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Comparative Seismic Analysis of Structure Using Bracing, Outrigger and Diagrid System

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ABSTRACT: As the population of world is increasing day by day the need for high-rise building grows equally but when height of the building increases it is more vulnerable to the lateral load so the designing need to be done carefully and structural system need to be selected according to the building's requirements so a building will be designed as per standards, which transfer lateral and vertical loads to the foundation safely. To resist lateral loads there are number of lateral load resisting system, bracing system is one of it that can be used as retrofitting for strengthening of the building or as lateral load resisting system. It transfer lateral load by means of tension and compression action. Another system that is a new concept that changes vertical columns orientation to diagonal is diagrid system, it changes all types of load to axial load to transfer them safely to the foundation. One of the structural systems that can be used as lateral load resisting system that adds to the buildings lateral stiffness and strength is outrigger system that is very effective system in case of resisting lateral load. In this paper, a 60 storeyed building is analysed by using Response Spectrum method for seismic zone III using Bracing, Outrigger and Diagrid system. The final results and conclusion will be based on the behaviour of building to the seismic forces and the comparative seismic parameters like base shear, lateral storey drift, displacement etc. by using Etabs

KEYWORDS: Bracing System, Outrigger System, Diagrid System, Response Spectrum Method, Base Shear, Lateral storey drift, Displacement.

I. INTRODUCTION

The rapid growths of urban population and consequent pressure on limited space have considerably influenced the residential development of city. The high cost of land, the desire to avoid a continuous urban sprawl, and the need to preserve important agricultural production have all contributed to drive residential buildings upward. As the height of building increase, the lateral load resisting system becomes more important than the structural system that resists the gravitational loads. To resist lateral loads there are number of lateral load resisting system, The systems that we are going to use in this papers are Bracing system, Outrigger system and Diagrid System

Bracing is a structural system that commonly used as lateral load resisting system to resist lateral loads such as wind and earthquake. Bracing system transfer lateral loads by means of tension and compression action, it means that when lateral load act on the building one will undergo tension and another will undergo compression. So the material commonly used in bracing is steel that has good strength in tension as well as compression. The beams and columns in a frame will carry vertical load and bracing will carry lateral loads.

Outriggers are deep, stiff beam which connects the central core to the exterior columns which help in keeping the columns in their position in turn reducing the sway, Outriggers act as stiff arms engaging outer columns/shear walls, when the lateral wind or earthquake force attacks the central core, central core tries to tilt, its rotation at the outrigger level induces a tension-compression couple in the outer columns acting in opposition to that movement acting on the core at that level.

Diagrid (diagonal grids) structure is a system of triangulated beams, straight or curved and horizontal ring that together make up a structural system for a skyscrapers (Tall Building). In short, it is made up of intersecting diagonal and horizontal components. It requires less structural steel than a conventional steel frame. The structural efficiency of diagrid system also helps in avoiding interior and corner columns, therefore allowing significant flexibility with the floor plan. Perimeter "diagrid" system saves approximately 20% structural steel weight when compared to a conventional moment-frame structure. The diagonal members in diagrid structural systems can carry gravity loads as



well as lateral forces due to their triangulated configuration. Diagrid structures are more effective in minimizing shear deformation because they carry lateral shear by axial action of diagonal members.

II. LITERATURE REVIEW

The present work is aimed at comparative study of analysis of Multi-Storeyed Buildings with Shear walls and Bracing Systems and combination of both. Following are the various literature reviews carried out by various researchers on Bracing system, Outrigger system and Diagrid system.

D.Sirisha (2019): Conducted Seismic Analysis and Design of Multistoreyed Building with and without Bracing According to IS Code and Euro Code by using ETABS Analysis of the structure have been done by Response Spectrum. The seismic performance of a structure with and without bracing configurations according to IS code and EURO code compared with respect to parameters like story displacement, story drift and story shear and found that:- The presence of diagonal bracing subjected to story displacement and story drift are increased about 20% and base shear reduces to 60%. From present work it has been identified that story drift of a structure with bracing is more compared to normal building. By providing bracing to a structure story drift reduces to about 40%. Story drift are considering increased about 10 to 25%, base shear is considering reduced about 50%. Base shear is reduced when diagonal bracing is added to building. It is observed that base shear is reduced to about 45% when compared to a building with bracing. Diagonal bracings are best bracing system for reducing the story displacement because of increased stiffness and the structure is proposed to be designed by Limit state method.

Roy Shyam Sundar (2017): He did study on Tall RC Structure with Outrigger System Subjected to Seismic and Wind Loading. He found that The maximum displacement at the top of structure Without outrigger system was 368.6 mm, which was reduced to 202.5 mm after providing outrigger at 0.4H, 0.7H & 1H. The reduction in drift is more than 50% at the story where outrigger is provided. The reduction in drift is more than 50% at the story where outrigger is provided. It can be concluded from this study that the outrigger system provides reduction in displacement, drift and base moment, which will further reduce the size and depth of foundation.

Sindhuja G J (2017): Performance study of high rise building with diagrid system under dynamic loading. The present work consists of analysis of 30 story linear building and analysis of diagrid systems with different diagonal angles that is 45 degree, 63 degree, 73 degree, 75 degree, 78 degree, 81 degree. The comparison between linear building and diagrid building is carried out. ETABS software is used for modelling and analysis of structure. Analysis results like story displacement, inter-story drift are presented here. Following are the conclusions inferred from the study:- Framing building without any load resisting system shows highest drift and displacement value as compared to diagrid system. Top story displacement is less for diagrid system with diagonal angle 63 degree. Between the region 63 degree to 75 degree (diagonal angle) diagrid system possesses better stiffness, story drift and story displacement are less in this region.

III. METHODOLOGY

In this study Comparative Seismic Analysis of Multi-storeyed Structure of 60 storeys with various plan Dimensions (32x32m), (36x36m), (40x40m) and an asymmetrical frame of 22 stories for each case such as Bare Frame, Bracing System, Outrigger System and Diagrid System will be carried out and we will find out the most suitable lateral load resisting system for the structure. This paper includes 1. modelling in E-TABS 2. Seismic Analysis to be done as per IS1893-2016. 3. model analysis in E-TABS. 4. Obtaining seismic parameters like base shear, lateral drift and displacement. 5. Observation and comparison of result. 6. Conclusion.

IV. PRELIMINARY DATA

The said structure is modelled as three dimensional structure and all the loads are applied, gravity loading such as dead load and live load in the direction of gravity, lateral loads such as seismic and wind, and the behaviour of the structure has been studied and it has been insured the drift and displacements are within the limits specified by Indian standards.

Material Properties

- └ Shear wall, column, Slab & beam – M40
- └ Reinforcement – Fe500
- └ Fe490 for structural steel – Fe490

Section Properties

- Beam - 300x450mm (For 32x32m plan), 300x500 (For 36x36m plan) and 300x550 (For 40x40m plan) and 300x600mm (For Asymmetrical plan)
- Shear wall - 300mm thk.
- └ Slab - 150 mm thk.
- Diagrid- 425x425mm (For 32x32m plan), 450x450mm (For 36x36m plan) and 475x475mm (For 40x40m plan) and 400x400mm (For Asymmetrical plan).

Seismic Loading

- Zone factor – 0.16, for zone III, Table 2 of IS1893:2016 Part I.
- Response reduction factor – 5, Table 7 of IS1893:2016 Part I.
- Soil Type – I, Hard soil, Table 1 of IS1893:2016 Part I
- Importance factor – 1, Table 6 of IS1893:2016 Part I
- Wind speed – 44m/s
- Structural class-C

V. STRUCTURAL MODELLING

In this study, structure will be modelled for the following cases:

1. 60 storeyed building will be modelled for Bare Frame, Bracing system, Outrigger system and Diagrid system for various plans 32X32, 36X36 and 40X40.
2. Analysis and conclusion of all Structures by using response spectrum method for (32x32). Types of Model: i. Bare Frame ii. Bracing system (X-type bracing at center) iii. Outrigger system (conventional) iv. Diagrid System (66.03° diagrid angle).
3. Analysis and conclusion by using response spectrum method for (36X36). Types of Model: i. Bare Frame ii. Bracing system (X-type bracing at center) iii. Belt Truss System iv. Diagrid System (71.56° diagrid angle).
4. Analysis and conclusion by using response spectrum method for (40x40). Types of Model: i. Bare Frame ii. Bracing system (X-type bracing at center) iii. Outrigger system with Belt Truss. iv. Diagrid System (74.57° diagrid angle).
5. Analysis and conclusion of all Structures by using response spectrum method for Asymmetrical plan.. Types of Model: i. Bare Frame ii. Bracing system (X-type bracing at center) iii. Outrigger system (conventional) iv. Diagrid System (69.51° diagrid angle).

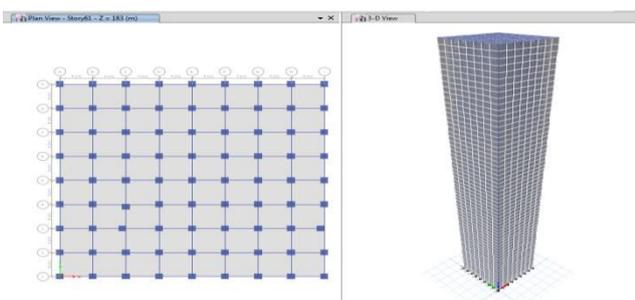


Fig. 1. Model of Bare Frame.

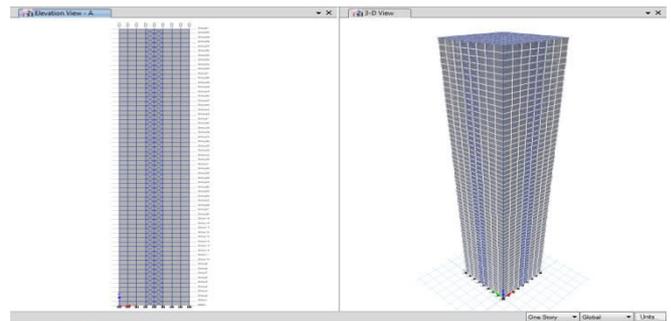


Fig. 2. Model of Bracing System.

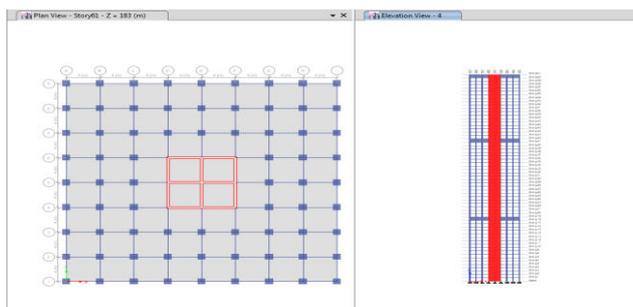


Fig. 3. Model of Outrigger System. (at 0.3H, 0.7H and 1H)

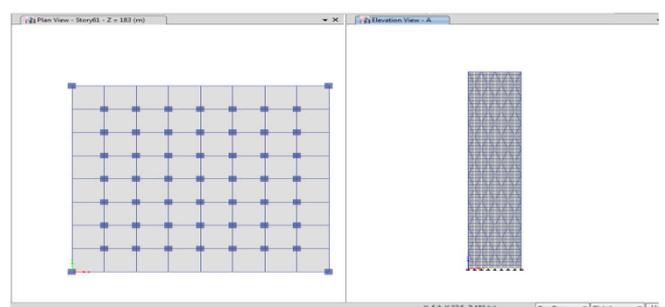


Fig. 4. Model of Diagrid system.

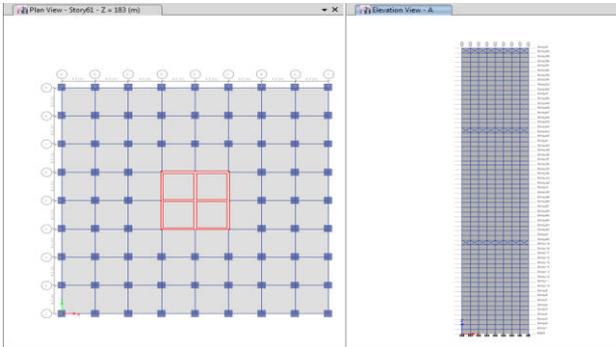


Fig. 5. Model of Belt Truss System.
 . (at 0.3H, 0.7H and 1H)

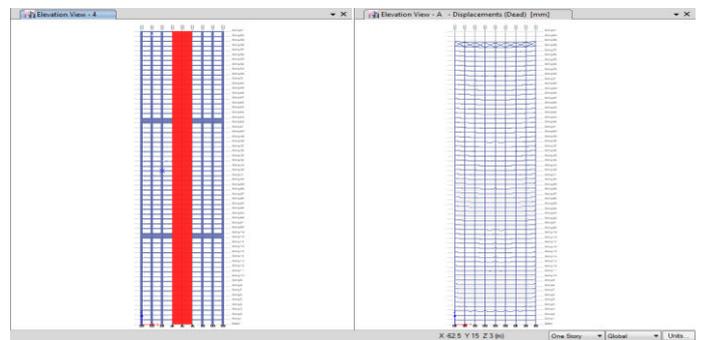


Fig. 6. Model of Outrigger System with belt truss.
 (at 0.3H, 0.7H and 1H)

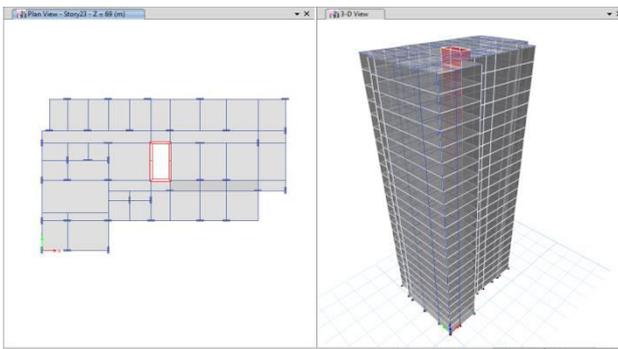


Fig. 7. Model of bare frame(Asymmetrical plan) .

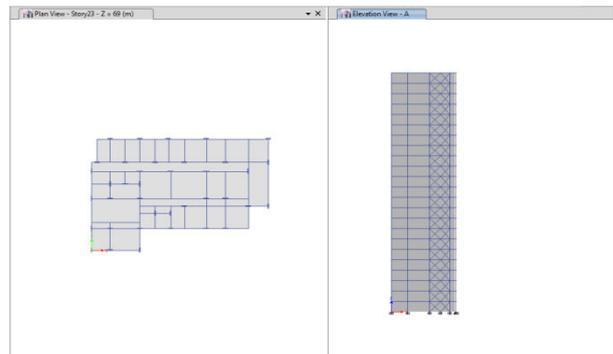


Fig. 8. Model of Bracing System (Asymmetrical Plan).

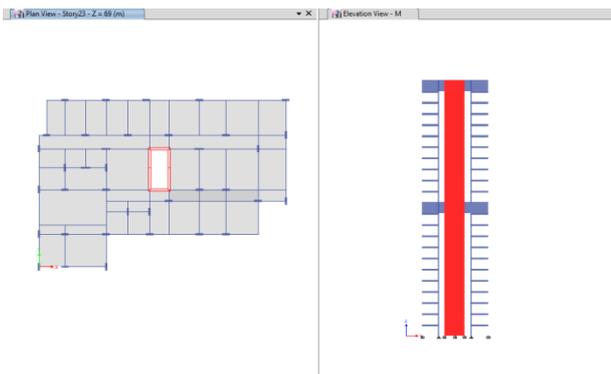


Fig. 9. Model of Outrigger system (Asymmetrical Plan).

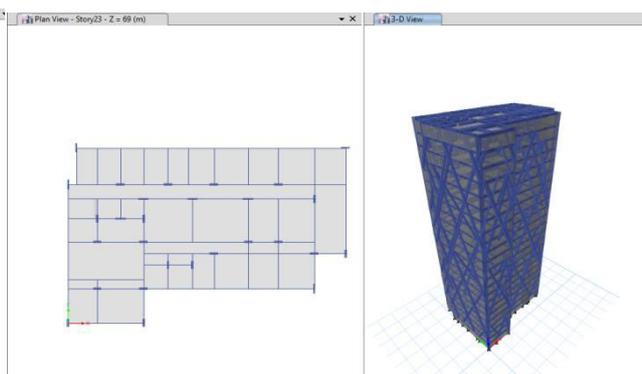


Fig. 10. Model of Diagrid system (Asymmetrical plan).



VI. RESULTS AND DISCUSSIONS.

TYPE OF FRAME	MAXIMUM STOREY DISPLACEMENT(MM)	MAXIMUM STOREY DRIFT	BASE SHEAR (KN)
BARE FRAME	170.18	0.001167	4902
BRACING SYSTEM	143.7	0.000983	4915
OUTRIGGER SYSTEM	104.06	0.000754	5071
DIAGRID SYSTEM	94.63	0.000611	4377

Table 1. Maximum Storey Displacement, Maximum Storey Drift and Base Shear for (32x32m) Frame.

TYPE OF FRAME	MAX STOREY DISPLACEMENT(MM)	MAX STOREY DRIFT	BASESHEAR (KN)
BARE FRAME	74.96	0.000568	3716
BRACING SYSTEM	65.01	0.000472	3725
OUTRIGGER SYSTEM	53.36	0.000385	3783
DIAGRID SYSTEM	51.315	0.000343	3268

Table 2. Maximum Storey Displacement, Maximum Storey Drift and Base Shear for (36x36m) Frame.

TYPE OF FRAME	MAX STOREY DISPLACEMENT(MM)	MAX STOREY DRIFT	BASE SHEAR(KN)
BARE FRAME	74.42	0.000522	4618
BRACING SYSTEM	65.22	0.00045	4640
OUTRIGGER SYSTEM	49.79	0.00036	4615
DIAGRID SYSTEM	53.05	0.000353	4074

Table 3. Maximum Storey Displacement, Maximum Storey Drift and Base Shear for (40x40m) Frame

TYPE OF FRAME	MAX STOREY DISPLACEMENT(MM)	MAX STOREY DRIFT	BASE SHEAR(KN)
BARE FRAME	21.7	0.000452	860.11
BRACING SYSTEM	16.18	0.000301	938.48
OUTRIGGER SYSTEM	14.9	0.000289	1111.46
DIAGRID SYSTEM	11.81	0.000414	1263

Table 4 . Maximum Storey Displacement, Maximum Storey Drift and Base Shear for Asymmetrical Frame.

VII. CONCLUSION AND FUTURE SCOPE

The most effective and deciding basic parameter studied during this whole analysis was drift and deflection of the structure. Chapter 6 shows the variation of drift and deflection of the structure with Bare frame, Bracing system, Outrigger system and Diagrid system. The following conclusions are made from the present study:

1. It is observed that deflection is reduced up to 15.5% for 32x32m frame, 13.27% for 36x36m frame, 12.36% for 40m x 40m frame and about 34.11% for asymmetrical structure after adding X-bracing at the center.

2. It is observed that drift is reduced up to 15.76% for 32x32m frame, 16.9% for 36x36m frame, 13.79 % for 40m x 40m and about 33.4% for asymmetrical structure frame after adding X-bracing at the center.
3. It is observed that deflection is reduced up to 39% after providing concrete outriggers for 32m x 32m frame (at 0.3H, 0.7H & 1H), 29% after providing belt truss for 36m x 36m frame (at 0.3H, 0.7H & 1H), 33.1% after providing multi-outriggers for 40m x 40m frame (at 0.3H, 0.7H & 1H) and about 38.2% after providing concrete outriggers (at 0.5H and H) where H is the height of structure.
4. It is observed that deflection is reduced up to 39% after providing concrete outriggers for 32m x 32m frame (at 0.3H, 0.7H & 1H), 29% after providing belt truss for 36m x 36m frame (at 0.3H, 0.7H & 1H), 33.1% after providing multi-outriggers for 40m x 40m frame (at 0.3H, 0.7H & 1H) and about 38.2% after providing concrete outriggers for asymmetrical structure (at 0.5H and H) where H is the height of structure.
5. It is observed that drift is reduced up to 35.38% after providing concrete outriggers for 32m x 32m frame (at 0.3H, 0.7H & 1H), 32.21% after providing belt truss for 36m x 36m frame (at 0.3H, 0.7H & 1H), 31.03% after providing multi-outriggers for 40m x 40m frame (at 0.3H, 0.7H & 1H) and about 36.06% after providing concrete outriggers for asymmetrical structure (at 0.5H and H) where H is the height of structure.
6. It is observed that deflection is reduced up to 44.5% after providing diagrids at 66.03° (for 32m x 32m frame), 31.54% after providing diagrids at 71.56° (for 36m x 36m frame), 28.71% after providing diagrids at 74.57° (for 40m x 40m frame) and about 45.85% after providing diagrids at 69.51° for asymmetrical model.
7. It is observed that drift is reduced up to 47.6% after providing diagrids at 66.03° (for 32m x 32m frame), 39.61% after providing diagrids at 71.56° (for 36m x 36m frame), 32.37% after providing diagrids at 74.57° (for 40m x 40m frame) and about 46.68% after providing diagrids at 69.51° for asymmetrical model.
8. It can be concluded from this study that Bracing, Outrigger and Diagrid systems system provides reduction in displacement, drift and base moment, which will further reduce the size and depth of foundation
9. From above results it can be concluded that diagrid structure offers maximum reduction in displacement and drift as compared to bracing and outrigger systems

FUTURE SCOPE

1. More detailed analysis such as Pushover analysis and time history analysis can be carried out of the said structure and their results can be compared.
2. Analysis can be done on more asymmetrical plan and the results can be compared with the symmetrical layout plan.
3. Analysis can be done on vertical irregular cross-sections and the results can be compared with the regular cross-sections.
4. Ductile detailing of the structure can be done.
5. Further optimization of the sizes of the members can be done.
6. The study can be carried by increasing height of building as well as for different zones.

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