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Analysis and Design of Diagrid Structure for High Raised Buildings

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ABSTRACT: Tall, elevated constructions are most impacted by lateral loads from wind and ground vibration. Therefore, these buildings require a unique structural design that will enable them to withstand both gravity and lateral loads. This study focuses on the diagrid structural system, one of several structural systems, to assess and design the diagrid structure while taking into account numerous configurations to determine the best configuration that will reduce costs.

In the proposed effort, a comparison between the diagrid and bare frame construction will be made. For the study and design, a 30m × 30m plan with 24 stories, each with a 3.6m story height, is taken into consideration. The analysis and design are done using the ETABS software.Members of the RCC and CFST are utilised as diagrids individually to determine the performance of each individual.

The seismic analysis is carried out using the response spectrum method of analysis. For various configurations, such as various geometries and inclinations of the diagrid members, the analysis results are compared in terms of top storey displacement, storey drift, base shear, time period for seismic and wind forces. In order to analyse and determine the ideal design with regard to cost and increased safety, 27 building options, including the bare frame, were modelled. In addition, the ability of the diagrid structure and the bare frame structure to support the lateral and vertical loads is also investigated.

KEYWORDS: Diagrid,ETABS, CFST, Response spectrum, seismic analysis.

I. INTRODUCTION

The lateral loads are the critical loads for these high-rise buildings, and the design, construction, and maintenance of the structure with respect to gravitational load is not a concern. The two most dangerous natural disasters that can happen are an earthquake and a strong wind. When there is a strong wind or earthquake, these lateral loads will significantly negatively impact the structure, leading to excessive drift and increased overturning moments.In order to protect the structure from various negative impacts such excessive drift and extended time periods, there are primarily three types of structural systems established, namely: i. Moment resisting frame system, ii. Shear wall system, and iii. Bracing system. The braced frame structural system, among various structural systems, is crucial for effectively resisting the lateral load through triangular arrangements. Out of all the braced structural systems, the diagrid structural system is the one in which the outer columns are arranged in an inclined manner so that these inclined members will resist the lateral load through the axial action of diagonal members rather than vertical column bending as in moment resisting framing system.

In this essay, the study of two 24-story, diagonally-builtbuildings made of reinforced cement concrete (RCC) and concrete-filled steel tubes (CFST) are described separately. The story response of a structure with various diagrid geometries, diagrids combined with vertical columns, and diagrids inclined at various angles are all shown. Also examined is the way that the outer and inner frames support lateral and gravitational loads. Modelling, analysis, and design are all accomplished using the ETABS software. For the seismic analysis, the response spectrum approach is employed.

The comparison of the analysis's findings is shown in terms of time, narrative displacement, tale drift, and base shear.

II. OBJECTIVES

The primary goal of the current work is to create diagrid buildings that will result in fewer negative impacts from lateral loads, among other goals are,

- Using the following criteria, assess how well the diagrid structural system performs under lateral loading
- Different orientation of the diagrids.
- Different geometric sections of the diagrids.

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- Combination of the moment resisting framed system + diagrids structural system.
- To know the behaviour of the structure with CFST diagrid.
- To know the dead and lateral load distribution between the internal and outer frames.
- To carry out the comparison between the RC and CFST diagrid structure with the simple moment resisting framed structure with respect to top storey displacement, storey drift, storey shear and time period.

III. METHODOLOGY

- A plan of dimension 30mx30m consists of 24 storeys with story height of 3.6m each is considered for Analysis.
- Using ETABS software, numerous models are produced, analysed, and constructed in accordance with IS codal regulations in order to achieve the ideal structural configuration that will result in cost-effective, fewer detrimental effects from the lateral loads.
- The different geometric sections of diagrid, such as square, circular, and rectangular sections, are chosen in case of RCC diagrid structure so that all the geometry should have approximately the same area of cross section, and in case of CFST diagrid structure so that all the geometry should have approximately the same area of cross section in order to analyse the storey response with respect to different geometry of the diagrid section.
- The response spectrum method of analysis is used to determine how the structure will respond to an earthquake.
- For the considered site location in Bengaluru, the loads are assigned in accordance with the IS standards.
- The top storey displacement, drift ratio, base shear, and time periods between the various configurations of the designed buildings are compared in the analysis results.
- In order to find the best configuration that will be cost-effective, two to three optimal configurations are selected from the analysis results. The dead and live loads carried by the inner and outer frames as well as the amount of material used by those configurations are also analysed.

4.2 BUILDING CONFIGURATIONS

To find the best building configuration that will have the fewest negative impacts from the earthquake and wind load, 27 models, including the traditional model of a moment-resisting framed structure, are taken into consideration in this study.

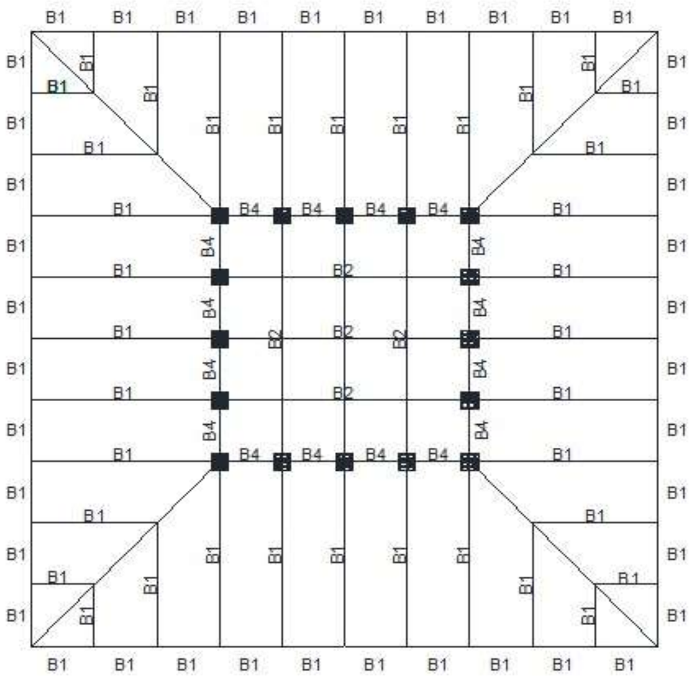

Figure 1.A typical building layout for all configurations is shown

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BUILDING PARAMETERS	DETAILS
Plan dimension	30m x 30m
Number of storey	24
Height of typical floor	3.6m
Size of core column	1000mm x 1000mm
Size of beam	1. 300mm x 600mm
	2. 300mm x 800mm
	3. 300mm x 1000mm
	4. 400mm x 650mm
Slab thickness	120mm
Grade of concrete	M 40
Grade of steel	Fe 500 for rebar
	fy 250 for CFST

Structural configurations	Size of members	Notations
Moment resisting framed structure	600mm x 600mm	MRFS
RCdiagrid structure		
Diagrid intersection at every 2nd storey		
Square diagrid	400mm x 400mm	RC2S
Circular diagrid	450mm	RC2C
Rectangular diagrid	300mm x 535mm	RC2R
Diagrid intersection at every 4th storey		
Square diagrid	400mm x 400mm	RC4S
Circular diagrid	450mm	RC4C
Rectangular diagrid	300mm x 535mm	RC4R
Diagrid intersection at every 6th storey		
Square diagrid	500mm x 500mm	RC6S
Circular	565mm	RC6C

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diagrid		
Rectangular diagrid	400mm x 625mm	RC6R
Diagrid intersection at every 8th storey		
Square diagrid	500mm x 500mm	RC8S
Circular diagrid	565mm	RC8C
Rectangular diagrid	400mm x 625mm	RC8R
CFST diagrid structure		
Diagrid intersection at every 2nd storey		
Square diagrid	400mm x 400mm, 10mm thick steel tube	CFST2S
Circular diagrid	450mm diameter with 12mm thick steel tube	CFST2C
Rectangular diagrid	300mm x 500mmm with 10mm thick steel tube	CFST2R
Diagrid intersection at every 4th storey		
Square diagrid	400mm x 400mm, 10mm thick steel tube	CFST4S
Circular diagrid	450mm diameter with 12mm thick steel tube	CFST4C
Rectangular diagrid	300mm x 500mmm with 10mm thick steel tube	CFST4R
Diagrid intersection at every 6th storey		
Square diagrid	400mm x 400mm, 10mm thick steel tube	CFST6S
Circular diagrid	450mm diameter with 12mm thick steel tube	CFST6C
Rectangular diagrid	300mm x 500mmm with 10mm thick steel tube	CFST6R
Diagrid intersection at every 8th storey		
Square diagrid	400mm x 400mm, 10mm thick steel tube	CFST8S
Circular diagrid	450mm diameter with 12mm thick steel tube	CFST8C

Rectangular diagrid	300mm x 500mmm with 10mm thick steel tube	CFST8R
Conventional building with 2 storey model with diagrids spaced at 6m c/c		
RC diagrid structure	Corner column = 800mm x 800mm Edge column = 500mm x 500mm Diagrid = 400mm x 400mm	RC2S+MRF
CFST diagrid structure	Corner column = 800mm x 800mm Edge column = 500mm x 500mm Diagrid = 400mm x 400mm with 10mm thick steel tube	CFST2S+MRF

Loading details	Load	IS CODE
1.Dead load on floor (kN/m^2)	1.5	IS 875_1
2.Live load on floor (kN/m^2)	2.5	IS 875_2
Wall load (kN/m)	12	
Parapet load (kN/m)	4	
Earthquake load details		
Zone	2	IS 1893_1:2016 ANNEX E
Zone factor	0.10	
Damping ratio (%)	5/100	
Importance factor	1	IS 1893_1:2016 Table 8
Response reduction factor for RC building with SMRF	5	IS 1893_1:2016 Table 9
Response reduction factor for RC building with SBF	4.5	
Soil type	2	
Percentage of imposed load considered in design	25	IS 1893_1:2016 Table 10

Wind load details		
Wind speed (kmph)	47	IS 875-3:2015_clause 6.2
Wind co-efficient		
Windward co-efficient	0.8	IS 875-3:2015_Table 5
Leeward co-efficient	0.25	
Risk co-efficient k_1	1	IS 875-3:2015_clause 6.3.1
Terrain co-efficient k_2 for category 4 & class C	1.0176	IS 875-3:2015_clause 6.3.1
Topography factor k_3	1	IS 875-3:2015_clause 6.3.3
Importance factor k_4	1	IS 875-3:2015_clause 6.3.4

Load combinations	IS code
1.5DL+1.5IL	IS 456:2000 Table 18
1.5DL ± 1.5(WL/EL)	
0.9DL ± 1.5(WL/EL)	
1.2DL + 1.2IL ± 1.2(WL/EL)	
1.2 [DL + IL ± (EL_X ± 0.3EL_Y)]	IS 1893_1:2016 Cl. 6.3.1
1.2 [DL + IL ± (EL_Y ± 0.3EL_X)]	
1.5 [DL ± (EL_X ± 0.3EL_Y)]	
1.5 [DL ± (EL_Y ± 0.3EL_X)]	
0.9DL ± 1.5(EL_X ± 0.3EL_Y)]	
0.9DL ± 1.5(EL_Y ± 0.3EL_X)]	

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IV. RESULTS AND DISCUSSIONS

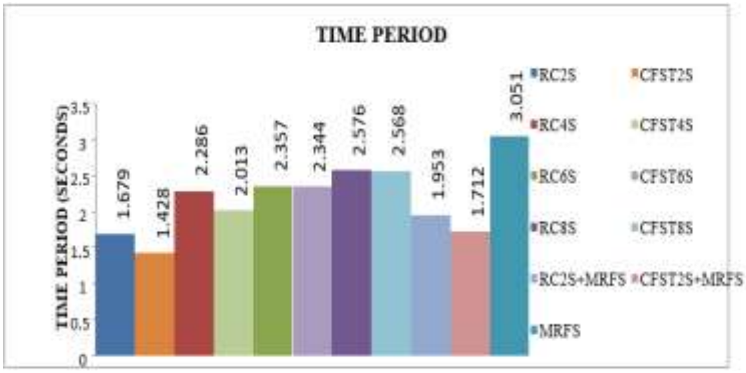

Fig.2.Time period for the structure for various diagrid designs

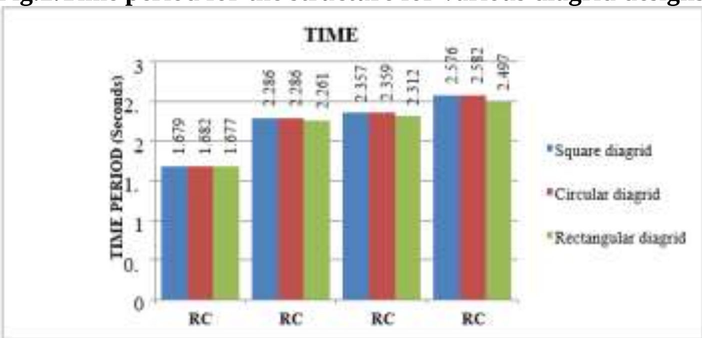

Fig.3.Time period of the structure for different geometry of RC diagrid sections

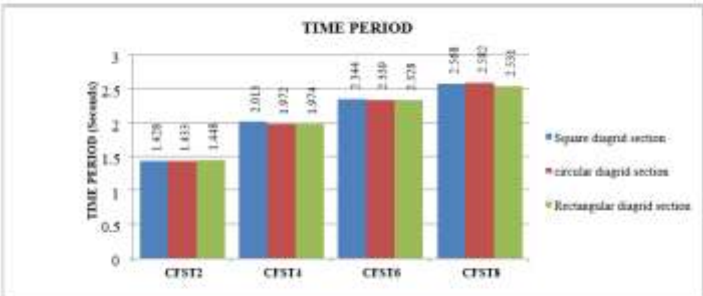

Fig.4. Time period of the structure for different geometry of CFST diagrid sections

DISCUSSION: It can be seen from the graphs that the time period increases as the diagrid inclination increases. When comparing diagrid buildings of the same size made of CFST and RCC, the CFST version exhibits higher stiffness because to its shorter time period. The different diagrid geometry has less of an impact on reducing the time for models with lower diagrid inclinations, such as the RC2 and CFST2 models. However, for models with higher storeys, such as the RC8 and CFST8, rectangular sections will shorten the building's construction time compared to the other two sections.

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STOREY DISPLACEMENT:

Fig.5 .4 Storey displacement of the structure for the seismic loading for different diagrid configuration

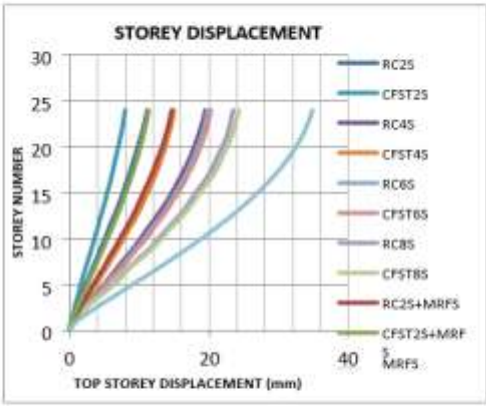

Fig.6. Storey displacement of the structure for the wind loading for different diagrid configuration

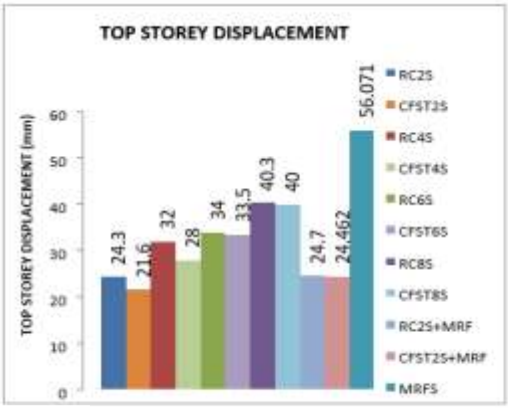

Fig.7 7 Top storey displacement of the structure for the seismic loading for different diagrid configurations

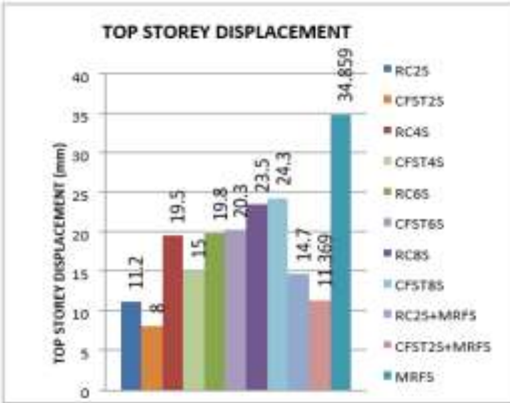

Fig.8 Top storey displacement of the structure for the wind loading for different diagrid configurations

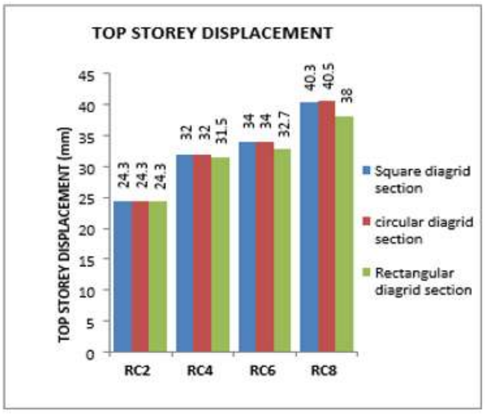

Fig.9. 9 Top storey displacement of the structure for the seismic loading for different cross section of RC diagrid

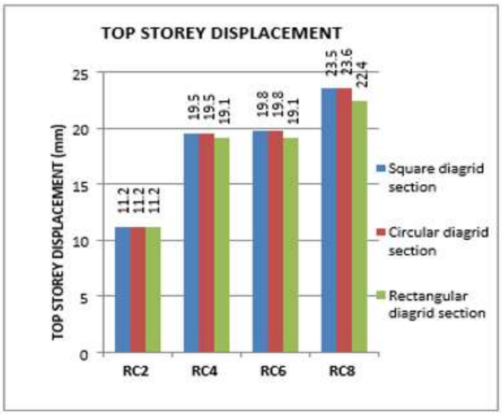

Fig.10 Top storey displacement of the structure for the wind loading for different cross section of RC diagrid

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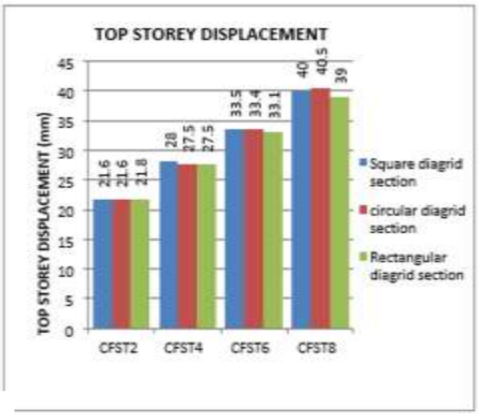

Fig.11

.11 Top storey displacement of the structure for the seismic loading for different cross section of CFST diagrid

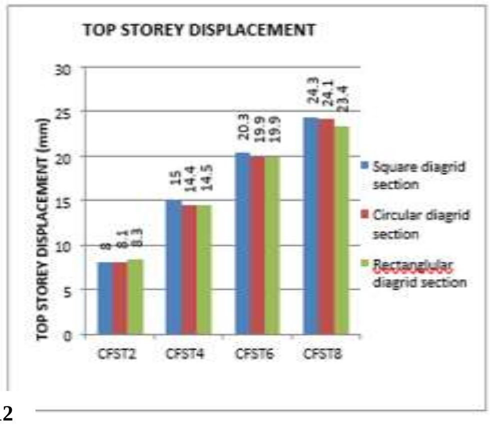

Fig.12

Top storey displacement of the structure for the wind loading for different cross section of CFST diagrid

DISCUSSION:From the graphs, it can be seen that the diagrid inclination increases along with the storey displacement. CFST diagrid structure results in a lower top storey displacement for the same size as RCC diagrid structure.

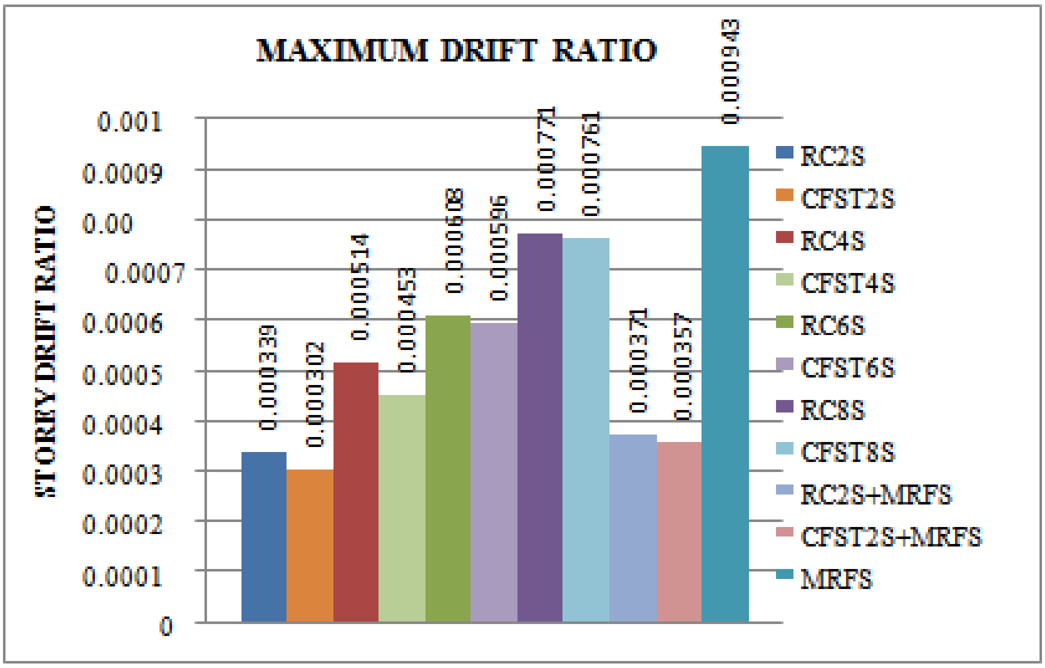

Fig.13 Maximum storey drift of the structure for the seismic loading for different diagrid configurations

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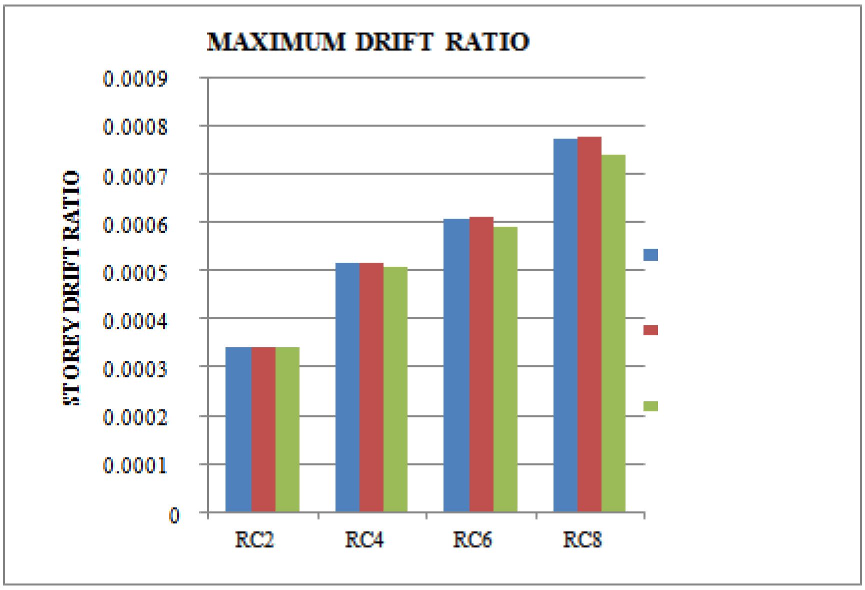

Fig.14 Maximum storey drift of the structure for the seismic loading for different cross section of RC diagrid

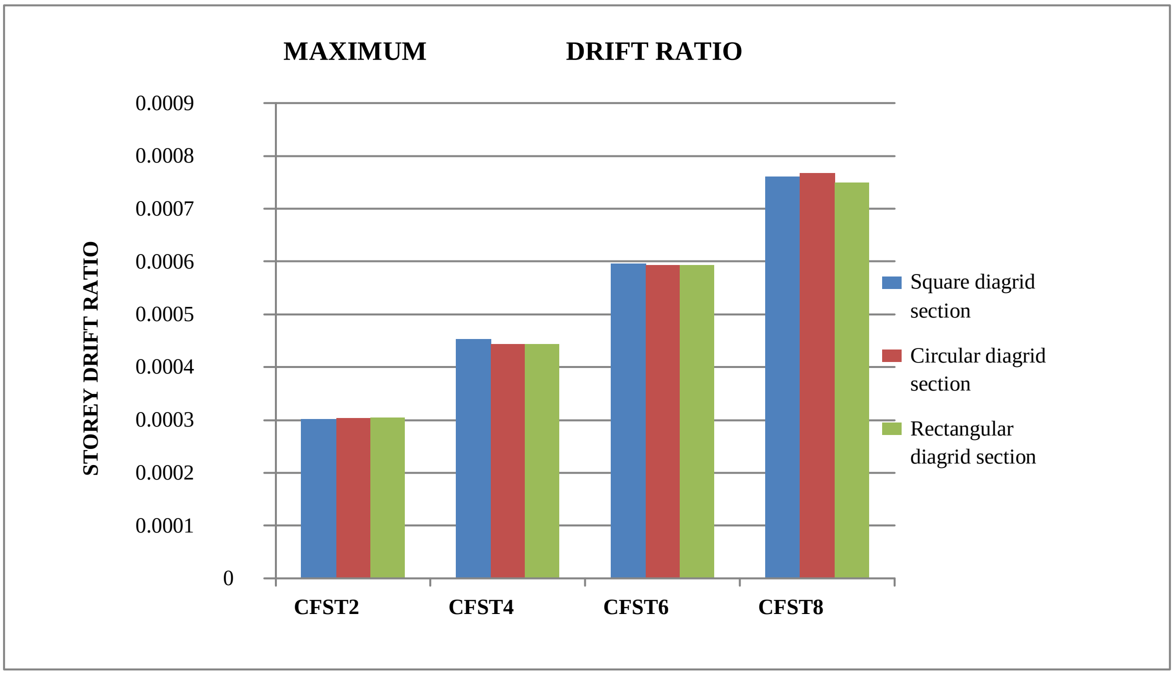

Fig.15 Maximum storey drift of the structure for the seismic loading for different cross section of CFST diagrid

DISCUSSION: All of the models' drift ratios fall within the permitted range of 0.004. It can be seen from the graphs that the drift ratio will rise as the diagrid inclination rises. The CFST diagrid structure provides a lower drift ratio for the same size as the RCC diagrid structure.

BASE SHEAR:

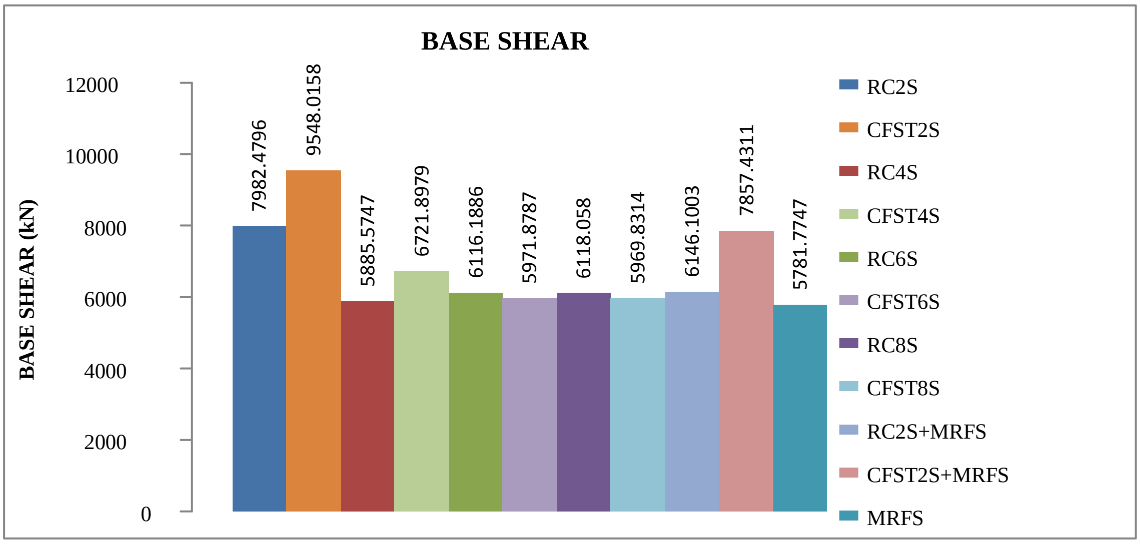

Fig.16 Base shear of the structure for the seismic loading for different diagrid configurations

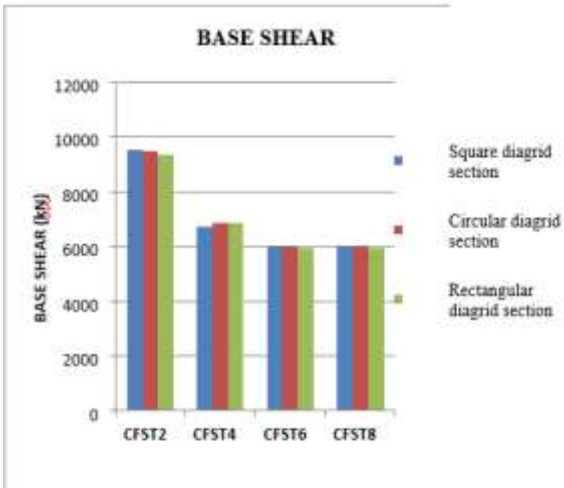

Fig.17 Maximum storey drift of the structure seismic loading for different cross section of CFST diagrid

DISCUSSIONS: Given that the base shear is directly proportional to the structure's weight and that the RC2 and CFST2 models have more diagrids, the base shear in these two models is, unsurprisingly, greater. The overall amount of material in the models with diagrids intersecting every fourth, sixth, and eighth stories does not vary significantly, and as a result, the analysis results did not differ significantly for all of those models. In comparison to other models, the weight and base shear findings are less for the moment-resisting framed structure since it only has vertical columns, not inclined ones. The varied section geometry has minimal impact on the analysis's findings.

V. CONCLUSIONS

1. When compared to moment-resisting framed buildings, all diagrid models exhibit enhanced storey response and time period.
2. The models that have the diagrids intersect every second story produce good results in terms of time reduction, storey displacement, and drift. The time period is cut by 45%, 25%, 23%, and 16% for the RC2S, CFST2S, RC2S+MRFS, and CFST2S+MRFS models, respectively, and the drift is cut by 64%, 68%, 61%, and 62%.
3. As the diagrids' inclination increases, the duration, storey displacement, and maximum drift will all rise.
4. The CFST construction performs well in comparison to the RCC structure.

SCOPE OF FORTHCOMING STUDIES

- There are only 24 stories allowed in the current study. Future research on constructions with more storeys is possible because the diagrid structure is particularly useful for high raised buildings.
- For the analysis in the current study, I used the square plan; in future studies, asymmetrical plans may also be used, allowing us to better understand how this diagrid structural system would behave in both the longer and shorter directions.
- The current study is restricted to looking at base shear, time periods, and storey displacement; however, future studies may also take additional factors such storey stiffness and overturning moment into account.
- In the present investigation, the structure has the same diagrid inclination throughout its height; in future work, different diagrid structural systems for various elevations may also be performed and compared to the structure with the same diagrid inclination throughout its height.

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