	50		322	18	74		320	18	78
321	16	48		334	19	73		320	16	76
329	5	1		352	5	50		345	5	48
328	6	1		355	6	36		345	6	47

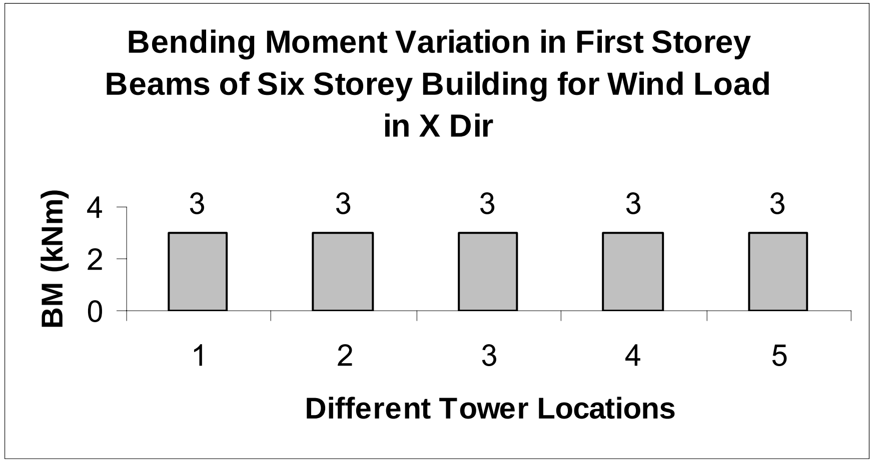


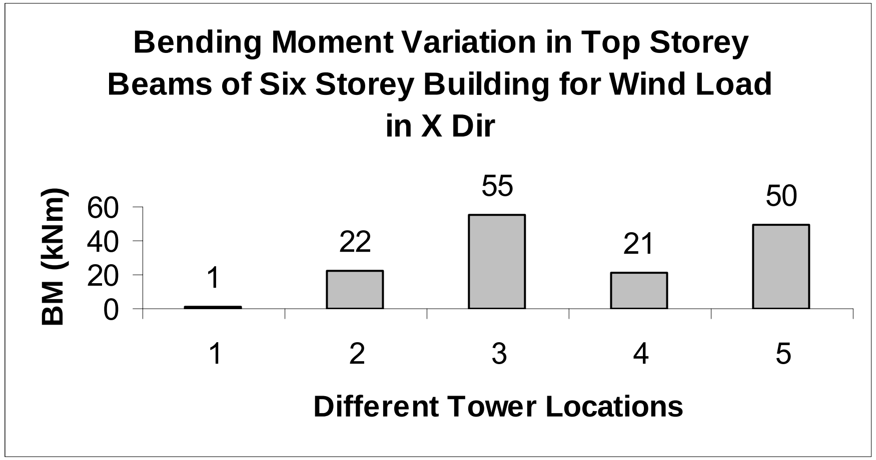


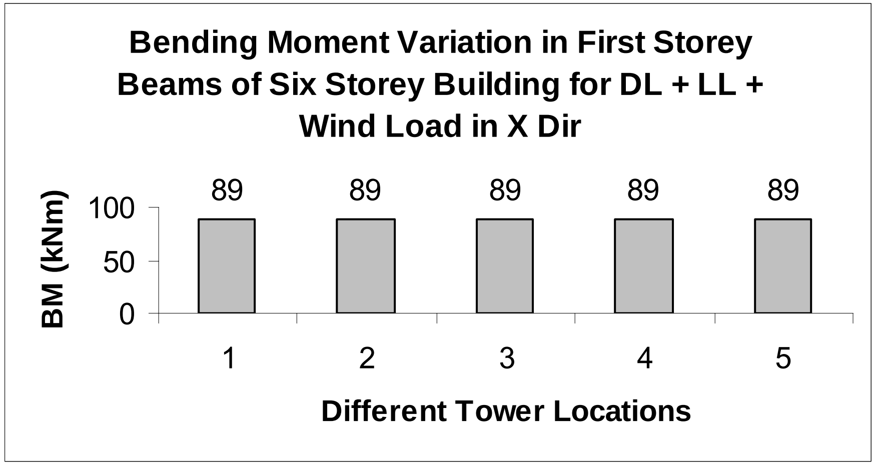


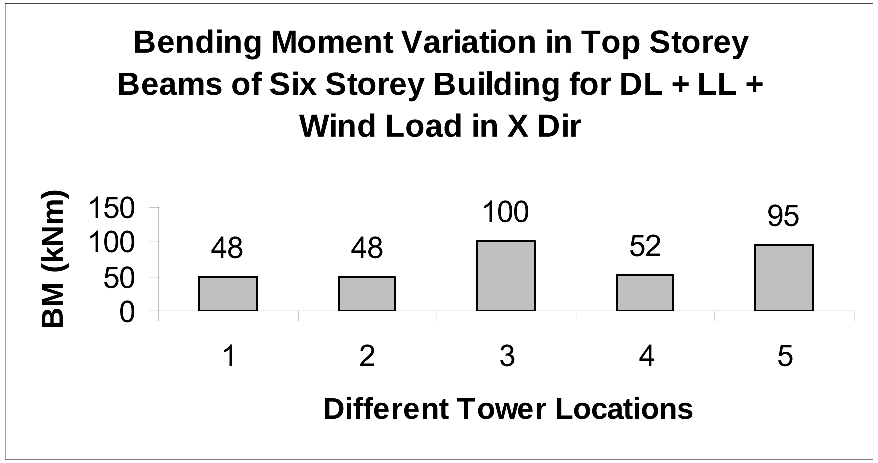


Legend			
1	Building without Tower		
2	Tower at Location 1		
3	Tower at Location 2		
4	Tower at Location 3		
5	Tower at Location 4		









Legend				
1	Building without Tower			
2	Tower at Location 1			
3	Tower at Location 2			
4	Tower at Location 3			
5	Tower at Location 4			

Chapter Four

Discussion of Results

The results obtained from the analysis of the problem can be divided into two sets – one for the three storey building and other for the six storey building.

The results for the analysis of three storey building with towers at four different locations can be summarized as below.

1. The maximum axial force in the first storey column in the building with tower at location 3 decreases by 34% during the earthquake loading in X direction as compared to the building without the tower.
2. The maximum axial force in the top storey column in the building with tower at location 2 increases by 166% during the earthquake loading in X direction as compared to the building without the tower.
3. The increase in the maximum axial force in the top storey column in the building with towers at locations 2 and 4 is of 28% for the dead load and the earthquake loading in X direction as compared to the building without the tower.
4. For the earthquake loading in X direction, the maximum bending moment in the first storey beam decreases by 37% for the tower locations 2 and 4 as compared to the building without the tower.
5. For the earthquake loading in X direction, the maximum bending moment in the top storey beam decreases by 34% for the tower locations 1 and 3 whereas it increases by 34% when the tower is installed at locations 2 and 4 as compared to the building without the tower.
6. When the earthquake loading is considered acting along the dead and the live loading, the maximum bending moment in the first storey beam decreases by 17% when the tower is installed at location 2.

The wind load effect on the axial forces in the columns of the first and top storeys and on the bending moments in the beams of the first and top storeys of the three storey building is as below.

1. The maximum axial force in the first storey column increases for all tower locations. The maximum increase of 382% occurs for the tower at location 1.
2. The maximum axial force in the top storey column increases phenomenally for all tower locations. The maximum increase of 3000% occurs for the tower at location 1.
3. The maximum axial force in the first storey column due to the combination of dead, live and wind load increases marginally when the tower is installed at locations 2 and 4. The maximum increase of 7% occurs for the tower at location 4.

4. The maximum axial force in the top storey column due to dead, live and wind load combination increases for the tower locations 2 and 4. The maximum increase of 32% occurs for the tower at location 4.
5. The maximum bending moment in the first storey beam remains constant with the tower installation at any location.
6. The maximum bending moment in the top storey beam increases phenomenally for all tower locations. The increase is up to 4200%.
7. The maximum bending moment in the top storey beam due to dead, live and wind load combination remains same with the towers at locations 1 and 3 whereas it increases with the towers at locations 2 and 4. The increase is up to 85% (48 kN to 90 kN).

The results for the analysis of the six storey building with towers at four different locations can be summarized as below.

1. The maximum axial force in the first storey column in the building with tower at any location decreases by 16% during the earthquake loading in Z direction as compared to the building without the tower.
2. The maximum axial force in the top storey column in the building with tower at locations 2 and 4 remains same but for towers at locations 1 and 3, it increases by 71% during the earthquake loading in Z direction as compared to the building without the tower.
3. The increase in the maximum axial force in the top storey column in the building with towers at locations 2 and 4 is of 15% for the dead load and the earthquake loading in Z direction as compared to the building without the tower.
4. For the earthquake loading in X direction, the maximum bending moment in the first storey beam decreases by 18% for all tower locations as compared to the building without the tower.
5. For the earthquake loading in X direction, the maximum bending moment in the top storey beam decreases by 12.5% for the tower locations 1 and 3 whereas it increases by 19% when the tower is installed at locations 2 and 4 as compared to the building without the tower.
6. When the earthquake loading is considered acting along the dead and the live loading, the maximum bending moment in the first storey beam decreases by 9.5% for all tower locations.

The wind load effect on the axial forces in the columns of the first and top storeys and on the bending moments in the beams of the first and top storeys of the six storey building is as below.

1. The maximum axial force in the first storey column increases for all tower locations. The maximum increase of 84% occurs for the tower at location 1.
2. The maximum axial force in the top storey column increases phenomenally for all tower locations. The maximum increase of 3400% occurs for the tower at location 1.

3. The maximum axial force in the first storey column due to the combination of dead, live and wind load increases marginally when the tower is installed at locations 2 and 4. The maximum increase of 5% occurs for the tower at location 4.
4. The maximum axial force in the top storey column due to dead, live and wind load combination increases for all tower locations. The maximum increase of 57% occurs for the tower at location 4.
5. The maximum bending moment in the first storey beam remains constant with the tower installation at any location.
6. The maximum bending moment in the top storey beam increases phenomenally for all tower locations. The increase is up to 5400%.
7. The maximum bending moment in the top storey beam due to dead, live and wind load combination remains same with the towers at locations 1 and 3 whereas it increases with the towers at locations 2 and 4. The increase is up to 108% (48 kN to 100 kN).

The base shears in X and Z direction for both three and six storey building do not show any variation with the installation of the tower at any of the four locations.

The fundamental time period also remains unchanged in both buildings with the tower installation.

The absolute top storey displacement of both the buildings reduces with the installation of the tower at any of the four locations. The reduction is by 35% in case of three storey building and by 20% for the six storey building.

Chapter Five

Conclusions

From the results obtained as above, the following conclusions can be drawn.

1. The results obtained by lumping the tower mass on the building roof and those obtained by modeling the tower on the roof show different variation for different tower locations.

2. The absolute storey displacement of a building gets reduced when the tower is installed over it. The reduction is more for smaller building heights.

3. The effect of earthquake loading on the buildings with roof top towers is to reduce the axial forces in bottom storey columns and to increase the same in the top storey columns. The effect is more predominant in smaller building heights.

4. The location of the tower on the building plan decides the increase or decrease in the maximum bending moment in the top storey beam. Thus certain locations may prove advantageous so as to cause reduction in forces.

5. The wind force increases the axial forces in the columns of the buildings with roof top towers. The increase in axial forces is more in case of higher buildings.

6. The maximum bending moments in top storey beams of the buildings with roof top towers increase substantially due to the wind load.

7. The earthquake loading governs the design of buildings without towers whereas the wind load becomes equally critical for building with roof top towers. This effect will be more so in case of high towers on high rise buildings.

Chapter Six

Scope of Further Study

There could be many permutations and computations of the said problem and each one would present a unique solution when analysed. The scope can be summarized as below.

- The variation in forces can be compared for various heights of towers with the same building height.

- The plan of the building can be unsymmetrical as against the symmetrical plan chosen in this report.

- Different characteristics of a masonry building and a steel tower necessitate the analysis of the tower as a secondary system. This can be done by developing response spectra at the roof height and analyzing the tower for this spectra.

- Since towers are being installed over unreinforced masonry structures also, the effect of these towers on the seismic response of such buildings can be studied.

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STAAD SPACE WITH TOWER 1 ON THREE STOREY BLDG SPECTRUM INPUT
START JOB INFORMATION
END JOB INFORMATION
INPUT WIDTH 79
UNIT METER KN
JOINT COORDINATES
1 0 0 0; 2 2.85 0 0; 3 5.85 0 0; 4 8.85 0 0; 5 11.7 0 0; 6 0 0 3.1;7 5.85 0 3.1; 8 11.7 0 3.1; 9 0
0 9.1; 10 5.85 0 9.1; 11 11.7 0 9.1;12 0 0 15.1; 13 5.85 0 15.1; 14 11.7 0 15.1; 15 0 0 18.2; 16
2.85 0 18.2;17 5.85 0 18.2; 18 8.85 0 18.2; 19 11.7 0 18.2; 20 0 3 0; 21 2.85 3 0;22 5.85 3 0;
23 8.85 3 0; 24 11.7 3 0; 25 0 3 3.1; 26 5.85 3 3.1;27 11.7 3 3.1; 28 0 3 9.1; 29 5.85 3 9.1; 30
11.7 3 9.1; 31 0 3 15.1;32 5.85 3 15.1; 33 11.7 3 15.1; 34 0 3 18.2; 35 2.85 3 18.2; 36 5.85 3
18.2;37 8.85 3 18.2; 38 11.7 3 18.2; 39 0 6 0; 40 2.85 6 0; 41 5.85 6 0;42 8.85 6 0; 43 11.7 6
0; 44 0 6 3.1; 45 5.85 6 3.1; 46 11.7 6 3.1; 47 0 6 9.1;48 5.85 6 9.1; 49 11.7 6 9.1; 50 0 6
15.1; 51 5.85 6 15.1; 52 11.7 6 15.1;53 0 6 18.2; 54 2.85 6 18.2; 55 5.85 6 18.2; 56 8.85 6
18.2; 57 11.7 6 18.2;58 0 9 0; 59 2.85 9 0; 60 5.85 9 0; 61 8.85 9 0; 62 11.7 9 0; 63 0 9 3.1;64
5.85 9 3.1; 65 11.7 9 3.1; 66 0 9 9.1; 67 5.85 9 9.1; 68 11.7 9 9.1;69 0 9 15.1; 70 5.85 9 15.1;
71 11.7 9 15.1; 72 0 9 18.2; 73 2.85 9 18.2;74 5.85 9 18.2; 75 8.85 9 18.2; 76 11.7 9 18.2; 77
2.85 3 3.1; 78 2.85 3 9.1;79 2.85 3 15.1; 80 8.85 3 3.1; 81 8.85 3 9.1; 82 8.85 3 15.1; 83 2.85
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8.85 9 0.3; 97 11.7 9 0.3; 98 11.7 9 2.8;99 9.025 9 0.3; 100 11.525 9 0.3; 101 9.025 9 2.8;
102 11.525 9 2.8;103 9.025 9.75 0.3; 104 11.525 9.75 0.3; 105 9.025 9.75 2.8;106 11.525
9.75 2.8; 107 9.775 24.75 1.05; 108 10.775 24.75 1.05;109 9.775 24.75 2.05; 110 10.775
24.75 2.05; 111 9.27475 14.745 0.54975;112 9.4 17.25 0.675; 113 9.5245 19.74 0.799498;
114 9.64975 22.245 0.92475;115 11.2752 14.745 0.54975; 116 11.15 17.25 0.675; 117
11.0255 19.74 0.799498;118 10.9002 22.245 0.92475; 119 9.27475 14.745 2.55025; 120 9.4
17.25 2.425;121 9.5245 19.74 2.3005; 122 9.64975 22.245 2.17525;123 11.2752 14.745
2.55025; 124 11.15 17.25 2.425; 125 11.0255 19.74 2.3005;126 10.9002 22.245 2.17525;
127 9.71237 23.4975 1.48738;128 10.2124 23.4975 2.11262; 129 10.8376 23.4975 1.61262;
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2.23788; 133 10.9629 20.9925 1.48737;134 10.2124 20.9925 0.862124; 135 9.46225 18.495
1.48775;136 10.2128 18.495 2.36275; 137 11.0878 18.495 1.61225;138 10.3372 18.495
0.737249; 139 9.33737 15.9975 1.61263;140 10.3376 15.9975 2.48762; 141 11.2126
15.9975 1.48737;142 10.2124 15.9975 0.612375; 143 9.27475 14.745 1.55;
144 10.275 14.745 2.55025; 145 11.2752 14.745 1.55; 146 10.275 14.745 0.54975;147
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153 9.10825 11.415 0.38325; 154 9.1915 13.08 0.4665; 155 9.1915 13.08 1.96667;156
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11.415 2.71675; 163 11.3585 13.08 1.96667;164 11.4417 11.415 2.38333; 165 11.3585
13.08 1.13333;166 11.4417 11.415 0.716667; 167 10.6917 13.08 0.4665;168 11.1083 11.415
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20.9925 2.23788;178 10.9629 20.9925 0.862124; 179 9.46225 18.495 2.36275;180 11.0878
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186 9.33737 15.9975 0.612375; 187 10.275 24.75 1.55;
MEMBER INCIDENCES
1 1 20; 2 2 21; 3 3 22; 4 4 23; 5 5 24; 6 6 25; 7 7 26; 8 8 27; 9 9 28;10 10 29; 11 11 30; 12 12
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DEFINE MATERIAL START
ISOTROPIC CONCRETE
E 2.17185e+007
POISSON 0.17
DENSITY 23.5616
ALPHA 1e-005
DAMP 0.05
ISOTROPIC STEEL
E 2.05e+008
POISSON 0.3
DENSITY 76.8195
ALPHA 1.2e-005
DAMP 0.03

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END DEFINE MATERIAL
CONSTANTS
MATERIAL CONCRETE MEMB 1 TO 191
MATERIAL STEEL MEMB 192 TO 423
MEMBER PROPERTY INDIAN
*COLUMNS 1 TO 57
1 TO 57 PRIS YD 0.45 ZD 0.45
*PEDESTAL
188 TO 191 PRIS YD 0.4 ZD 0.4
*BEAMS 58 TO 187
58 TO 187 PRIS YD 0.5 ZD 0.23
*TOP HORI
196 TO 199 TABLE ST ISA50X50X5
404 TO 407 TABLE ST ISA50X50X5
*MAIN PANEL 5
203 207 211 215 352 TO 355 TABLE ST ISA50X50X6
*DIAG PANEL 5
216 220 224 228 232 TO 243 TABLE ST ISA50X50X5
*HORI PANEL 5
356 TO 363 TABLE ST ISA50X50X5
*SECON HORI PANEL 5
364 TO 367 TABLE ST ISA50X50X5
*MAIN PANEL 4
202 206 210 214 368 TO 371 TABLE ST ISA50X50X6
*DIAG PANEL 4
217 221 225 229 244 TO 255 TABLE ST ISA50X50X5
*HORI PANEL 4
372 TO 379 TABLE ST ISA50X50X5
*SECON HORI PANEL 4
408 TO 411 TABLE ST ISA50X50X5
*MAIN PANEL 3
201 205 209 213 380 TO 383 TABLE ST ISA50X50X6
*DIAG PANEL 3
218 222 226 230 256 TO 267 TABLE ST ISA50X50X5
*HORI PANEL 3
384 TO 391 TABLE ST ISA50X50X5
*SECON HORI PANEL 3
412 TO 415 TABLE ST ISA50X50X5
*MAIN PANEL 2
200 204 208 212 392 TO 395 TABLE ST ISA60X60X6
*DIAG PANEL 2
219 223 227 231 268 TO 279 TABLE ST ISA50X50X5
*HORI PANEL 2
396 TO 403 TABLE ST ISA50X50X5
*SECON HORI PANEL 2
416 TO 419 TABLE ST ISA50X50X5
*MAIN PANEL 1
192 TO 195 296 TO 303 TABLE ST ISA75X75X6
*DIAG PANEL 1
288 TO 295 304 TO 319 TABLE ST ISA70X70X6
*SECON PANEL 1
320 TO 351 TABLE ST ISA60X60X6
*HORI PANEL 1
280 TO 287 TABLE ST ISA50X50X5
*SECON HORI PANEL 1
420 TO 423 TABLE ST ISA50X50X5
SUPPORTS
1 TO 19 FIXED
DEFINE 1893 LOAD
ZONE 0.24 RF 3 I 1.5 SS 2 ST 1
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SELFWEIGHT
JOINT WEIGHT
103 104 WEI 0.35
109 110 WEI 0.898
107 108 WEI 1.198
114 118 WEI 0.48
112 113 116 117 WEI 0.36
111 115 WEI 0.53
MEMBER WEIGHT
58 61 68 71 72 75 82 85 UNI 1.43
59 60 69 70 73 74 83 84 UNI 1.5
62 64 66 76 78 80 115 TO 117 131 142 143 UNI 2.85
63 65 67 77 79 81 104 106 107 130 132 133 UNI 3
100 103 122 125 126 129 148 151 UNI 1.54
105 110 118 121 134 137 144 147 UNI 3.09
101 102 123 124 127 128 149 150 UNI 2.18
108 109 119 120 135 136 145 146 UNI 4.43
111 114 138 141 UNI 3.1
112 113 139 140 UNI 4.5
86 89 96 99 UNI 0.53
90 92 94 159 TO 161 UNI 1.06
87 88 97 98 UNI 0.57
91 93 95 156 TO 158 UNI 1.14
152 155 175 UNI 0.59
162 165 172 UNI 1.17
153 154 173 174 UNI 0.83
163 164 170 171 UNI 1.68
166 169 UNI 1.18
167 168 UNI 1.71
LOAD 1 SEISMIC X
SELFWEIGHT X 1
SELFWEIGHT Y 1
SELFWEIGHT Z 1
JOINT LOAD
103 104 FX 0.35
103 104 FY 0.35
103 104 FZ 0.35
109 110 FX 0.898
109 110 FY 0.898
109 110 FZ 0.898
107 108 FX 1.198
107 108 FY 1.198
107 108 FZ 1.198
114 118 FX 0.48
114 118 FY 0.48
114 118 FZ 0.48
112 113 116 117 FX 0.36
112 113 116 117 FY 0.36
112 113 116 117 FZ 0.36
111 115 FX 0.53
111 115 FY 0.53
111 115 FZ 0.53
MEMBER LOAD
58 61 68 71 72 75 82 85 UNI GX 1.43
58 61 68 71 72 75 82 85 UNI GY 1.43
58 61 68 71 72 75 82 85 UNI GZ 1.43
59 60 69 70 73 74 83 84 UNI GX 1.5
59 60 69 70 73 74 83 84 UNI GY 1.5
59 60 69 70 73 74 83 84 UNI GZ 1.5
62 64 66 76 78 80 115 TO 117 131 142 143 UNI GX 2.85
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62 64 66 76 78 80 115 TO 117 131 142 143 UNI GY 2.85
62 64 66 76 78 80 115 TO 117 131 142 143 UNI GZ 2.85
63 65 67 77 79 81 104 106 107 130 132 133 UNI GX 3
63 65 67 77 79 81 104 106 107 130 132 133 UNI GY 3
63 65 67 77 79 81 104 106 107 130 132 133 UNI GZ 3
100 103 122 125 126 129 148 151 UNI GX 1.54
100 103 122 125 126 129 148 151 UNI GY 1.54
100 103 122 125 126 129 148 151 UNI GZ 1.54
105 110 118 121 134 137 144 147 UNI GX 3.09
105 110 118 121 134 137 144 147 UNI GY 3.09
105 110 118 121 134 137 144 147 UNI GZ 3.09
101 102 123 124 127 128 149 150 UNI GX 2.18
101 102 123 124 127 128 149 150 UNI GY 2.18
101 102 123 124 127 128 149 150 UNI GZ 2.18
108 109 119 120 135 136 145 146 UNI GX 4.43
108 109 119 120 135 136 145 146 UNI GY 4.43
108 109 119 120 135 136 145 146 UNI GZ 4.43
111 114 138 141 UNI GX 3.1
111 114 138 141 UNI GY 3.1
111 114 138 141 UNI GZ 3.1
112 113 139 140 UNI GX 4.5
112 113 139 140 UNI GY 4.5
112 113 139 140 UNI GZ 4.5
86 89 96 99 UNI GX 0.53
86 89 96 99 UNI GY 0.53
86 89 96 99 UNI GZ 0.53
90 92 94 159 TO 161 UNI GX 1.06
90 92 94 159 TO 161 UNI GY 1.06
90 92 94 159 TO 161 UNI GZ 1.06
87 88 97 98 UNI GX 0.57
87 88 97 98 UNI GY 0.57
87 88 97 98 UNI GZ 0.57
91 93 95 156 TO 158 UNI GX 1.14
91 93 95 156 TO 158 UNI GY 1.14
91 93 95 156 TO 158 UNI GZ 1.14
152 155 175 UNI GX 0.59
152 155 175 UNI GY 0.59
152 155 175 UNI GZ 0.59
162 165 172 UNI GX 1.17
162 165 172 UNI GY 1.17
162 165 172 UNI GZ 1.17
153 154 173 174 UNI GX 0.83
153 154 173 174 UNI GY 0.83
153 154 173 174 UNI GZ 0.83
163 164 170 171 UNI GX 1.68
163 164 170 171 UNI GY 1.68
163 164 170 171 UNI GZ 1.68
166 169 UNI GX 1.18
166 169 UNI GY 1.18
166 169 UNI GZ 1.18
167 168 UNI GX 1.71
167 168 UNI GY 1.71
167 168 UNI GZ 1.71
SPECTRUM CQC 1893 TOR X 0.06 ACC SCALE 1 DAMP 0.05 LIN MIS
SOIL TYPE 2
LOAD 2 SEISMIC Z
SPECTRUM CQC 1893 TOR Z 0.06 ACC SCALE 1 DAMP 0.05 LIN MIS
SOIL TYPE 2
LOAD 3 DEAD LOAD
SELFWEIGHT Y -1
```

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JOINT LOAD
103 104 FY -0.35
109 110 FY -0.898
107 108 FY -1.198
114 118 FY -0.48
112 113 116 117 FY -0.36
111 115 FY -0.53
LOAD 4 LIVE LOAD
MEMBER LOAD
58 61 68 71 72 75 82 85 UNI Y -2.85
59 60 69 70 73 74 83 84 UNI Y -3
62 64 66 76 78 80 115 TO 117 131 142 143 UNI Y -5.7
63 65 67 77 79 81 104 106 107 130 132 133 UNI Y -6
100 103 122 125 126 129 148 151 UNI Y -3.08
105 110 118 121 134 137 144 147 UNI Y -6.18
101 102 123 124 127 128 149 150 UNI Y -4.35
108 109 119 120 135 136 145 146 UNI Y -8.85
111 114 138 141 UNI Y -6.2
112 113 139 140 UNI Y -9
86 89 96 99 UNI Y -1.07
90 92 94 159 TO 161 UNI Y -2.17
87 88 97 98 UNI Y -1.14
91 93 95 156 TO 158 UNI Y -2.28
152 155 175 UNI Y -1.17
162 165 172 UNI Y -2.35
153 154 173 174 UNI Y -1.65
163 164 170 171 UNI Y -3.36
166 169 UNI Y -2.36
167 168 UNI Y -3.42
LOAD 5 WIND X
JOINT LOAD
1 15 58 72 FX 3.7
20 34 39 53 FX 7.4
6 12 63 69 FX 10.85
25 31 44 50 FX 21.7
9 66 FX 14.3
28 47 FX 28.6
*TOWER
107 109 FX 0.8125
107 109 FX 0.635
114 122 FX 1.335
113 121 FX 1.47
112 120 FX 1.6025
111 119 FX 2.805
103 105 FX 1.9725
LOAD 6 WIND Z
JOINT LOAD
1 5 58 62 FZ 2.83
2 4 59 61 FZ 5.81
20 24 39 43 FZ 5.67
21 23 40 42 FZ 11.62
3 60 FZ 5.96
22 41 FZ 11.92
*TOWER
107 108 FZ 0.8125
107 108 FZ 0.635
114 118 FZ 1.335
113 117 FZ 1.47
112 116 FZ 1.6025
111 115 FZ 2.805
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103 104 FZ 1.9725
LOAD COMB 7 1.5(DL+LL)
3 1.5 4 1.5
LOAD COMB 8 1.2(DL+LL+ELX)
1 1.2 3 1.2 4 1.2
LOAD COMB 9 1.2(DL+LL-ELX)
1 -1.2 3 1.2 4 1.2
LOAD COMB 10 1.2(DL+LL+ELZ)
2 1.2 3 1.2 4 1.2
LOAD COMB 11 1.2(DL+LL-ELZ)
2 -1.2 3 1.2 4 1.2
LOAD COMB 12 1.5(DL+ELX)
1 1.5 3 1.5
LOAD COMB 13 1.5(DL-ELX)
1 -1.5 3 1.5
LOAD COMB 14 1.5(DL+ELZ)
2 1.5 3 1.5
LOAD COMB 15 1.5(DL-ELZ)
2 1.5 3 1.5
LOAD COMB 16 1.2(DL+LL+WLX)
3 1.2 4 1.2 5 1.2
LOAD COMB 17 1.2(DL+LL-WLX)
3 1.2 4 1.2 5 -1.2
LOAD COMB 18 1.2(DL+LL+WLZ)
3 1.2 4 1.2 6 1.2
LOAD COMB 19 1.2(DL+LL-WLZ)
3 1.2 4 1.2 6 -1.2
LOAD COMB 20 1.5(DL+WLX)
3 1.5 5 1.5
LOAD COMB 21 1.5(DL-WLX)
3 1.5 5 -1.5
LOAD COMB 22 1.5(DL+WLZ)
3 1.5 6 1.5
LOAD COMB 23 1.5(DL-WLZ)
3 1.5 6 -1.5
PERFORM ANALYSIS
PRINT MODE SHAPES
LOAD LIST 1 TO 23
CHECK CODE MEMB 192 TO 423
STEEL MEMBER TAKE OFF LIST 192 TO 423
LOAD LIST 1 TO 23
PRINT SUPPORT REACTION
START CONCRETE DESIGN
CODE IS13920
*TRACK 2.0 ALL
UNIT MMS NEWTON
DESIGN BEAM 58 TO 187
DESIGN COLUMN 1 TO 57 188 TO 191
END CONCRETE DESIGN
UNIT METER KN
PRINT MEMBER FORCES LIST 1 TO 423
PRINT MAXFORCE ENVELOPE NSECTION 1 LIST 1 TO 423
PRINT STORY DRIFT
FINISH
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