"Comparative Analysis of Telecommunication Tower Mounted On Roof Top with Base Isolation System"

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Abstract— During an earthquake, the building produces this motion, resulting in peak floor accelerations higher than the peak ground acceleration. Thus earthquake ground motion can cause significant or severe structural damages. The use of base isolation is the best method to reduce inter-storey drift and floor accelerations. In this present study, the seismic analysis of 4 legged self-supporting rooftop telecommunication towers has been studied under the effect of wind analysis as per IS 875 (part 3): 2015 along with seismic forces under Indian seismic code of practice IS 1893:2016. In this dissertation, the forces developed due to wind as well as dynamic analyses are considered and the base isolation is to be provided to the structure to overcome them. In the following study displacement and drift in roof top tower, base shear and storey forces in host structure, axial forces in columns supporting tower are the main parameters considered for the study. This paper also intends to demonstrate how an isolation system can be efficient, evaluating its effectiveness for the building in terms of maximum shear force, maximum bending moment, base shear, storey drift and storey displacement reductions. Analysis of the structures are done using SMRF frame in Zone-III i.e. building situated in Indore (M.P.) region and response of structure like storey displacement, storey drift, storey stiffness, overturning moment, storey shear were observed, plotted in graphs. An overall comparison of G+9 structures with isolator and without isolator were observed. Earthquake also affects the economy of the nation, so essential proper measures of prevention must be developed. There are many concepts of designing a building as earthquake resistant structure; the concept used in this project is base isolation. There are many types of base isolation systems but lead rubber bearing (LRB) is used as base isolation system in this project, LRB is most widely used as isolation system for buildings.

Keywords: Telecommunication Tower, Seismic Effects, Wind Effects, Roof Mounted Tower, Base Isolation, Etabsv18, RCC Structures

I. Introduction

Telecommunication towers are tall structure usually designed for supporting parabolic antennas which are normally used for microwave transmission for communication, also used for sending radio, television signals to remote places and they are installed at a specific height. These towers are self-supporting structures and categorized as three-legged and four-legged space trussed structures. The self-supporting towers are normally square or triangular in plan and are supported on ground or on buildings. Triangular towers attract lesser wind loads compared with square towers.

However they are used only for smaller heights of tower due to difficulties in joint detailing and fabrication using angle sections. Telecommunication towers or lattice towers are classified into three categories that are Guyed masts, monopole and self-supporting towers. Generally, they act as cantilever trusses and are designed to carry wind load as the only source of environmental loads. Except for critical structures built in high seismic hazard areas, earthquake-induced loads are generally neglected in design. The major cause of failures of telecommunication tower throughout the world though still remains to be high intensity winds (HIW). The major problem faced is the difficulty in estimating wind loads as they are based on a probabilistic approach. There have been several studies in telecommunication towers taking into consideration the wind as well as seismic effect. These towers even though demand more steel but cover less base area, due to which they are suitable in many situations. The availability of land which satisfies ideal installation conditions in urban areas is extremely limited giving no alternative but to adopt roof top towers with marginal adjustment in position but not in height. This practice is mainly due to the fact that telecommunication towers built on ground have shown good performance in past earthquakes. However, towers mounted on rooftops respond to lateral motions differently than those built on firm ground.

Radio masts and towers are, typically, tall structures designed to support antennas (also known as aerials) for telecommunications and broadcasting, including television. There are two main types: guyed and self-supporting structures. They are among the tallest man-made structures. Masts are often named after the broadcasting organizations that originally built them or currently use them. In the case of a mast they are called radiator or radiating tower, the whole mast or tower is itself the transmitting antenna. They are also known as Telecommunication towers.

People are structurally illiterate and want to install the telecommunication tower on the existing buildings for the sake of additional earning without caring for public safety. Such installed towers are the potential hazards for the public and may cause fatal accidents.

This study is aim to find out if the forces in telecommunication tower design to be installed at ground level is similar to the tower design with building model. Also to find out if the load on building structure is nominal and can be with stand by the building elements easily or not.

A. Base Isolation

The concept of base isolation is explained through an example building resting on frictionless rollers. When the ground shakes, the rollers freely roll, but the building above does not move. Thus, no force is transferred to the building due to shaking of the ground; simply, the building does not experience the earthquake. Now, if the same building is rested on flexible pads that offer resistance against lateral movements, then some effect of the ground shaking will be transferred to the building above. If the flexible pads are properly chosen, the forces induced by ground shaking can be a few times smaller than that experienced by the building built directly on ground, namely a fixed base building. The flexible pads are called base-isolators, whereas the structures protected by means of these devices are called base-isolated buildings. The main feature of the base isolation technology is that it introduces flexibility in the structure. As a result, a robust medium-rise masonry or reinforced concrete building becomes extremely flexible. The isolators are often designed to absorb energy and thus add damping to the system. This helps in further reducing the seismic response of the building. Several commercial brands of base isolators are available in the market, and many of them look like large rubber pads, although there are other types that are based on sliding of one part of the building relative to the other. A careful study is required to identify the most suitable type of device for a particular building. Also, base isolation is not suitable for all buildings. Most suitable buildings for base-isolation are low to medium-rise buildings rested on hard soil underneath. High-rise buildings or buildings rested on soft soil are not suitable for base isolation.

1) Theoretical Content Concept of Base Isolation: -

The concept of base isolation represents a radical departure from the current seismic design practice. In this technique of base isolation, the building is detached or isolated from the ground in such a way that only a very small portion of seismic ground motions is transmitted up through the building. In other words, although the ground underneath it may vibrate violently, the building itself would remain relatively stable. This results in significant reduction in floor accelerations and inter-storey drifts, thereby providing protection to the building components and contents. The system decouples the structure from horizontal components of the ground motion by interpose structural elements with low horizontal stiffness between the structure and the foundation. Base Isolation falls into general category of Passive Energy Dissipation.

Lead-plug bearings are made up of low-damping elastomers and lead cores with diameters between 15 to 33% of the bonded diameter of the bearing. A laminated-rubber bearing provides the desired displacements for seismic isolation. By combining laminated-rubber bearings with a lead-plug insert, which provides hysteretic energy dissipation, the damping required for a successful seismic isolation system can be incorporated in only a single composite component. The maximum shear strain range for lead- plug bearings varies as a function of manufacturer but is generally between 125% and 20%... LRB isolators have cylindrical rubber bearings, which are reinforced with steel shims. Shims and rubber is placed as alternate layers. Steel plates are also provided at the two ends of the isolator. The steel shims boost the load carrying capacity, thus the structure is stiff under vertical loads and flexible under horizontal loads. The fundamental principal of base isolation system is to rectify the response of the structure so that the ground can move below the structure without transferring these motions into the superstructure. In an ideal system to achieve this flexibility in buildings this separation would be total. But In the existing world there is a need to have some contact between the superstructure and sub structure.

The primary aim of this study is: -

- Design and normal seismic analysis of RCC structure with mounted roof tower with fixed bases.
- Study types of base isolators, their elements, and effect on structures.
- Using ETABS software, to perform and present a development of theoretical and analytical aspect of the behaviour of base isolated

B. Purpose of Base Isolation

The basic criteria while providing superior seismic resistance of a building is the difficulty in minimizing the inter storey drift and floor accelerations simultaneously. Large inter storey drifts cause damage to non- structural components. These drifts can be minimized by stiffening the structure, but this leads to amplification of the ground motion, which leads to high floor acceleration, which can damage non-structural components. Making the system more flexible can reduce floor acceleration, but this leads to large inter storey drifts. The only practical way of reducing inter storey drift and floor acceleration simultaneously is to use Base Isolation, which provides the necessary flexibility, with the displacements concentrated at the isolation level. In traditional approaches, in order to achieve capacity we should increase the elastic strength or else to maintain ductility. This leads to increase in floor accelerations and damage to structural components. Where as in Base Isolation, rather than increasing capacity we decrease demand as we cannot indefinitely increase the strength of the structure. As earth quakes cannot be predicted or controlled, we modify demand by mitigating effects of the foundation to super structure. There are many possible ways to strengthen the system by introducing several devices in structural system. These include elastomeric bearings, sliders, rollers, sliding plates, rocking foundations etc. Of these elastomeric bearings and sliding foundations are most practical ones. Seismic isolation is intended to prevent earthquake damage to structures, buildings and building contents. One type of seismic isolation system employs load bearing pads, called Isolators. Since the isolators carry large vertical loads and deform to significant lateral displacement, the components of the structure above and below the isolator need to be designed properly. Specifically, to make isolation system work in proper manner, the structure should be free to move in any direction up to the maximum specified displacement. Base isolation is achieved by inventing several isolation devices to meet the desired requirements of an earthquake resistant structure.

C. Main Objectives of Base Isolation

- To lengthen Period of vibration
- To reduce Relative displacements
- Maintain Rigidity at low seismic intensity of loads

Whenever the earth quake risk is higher and to develop an effective and economical seismic resistant structure we adopt isolation technique. Safety is the major criterion to be considered. If Earth Quake forces are dominant compared to other forces then we use Base Isolation. Flexibility and damping are the major aspects in Base isolation.

D. Isolation Devices

For superior seismic isolation of a structure we have to choose the appropriate system and the essential features for such system should be as follows:

- Capable in supporting the structure
- Provide horizontal flexibility
- Capable to dissipate energy

Isolation system should be rigid for low lateral loads to avoid vibration at frequent minor earthquakes or wind loads. Basic Requirements to develop a new base isolation device by overcoming the possible disadvantages of other devices are:

- Possibly its manufacturing should be a combination of several types of seismic isolators.
- Accommodation of tension forces should not occur suddenly but progressively in order to prevent impact loads on the isolated super structure.
- Permanent tension capacity to receive tension forces should occur in isolator.

E. Elements of Base Isoaltor:

1) Isolation system- The various isolators, which reduce the time period shift of the structure to a period, range of 2 to 3 sec, with the isolation system. In base isolation structure, only isolation system show non-linear behaviour, while structure and soil system are shows linear behaviour.
2) Structural system- This system consists of structural component of superstructure as well as foundation. The inter storey drift for isolated structure is very low so, that the super structure can conveniently be assume to behave like linear elastic manner.
3) Soil system- The sub soil system exhibits its own stiffness and damping properties which may or may not affect the response of the structure which is situated upon it. This influence of the interaction between the soil and structure becomes significant in case of loose subsoil strata.

F. Lead Rubber Bearing: -

The second type of elastomeric bearings is lead-rubber bearings (LRB). This base isolation system, provides the combined features of vertical load support, horizontal flexibility, restoring force, and damping in a single unit. A lead-rubber bearing is formed of a lead plug force fitted into a pre-formed hole in an elastomeric bearing. The lead core provides rigidity under service loads and energy dissipation under high lateral loads. When subjected to low lateral loads such as minor earthquake the lead-rubber bearing is stiff both laterally and vertically. The lateral stiffness results from the high elastic stiffness of the lead plug and the vertical rigidity. A major advantage of the lead-rubber bearing is that it combines the functions of rigidity at service load levels flexibility at earthquake load levels and damping into a single compact unit. The LRB also provides energy absorbing capacity through additional hysteretic damping in yielding of the lead core that reduces the lateral displacements of the isolator, especially under ambient vibrations. The force deformation behaviour of the LRB is generally represented by nonlinear characteristics following a hysteretic nature. The characteristics of the lead material have been considered in the production of LRB systems. In general, lead has a low yield point when its shear stress reaches 10Mpa and it exhibits elasto-plastic behaviour. Lead is also resistant Lead rubber bearing isolator to repeated loads and can renew itself over time following deformation. The system has a high initial stiffness against minor horizontal forces that may affect the structure, caused by either wind or mild earthquakes. The most important disadvantage of this system is that when the system is exposed to strong ground motion, it is impossible to determine whether damage to the lead core in the centre has occurred.

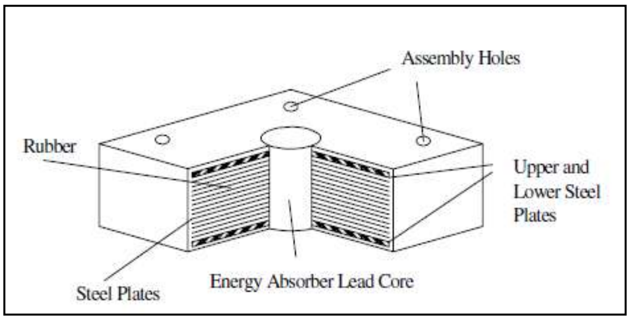


Fig. 1: Lead Rubber bearing

II. PROBLEM STATEMENT

Recently various studies have been done on design of Telecommunication Towers, but in most studies the researchers have considered the effect of wind and seismic forces on the four legged self-supporting towers. However, no researches have provided the measure to overcome the effects of lateral forces. In this study, the prevention of the structure with preventive measure in the form of Base Isolation is to be provided.

III. METHODOLOGY

Step - 1: Initial setup of Standard Codes and Country codes. The standard codes to be used in design were entered accordingly.

Step - 2: Creation of Grid points & Generation of structure After getting opened with ETABS we select a new model and a window appears where we had entered the grid dimensions and story dimensions of our building.

Step - 3: Defining of property Here we had first defined the material property by selecting define menu material properties. We add new material for our structural components (beams, columns, slabs) by giving the specified details in defining. After that we define section size by selecting frame sections & added the required section for beams, columns etc.

Step - 4: Assigning of Property After defining the property, we draw the structural components using command menu. Draw line for beam for beams and create columns in region for columns by which property assigning is completed for beams and columns.

Step - 5: Assigning of Supports By keeping the selection at the base of the structure and selecting all the columns we assigned supports by going to assign menu joint\frame Restraints (supports) fixed.

Step - 6: Defining of loads In ETABS all the load considerations are first defined and then assigned. The loads in ETABS are defined as using static load cases command in define menu.

Step - 7: Assigning of Dead loads After defining all the loads. Dead loads are assigned for external walls, internal walls in E-Tabs automatically taken care by software.

Step - 8: Assigning of Live loads Live loads for roof and floor are assigned separately for the entire structure.

Step - 9: Assigning of wind loads Wind loads are defined and assigned as per IS 875 1987 PART 3 by giving wind speed and wind angle.

Step - 10: Assigning of Seismic loads Seismic loads are defined and assigned as per IS 1893: 2016 by giving zone, soil type and response reduction factor in X and Y directions.

Step - 11: Assigning of load combinations Using load combinations command in define menu automatically produces load combinations as per codes chosen.

Step - 12: Analysis After the completion of all the above steps we have performed the analysis and checked for errors. Correcting the errors the comparison graphs are formed.

Step-13: Give Base isolation parameters of LRB. After analysis with fixed base, the base is isolated by LRB technique to make structure earthquake resistant. Hence its LRB parameters are found from isolation design procedure and assigned in required field of LRB formulation.

A. Assigning Properties of LRB in ETABS

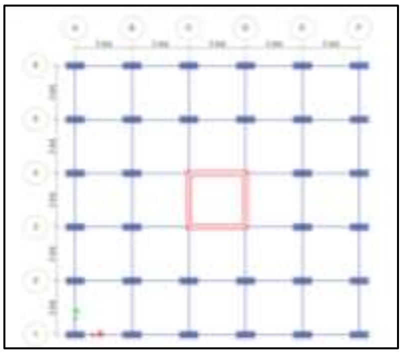
- *Insert a story at 0.5m above base*
- *Click on define*
- *Click on link properties*
- *Click on add new property*
- *Name it as LRB*
- *click on LRB*
- *assign properties*
- *Isolator type is Isolator 1*
- *Assign direction properties*
- *In direction U1, Effective stiffness is KV, it is linear*
- *In direction U2, Linear Effective stiffness is Keff(R), Non-linear Effective stiffness is KH*
- *In direction U3, Linear Effective stiffness is Keff(R), Non-linear Effective stiffness is KH*
- *Damping is 5% and post yield stiffness ratio is 0.1*
- *Yield strength is QR*
- *This completes defining LRB properties*
- *Next step is to select all the nodes at LRB story*
- *Click on assign>Joint or point>Link properties>Select LRB*
- *This completes assigning link properties*

B. Specifications of Models

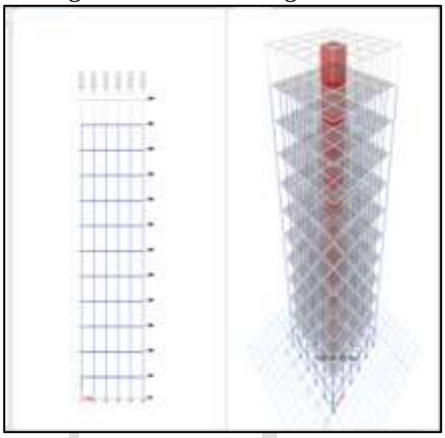
Five models for G+9 storey RC Building of area 15 m x 15 m. with shear wall at the centre portion of the building have been prepared and compared in zone III as per IS 1893:2016. It has been also analyzed for the wind effects for the location of Indore. The structure with roof mounted tower of height 15 m. above the top of stair case cabin and also with the use of rubber base isolator at different location have been prepared and analyzed.

C. Details of Models:

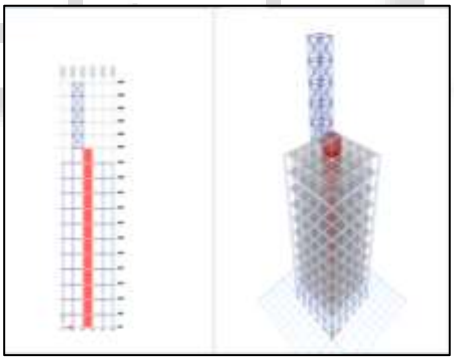
PLAN OF THE BUILDING



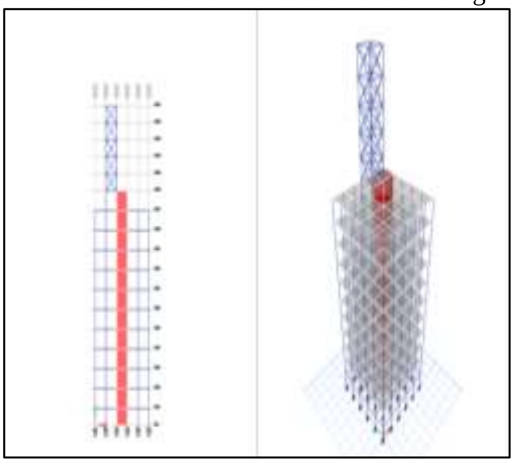
1) Model 1 – Regular Frame Building



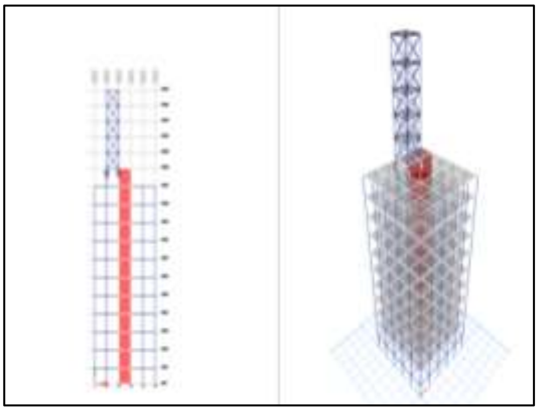
2) Model 2 – Regular Frame Building with roof mounted telecommunication tower



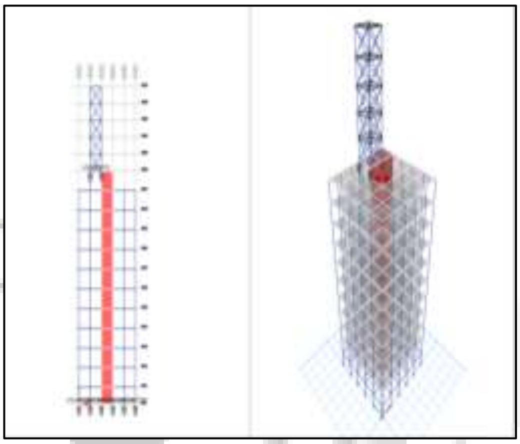
3) Model 3 – Regular Frame Building with roof mounted tower and base isolator at the base of the building



4) Model 4 – Regular Frame Building with roof mounted tower and base isolator at the base of the tower.



5) Model 5 – Regular Frame Building with roof mounted tower and base isolator at the base of the building as well as at the base of the tower.



The dimensions of beams, columns and slab are kept constant for the purpose of analysis. Other data used for the purpose of analysis have been taken from IS 1893:2016 and IS 875 Part III – 2015.

General Properties	
Location of Building	Indore
No. of storeys	G+9
Typical Storey Height	3.5 m.
Size of Column	400 mm x 1000 mm
Size of Beam	400 mm x 450 mm
Thickness of Slab	150 mm.
Thickness of Wall	230 mm.
Height of Tower	15 m.
Angle section for vertical and horizontal members of tower	ISA 200 x 200 x 25 mm.
Angle section for bracing elements	ISA 150 x 150 x 10 mm.
Material Properties	
Grade of Concrete	M 30
Grade of Steel Rebar	Fe 500
Grade of Steel Section	Fe 250
Type of Loading	
Wall Load	14 KN/m
Live Load	2 KN/m^2
Floor Finishing	1.5 KN/m^2

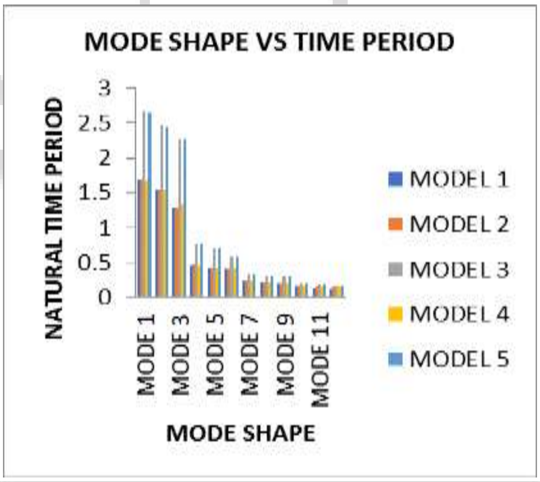
Seismic Details (IS 1893:2016)	
Seismic Zone	III
Zone Factor	0.16
Importance Factor	1
Type of Soil	II - Medium
Building Type (R)	5 (SMRF)
Wind Coefficients (IS 875 Part III – 2015)	
Basic Wind Speed	47 m/s
Terrain Category	IV
Importance Factor	1
Risk Coeff.	1
Topography factor	1

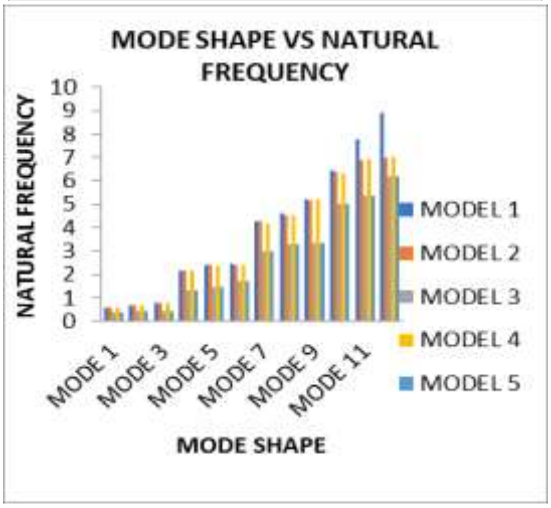
D. Input Data for Lead Rubber Base Isolator in ETABS Programming

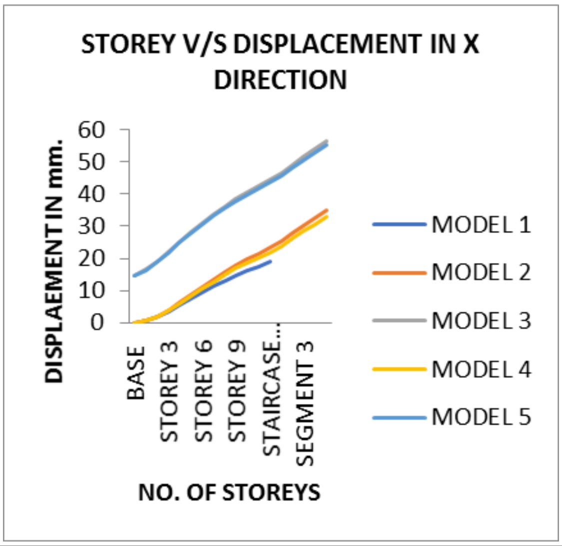
U1 = 11908 KN/m
U2 & U3 (Linear) = 2715 KN/m
U2 & U3 (Non Linear) = 27168 KN/m
Dy = 0.002049 m.
Yield Strength Fy = 55.674 m
β = 0.05

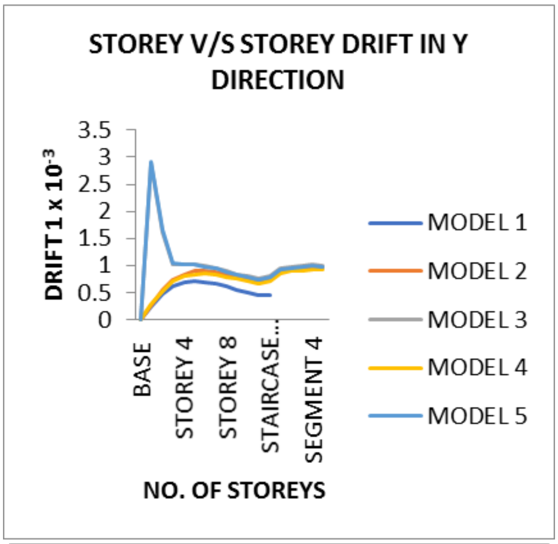
IV. RESULTS

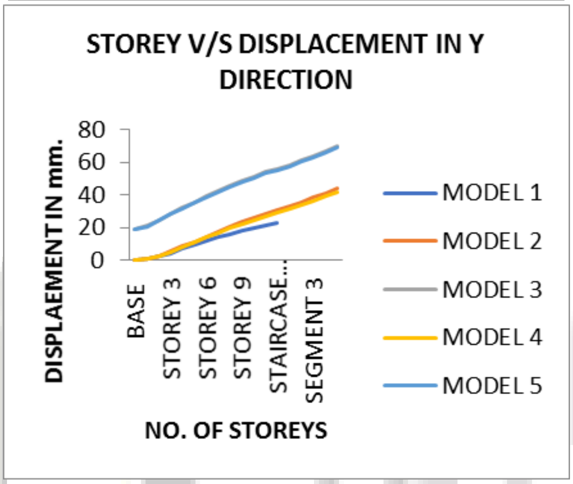
The results of five building models are presented here. The analysis carried out is Response Spectrum (Linear Dynamic) analysis. The result of Drift & Displacement in both direction and the value of base shear were presented for different types of models.






STOREY V/S DISPLACEMENT IN X DIRECTION
DISPLAEMENT IN mm.
NO. OF STOREYS
BASE
STOREY 3
STOREY 6
STOREY 9
STAIRCASE...
SEGMENT 3
MODEL 1
MODEL 2
MODEL 3
MODEL 4
MODEL 5


STOREY V/S STOREY DRIFT IN Y DIRECTION
DRIFT 1 x 10-3
NO. OF STOREYS
BASE
STOREY 4
STOREY 8
STAIRCASE...
SEGMENT 4
MODEL 1
MODEL 2
MODEL 3
MODEL 4
MODEL 5


STOREY V/S DISPLACEMENT IN Y DIRECTION
DISPLAEMENT IN mm.
NO. OF STOREYS
BASE
STOREY 3
STOREY 6
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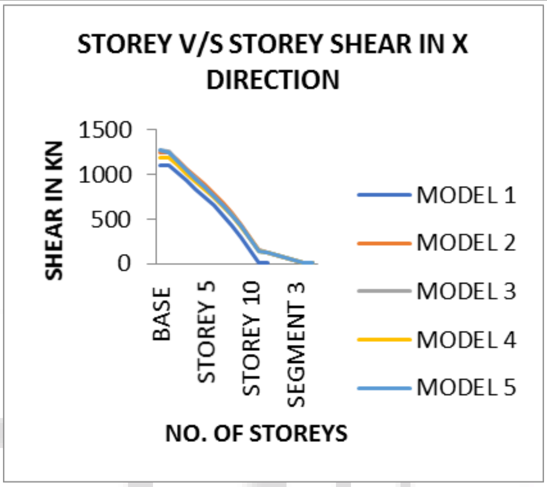
STAIRCASE...
SEGMENT 3
MODEL 1
MODEL 2
MODEL 3
MODEL 4
MODEL 5


STOREY V/S STOREY SHEAR IN X DIRECTION
SHEAR IN KN
NO. OF STOREYS
BASE
STOREY 5
STOREY 10
SEGMENT 3
MODEL 1
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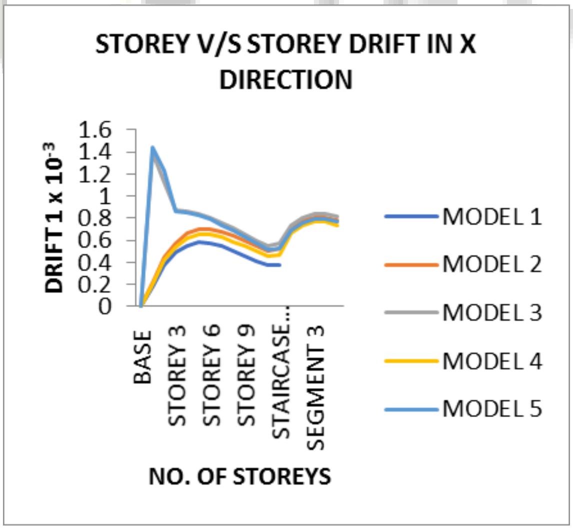
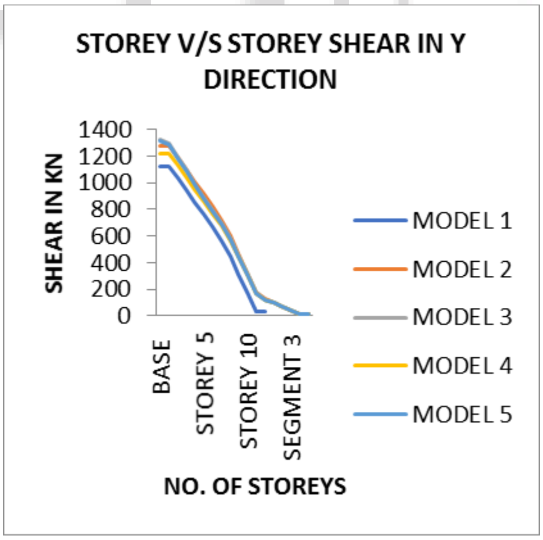
MODEL 3
MODEL 4
MODEL 5


STOREY V/S STOREY DRIFT IN X DIRECTION
DRIFT 1 x 10-3
NO. OF STOREYS
BASE
STOREY 3
STOREY 6
STOREY 9
STAIRCASE...
SEGMENT 3
MODEL 1
MODEL 2
MODEL 3
MODEL 4
MODEL 5


STOREY V/S STOREY SHEAR IN Y DIRECTION
SHEAR IN KN
NO. OF STOREYS
BASE
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MODEL 1
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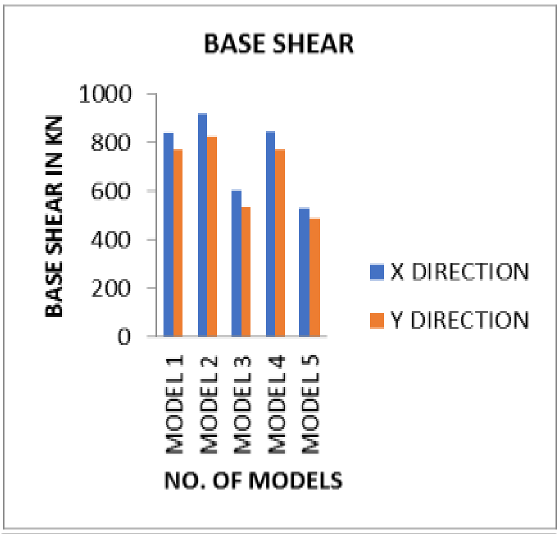
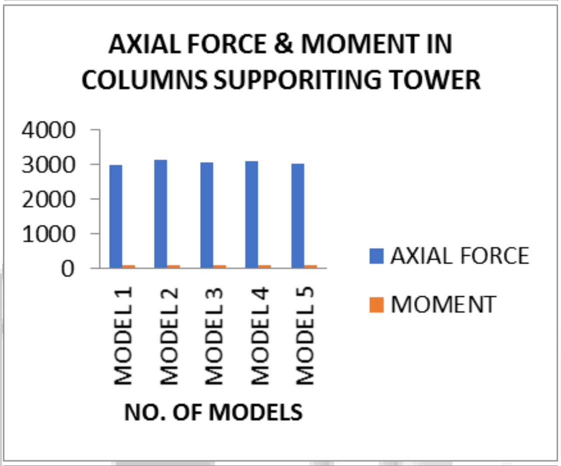
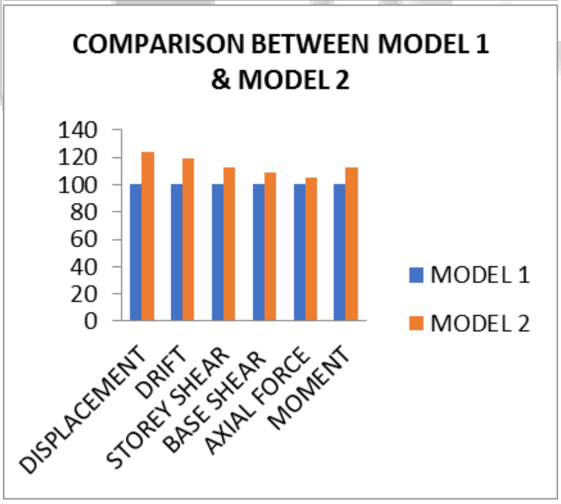
MODEL 5







V. CONCLUSIONS:

In this thesis, various frames and structures having different configuration but with the same dimension have been analysed to study their behaviour when subjected to lateral loads. All the frames and structures were analysed with the same method as stated in IS 1893- part 1: 2016 & IS 875 Part III - 2015. The results obtained for the building carried out through response spectrum approach and will be near to realistic response of the structure to the actual. Following conclusions are made on the basis of the study –

- It is been observed that the loads on RCC structure have been varied slightly and can be withstand by the existing member but there is a need of proper design check of the RCC structural member before installation of telecommunication tower on the existing structure.
- Mode periods are increased & natural frequency decrease after installing the base isolators which increases reaction time of a structure during earthquake.
- At base more storey drift was observed for base isolated model as compared to model of fixed base building. As storey height increases, the storey drifts in base isolated building model drastically decreases as compared to model of fixed base building.
- It has been observed that storey shear force, bending moment, base shear decreases; whereas increase in lateral displacements were observed for bottom storey then gradually decreases for top storey of base isolated building as compared with fixed base building model.
- Point displacements are increased in first three stories after providing LRB which is important to make a structure flexible during earthquake and relative point displacement between stories were significantly reduced after LRB is provided which reduces axial load on column hence educed reinforcement in column.
- Further, rooftop towers cannot be based on analytical results obtained for a similar configuration situated at ground level, since the member forces in the tower mounted on rooftop are more than the member forces of tower installed at ground level.
- If ever it is been decided to install the telecommunication tower on the existing building, it is essential to check the design of building model with communication tower before installation otherwise structural failure may cause fatality to the victims as the structure is quit heavy and may cause the fatal injury.
- Finally it is concluded that after LRB is provided as base isolation system it increases the structures stability against earthquake and reduces reinforcement hence make structure economical.

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