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COMPARATIVE STUDY OF DIAGRID STRUCTURE WITH OTHER STRUCTURAL SYSTEMS FOR TALL STRUCTURES

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ABSTRACT

The building became more and more slender because of vertical development due to less availability of land in recent year it is dangerous in the earthquake. In high rise buildings, lateral load governing force in design as the height of building increases, lateral load becomes more dominant than gravity load. Lateral load include Wind load and Seismic Load are act on the high rise building. These loads are resisted by various lateral load resisting systems. In this paper, discus aboutthe comparison of different types of lateral load resisting systems. The study mainly focuses on determining the most effective and economical system which can resist lateral load such as wind load and seismic load. Based on literature review, carry out comparative study of various lateral load resisting systems such as Shear wall, Belt Truss, Outrigger, Belt Truss + Outrigger, Diagrid, Staggered Truss, Tube in Tube system of 10 story structure with plan dimension of 18m X 18m. Analysis has been carried out using ETABS-2017 for different method of analysis for static earthquake forces, dynamic earthquake forces (Response Spectrum analysis as per guidelines of IS: 1893- (Part 1) 2016) and static wind forces as per IS 875 (Part-3)-2015 and design based on IS: 800-2000 and found that storey Displacements and storey drifts are observed to be less in Diagrid systems in X-Direction as compared to other lateral load resisting system.

Keywords: *High rise building, Structural system, Dynamic analysis, Seismic load, Wind load, Belt Truss, Outrigger, Belt Truss + Outrigger, Diagrid, Staggered Truss, Tube in Tube.*

I. INTRODUCTION

High rise building is playing a very important role in the development of any country in Morden world. India has faced many disaster activity in past such as earthquake, tsunami etc. In our country Earthquake has become more and more frequent in some part. As the earthquake is natural disaster, we cannot predict it but we can reduce damages by providing various lateral load resisting system in building. Buildings are subjected to two types of load (I) Vertical load due to gravity, and (II) Lateral load due to earthquake and wind. Lateral load resisting system is provided to resist seismic load and wind load. Generally multi-storey building is governed by lateral loads. Various Lateral load resisting systems are used to such as Shear wall, Belt Truss, Outrigger, Belt Truss + Outrigger, Diagrid, Staggered Truss, Tube in Tube etc. These systems may increase the stiffness of the structure and absorb lateral forces acting during earthquake and wind. In past many research was done by Zhao and Zhang (2014) Studied curved or straight diagonals, Khushbu and Paresh(2013) observed optimal angle for Diagrid structure ranges between 65° to 75°, Moon (2008) studied uniform angle Diagrid structures, with aspect ratios raging from about 4 to 9 and found the range of the optimal angle is from approximately 60 to 70 degrees, Mashhadiali and Kheyroddin (2012) Studied new structural system – Hexagrid According to the results hexagrid system has a better architectural view, more ductility and stiffness, Manthan at al. (2016) studied comparative study of Diagrid and Convention Frame building, Montuori et al.(2015) Studied Diagrids, horizontal Hexagrids and vertical hexagrid tube configurations and observed The optimal angle for the vertical hexagrid is in the range 40°–50°, Kim et al.(2009) According to the analysis results The braced tube structures showed greater strength compared with framed tube structures. In this paper, various Lateral load resisting systems are compared in terms of various parameters such as storey displacement, storey drift, Base shear, Modal time period result of static earthquake forces, dynamic earthquake forces -Response Spectrum method and static wind forces using ETABS-2017 software.

A. Shear wall: RC buildings often have vertical plates like RC wall called shear wall in addition to slabs, beams and columns. Shear wall generally starts at foundation level and are continued throughout the building height. Shear walls are like vertically oriented wide beams that carry earth quake loads downward to the foundation. Since shear wall carry large horizontal earth quake forces the overturning effect on them are large.

B. Belt Truss: Belt truss system is commonly used as one of the structural system to effectively control the excessivedrift due to lateral load, so that, during lateral load due to either wind or earthquake load, the risk of structural and non-structural damage can be minimized. It is a horizontal structure which is provided on perimeter to connect exterior column.

C. Outrigger: Outrigger is used to resist drift at particular storey. It is a horizontal structure which is connected to exterior column and the core to minimize the effect of lateral displacement in the top storey. Outrigger in two or three numbers depending upon the height of the building and storey displacement.

D. Diagrid System: This system consists of grids of RCC or steel placed in a structure diagonally with certain specific geometry. In Diagrid system, all vertical columns at the periphery is removed and replaced by inclined columns. Diagrid is particular type of truss which made up of a series of triangulated truss system. Diagrid structures are more effective in minimizing shear deformation because they carry lateral shear by axial action of Diagrid member.

E. Staggered Truss: The Staggered truss system is a type of structural steel framing used in high-rise buildings. The system consists of a series of story-high trusses spanning the total width between two rows of exterior columns and arranged in a staggered pattern on adjacent column lines.

F. Tube in Tube: A Tube in Tube is nothing but a normal frame structure but with closely spaced columns and spandrel beams located on the perimeter of the building. These structure are basically designed to act like a hollow tube which are perpendicular to the ground.

II. PARAMETRIC STUDY

For the parametric comparison, a symmetrical building is selected. Steel buildings of 10 story are modelled, analysed and designed in ETABS-2017 for various structural systems such as Shear wall, Belt Truss, Outrigger, Belt Truss + Outrigger, Diagrid, Staggered Truss, Tube in Tube and Conventional frame. Analysis and design is carried out for dead load, live load, lateral earthquake load and lateral wind load. For earthquake loads, both static and response spectrum analysis is performed. To consider extreme conditions of lateral loads, the buildings are considered to be located in Zone V.

Building configuration

The physical properties and data of the building considered for the present study is as follows

Plan Area :	18 m × 18 m
Location :	Bhuj, India
Typical Storey Height :	3 m
Steel Sections :	Fe 250
Concrete (Slabs) :	M 25
Dead Load :	3 kN/m^2
Live Load :	2.5 kN/m^2
Wall/Cladding Load :	4 kN/m
Slab Thickness :	120 mm

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Earthquake Load:	As per IS 1893 (Part 1) :2016
Importance Factor:	1
Response Reduction Factor :	5
Modal Damping :	2%
Wind Load :	As per IS: 875 (Part 3) - 2015
Basic Wind Speed:	50 m/s
Factor K1, K3, K4:	1
Terrain Category :	2
Steel Design Code:	IS 800:2007
Limiting Top Storey Displacements :	H/500
Limiting Inter Storey Drifts :	0.004h

A. Conventional frame building

For the design of columns, built-up box sections are used and for the design of beams, Indian Standard I-Sections are used while the slabs are considered of RCC. Buildings are divided into two parts along the height of the buildings in terms of optimum size of column sections. All sections in buildings are optimized for design sections. The typical plan, beam arrangements, elevation and 3D views of a 10 storey conventional frame building are shown in the Figure 1 (a). Optimum design sections for 10 storey building are shown in Table

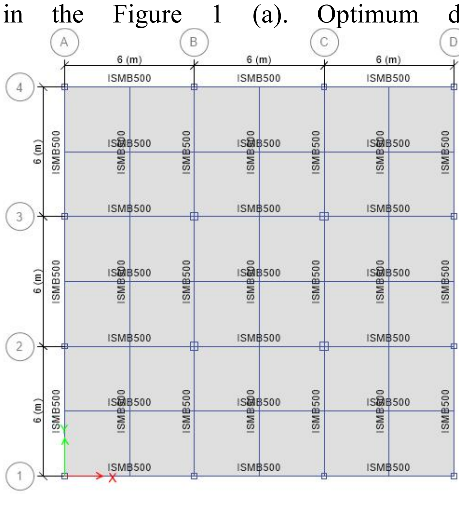


Fig. 1 (a): Typical Floor and Beam Arrangement

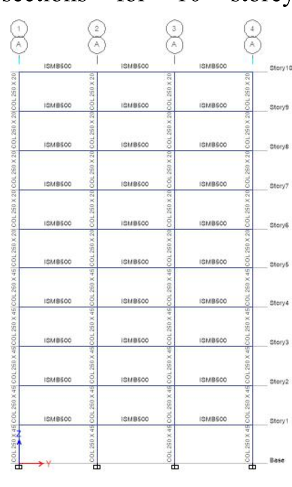


Fig. 1 (b): Elevation

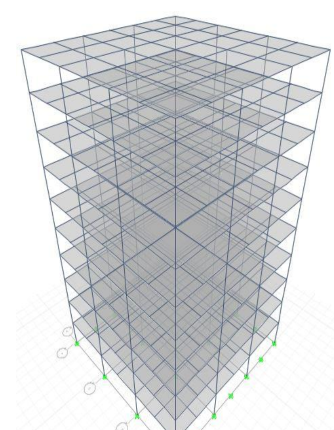
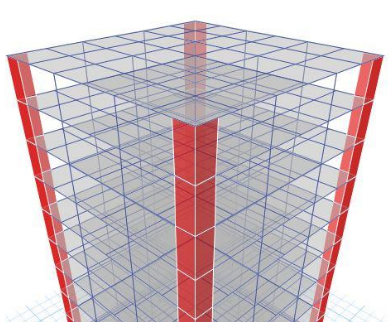


Fig. 1(c): 3D View

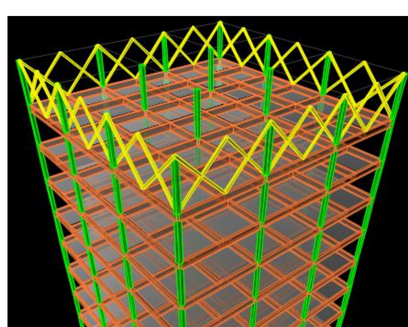
Fig. 1: Conventional Frame Building

The typical plan, beam arrangements of a 10 storey Shear wall, Belt Truss, Outrigger, Belt Truss + Outrigger, Staggered Truss are same as shown in the Figure 1 (a) and for Tube in Tube structure shown in Figure 8.

B. Shear wall



C. Belt truss



D. Outrigger

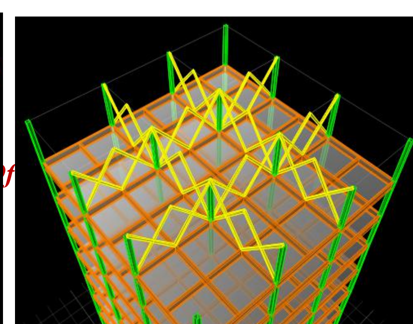


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Fig. 2: Shear wall *Fig. 3: Belt Truss system* *Fig. 4: Outrigger system*

E. Belt truss + outrigger

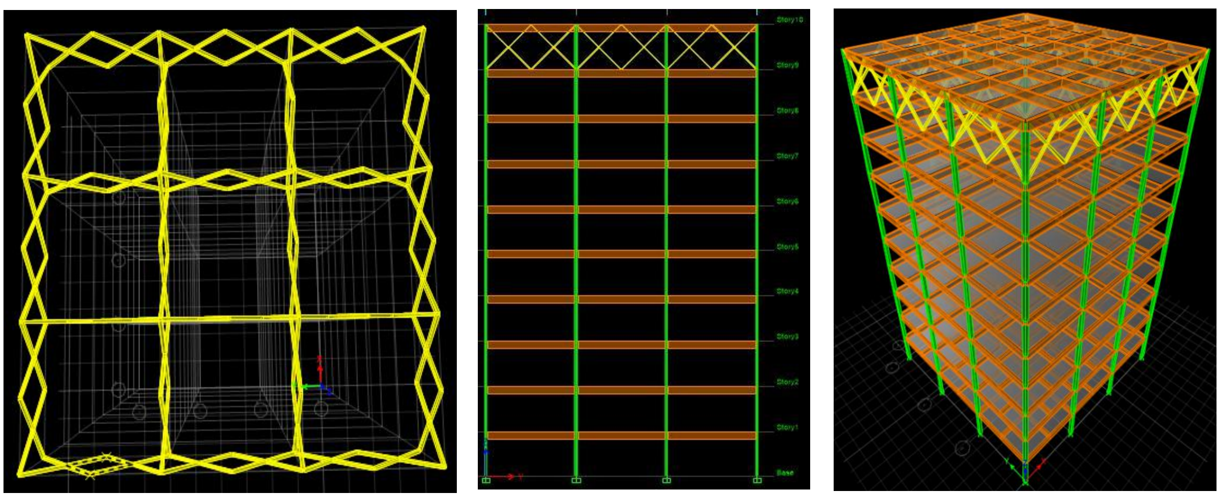

Fig. 5 (a): Typical Floor and Beam Arrangement *Fig. 5 (b): Elevation* *Fig. 5 (c): 3D View*

Fig. 5: Belt Truss + Outrigger system

F. Diagrid structure

The structural elements like columns, beams and Diagrids are assigned structural steel properties while the slabs are considered of RCC. All sections in buildings are optimized for design sections. For the design of Diagrids and columns, built-up box sections are used and for the design of beams, Indian Standard I-Sections are used. The typical plan, beam arrangements, elevation and 3D views of a 10 storey Diagrid building are shown in Figure 6.

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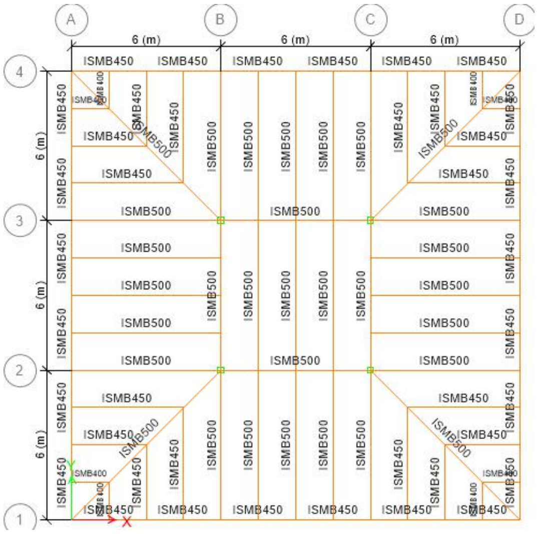


Fig. 6 (a): Typical Floor and Beam Arrangement

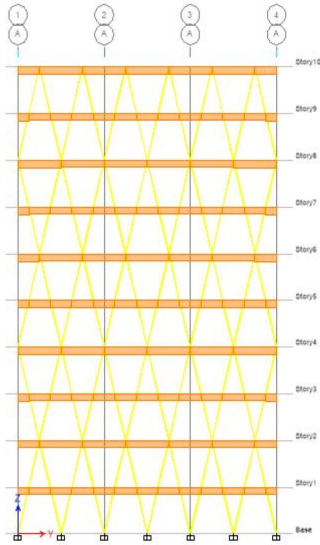


Fig. 6 (b): Elevation

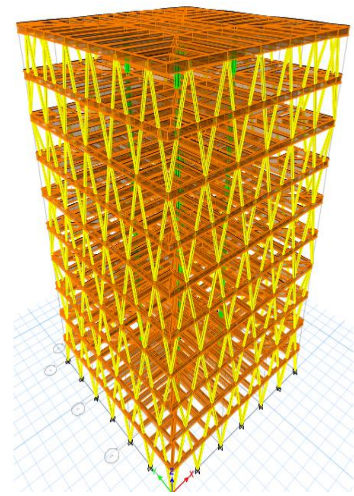


Fig. 6 (c): 3D View

Fig. 6: Diagrid Structure

G. STAGGERED TRUSS

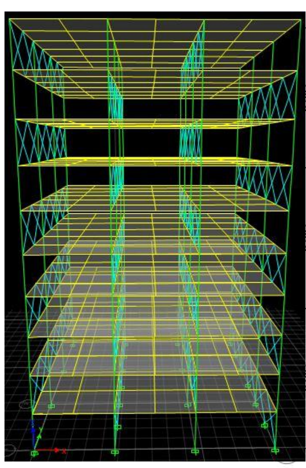


Fig. 7 (a) : 3D View of Staggered Truss System

Fig. 7 : Staggered Truss System

H. TUBE IN TUBE

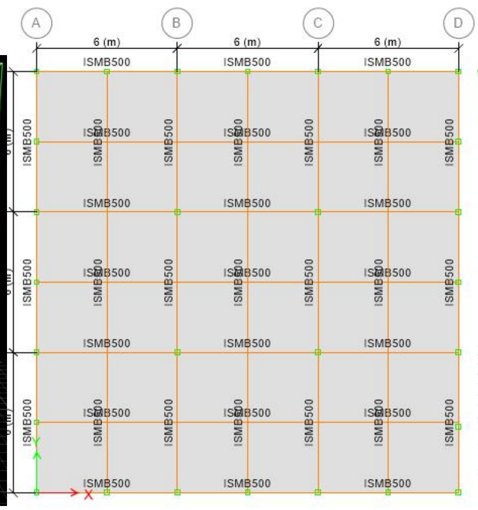


Fig. 8 (a): Typical Floor and Beam Arrangement

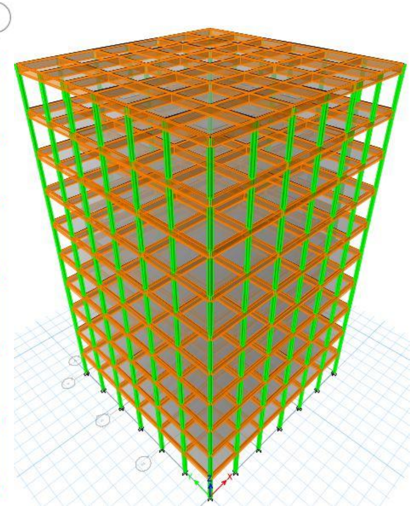


Fig . 8 (b): 3D View

Fig . 8: Tube in Tube Structure

Table 1: Design Sections for 10 Storey Building

DESIGN SECTIONS FOR 10 STOREY BUILDING								
BUILDING	**TYPE**	**FROM**	**TO**	**DIAGRID/ BRACING**	**COLUMN**	**BEAM 1**	**BEAM 2**	**BEAM 3**
10 Storey	Conventional frame	0	5	---	COL 250 X 45	ISMB 500	ISMB 500	ISMB 500
		6	10	---	COL 250 X 20			
	Shear wall	0	5	---	COL 250 X 40	ISMB 500	ISMB 500	ISMB 500
		6	10	---	COL 250 X 20			

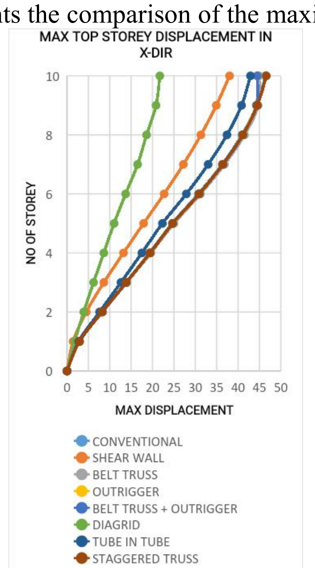
	Belt Truss	0	5	---	COL 250 X 45	ISMB 500	ISMB 500	ISMB 500
		6	10	---	COL 250 X 20			
		Top		BRC 115 X 15				
	Outrigger	0	5	---	COL 250 X 45	ISMB 500	ISMB 500	ISMB 500
		6	10	---	COL 250 X 20			
		Top		BRC 115 X 10				
	Belt Truss + Outrigger	0	5	---	COL 250 X 45	ISMB 500	ISMB 500	ISMB 500
		6	10	---	COL 250 X 20			
		Top		BRC 115 X 10				
	Diagrid	0	5	DIA 125 X 20	COL 250 X 47	ISMB 400	ISMB 450	ISMB 500
		6	10	DIA 115 X 15	COL 250 X 30			
	Staggered Truss	0	5	BRC 115 X 15	COL 250 X 45	ISMB 500	ISMB 500	ISMB 500
		6	10		COL 250 X 20			
	Tube in Tube	0	5	---	COL 250 X 45	ISMB 500	ISMB 500	ISMB 500
		6	10	---	COL 250 X 25			

III. RESULTS AND DISCUSSION:

Results of various parameter like maximum top storey lateral displacement, maximum storey drift, maximum base shear and fundamental time period are given below. Results are same in both axis for all other structural system except Staggered Truss system because bracing is providing in only one direction in staggered pattern.

A. Maximum top storey displacement

Figure 9 represents the comparison of the maximum top storey displacements in various structural systems.



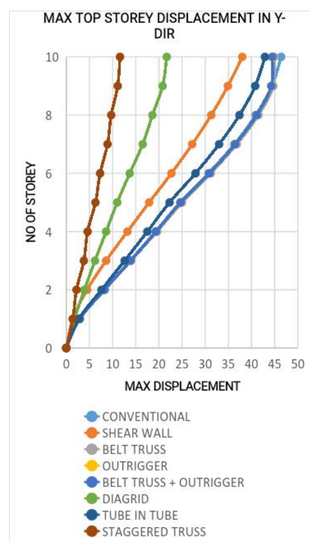


Fig. 9 (a): Maximum Top Storey Disp. in X-Direction *Fig. 9 (b): Maximum Top Storey Disp. in X-Direction*

Fig. 9 : Maximum Top Storey Displacement

B. Maximum storey drifts

Figure 10 represents the comparison of the maximum storey dirftin various structural systems

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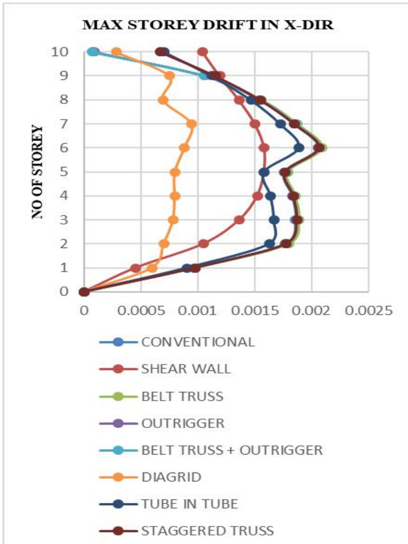

Fig. 10 (a): Maximum storey dirft in X-Direction

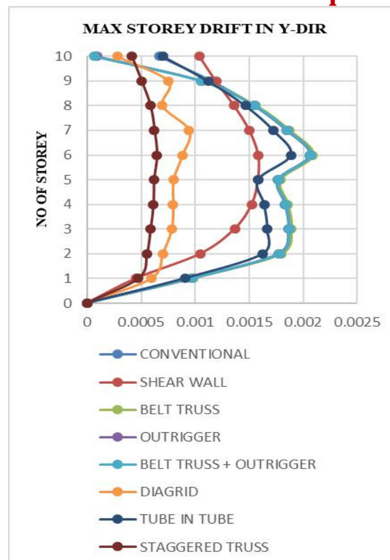

Fig. 10 (b): Maximum storey dirft in X-Direction

Fig. 10: Maximum storey dirft

C. Maximum base shear

The Figure 11 represents the comparison of the maximum base shear for various system. It is shown that Diagrid system is stiffer than the other structural system in X-direction and Staggered Truss system is stiffer than other in Y-Direction.

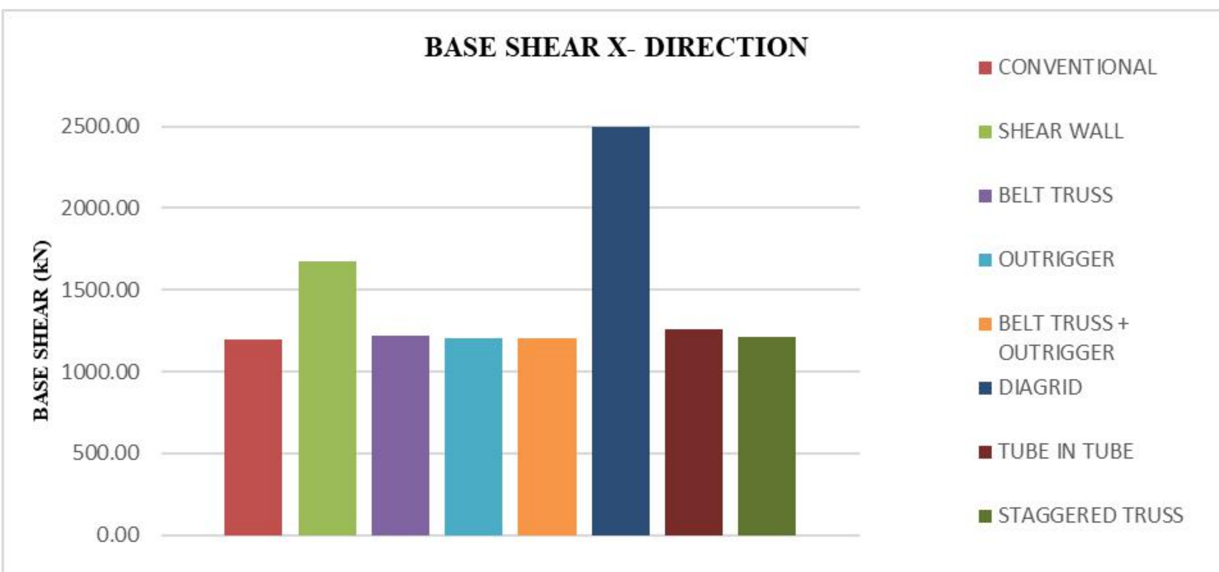

Fig. 11 (a): Maximum base shear in X-Direction

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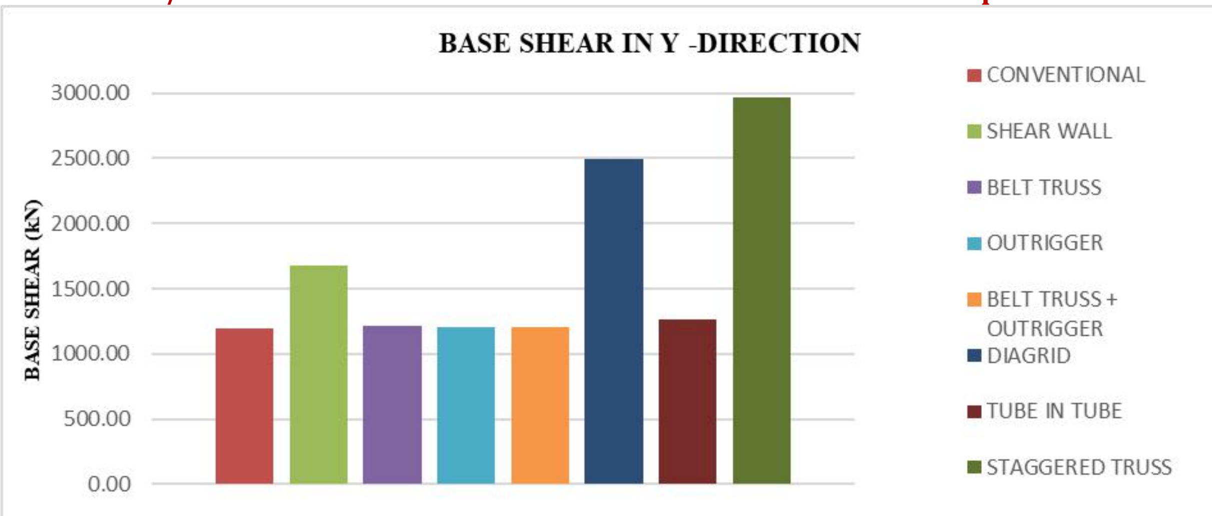

Fig. 11 (b): Maximum base shear in Y-Direction
Fig. 11: Maximum base shear

D. Time period

Figure 12 represents the comparison of the time period. It is observed from the graph that Time Period is maximum for the building with Belt Truss and minimum for Diagrid structure than all other system. Thus it is observed that the Diagrid structure is stiffer than other structural system.

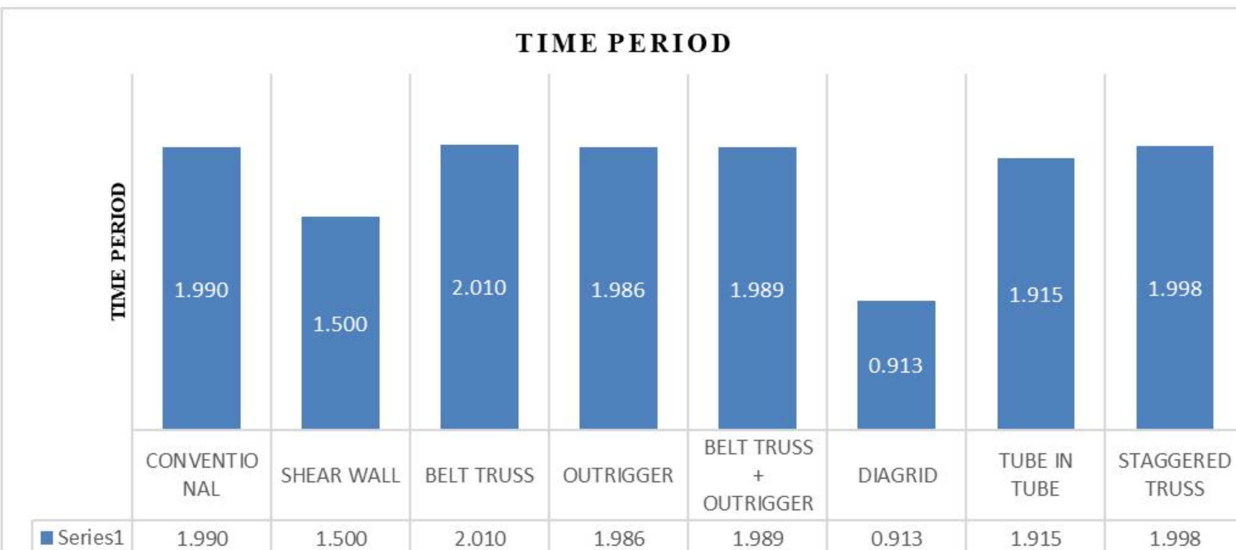

Fig. 12: Time period

IV. CONCLUSION

The 10 storied building with different structural system is analysed and design. Based on the numerical study, the following major conclusions can be drawn:

1) Displacements on each storey and storey drifts are observed to be less in Diagrid systems in X-Direction as compared to other lateral load resisting system.

2) Displacements on each storey and storey drifts are observed to be less in Staggered Truss systems in Y-Direction as compared to other lateral load resisting system.

3) Base Shear is maximum for Diagrid system than the other structural system in X-direction and Base Shear is maximum for Staggered Truss system than other lateral load resisting system in Y-Direction because in Staggered Truss system trusses are provided in Y-Direction.
4) Time Period is maximum for the building with Belt Truss and minimum for Diagrid structure than all other system.
5) It is shown that Diagrid system is stiffer than the other structural system in X-direction andStaggered Truss system is stiffer than other structural system in Y-Direction because in Staggered Truss system trusses are provided in Y-Direction.

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