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Seismic Analysis of Latticed Shell Tube RC Framed Building

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Abstract **- The combination of Lattice shell tube and RC core walls systems, have proved to be most powerful lateral force resisting system. The bare frame system is efficient in resisting lateral loads by locating lateral systems at the building perimeter, and the braced tube system efficiently resists the lateral shear by axial forces in the diagonal members. It also reduces the shear lag efficiently. With above point of view, the model with bare frame system and different bracing systems such as X and single diagonal with different number of stories are prepared in SAP software. The same model is prepared for different seismic zones in India starting from zone II. Time history analysis are applied and analytical results are compared.**

Keywords—Lattice shell tube; lateral force; braced tube.

I. INTRODUCTION

A tall building may be defined as one whose structural system has to be modified to make it sufficiently economical to resist lateral forces due to wind or earthquakes within the prescribed criteria for strength, drift and comfort of the occupants.

High rise buildings are usually designed to resist moderate and frequently occurring earthquakes. They are expected to possess sufficient strength and stiffness to control deflection. Modern tall buildings may go over 460m in height. Tall buildings must have a complete structural system capable of carrying all gravity loads to its foundation in life span of building. Conventionally designed columns of a structure cannot carry the weight of the building and tolerate the large sideways movement caused by the motions of earthquake and/or wind. Earthquake and wind gusts are idealized as equivalent static load of certain magnitude that must be resisted by the structure. There are more and more complicated super high rise buildings constructed all over the world. Higher requirement are urged for seismic behavior of RC frame, which is the main core system for high rise buildings resisting seismic lateral forces now a days.

High rise buildings are usually designed to resist moderate and frequently occurring earthquakes. They are expected to possess sufficient strength and stiffness to control deflection.

In the construction of RC Framed buildings exclusively, a new structural system is introduced called the Latticed Shell Tube System.

Lattice Shell Tube system

It is a new system in which the RC core wall is a solid cylinder, so its shear rigidity is large: the planar size of the external latticed shell tube is also large, and hence its capacity to resist overthrow is high. Therefore under horizontal loads, the horizontal shear force is directed mainly to the RC core wall, and overturning moment is undertaken mostly by latticed shell tube. The shear rigidity of RC core wall is big, and the resisting overthrow capability of external latticed shell tube is hence powerful.

II. OBJECTIVES AND LITERATURE

The main objective of the present study is to determine seismic behavior of a new structural system in resisting the lateral loads due to earthquake using various parameters of comparison such as bracing systems and storey height. Numerical modelling and analysis is carried out using Finite Element Software i.e. SAP (Structural Analysis Programing) The modal analysis is conducted to know fundamental time period, natural frequency etc. Response spectrum is generated for all zones as per IS 1893(Part I) 2002 which is used for equivalent static analysis and response spectrum analysis. And parameters such as inter storey drift, base shear and displacement are determined.

A. Literature Review

The origin of Latticed Shell tube lies in" tube" structures where most work was done by many of the researchers.

Many researchers have conducted studies related this particular system starting from tube or bundled system.

Fazlur khan designed many systems which have been the basic for many modern construction practices of high rise building. Another major innovation by Fazlur Khan was the introduction of X Bracing system, which effectively resisted the lateral load.

Jayesh A Dalal and Atul K Desai have performed Wind and Seismic Analysis for Lattice Shell Tube RCC Framed buildings. According to their study which is performed for a building in Surat, which lies in the seismic zone III as per IS 1893:2002. The frames are assumed to be fixed at the bottom and the soil structure interaction is neglected. The mathematical models ranging from G+40 to G+100 stories are prepared with $ bays in X direction and 4 bays in Y direction.

The models are analyzed by using 3 different bracing systems. The parametric analysis was started with the most well-known and highly used approaches to effectively brace a building were modeled first. These include: bracing the center bay only, bracing the exterior bays only, upon analyzing these layouts, more specific differences were looked at including: different orientations of members, adding additional bracing at problem areas of the structure, bracing through multiple floors i.e. mega bracing. Different shapes of the building were also considered such as square octagonal and circular.

In this study, performance of bracing configuration and suitability in different types of building is checked. Different models have been modeled at the interval of 10 starting from Ground + 40 stories to Ground + 100 stories. Their performance is analyzed using three bracing system which are in practice now a day's viz. X-bracing, V–bracing and Inverted V-bracing system subjected to earthquake and wind loading. Keeping in view the above literature the present study intends to prepare numerical models using Finite Element software and perform the modal analysis to determine the fundamental time period and frequency.

Project description and modelling

The lateral deformation of the latticed shell tube under a horizontal load is mainly shear deformation, while that of RC core wall is bending deformation. The combination of Lattice shell tube and RC core walls systems, have proved to be most powerful lateral force resisting system. The bare frame system is efficient in resisting lateral loads by locating lateral systems at the building perimeter, and the braced tube system efficiently resists the lateral shear by axial forces in the diagonal members. Higher requirement are urged for seismic behavior of RC frame, which are the main core systems for high rise buildings resisting seismic lateral forces. The taller the building, the greater will be the effect of wind loads or similar lateral loads.

For this study, a building in zone III considered in Jayesh A Dalal and Atul K Desai 2013 has been referred for validation of the model. In their research work they have considered G+40 storeys to G+100 storey of building height at an interval of 10 stories are prepared with 4 bays in X direction and 4 bays in Y direction. Different shapes of the building is considered. Modelling is done using the ETABS software. In the present work single shape of the building is considered and modelling is done using SAP 2000 software. From the result and analysis it is found that displacement and storey drift are in line with the literature. Hence the models of the above mentioned paper are considered as reference models for the present work. A total of 48 models have been generated with varying storey heights and adopting different bracing systems along with bare frame.

The following models have been considered in the present work.

Model I: Bare frame system with varying storey heights

Model II: Single Diagonal with varying storey heights

Model III: X bracing with varying storey heights

3D Models considered in the present work are shown in the Fig

III MODELLING AND ANALYSIS

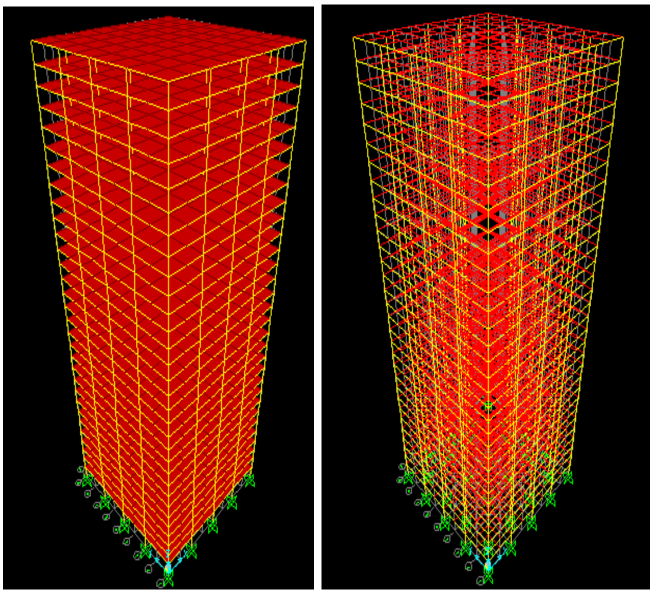

Fig 1 Bare Frame

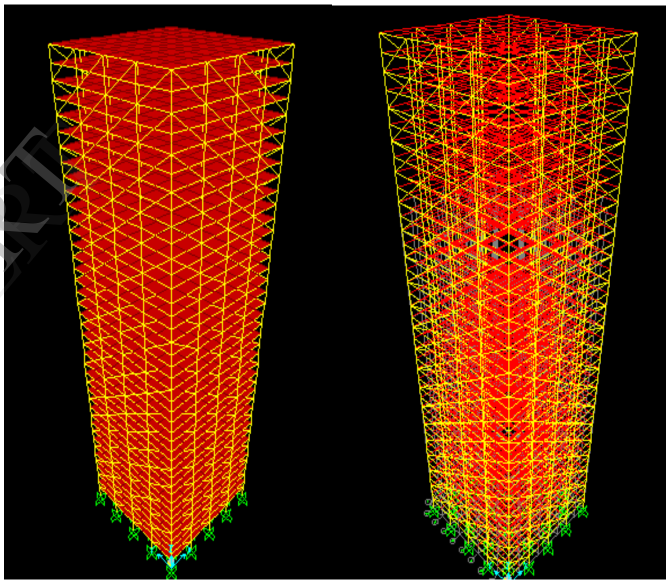

Fig 2 Single Diagonal

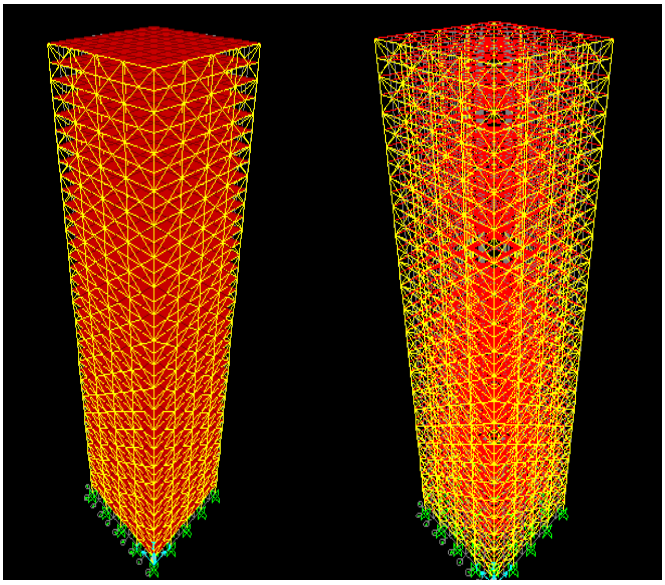

Fig 3 X Bracing

Height of each storey	3.5m
Height of ground floor	4.0m
Seismic zones considered	Zone II to Zone IV
Dead Load	2 KN/m
Imposed Load or Live Load	4 KN/m
Earthquake Load	As per IS:1893 (Part-1) 2002
Importance Factor	1
Response reduction factor as per code	5
Critical damping as per code	5%
Grade of Concrete and Steel	M20 and Fe 415
Depth of Slab	150mm
Size of beam	1.0mx1.0m
Size of Column	1.7m x 1.7m
Building Heights considered	109 m to 214 m
Dimension of the building	10m x 10m

B. Modelling

Modelling of high rise building with varying storey heights and with 4 bays along X axis and 4 bays along Y axis for 3 models is performed.

This research work is carried out to compare the dynamic response of RC buildings with and without bracing systems. Totally 48 models are considered for dynamic analysis which includes equivalent static and response spectrum analysis. From modal analysis natural frequency is obtained. From equivalent static and response spectrum analysis base shear, storey shear, storey drift, displacement results for all zones as per IS 1893 (Part I) 2002 are obtained.

Equations

The total design lateral force or design seismic base shear (Vh) along any principal direction shall be determined by the following expressions:

$$Vb = Ah.\ W \quad \ldots\ldots\ldots\ldots (5.1)$$

$$Ah = \frac{ZISa}{2Rg} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5.2)$$

Where

Ah = Design horizontal acceleration spectrum value.

Z = Zone factor

I = Importance factor, depending upon the functional use of the structures, characterized by hazardous consequences of its failure, post-earthquake functional needs, historical value, or economic importance.

R= Response reduction factor, depending on the perceived seismic damage performance of the structure, characterized by ductile or brittle deformations.

Sa/g = Average response acceleration co efficient, in case design spectrum is specifically prepared for a structure at a particular project site.

The approximate fundamental natural period of vibration (Ta), in seconds, of a moment – resisting frame building without brick in fill panels may be estimated by empirical expression:

Ta= 0.075 h 0.75 for RC frame building.

Ta= 0.085 h 0.75 for steel frame building.

The approximate fundamental natural period of vibration (Ta), in seconds, of all other buildings, including moment – resisting frame buildings with brick infill panels, may be estimated by empirical expressions:

Ta = 0.09 h/√d

Where
h= height of building in m.
d= Base dimension of the building at the plinth level in m, along the considered direction of the lateral force.

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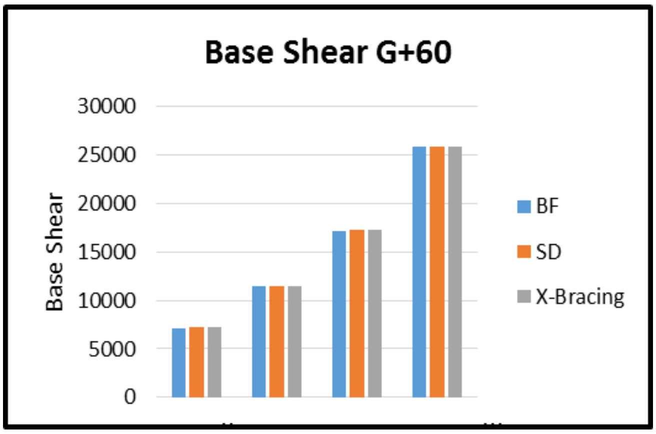


Base Shear along X axis for G+60 storey height

Base shear for zone V appears to be more compared to other seismic zones from the above table.

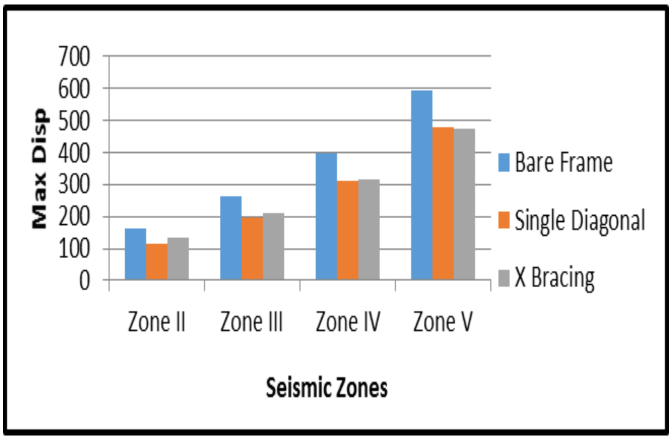
BASE SHEAR				
Models	**Zone II**	**Zone III**	**Zone IV**	**Zone V**
BF	**7154.48**	**11447.17**	**17170.76**	**25756.14**
SD	**7171.82**	**11474.92**	**17212.38**	**25818.57**
XB	**7189**	**11502.66**	**17253.99**	**25880.99**

The base shear values for different storey heights are calculated and plotted. And the one for the maximum storey height is shown above in the figure.

Results of Equivalent static methods of analysis

Equivalent static method of analysis is as per IS 1892 2002 (part I). The displacement and drift results are summarized in the table and graph below.

Displacement in various seismic zones for different bracing systems.



Displacement

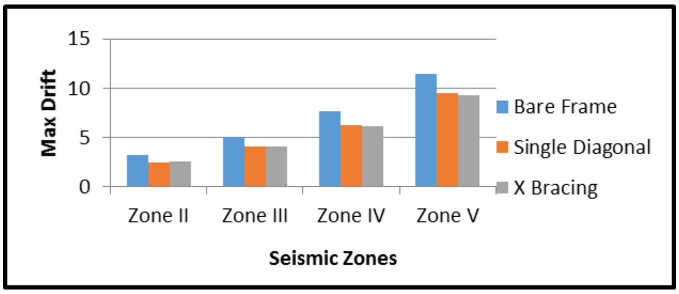
Displacement due to bare frame structure is found to be more, hence it is evident that both single diagonla and X bracing perform well compared to bare frame structure.

G+60				
	Zone II	**Zone III**	**Zone IV**	**Zone V**
BF	**164.7303**	**263.6049**	**395.4378**	**593.1871**
SD	**114.5025**	**195.6288**	**308.923**	**478.8643**
XB	**131.5669**	**210.5336**	**315.8224**	**473.7557**

Inter storey drift is the result of displacement. The inter storey drift and displacement are inter related. The results of equivalent static and dynamic analysis are compared.

The maximum storey height is considered and the results are plotted with seismic zones as ordinate and displacement as abscissa. The above results helps us analyze results obtained for various zones and storey heights.

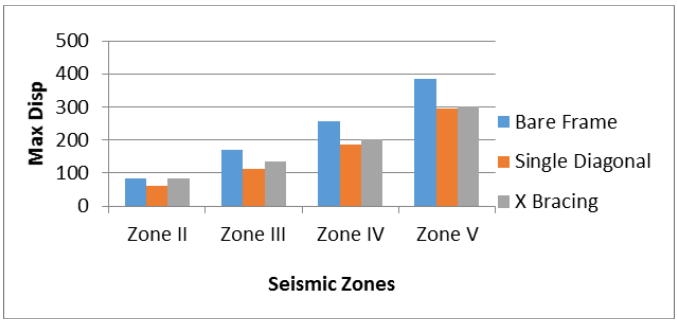
Maximum drift



The maximum inter storey drift can be visualized due to bare frame structure.it is significant that X – Bracing system in resisting the lateral displacement.

G+60				
	Zone II	**Zone III**	**Zone IV**	**Zone V**
BF	**3.19055**	**5.104886**	**7.657335**	**11.48601**
SD	**2.452301**	**4.069827**	**6.252452**	**9.540741**
X B	**2.593814**	**4.129809**	**6.177802**	**9.249791**

Dynamic response displacement

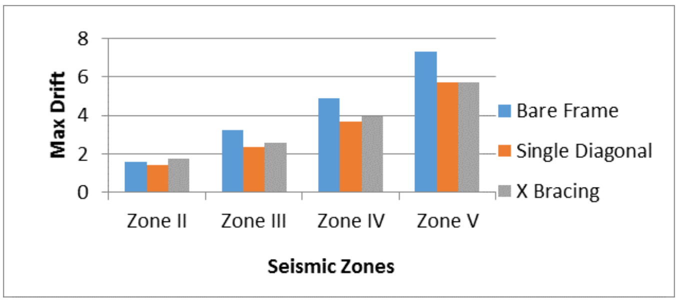


The maximum inter storey drift can be visualized due to bare frame structure.it is significant that X – Bracing system in resisting the lateral displacement.

G+60				
	Zone	**Zone**	**Zone**	**Zone**
BF	**83.77**	**170.43**	**255.68**	**383.56**
SD	**62.76**	**113.41**	**185.6**	**293.89**
X B	**83.91**	**134.09**	**201.29**	**301.77**

The dynamic response results are summarized below. The comparison between equivalent static and dynamic response results gives us a clear picture of the performance of various bracing system and the behavior of the same building in different seismic zones of India.

Dynamic response drift



G+60				
	Zone II	**Zone III**	**Zone IV**	**Zone V**
BF	**1.59**	**3.25**	**4.87**	**7.313**
SD	**1.396**	**2.37**	**3.7**	**5.72**
X B	**1.734**	**2.56**	**3.94**	**5.718**

The inter storey drift due to the response spectrum analysis is summarized in the above table. It shows that the seismic zone V shows greater inter storey drift. But clearly it can be seen that the X bracing system offers more resistance to later deflection.

Fundamental Time Period

	BARE FRAME	SINGLE DIAGONAL	X BRACING
G+30	3.956	3.524	3.26
G+40	5.58	5.01	4.67
G+50	7.36	6.71	6.332
G+60	9.4	8.67	8.24

The fundamental natural period is obtained as a result of modal analysis.

Conclusion

The results are extracted and it clearly shows that the X bracing has shown significant variation. This system of lateral load resisting system is more efficient as it resists the displacement and hence the inter storey drift very effectively.

Scope for Future work

The present study includes various parameters such as varying storey height, bracing systems and seismic zones of India. Study in this regard with irregular shape of building may be conducted for various bracing systems. The response of the same kind of structure in different seismic zones may be evaluated as square or regular shape of building has been considered for the present study.

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