Efficacy of Lateral Load Resisting Systems in High-Rise Structures

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Abstract High-rise structures are subjected to lateral loads such as wind and seismic loads during their life span. Therefore, adopting an effective lateral load resisting system in high-rise structures is important to resist the lateral loads. In this paper, different lateral load resisting systems to resist seismic loads in high-rise structures has been studied individually. Outrigger, diagrid and diagonal strut with masonry infill are considered as the lateral load resisting systems in this study. The individual efficacy of each lateral load resisting system has been assessed based on the maximum lateral displacements taking place in the high-rise structure. Response spectrum method of analysis is adopted for carrying out the seismic analysis of the high-rise RC building model in ETABS. The seismic analysis is carried out considering load combinations as per IS 1893(Part 1):2016. The results show that, the diagonal strut with masonry infill have lower storey displacements in the comparative study. It is also observed from the results of the analysis carried out, the outrigger system when applied in the structure results in comparative larger storey displacements. The diagrid system which has been adopted shows storey displacements greater than the diagonal strut with masonry infill but lesser than the outrigger system. Hence, the diagonal strut with masonry infill system has been observed to comparatively resist more of the lateral displacements and is effective.

Keywords: Seismic analysis, Outrigger, Diagrid, Diagonal strut, High-rise, Lateral load

List of notations

- DL = Dead Load
- LL = Live Load
- EQX = Seismic load in X direction
- EQY = Seismic load in Y direction

1.Introduction

The development of the high-rise building indicates the growth of the city closely. The process of urbanization, which has started with the age of industrialization, is still in progress in developing countries. Industrialization causes migration of people to urban centers where job opportunities are significant. The land for buildings to accommodate this migration is becoming scarce, resulting in sudden increase in the cost of land. The result is high-rise buildings, as they provide a large floor area in a relatively small area of land in urban centers. High-rise structures must withstand many lateral loads in their life span such as Wind load and Seismic load. Hence, the structure must be designed accordingly to resist such lateral loads.

Hyun-Su kim et al (2017) examined the control performance of a smart outrigger damper system for reducing both the wind and seismic responses. Their results show that, the smart outrigger damper system could provide a good performance towards reducing the deflections for cases of wind and earthquakes.

Reihaneh et al(2019) worked on outrigger-belt truss system and on identifying the optimum location of such a system in tall structures. Reihaneh et al(2019) learnt from the outcome of their work that, there was an improvement in the seismic performance of the structure when the outrigger system was placed at 0.6 to 0.8 times the total height of the structure.

Vijay N Rathod et al Analyzed reinforced concrete structure with masonry infill wall using different modeling techniques such as Diagonal strut method, shell and plate element method etc. The analysis shows that the natural period of the structure by diagonal strut model does not differ significantly when compared to the shell or membrane element modeling

Manthan I et al(2016) considered diagrid system for the comparative study. Statistical analysis of tall buildings in done and presented for buildings having elevation more than 150 m or 40 storey. The analysis shows that a diagrid structure performs good when compared with conventional frame structures and increase in steel weight while increasing the height of building is less in diagrid structures.

Khushbu Jani and Paresh V. Patel(2013) Analyzed and designed 36 storey diagrid steel building. A floor plan of 36 m × 36 m size is considered. Dynamic loading along wind and across wind are considered for the analysis and design of the structure. Load distribution in diagrid system has been studied for the considered building. Similarly, analysis and design of 80, 70, 60 and 50 storey diagrid structures are carried out.

It is learnt from the literature, there are many forms of lateral load resisting systems adopted in high rise structures whose comparative study on individual efficacy need to be introspected.

The objective of this study is towards determination of the efficacy of different lateral load resisting systems adopted in High rise (Diagonal struts with masonry infill, Outrigger and Diagrid), subjected to seismic loads as a lateral load is investigated.

2.Analytical investigations of high-rise structural models

- Diagonal strut with masonry infill, outrigger system and diagrid system are modeled in ETABS. Diagonal strut is designed as per equivalent diagonal strut method. Seismic analysis is carried out by response spectrum method.

2.1 Details of models of high-rise structural models

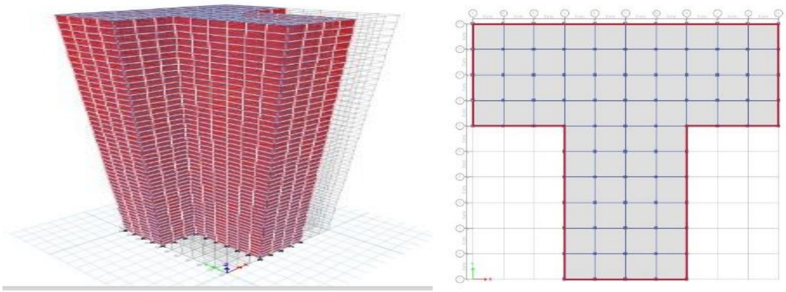
The basic geometrical details of the high-rise RC structure adopted for the analysis with various lateral load systems are:

- Plan shape: T
- Number of storeys: 50
- Each Storey height: 3 m
- Span of each bay: 5 m
- Thickness of shearwall: 250 mm
- Total area: 1600 m^2
- Soil type: 2
- Importance factor: 1.5
- Seismic zone: 3
- Live load: 3 kN/m^2 as per IS875(Part2)
- seismic analysis using Response spectrum in earthquake in X and Y directions as per IS1893(2016).
- Grade of concrete used for column, diagonal strut and beam: M40
- Grade of concrete used for slab: M30
- Grade of steel: Fe415
- Column dimensions: 600 mm x 600 mm
- Beam dimensions: 300 mm x 600 mm

2.1.1 Details of diagonal strut with masonry infill system

- Diagonal strut dimension: 250 mm x 920 mm

The isometric view of the high-rise structure having the diagonal strut with the masonry infill (figure 1a) and the diagonal strut system indicated in the plan of the structure (figure 1b) is shown in figure 1.



(a) (b)

Fig.1(a) Isometric view of the high-rise structure having diagonal strut with masonry infill, (b) diagonal strut with masonry infill system in plan

2.1.2 Outrigger system

- Grade of concrete used for shear wall: M30
- Grade of concrete used for slab: M20
- Grade of steel: Fe250
- Column dimensions (Steel tube): 400 mm x 400 mm (20 mm thick)
- Steel section used for beam: ISMB350
- Shear wall column dimension: 400 mm x 400 mm
- Shearwall thickness: 250mm, shearwalls provided in the central portion
- The outrigger is provided at storey 15, storey 30 and storey 45.

The isometric view of the high-rise structure having the outrigger system (figure 2a) and the outrigger system indicated in the plan of the structure (figure 2b) is shown in figure 2.

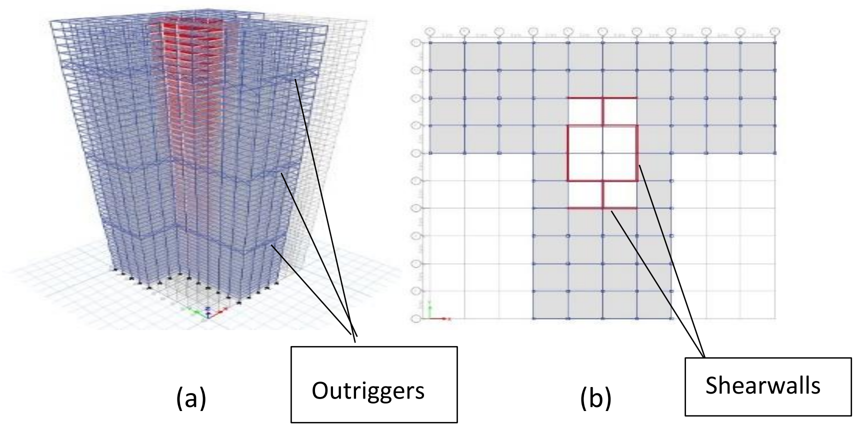


Fig.2(a) Isometric view of the high-rise structure having outrigger system, (b) outrigger system in plan

2.1.3 diagrid System

- Grade of concrete used for slab: M20
- Grade of steel: Fe250
- Column dimensions (Steel tube): 400 mm x 400 mm and 40 mm thick
- Diagrid dimensions (Pipe section): diameter : 400 mm and 40 mm thick
- Steel section used for beam: ISMB350

The isometric view of the high-rise structure having the diagrid system (figure 3a) and the diagrid system indicated in the plan of the structure (figure 3b) is shown in figure 3.

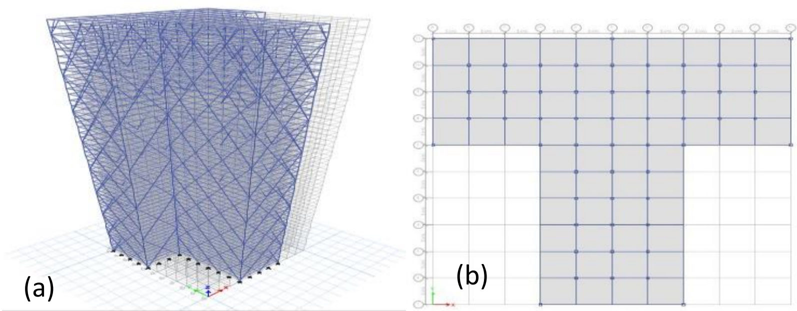


Fig.3(a) Isometric view of the high-rise structure having diagrid system, (b) diagrid system in plan

3.Results and discussions

The maximum storey displacements that were obtained by analyzing different lateral load resisting systems adopted in High rise structures (Diagonal struts with masonry infill, Outrigger and Diagrid) under critical load combinations have been presented in tables 1,2 and 3 respectively.

Table 1. Maximum storey displacement in diagonal strut with masonry infill system

Load combinations	Maximum storey displacement in X direction (mm)	Maximum storey displacement in Y direction (mm)
1.2 (DL + LL + EQX+0.3EQY)	2.600 (Storey 50)	2.100 (Storey 50)
1.5 (DL + EQX +0.3EQY)	3.200 (Storey 50)	2.400 (Storey 50)
1.5 (DL + LL)	0.400 (Storey 50)	0.600 (Storey 50)

Table 2. Maximum storey displacement in outrigger system

Load combinations	Maximum storey displacement in X direction (mm)	Maximum storey displacement in Y direction (mm)
1.2 (DL + LL + EQX+0.3EQY)	6.158 (Storey 50)	13.718 (Storey 50)
1.5 (DL + EQX +0.3EQY)	7.317 (Storey 50)	11.749 (Storey 50)
1.5 (DL + LL)	2.021 (Storey 45)	12.530 (Storey 50)

Table 3. Maximum storey displacement in diagrid system

Load combinations	Maximum storey displacement in X direction (mm)	Maximum storey displacement in Y direction (mm)
1.2 (DL + + EQX+0.3EQY)	LL6.070 (Storey 50)	11.672 (Storey 50)
1.5 (DL + EQX +0.3EQY)	7.289 (Storey 50)	10.266 (Storey 50)
1.5 (DL + LL)	5.078 (Storey 9)	8.942 (Storey 50)

4.Conclusion

- The High-rise structure adopted with the diagonal strut with masonry infill has lower values of storey displacements when compared to the high-rise structure with outrigger and diagrid systems.
- The diagrid system which has been adopted results in storey displacements greater than the diagonal strut with masonry infill but lesser than the outrigger system.
- It is inferred from this present study that, the diagonal strut with masonry infill system comparatively resists lateral displacements effectively.

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