RESEARCH ARTICLE OPEN ACCESS

Innovative Design of Tall Buildings

Mirza Aamir Baig ,Md. Ghani Haider
Department of Civil Engineering
Department of Civil Engineering
Al-Falah University, Dhauj Faridabad
Corresponding Author: Mirza Aamir Baig

ABSTRACT: High rises have involved interest for designers for as far back as century. All the more along these lines, the previous three decades have seen various structures ascending starting from the earliest stage, resisting gravity. Burj Khalifa Dubai, Taipei, Petronas twin pinnacle, Empire state building are a portion of the living instances of designing wonders.

What befalls a structure when it achieves such inconceivable statures separated from the surprise that it will be, it likewise represents a colossal measure of test for the basic architect. Since then these structures are looked by administration stacking conditions. Two crushing powers of nature, wind and quake become extremely basic for these structures. The harmony among solidness and pliability to be given turns into the directing components to the plan of such structures. Ordinarily giving enough firmness against enormous burdens does not appear to fulfill the necessities. These structures are regularly given adequate malleability so as to scatter the colossal measure of powers. Be that as it may, there is a limit, with respect to how much flexibility can be given in a structure. A fast count demonstrates that the highest floor relocation that can be securely borne by a 500 m tall structure is nearly 2m. The structure would not come up short if its top story uproots by 2m. In any case, this measure of removal would make a few viable troubles and distress its occupants. That must be dealt with.

The arrangement lies in finding increasingly more imaginative auxiliary design that can give the ideal harmony between the over two parameters.30 to 40 years' prior the majority of the basic setups depended on supporting, giving shear dividers and generally basic steel developments. It is just as of late increasingly more research has gone in to inventive materials and furthermore auxiliary designs. Use of different sorts of dampers and isolators have been utilized in dispersing this vitality. Much research has gone into advancement of TMDs, ATMDs, BTMDs, and seismic base isolators. Research has likewise gone into different sort of examinations method as increasingly strong powerful investigation, sucker investigation, time history investigation and execution based investigation.

Here an endeavor has been made to explore the relative benefits and negative marks of various kinds of auxiliary setups to comprehend their conduct under seismic and wind loads. The structure considered is of 50 stories. Different designs that have been considered incorporates propped frameworks, shear divider frameworks, dampers and isolators. The examinations results have been organized and plotted to comprehend their conduct. Time history investigation and execution based examination by sucker investigation have additionally been concentrated to comprehend the conduct of structures

KEYWORDS
Structural Motions, Damping, Passive and Active control devices, TMD, AMD

Date Of Submission: 28-07-2019 Date Of Acceptance: 10-08-2019

I. INTRODUCTION

A tall building cannot be defined in a single definition. There are various characteristics based on which it can be explained namely Height Relative to Context, Proportion and Tall Building Technologies**.** Not only height but also the context determines the building to be classified as tall buildings.

a building of perhaps 14 or more stories or over 50 meters in height could perhaps be used as a threshold for considering it a "tall building. the changing floor to floor height between differing buildings and functions versus but what happens to a structure when it reaches such unimaginable heights apart from the amazement that it is, it also poses an enormous amount of challenge for the structural engineer. Because then these structures are faced by service loading conditions. Two devastating forces of nature, wind and earthquake become really critical for these structures. The balance between stiffness and ductility to be provided becomes the guiding factors for the design of such structures. Conventionally providing enough stiffness against huge loads does not seem to satisfy the requirements. These structures are often provided with sufficient ductility in order to dissipate the enormous amount of forces. But there is a limit, as to how much ductility can be provided in a structure.

classified as tall buildings. Whereas sometimes the big/large footprint Buildings that are tall are not considered as tall building due to their size/floor area. Again, a tall building is not just about height but also about proportion. In low urban backgrounds the building which gives a slender look are

The building based on technologies of being a product of "tall" (e.g., specific Vertical transport technologies, structural wind bracing as a product of height, etc.), then this Building can be classed as a tall building. Although number of floors is a poor indicator of defining a tall building due to

Structural systems for tall buildings

Following are the Structural systems for tall buildings:

1. Rigid frame systems
2. Braced frame and shear-walled frame systems
3. Outrigger systems
4. framed-tube systems
5. braced-tube systems
6. bundled-tube systems

Objectives

Following are the main objectives of the work:

- Comparison of behavior of different structures of reinforced concrete (framed structures, braced systems, shear walls systems).
- Comparison of Effects of Seismic & Wind Forces on High Rise Buildings with different structural configuration and to compare the key parameters.
- Study the impact of base isolation on the above structures.

Study the impact of dampers for the above structures

II. MODELS CONSIDERED FOR ANALYSIS

Following six types of models have been considered for analysis. It was attempted to choose models that are representative of actual building types that are being constructed nowadays. Type A is regular framed structure with columns. Type B hybrid braced framed structure with bracings of Type 1 in periphery and columns. Type C hybrid braced framed structure with bracings of Type 2 in periphery and columns. Type D is tube in tube.

Table 1 Structural Description

Model ID	Description
Type A	Regular Frame Structure
Type B	Hybrid braced framed structure with bracings in periphery
Type C	hybrid braced framed structure with bracings in periphery and columns
Type D	Tube structure with shear walls and columns
Type E	Tube in Tube structure with shear walls and columns
Type F	Simple framed structure with Tuned Mass Dampers
Type G	Simple framed structure with Base Isolation

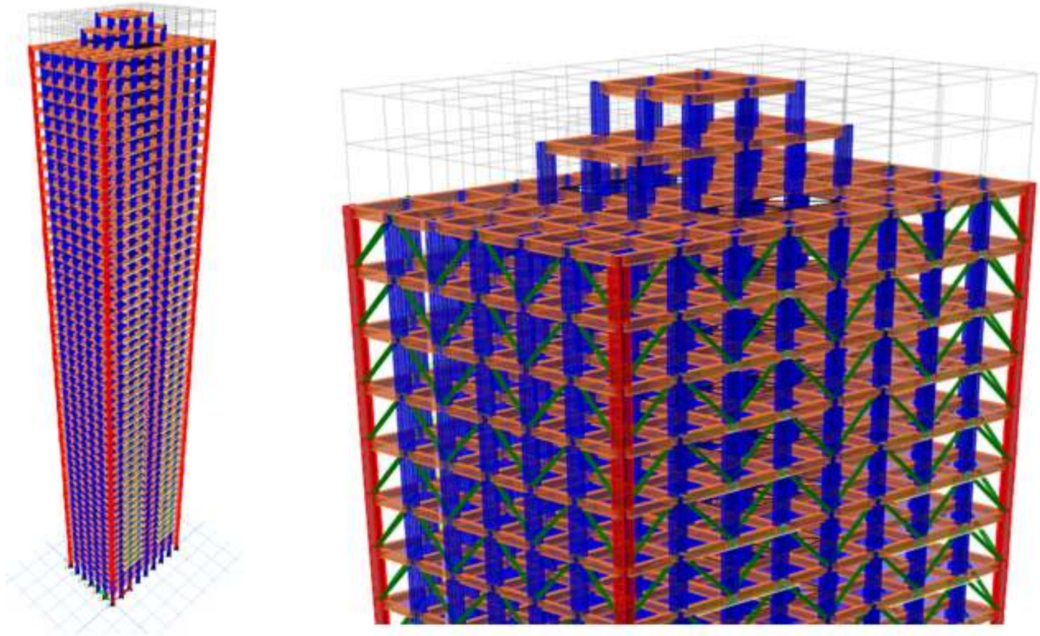

Fig.1: Base Model considered for Analysis

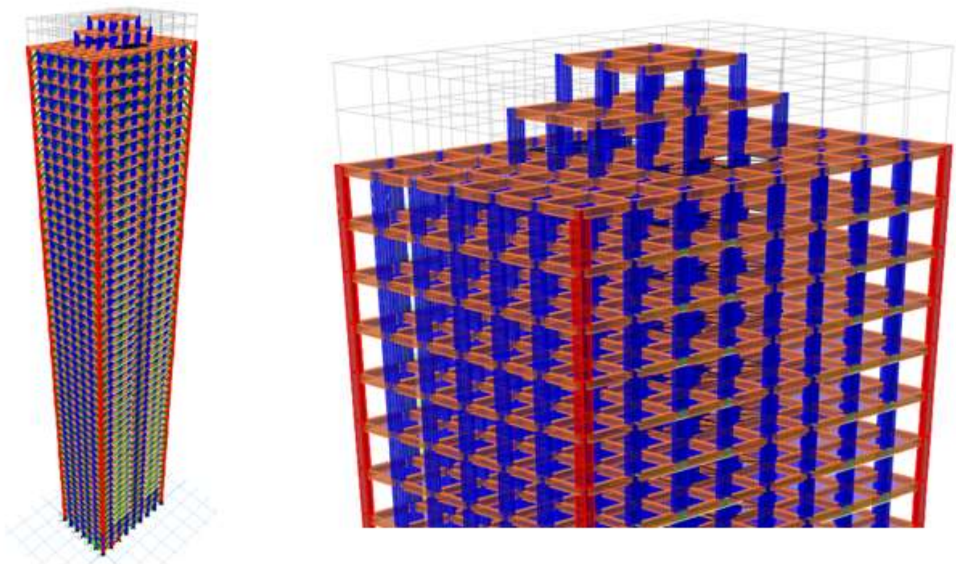

Fig.2: Hybrid braced framed structure with bracings in periphery

III. METHOD OF ANALYSIS

A. Static Analysis

The static method is the simplest one-it requires less computational effort and is based on the formulae given in the code. First, the design base shear is computed for the whole building and it is then distributed along the height of the building. The lateral forces at each floor level thus obtained are distributed to individual lateral load resisting elements.

B. Dynamic Analysis

Dynamic analysis shall be performed to obtain the design seismic forces and its distribution to different levels along the height of building and to the various lateral load resisting elements in following cases:

- Regular Building – Greater than 40 m height in zone IV and V and those greater than 90 m in height in zone II and III.
- Irregular building – All framed buildings higher than 12 m in zone IV and V, and those greater than 40 m height in zone II and III.

- For irregular building lesser than 40 m in height in zone II and III, dynamic analysis even though not mandatory, is recommended.

B.1 Response spectrum method

Response spectrum method is simply a plot of peak or steady state response (displacement, velocity or acceleration of a series of oscillators of varying natural frequency that are forced into motion by same base vibration or shock.

B.2 Pushover analysis (non-linear static method)

Pushover method of analysis is a technique in which a structural is modeled with non-linear properties (such as steel yield, plastic hinges) and permanent gravity load is subjected to an incremental load applied laterally from '0' value to prescribed ultimate displacement or until the structure become unstable to withstand the further forces

B.3 Non- linear time history analysis

It is an analysis of dynamic response of structure at each increment of time, when its base is subjected to any specific ground motion time history (compatible time history for medium soil IS-1893:2002-Part 1)

Model Parameters

For the analysis of multi storied building six types of models have been considered for analysis. Type A is regular framed structure with columns. Type B hybrid framed structure with shear wall in periphery and columns. Type C hybrid framed structure with shear wall in centre and columns. Type D is tube structure. Type E is hybrid framed structure with lift core in centre. Type F is tube in tube system. All the different types of models considered are analysed for 50 storey.

In the current study main goal is to compare the Static and Dynamic Analysis of different types of building.

Design Parameters- Here the Analysis is being done for G+50, (rigid joint regular frame) building by computer software using ETABS.

Design Characteristics: - The following design characteristics are considered for Multi-storey rigid jointed frames

S.No	Particulars	Dimension/Size/Value
1.	Model	G+50
2.	Seismic Zones	IV
3.	Floor height	3M
4.	Basement	4M
5.	Building height	161.6m
6.	Plan size	20mx12m
8.	Size of columns	0.3mx0.75m
9.	Size of beams	0.3mx0.75m &0.3mx0.6m
10	Shear Walls	0.23m
11.	Thickness of slab	125mm
12.	Earthquake load	As per IS-1893-2002

Seismic Load

As per IS: 1893, Noida is located in Seismic Zone IV.

Design base shear, V = Z I W Sa/2 R g

Wind Load

The wind velocity at Noida is 47m/s. The other parameter of wind load as per IS: 875 (Part-3).

IV. ANALYSIS RESULTS AND DISCUSSIONS

The results of the models analysed have been tabulated and plotted here. More or less the results are as expected. The results are tabulated both individually for each type of building as well as for comparison between different models to study their comparative merit or demerit for each type of building.

Table 2 Seismic Parameter

Seismic Parameters				
Seismic Zone (Z)		IV	Soil Type (S)	Medium
Response Reduction Factor (R)		5	Importance Factor (I)	1
Seismic Weight (W)		480435.44	Zone Factor	0.24
Total Height (m)		170	Length along X (m)	32
Basement Height (m)		8	Width along Y (m)	21
Height of Mumty (m)		0	Effective Height (m)	170
Acceleration, g (mm/s^2)		9806.65	Default Scale Factor	980.67
EQX	-4431.816	0.00E+00	Scale X	**1.00**
EQY	0.00E+00	-4431.8159		980.67
SPECX	4431.8012	0.0012	Scale Y	**1.00**
SPECY	0.0006	4431.8136		980.67

Time Period and Base Shear						
Detail	Time Period (s)		S_a/g	A_h	V_B	% A_h
Bare Frame	T_a	**3.531**	0.385	0.0092	4441	0.92%
Above Basement	T_a	**3.406**	0.399	0.0096	4605	0.96%
With Infil	T_x	**2.705**	0.503	0.0121	5798	1.21%
	T_y	**3.339**	0.407	0.0098	4697	0.98%
Avarage	$T_{avgx.}$	**3.118**	0.436	0.0105	5030	1.05%
	$T_{avgy.}$	**3.435**	0.396	0.0095	4565	0.95%
Above Basement	T_x	**2.577**	0.528	0.0127	6084	1.27%
	T_y	**3.182**	0.427	0.0103	4929	1.03%
Without Mumty	T_x	**2.705**	0.503	0.0121	5798	1.21%
	T_y	**3.339**	0.407	0.0098	4697	0.98%

Building Lateral Displacement Check						
Permissible	WLX	340	Actual	WLX	267.5	**SAFE**
	WLY	340		WLY	627	**FAIL**
	EQX	680		SPECX	272	**SAFE**
	EQY	680		SPECY	331.9	**SAFE**

Permissible	WLX	340	Actual	DL+WLX	267.5	SAFE
	WLY	340		DL+WLY	627	FAIL
	EQX	680		DL+SPECX	272	SAFE
	EQY	680		DL+SPECY	331.9	SAFE
Permissible	WLX	340	Actual	DL-WLX	267.5	SAFE
	WLY	340		DL-WLY	627	FAIL
	EQX	680		DL-SPECX	272	SAFE
	EQY	680		DL-SPECY	331.9	SAFE

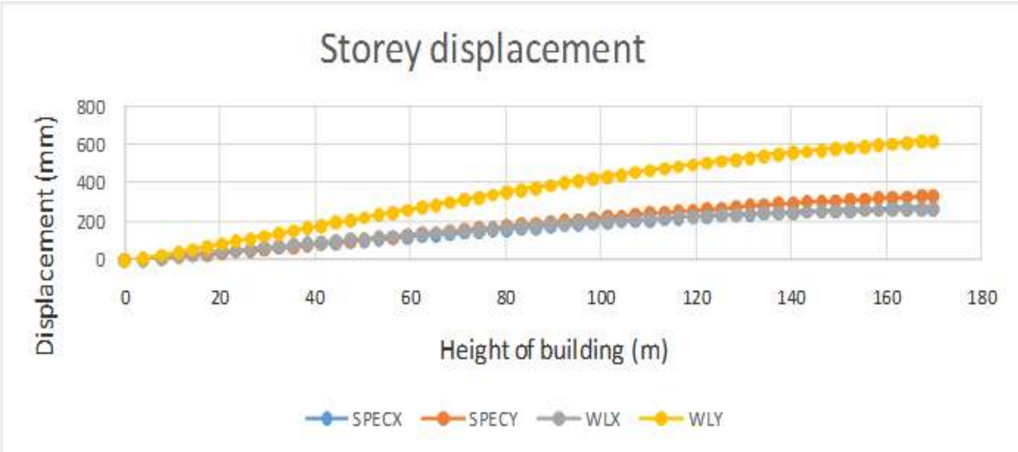

Fig **3** Storey displacement Type A

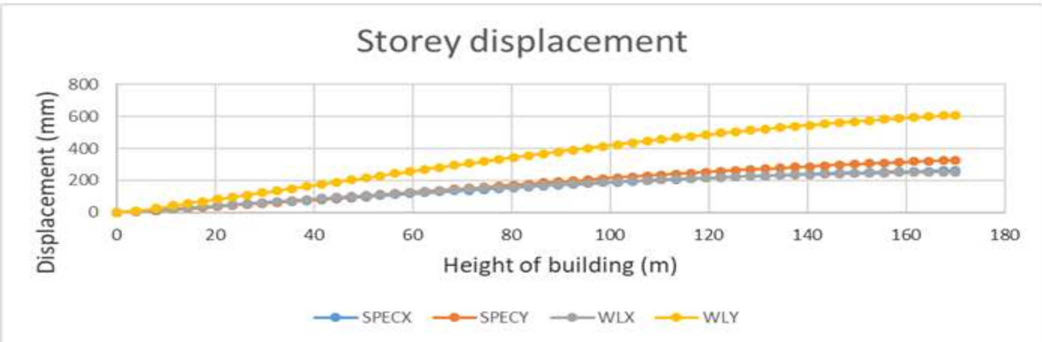

Fig 4 Storey displacement Type B

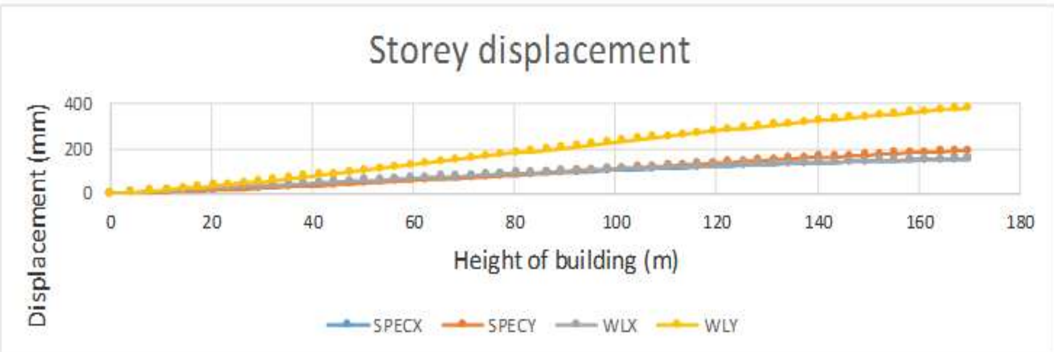

Fig 5 Storey displacement Type C

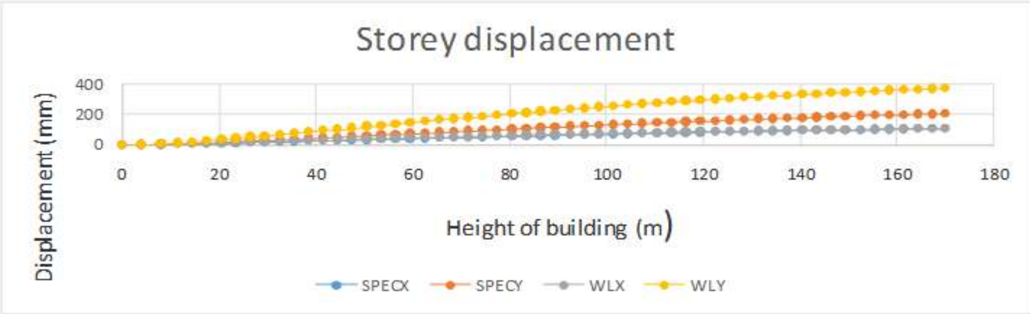

Fig 6 Storey displacement Type D

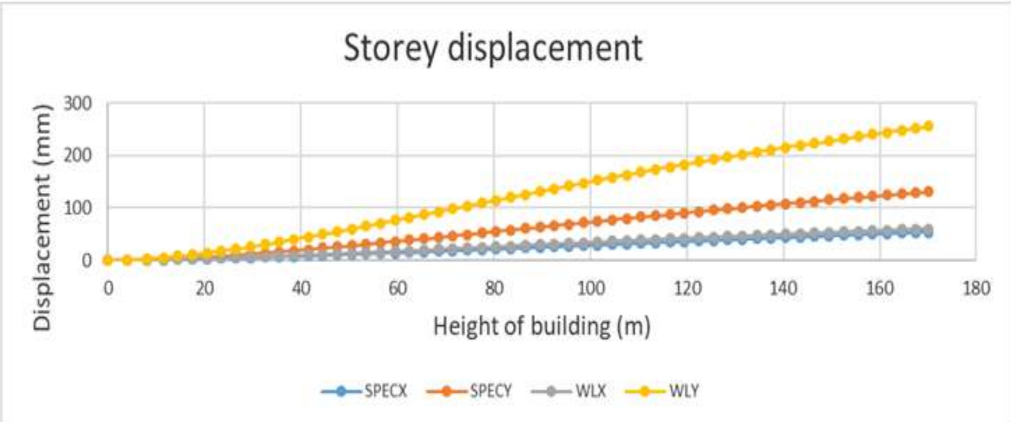

Fig 7 Storey displacement Type E

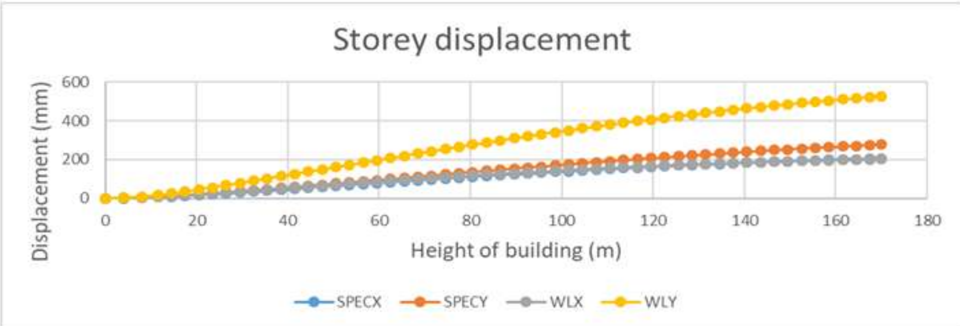

Fig 7 Storey displacement Type F

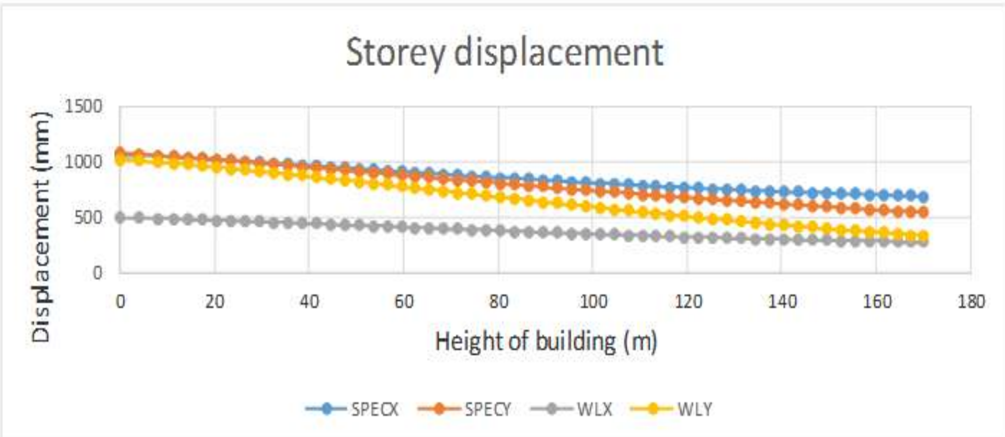

Fig 8 Storey displacement Type G

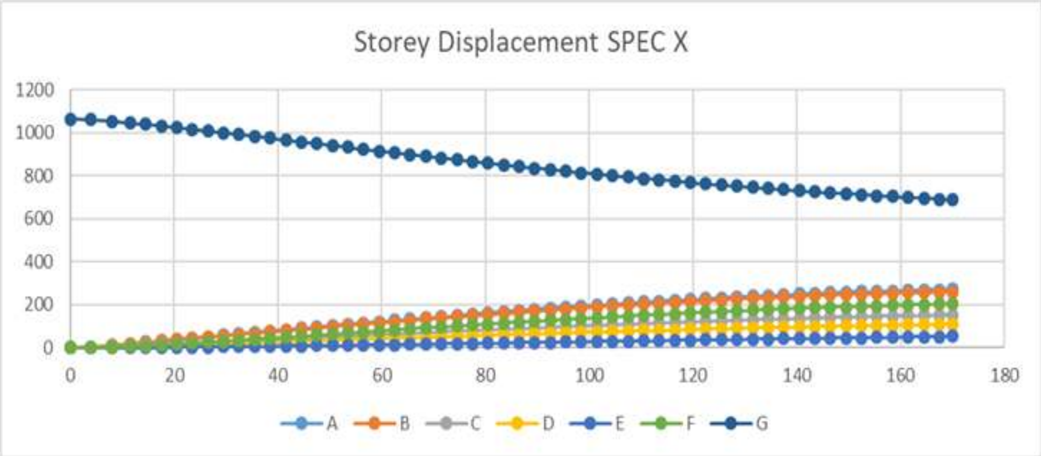

Fig 9 Storey displacement Type A

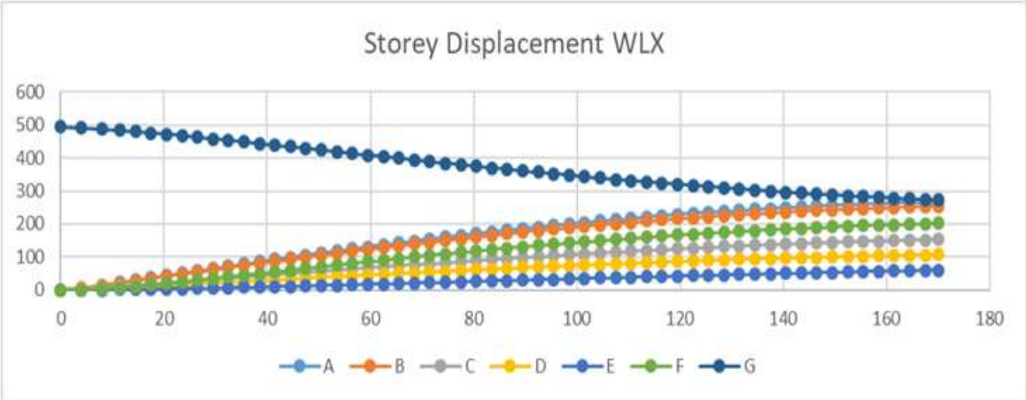

Fig 10 Storey displacement Type A

Table 3 Base Shear (kN)

Base Shear (kN)							
Load	Type A	Type B	Type C	Type D	Type E	Type F	Type G
SPEC X	4268.132	4481.458	4475.327	4727.562	5139.829	4388.14	11369.01
SPEC Y	4268.117	4481.43	4475.322	4727.565	5063.677	4414.117	11137.94
WLX	5145.435	5145.435	5145.435	5145.435	5145.435	5145.435	5145.435
WLY	10080.85	10080.85	10080.85	10080.85	10080.85	10080.85	10080.85

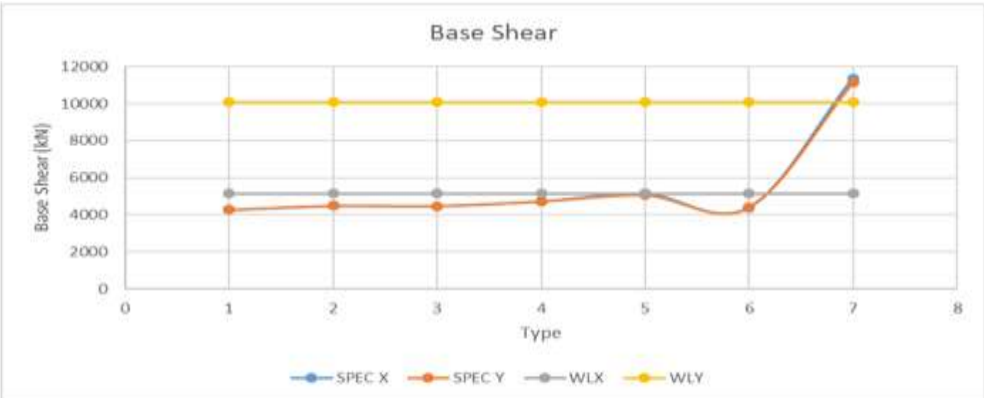

Fig 11 Base Shear (kN)

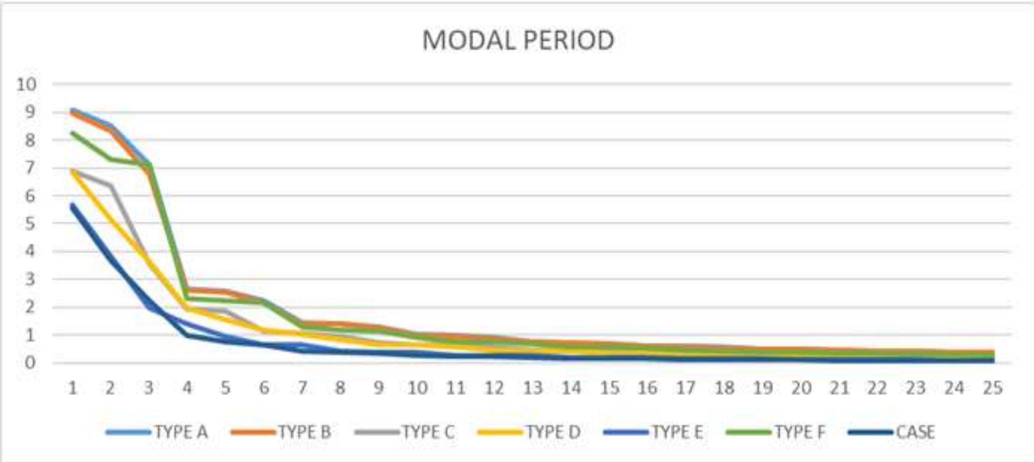

Fig 12 Modal Period

V. CONCLUSIONS

Seven types of models have been considered for analysis along with one case study. It was attempted to choose models that are representative of actual building types that are being constructed nowadays. Care was taken to incorporate the fundamental concepts governing the design of hybrid innovative tall structures being constructed these days. Type A is regular framed structure with columns. Type B hybrid framed structure with bracing in the periphery at each bay on every floor. Type C hybrid framed structure with bracing in the periphery at different bays and different storeys. Interestingly this type works better than regular bracing. Type D is tube structure. Type E is Tube in Tube system. Type F was modelled with Tuned Mass Dampers. Type G was modelled with Base Isolators. And one complete building with 5BHK flat having beams, slabs and shear walls modeled in the structure was also analyzed for comparisons.

A look at the comparison plots for responses of all the types suggest the following conclusions.

Type G, model with base isolation has the maximum base shear as well as storey displacement at the base. This is the allowable displacement in order to dissipate the energy which is beneficial for the structure.

In decreasing order of base shear, we have the models respectively as Type E (Tube in Tube), Type D (Tube), Type B (Bracing Type 1), Type C (Bracing Type 2), Type F (Model with Tuned Mass Dampers) and finally Type A (Regular Framed). It is interesting to note that Type A still attracts the lowest base shear and is the most lightweight structure.

Both the braced structures showed one very interesting behavior. Type C, where bracing has been done at a gap of few floors is much lighter than Type B, where bracing has been done at every floor. But, the storey displacement of Type C is much reduced than Type B. We may conclude that, if bracing system is chosen then bracing as given by Type C is most suitable for tall structures. Type B while effective to some extent is not much economical.

Tube in Tube systems, as in case of Type E attracts much more base shear than Tube structures as in Type D, but the displacement is much less. This is an ideal situation where our structure is sufficiently heavy as well as rigid. Shear walls are effective in buildings only up to certain height limits, usually within 35 – 40 storeys, but structures in the form of Tube or Tube in Tube perform much better than regular shear wall structures.

Type F is our model with Tuned Mass Dampers. It is seen that the mass of the structure is not increased by more than 1 – 2 percent of the mass of the regular structure, but its displacements are considerably reduced. This is being clearly validated by the response of Type F model which has almost same base shear as Type A, but much less storey displacement than Type A.

The approach for design of structures for wind and earthquake are diagonally apart. Wind forces are generally push forces that tries to topple or bend the structure vertically. They are applicable on the exposed face of the structures. In order to safeguard the structure for wind, one very simple solution can be to make the structure heavier. Heavier the structure, better its ability to resist wind forces.

But earthquake forces are totally different. They are basically inertia forces, which depend on the mass of the structures. The structures on action of earthquake forces rarely topple over or fall down. They actually collapse just under its own vertical axis. Since earthquake forces depend upon the weight/mass of the structure, heavier the structure, more earthquake force it attracts. The idea is to make the structure lighter. Lighter the structure, better it is for the structure to resist earthquake forces.

To be able to balance, these two contradictory principles of design is a real challenge for structural engineers.

REFERENCES

[1]. Ashik S. Parasiya Paresh Nimodiya "A review on comparative analysis of brace frame with conventional lateral load resisting frame in rcc structure using software".
[2]. Suresh P, Panduranga Rao B, Kalyana Rama J.S "Influence of diagonal braces in RCC Multi-storied frames under wind loads: A case study
[3]. Umesh.R.Biradar, Shivaraj Mangalgi **"**seismic response of reinforced concrete structure by using different bracing systems".
[4]. Mohammed yousuf, P.M. shimpale "Dynamic Analysis of Reinforced Concrete Building with Plan Irregularities".
[5]. Mr. S.Mahesh, Mr. Dr.B.Panduranga Rao "Comparison of analysis and design of Regular and irregular configuration of multi-Story building in various seismic zones and Various types of soils using ETABS and STAAD".
[6]. Nauman Mohammed, Islam Nazrul "Behaviour of Multistorey RCC Structure with Different Type of Bracing System (A Software Approach)".
[7]. S.Zubair Ahmed, K.V.Ramana, Ramancharla Pradeep Kumar "Seismic Response of RC frame structure with soft storey".
[8]. Jain. S K, IIT Roorkee Review of Indian seismic code, IS 1893 (Part 1): 2002
[9]. Reddy K. R. C, Sandip A. Tupat (2012). "The effect of zone factors on wind and earthquake loads of high-rise structures" .
[10]. Shahzad Jamil Sardar and Umesh. N. Karadi (2014) **"**effect of change in shear wall Location on storey drift of multistory building subjected to lateral loads".
[11]. S.R. Thorat and P.J. Salunke **"**Seismic Behaviour of Multistorey Shear Wall Frame Versus Braced Concrete Frames".
[12]. David T. Finley, Ricky A. Cribbs "Equivalent Static vs. Response Spectrum A Comparison of Two Methods".

AUTHORS PROFILE

Mr. Mirza Aamir Baig has done M.Tech in "Earthquake Engineering (Structures)" from Jamia Millia Islamia.

He has a 6 years of academic experience at Alfalah University. He pursued B.Tech(Civil Engineering)from Bharath University at Chennai. He has worked at NTPC, Nabinagar (Bihar) in construction domain. He has done one-year project on "Offshore jacket Platform using SACS Software".
His area of expertise includes "Earthquake Resistant Design of structures "and the software like "STADD, ETAB, SACS and SAP" for analysis of structures. He is also a freelance designer in "Building Design".

Mirza Aamir Baig" Innovative Design of Tall Buildings" International Journal of Engineering Research and Applications (IJERA), Vol. 09, No.08, 2019, pp. 42-51