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Analysis of Different Structural System of Tall Building

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Abstract - In the new era of the construction industry, the building height is observed more and more slender and more susceptible to sway and hence dangerous in the earthquake, It has been a task of a structural engineer to find a good structural system. A good structural system can easily resist lateral load and easily transfer the lateral load to the soil. For that, shear wall and bracing are a good solution for resisting the lateral loads. Also, there so many systems use in the high-rise building. In the present study, various lateral load resistance systems have been introduced that can inhibit lateral forces, which improves the strength and stiffness of column such as Moment frame systems, Moment frame - structural wall systems (MFS), Framed-tube system (FT), Tube-in-tube system (TT), Outrig ger trusses, Outrigger with variable depth trusses, Outrigger trusses with belt trusses, Diagrid uniform angle, Diagrid Varying-angle. All the models are satisfying. Indian structural codes - IS 456-2000, IS 1893 - 2016, 2016, IS 132920, IS 875. All the structural system is compared with different height to rectify the lateral load impact with increasing the building height. The analysis of the structure is done in Etabs 2018 software.

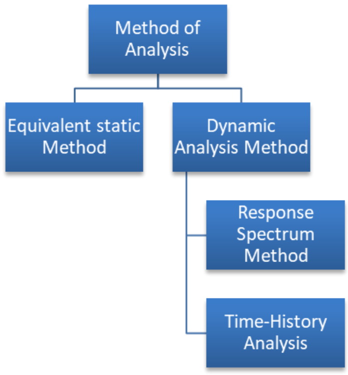
***Key Words*:** High Rise Building, Moment frame systems, Moment frame - structural wall systems, Framed-tube system, Diagrid System, Outrigger system, Story drift, Story Displacement, Base Shear optics, photonics, light, lasers, templates, journals

1.INTRODUCTION

High-rise structures are becoming increasingly popular around the world. The fundamental goal of current construction technology and computer software has been to develop safer buildings while keeping the project's overall finances in mind. A high-rise building, often known as an apartment tower, an office tower, an apartment block, or a block of flats, is a tall structure used for residential and/or commercial purposes. In different places, they are referred to as "Multi Dwelling Units" or "Vertical Cities." Understanding the behaviour of structural members subjected to stresses and loads and constructing them with economy and elegance to provide a safe, serviceable, and enduring structure is what structural design is all about. Varied design methodologies and codes produce different outcomes in structural analysis and design, resulting in variations in structure behaviour, costs, and durability. This type of research yields a wealth of knowledge about structural design, such as how one country code differs from another in terms of correctness, safety, complexity, and details.

1.1 Method of Analysis for lateral loads

Equivalent Lateral Force (ELF) Analysis & Response Spectrum Analysis are types of linear elastic analysis but the difference is, one is static analysis while the other is dynamic analysis. In the present study, the analysis of the structure is made for seismic loads using Response Spectrum Analysis.



- **Equivalent Lateral Force (ELF) Analysis**

The ELF analysis is based on a static cantilever beam assumption. There is a minor influence of the second mode of the structure being taken into account in the tale shear distribution, but nothing more. The amount of seismic base shear taken into account for building design is determined by the building's estimated period, site-specific ground acceleration and reaction spectrum curve, site class, and kind of building system utilized to resist lateral forces. This type of analysis should only be utilized when the structure is symmetric, torsion is limited, there are no vertical or horizontal abnormalities in the system, and the principal mode of the structure governs the structural dynamics. This indicates that ELF analysis produces rather accurate findings for short, symmetrical, and regular structures.

- **Response Spectrum Analysis (RSA)**

A dynamic analysis of a structure is known as RSA. It's called dynamic analysis because it considers the structure's mode shapes and modal mass participation for various building frequencies. There are multiple vibration frequencies in each building, not simply one. When an earthquake strikes, the building's response is a combination of the building's natural frequencies. You must realize that no structure, whether man-made or natural, would ever respond to earthquakes that occur outside of its natural frequency. The shape each mode generates is known as an eigenvector, and the frequencies of the structure are known as eigenvalues. Only the first few natural frequencies are required to capture the structure's overall reaction. Because RSA is based on the building's mode shapes and natural periods, it records a more realistic "natural" reaction to seismic shaking. Because the storey forces are generated using eigenvectors, storey accelerations, and storey mass, the building's "dynamic" response is more realistic.

- **Time History Analysis**

It is an analysis of the dynamic response of the structure at each increment of time when its base is subjected to a specific ground motion history. This means the method requires site-specific ground motion studies. However, in the majority of cases, the time history method is not warranted.

2. ALALYSIS & DESIGN

This study's methodology is based on a comparison of structural system behavior on tall buildings with various types of structural systems for different building heights, storeys, and load intensities. Shear walls, outriggers, and diagrid are all taken into account in this project, with outriggers being placed in the best possible area to ensure optimum use. This research is meant to assist clarify the complexity in selecting the appropriate type of system for a building based on the height, location, and loading intensities of the structure.
Comparison of Various Structural systems are mentions below,

1 Moment frame systems (M.F)
2 Moment frame - structural wall systems (M.F.S)
3 Framed-tube system (F.T)
4 Tube-in-tube system (T.T)
5 Outrigger trusses (O.T)
6 Diagrid uniform angle (D.G)

2.1 Model Configurations

All models have prepared using Etabs software each system have 5 models according to 10 to 50 story building.

Geometry Data	
No of storey	50,40,30,20,10
Span of building	32 x 30 M
Floor height	3.0 M
Height of the building	150 M
Grade of Concrete	M 45, M 30
Grade of Steel	HYSD 550

Loading Data	
Live load	2 KN / Sqm
Super dead load	1 KN / Sqm
Partition load	14 KN / M
Partition load (INTERIOR)	10 KN / M
Seismic parameter	
Zone	III
Zone factor	0.16
Soil type	Medium
Response reduction factor	3
Importance factor	1.2
Time Period (X)	2.386,1.909,1.431,0.954,0.477
Time Period (y)	2.464,1.971,1.478,0.985,0.492

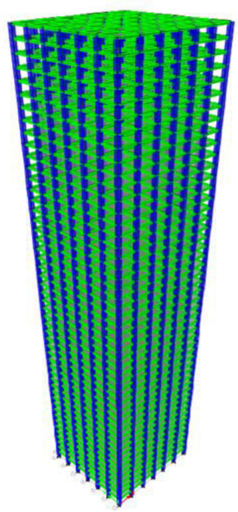


Fig-Moment Frame System

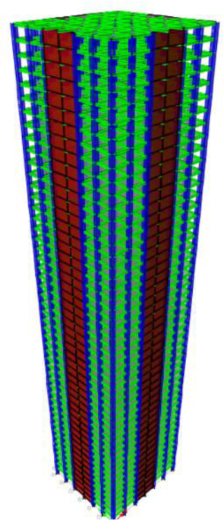


Fig-Moment Frame Structural wall

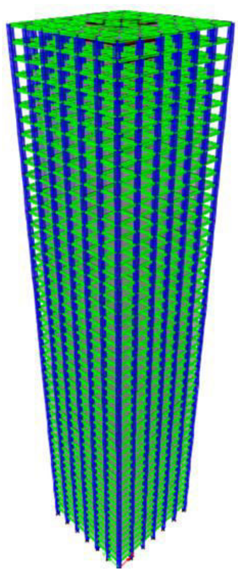


Fig -Frame Tube System

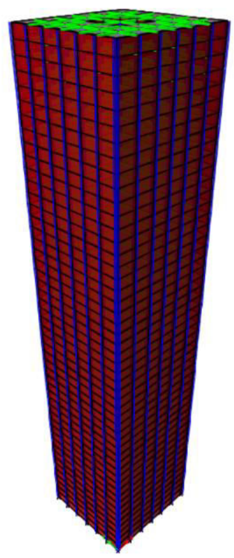


Fig -Tube-in-Tube System

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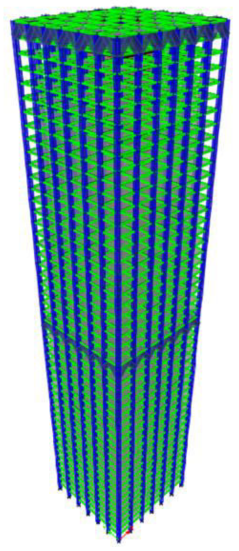


Fig -Out-Trigger System

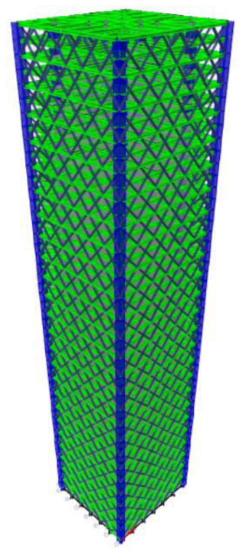


Fig -Día-Grid System

2.2 Loadings

- Dead Load

The building weight and its content is considered in the dead load and calculated based on material densities by the program

- Live Load

The building live load is taken as 2kN/m² Super Dead load is taken as 1kN/m²

The Partition loads (outer) is taken as 14 KN/m and Partition load (interior) is taken as 10 KN/m

- Seismic Load

For the analysis, various types of structures were investigated. As a result, using Table 9 of IS 1893(Part I) 2002, the response reduction factor is R=3.0.

Because this structure can be used as a general structure, the Importance factor, I=1.0 from Table 8 of IS 1893(Part I) 2002 is used to represent its structural importance.

The behavior of all structural systems is analyzed for seismic zone III, as defined by IS 1893(Part I) 2002. According to Table 2 of IS 1893(Part I) 2002, the Zone Factors and Seismic Intensities are as followed.

Natural Time Period for Rigid System

$T_a = (0.09 \times h)/\sqrt{d}$

- Wind Load

Wind loads will be developed according to Indian standard.

Basic Wind Speed Vb = 39, Terrain category =4, Structure class=B

Risk co-efficient k1=1, Topography k3=1

- Assumptions

1. Material: It is assumed that concrete is linearly elastic. Where the specified concrete compressive strength $f'c$ is considered to be 30 Mpa, as used in practical tall building applications.
2. Participating components: Only the fundamental structural components are thought to be involved in the overall behavior. Secondary structural components and nonstructural components, such as staircases, partitions, cladding, and apertures, are thought to have insignificant effects.
3. Floor slabs: in all models, floor slabs are assumed to be rigid in plane and have a thickness of 150 mm.
4. Cracking: Reduced moment of inertia represents the effect of cracking in reinforced concrete members caused by flexural tensile stresses.
5. Constraints: Fixed supports are the supporting bases of all structural models.

3. COMPARTION OF ANALYSIS RESULT

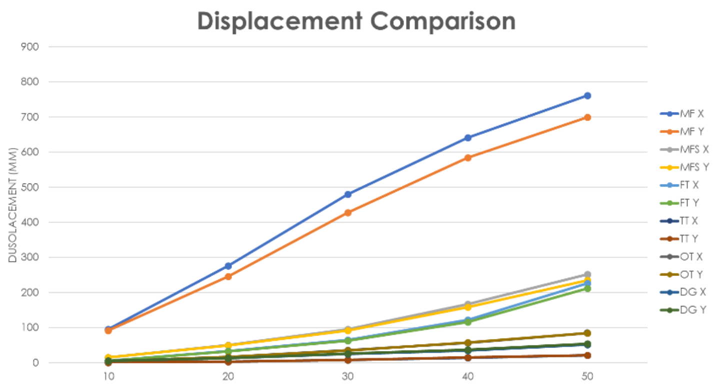
3.1 Comparison of Maximum Displacement

H	M.F		M.F.S			F.T		
	X-Dir	Y-Dir	X-Dir	Y-Dir	% (dec.)	X-Dir	Y-Dir	% (dec.)
10	95.86	91.29	15.352	15.02	83%	6.297	6.288	93%
20	276.3	245.9	50.611	49.37	81%	34.05	32.88	87%
30	480.1	428.1	95.34	92.30	80%	64.96	62.22	86%
40	641.3	584.2	167.5	158.1	73%	122.70	115.8	80%
50	761.9	699.4	251.4	235.6	67%	226.30	212.3	70%

T.T			O.T			D.G		
X-Dir	Y-Dir	% (dec.)	X-Dir	Y-Dir	% (dec.)	X-Dir	Y-Dir	% (dec.)
0.86	0.934	98%	4.024	4.026	95%	5.319	5.707	94%
3.404	3.568	98%	17.23	16.92	93%	12.40	13.47	95%
8.084	8.547	98%	35.89	35.35	92%	25.45	26.67	94%
14.31	15.057	97%	56.97	58.10	90%	35.26	37.52	94%
21.16	22.028	97%	84.76	84.44	88%	51.73	54.45	92%

The above table show the comparison of different structural system when response spectrum load case applied to building. A moment frame structural system is not satisfying Indian standard displacement limitation while all other models are passed the displacement limitations.

As per the result of displacement the tube in tube structure is more resistive to lateral load as compare to dia grid structure but the tube is tube system is not economical as well as not acceptable as per architectural and practical requirements so, dia grid structural system is more advisable.

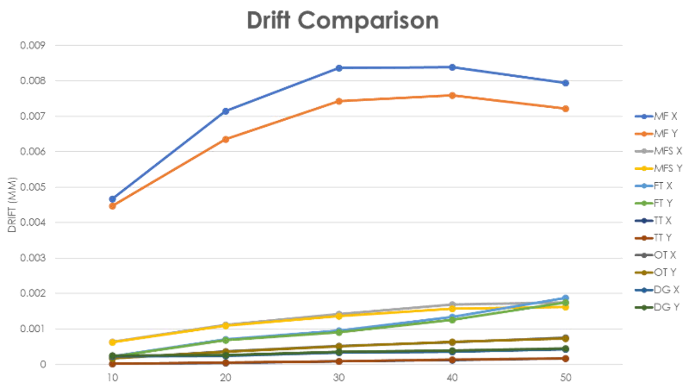


3.2 Comparison of Maximum Drift

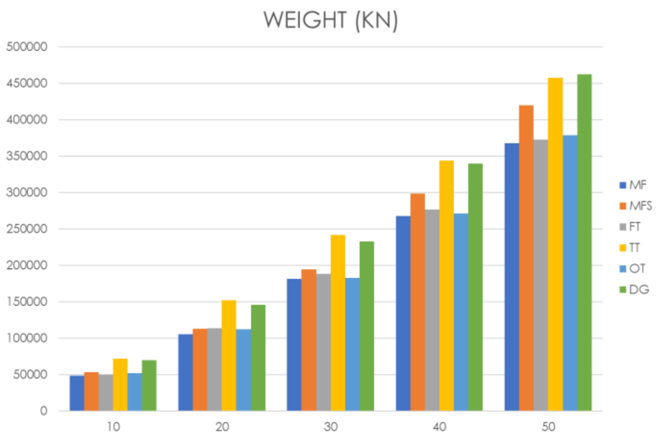
H	M.F		M.F.S			F.T		
	X-Dir	Y-Dir	X-Dir	Y-Dir	% (dec.)	X-Dir	Y-Dir	% (dec.)
10	0.00467	0.004466	0.00064	0.000626	86%	0.000224	0.000223	95%
20	0.007144	0.006359	0.001121	0.001091	84%	0.00071	0.000684	90%
30	0.00836	0.007427	0.001416	0.001365	83%	0.000955	0.000912	88%
40	0.008387	0.00759	0.001685	0.001578	80%	0.00134	0.00126	84%
50	0.007942	0.007216	0.00175	0.001621	78%	0.001872	0.001745	76%

T.T			O.T			D.G		
X-Dir	Y-Dir	% (dec.)	X-Dir	Y-Dir	% (dec.)	X-Dir	Y-Dir	% (dec.)
0.00001	0.000018	99%	0.000168	0.00016	96%	0.000234	0.00024	95%
0.00004	0.000048	98%	0.000369	0.00036	94%	0.000245	0.00026	96%
0.00008	0.000093	98%	0.000523	0.00051	93%	0.000335	0.00035	95%
0.00012	0.000137	98%	0.000624	0.00063	92%	0.000361	0.00038	95%
0.00016	0.000173	97%	0.000759	0.00073	90%	0.000428	0.00045	94%

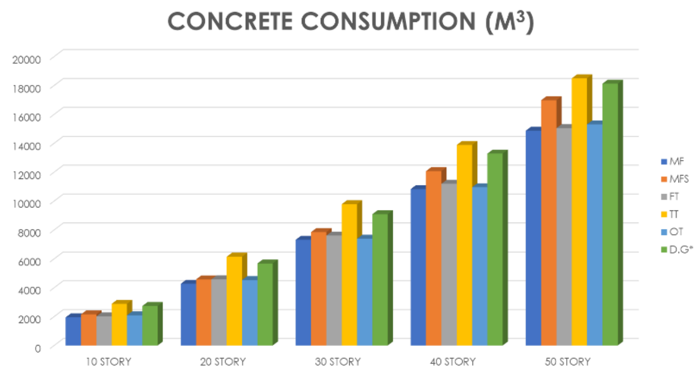
The above table represent the value of drift while application of response spectrum load case. All the structural system is passed in drift limitation criteria as per Indian standard code. All the models are compared with the conventional moment frame structure.



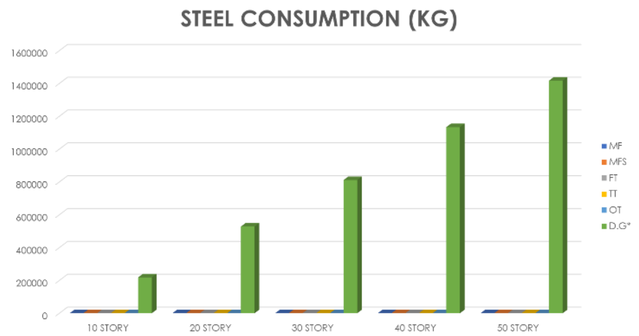
3.3 Comparison of weight



3.4 Comparison of concrete consumption



3.5 Comparison of structural steel consumption



4. CONCLUSIONS

1. Up to 20 story M.F.S and F.T system perform almost similar also the section sizes is same therefore up to 20 story structure moment frame system is better.
2. After 20 story the Tube system is better because of the more resistant of lateral load with lower section sizes.
3. In the Tube in Tube structure, the maximum top storey movement is significantly less. Additionally, Storey Drifts of Tube in Tube Structure Systems are very less proportional to the tube, shear wall, and moment frame systems. And, when compared to other lateral systems, it is more effective in resisting lateral stresses, but it increases the concrete quantity, making it an uneconomical option.

4 Frame tube system is more economical and suitable proportional to Tube in Tube systems.
5 The outrigger system is more resist to lateral load as compare to all other system except tube in tube system,
6 Also, tube in tube system is very much costlier as the point of economic as well as safe the outrigger system is best option.
7 The outrigger system is not only good at regulating overall lateral displacement, but it's also good at preventing inter-storey drifts in tall buildings.

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