

Comparative Study of Tube in Tube Structure and Frame Tube Structure

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Abstract - Now a day there is need for multi-storied building due to overcrowding of cities. Multi-storied buildings are used for office, complex, residential flats, public centre's, etc. These multistoried buildings can be transformed into tall buildings in order to achieve more floor space but occupy less land space. Over the past few years tubular structures are becoming a common feature in tall buildings. Tube structures are particularly suitable for all tall buildings. In the design of tall buildings, lateral loads play predominant role. The lateral loads are wind load and seismic load. The seismic analysis is carried out by using Equivalent static method. The modeling and analysis is done using staad pro software. The Frame Tube Structure and Tube in Tube Structure are modeled and compared with the conventional moment resisting frame Structure. The Analysis and comparison is made for characteristics such as maximum displacement and Storey Drift of these structures. The study of seismic behaviour of tube structures is carried for these structures for zone IV.

Key Words: High rise buildings, Seismic analysis, Equivalent static method, Tube structure, staad pro.

1. INTRODUCTION

With the application of new materials and advanced technologies, modern tall buildings are becoming lighter and more slender than their predecessors, thus they are more sensitive to wind forces and earthquake forces. In addition, along with the development of modern cities, a large number of tall buildings may be constructed in a small zone. The interference effects of wind loads and earthquake load responses on tall buildings depend largely on their relative location, building geometry, upstream terrain, building orientation and wind velocity, etc.

The correct estimation of the wind forces and earthquake forces acting on tall buildings is very essential for the safe design of structural elements. Such RCC buildings are analysed and designed for wind and earthquake under software environment.

1.1 Seismic Design

Structural design of buildings for seismic loading is primarily concerned with structural safety during major earthquakes, but serviceability and the potential for economic loss are also of concern. Seismic loading requires

an understanding of the structural behavior under large inelastic deformations. Behavior under this loading is fundamentally different from wind or gravity loading, requiring much more detailed analysis to assure acceptable seismic performance beyond the elastic range. Some structural damage can be expected when the building experiences design ground motions because almost all building codes allow inelastic energy dissipation in structural systems.

1.2 Need of Seismic Analysis

A large number of reinforced concrete multistorey frame buildings were heavily damaged and many of them collapsed completely in Bhuj earthquake of 2001 in the towns of Katch District (viz., Bhuj, Bhachao, Anjar, Gandhidham and Rapar) and other district towns including Surat and Ahmadabad. In Ahmadabad alone situated at more than 250 kilometres away from the Epicentre of the earthquake, 69 buildings collapsed killing about 700 persons. Earlier, in the earthquake at Kobe (Japan 1995) large number of multistorey RC frame buildings of pre 1981 code based design was severely damaged due to various deficiencies. Such behaviour is normally unexpected of RC frame buildings in MSK Intensity VIII and VII areas as happened in Katch earthquake of January 26, 2001. The aim of this Project is to bring out the main contributing factors which lead to poor performance during the earthquake and to make recommendations which should be taken into account in designing the multistorey reinforced concrete buildings so as to achieve their adequate safe behaviour under future earthquakes. The Indian Standard Code IS: 1893 was suitably updated in 2002 and 2016 so as to address the various design issues brought out in the earthquake behaviour of the RC Buildings.

1.3 Material Properties

In India, the design of the reinforced concrete frames is based on IS 456 design code. A typical value of concrete compressive strength, f_{ck} and reinforcing yield stress, f_y is equal to 25 N/mm² and 415 N/mm² respectively. The concrete modulus elasticity, E is 20000 N/mm² and shear modulus, G is 10000 N/mm² were taken in the design consideration. These values were applied for all modal frames which were assumed designed for similar strength of materials.

1.3 Loadings

There are two types of loads that are considered in this study; i) gravity load ii) lateral load. Gravity loads carried the dead load and live load, while lateral loads considered either wind, seismic or earthquake loads.

Gravity Load

This loading represents all tributary dead loads and live loads. The dead load included cladding and concrete self weight with concrete density equal to 25kN/m^3 . Based on IS: 456, the live load was taken as 3.0kN/m^2 for each building which are categorized under residential and offices occupancy class. The loads were distributed uniformly on all beams between of column lines.

Lateral Load

In order to compare the performance of wind and earthquake loads on the reinforced concrete buildings, the static lateral loads of wind and earthquake forces were analyzed. Besides, for the comparison purpose of existing lateral load design in IS 1893:2002. Earthquake load can be evaluated by three methods, such as Equivalent static method, Response Spectrum method & Time History Analysis method.

1.3 Objectives

1. To Analyse Tube Structures.
2. To Study Seismic Behaviour of Tube Structures.
3. To Analyse Effect Of Earthquake Loads On Tube Structures.

2. TUBE STRUCTURE

In engineering tube system, a building is designed to act like a hollow cylinder, cantilevered perpendicular to the ground in order to resist lateral loads (wind, seismic, etc.). This system was introduced by Fazlur Rahman Khan while at Skidmore, Owings and Merrill's (SOM) Chicago office. The first example of the tube's use is the 43-story Khan-designed DeWitt-Chestnut Apartment Building in Chicago, Illinois, completed in 1963.

The system can be constructed using steel, concrete, or composite construction (the discrete use of both steel and concrete). It can be used for office, apartment and mixed use buildings. Most buildings in excess of 40 stories constructed since the 1960s are of this structural type.

2.1 Concept

The tube system concept is based on the idea that a building can be designed to resist lateral loads by designing it as a hollow cantilever perpendicular to the ground. In the simplest incarnation of the tube, the perimeter of the

exterior consists of closely spaced columns that are tied together with deep spandrel beams through moment connections. This assembly of columns and beams forms a rigid frame that amounts to a dense and strong structural wall along the exterior of the building.

This exterior framing is designed sufficiently strong to resist all lateral loads on the building, thereby allowing the interior of the building to be simply framed for gravity loads. Interior columns are comparatively few and located at the core. The distance between the exterior and the core frames is spanned with beams or trusses and intentionally left column-free. This maximizes the effectiveness of the perimeter tube by transferring some of the gravity loads within the structure to it and increases its ability to resist overturning due to lateral loads.

2.1 Types of Tube Structures

2.2.1 Framed Tube

This is the simplest incarnation of the tube. It can take a variety of floor plan shapes from square and rectangular, circular, and freeform. This design was first used in Chicago's DeWitt-Chestnut apartment building, designed by Khan and completed in 1963, but the most notable examples are the Aon Center and the original World Trade Center towers.

2.2.2 Trussed Tube

Also known as the braced tube, it is similar to the simple tube but with comparatively fewer and farther-spaced exterior columns. Steel bracings or concrete shear walls are introduced along the exterior walls to compensate for the fewer columns by tying them together. The most notable examples incorporating steel bracing are the John Hancock Center, the Citigroup Center and the Bank of China Tower.

2.2.3 Tube in Tube

Also known as hull and core, these structures have a core tube inside the structure, holding the elevator and other services, and another tube around the exterior. The majority of the gravity and lateral loads are normally taken by the outer tube because of its greater strength. 780 Third Avenue, a 50-story concrete frame office building in Manhattan, uses concrete shear walls for bracing and an off-center core to allow column-free interiors.

2.2.4 Bundled Tube

Instead of one tube, a building consists of several tubes tied together to resist the lateral forces. Such buildings have interior columns along the perimeters of the tubes when they fall within the building envelope. Notable examples include Willis Tower and One Magnificent Mile. The bundle tube design was not only highly efficient in economic terms, but it was also "innovative in its potential for versatile formulation of architectural space. Efficient towers no longer

had to be box-like; the tube-units could take on various shapes and could be bundled together in different sorts of groupings." The bundled tube structure meant that "buildings no longer need be boxlike in appearance: they could become sculpture.

3. LITERATURE REVIEW

Following technical papers of various journals are studied to understand the importance and necessity of the present research in consideration of wind and seismic resistant design.

Mohan K T¹, Rahul Y² and Virendra kumara KN³ (2017)

[1]: In this study G+59 story reinforced concrete building was considered. The structures is approximately 316.8 height, gravity and lateral load calculations can be done directly by SAP. The load combinations is based on IS: 456-2000 and IS 1893 (part1):2002. The two types of analysis method are carried out equivalent static and response spectrum analysis by comparing the square frame tubed structure, tube in tube structure reduces the displacement by 43.45%. Comparing the two square frame tube in tube structure rectangular, triangular and hexagonal structures are increased displacements by 34.8%, 62.72%, 43.34% respectively.

Basavanagouda patil (2016) [2]: In this study tall steel structure is used for the study having 88 number of floors of 3.6m height, total height is 316.8 m. the modal is analysed by using ETABS software. the analysis is done for tube structure of different configuration having square, rectangular, triangular, and hexagonal geometric configuration are modelled using ETABS. Dynamic time history analysis results are comparatively lower than that of the high rise structural system, dynamic analysis is preferable. From the overall results and discussion is can be concluded that structure is preferable for high rise structures in place of conventional beam column moment resisting frame steel system.

Tanneeru sreevalli, N. Harika priya(2017) [3]: In this study 30 story reinforced concrete building is modelled and analysed by ETABS software, which are having the different shear wall area to floor area ratio of tube in tube structure, using static earth quake and response spectrum an analysis method .

Nimmy dileep (2015) [4]: In this study the seismic performance of tube in tube structures three models were developed in SAP2000 software by varying location of the thinner tubes. And the structures is analyses by equivalent static, response spectrum method and also time history analysis is done and the output of three models are evaluated to have a comparative study of tier seismic performance . From the above study it is concluded that time history analysis predict the structural response more accurately than equivalent static analysis and response analysis.

Archana J (2016) [5]: In this study 16 story RC building was considered. The structures approximately 48.3m, tall and is 23m wide and 34.450m length, wind load and seismic load calculations are done by ETABS . here mainly static and repose spectrum analysis are carried from result comparing bare frame structure to other two systems .from the comparison of analysis result tube in tube structure with centres tube is recommended as a structural system for tall building than bare frame structures and tube mega frame systems.

4. METHODOLOGY

1. For the study reinforced concrete structure is considered, having 33 stories of height 115.5m each floors is considered as 3.5m height.
2. For the reference base model, a regular reinforced concrete moment resisting bare frame model is considered.
3. Tube-in-Tube and Frame Tube structure are modelled with reference to base model by using Staad-pro Software.
4. The floor height is kept constant for all models in order to get consistent results.
5. To understand the behaviour under lateral loads the loads are applied as per IS 1893: 2002 are used.
6. Based on the results and responses from applied gravity and seismic loads, conclusion will be made.

4.1 Modeling And Analysis

Three models are considered for analysis.

Model 1 CMRF -Conventional Moment resisting frame.

Model 2 FTS- Frame tube Structure.

Model 3 TITS- Tube in tube Structure.

Type Of Structure	CMRF	FTS	TITS
Zone	IV	IV	IV
Storey Height(mm)	3.5	3.5	3.5
No. Of Storey	33	33	33
Bay Length(mm)	3.2	3.2	3.2
Material	Fe415, M25	Fe415, M25	Fe415, M25
Size Of Columns(mm)			
Outer	0.8*0.8	0.8*0.8	0.8*0.8
Ground To 10thFloor	0.65*0.65	0.65*0.65	0.65*0.65
11th To 20th Floor	0.5*0.5	0.5*0.5	0.53*0.53
21st To 33rd Floor			
Inner	0.8*0.8	0.8*0.8	1.0*1.0
Ground To 10thFloor	0.65*0.65	0.65*0.65	0.8*0.8

11th To 20th Floor	0.5*0.5	0.5*0.5	0.65*0.65
21st To 33rd Floor			
Size Of Beams			
Main Beams	0.3*0.3	0.4*0.3	0.65*0.3
Secondary Beams		0.32*0.3	0.6*0.3
Slab Thickness	0.150	0.150	0.150

Type Of Structure	CMRF	FTS	TITS
Zone Factor(Z)	0.24	0.24	0.24
Importance Factor(I)	1.5	1.5	1.5
Response Reduction Factor(R)	5	5	5
Damping Factor	0.05	0.05	0.05
Period in X and Z dir.(seconds)	2.64	2.64	2.64

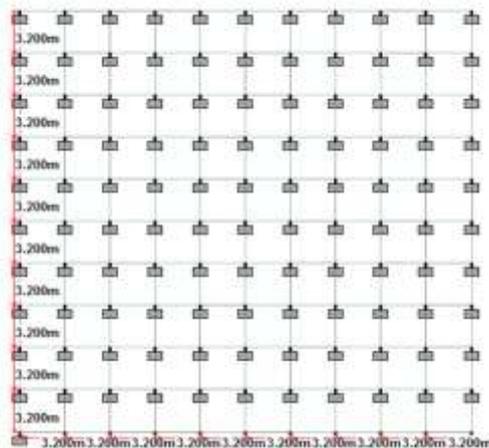


Fig -1: Conventional Moment resisting frame

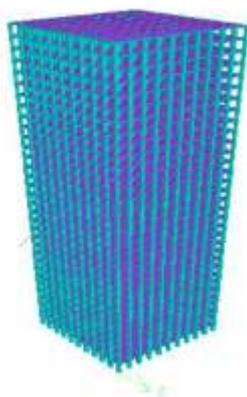


Fig -2: 3D Rendered View of CMRF

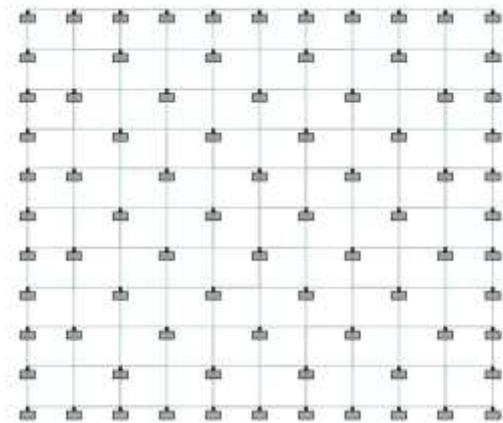


Fig -3: Plan of Frame tube Structure

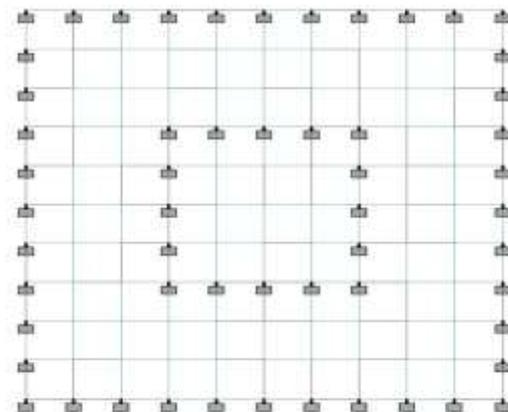


Fig -4: Plan of Tube in Tube Structure

5. RESULTS & DISCUSSION

Max. Results	Zones	CMRF	FTS	TITS
Node Displacement (mm)	Zone-IV	185.524	134.319	114.868
Storey Drift (mm)	Zone-IV	0.0019922	0.0017828	0.001394

Maximum Displacement

From above Results and below Graph given it is seen that, the maximum displacement is less for Tube in Tube Structure and Frame Tube structure than Conventional Moment resisting frame.

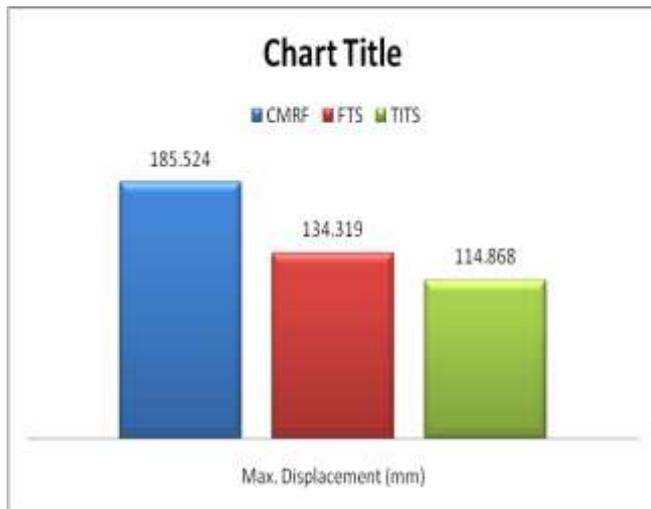


Chart -1: Max Displacement

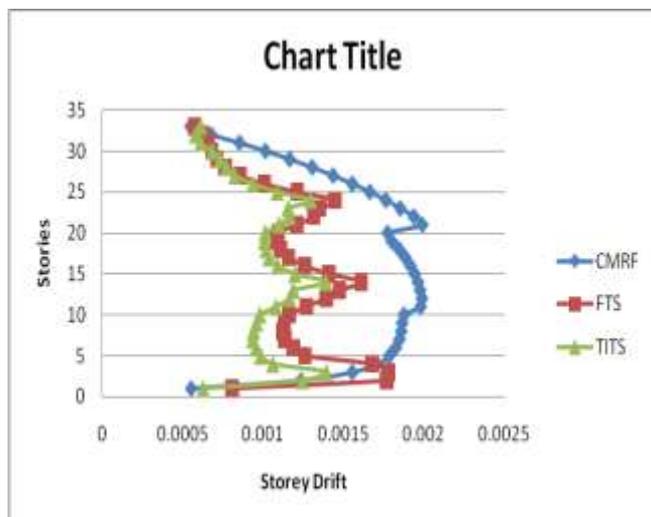


Chart -2: Storey Drift

Storey Drift

Storey drift is less for Tube in Tube structure and Framed Tube structure than Conventional Moment resisting frame which is major effect consider for seismic evaluation.

6. CONCLUSIONS

- Both Tube Structures strongly resists earthquake forces as compare to Conventional Moment resisting frame.
- Both Tube Structures strongly support the earthquake design philosophy of Strong Column and Weak Beam.
- Tube in Tube Structure reduces maximum displacement about 38% as compared to maximum displacement of Conventional Moment resisting frame for seismic zones IV.

- Frame Tube Structure reduces maximum displacement about 27% as compared to maximum displacement of Conventional Moment resisting frame for seismic zones IV.
- The story drift for tube in tube structure is reduced about 30.8% for zone IV in comparison to Conventional Moment resisting frame.
- The story drift for framed tube structure is reduced about 10.5% for zone IV in comparison to Conventional Moment resisting frame.

7. FUTURE SCOPE

This study work is restricted to only for one seismic zone that is zone-IV, no other zones are considered. In this study we used only equivalent static method for analysis. The future study can continue by following points,

- By considering other seismic zones such as zone II, III and V.
- By considering results of Base shear.
- By adopting other methods of seismic analysis such as

1. Response spectrum analysis
2. Time history analysis
3. Push over analysis

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