COMPARATIVE STUDY OF BARE FRAME CONVENTIONAL BUILDING WITH BRACING, OUTRIGGER AND DIAGRID STRUCTURES DURING EARTHQUAKE LOADS

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Abstract- *High-rise structures are mostly affected by lateral loads and vulnerable to seismic forces. Earthquake is one of the most devastating natural calamities known to man. Most earthquake related deaths are caused by the collapse of structures. The structural configuration plays a role of paramount importance in reducing the death toll in an earthquake. Numerous researchers have suggested the use of seismic isolation as a method to reduce vibrational damage and to increase seismic sustainability. In this study, the response of various structural configuration regular structure with Bare frame-regular building, diagrid system and bracing syste and outrigger system, are evaluated. For the analysis, 30 storey building is considered. The analytical methods used in this dissertation work are equivalent static method and response spectrum method. The seismic parameters for earthquake loads and functions are set as per IS1893-2002. The FEA software ETABS v15 is used for analysis, In this work, various parameters like storey drift, storey displacement, time period, frequency and base shear, are obtained for all the models and have been compared*

Keywords- ETABS, Bracing, Diagrid, Outrigger, Seismic Forces, Storey displacement, Frequency, Base shear, etc

I. INTRODUCTION

Earthquake is one of the most destructive natural disaster. The death occurs due to earthquake was resulted because of collapse of structures. The different types of configurations are very much importance in death rate. Many researchers have suggested to use the proper base isolation systems to reduce the damage happening due to vibrations. Base isolators are very effective for low & medium rise structures. However, for high rise structures, it is not recommended due to its higher over turning moments. The high rise structures are in trend now because of scarcity of land. There is a need to understand the behaviour of dynamic response of the structure. Number of studies has to be carried out to understand the various configuration and their responses during dynamic loads. The main way forward towards the resistant towards earthquake design is to improve the lateral stability of structure. The stability in the form of deformability, ductility capacity and limited damage to the structure with no collapse. The reinforcement detailing is main responsible for the elastic behaviour to avoid any brittle failure. Hence, the primary task of an engineer is to design the structure to withstand for earthquake and exhibit higher ductility to withstand the same. The structure has to withstand for the design period stably.

1.1 BRACING

The main reason for the structure to become more sensitive is due to slenderness of the structure, as the building height increases, the slenderness of the building will drastically increase. This can be over ruled by careful design by providing lateral resisting systems. Which will make the structure stiff, stable and light weight. A bracing system is one such structural system which makes the structure stable under lateral loadings

1.2 DIAGRID

It can be easily recognized by the most of the people, due to its appearance. This system avoids the additional structural elements to support the facades. There by increasing the outside view due to less obstructions. It is an efficient system for architects due to avoiding the interior and corner columns, which will allow the flexibility in the floor space. As a economy consideration, it can save up to 20 percent by weight of structural members when it is compared with conventional frame system.

1.3 OUTRIGGER

The system consists of main concrete core, which will be stiff and stable. The outrigger is the structural member which connects the exterior columns from centre core, which will be up to 2 floors deep. These outriggers are placed parallel along both directions.

Types of outrigger structural system:

It has been classified based on the type of connectivity and location.

- Conventional Outrigger System
- Virtual Outrigger system

Conventional outrigger system:

It is one of the normal type of outrigger system which we see usually, where the outrigger trusses or beams are directly connected with the shear core or braced frames to the outer columns. There is no need the connection to the edges of the building. The outrigger numbers usually varies with the height of the building.

Virtual outrigger system:

The basic idea involved in the virtual outrigger system, which are very much stiff in their own plane. Here the trusses are not directly connected to the core. The load transfer takes place from core to truss. The outrigger trusses will convert the lateral couples in to longitudinal couples in columns. The basement walls and the belt trusses acts like virtual outriggers.

II. LITERATURE REVIEW

[**Narsireddy et al..,2018**] in this study five models are considered, one is conventional steel frame and other four are diagrid frames in which diagrid is connecting to one, two, three storeys. All models are of G+ 25 storeys. They are modelled and analyzed in seismic and wind load conditions using ETABS 2013, for seismic analysis zone 4 is considered, wind speed of 44 m/s is considered in wind analysis. The five models are analyzed and the parameters like storey displacement, story drift, time period, axial force, bending moment are compared. Finally, it is concluded that model 3 gives the better results for all above parameter. From the study it is concluded the Diagrid structure is gives better results in seismic and wind analysis than conventional steel structure. The storey displacement is minimum in Diagrid structure as compared to conventional frame. In different seismic and wind load analysis the model 3 gives the better results, in storey displacement, storey drift, bending moment, axial force conditions.

[**Reza Kamgar et al..,2018**] **l**, in this present paper, for maximizing the efficiency of the outrigger belt truss system, a methodology is proposed here and also an attempt is made based on finding the optimum location of outrigger system is evolved. Here a tall building is modelled with a hybrid pattern by including framed tube, shear core and outrigger system. In this approach, box sections are used for tube systems. The optimum location of outrigger is calculated manually by applying loads in 3 different patterns viz, UDL, triangulated loading and concentrated loading at top of structure. And the accuracy is also checked by considering various examples and it is found that th proposed method is accurate.

[Tejesh R et al..,**2018]** In the present study 15 storey steel structure of height 45m (3m each storey) was considered. The structure was designed as per IS 800:2007 code with dead load, live load earthquake load combinations and wind load combinations. Dynamic analysis (response spectra) was performed using ETABS software assuming response reduction factor as 5, importance factor as 1, seismic zone II and type of soil is 2. The analysis was performed according to IS 1893.The analysis was performed for building without bracing, with X bracing and V-bracing. The results were compared and studied. It was found that displacement of the structure was more in the structure without bracing than other models. It was also observed that lateral loads were more in the case of X-bracing. Finally, it can be concluded that X-bracing is better for wind loading and V-bracing is better for earthquake loading,

III. ANALYSIS

3.1 EQUIVALENT STATIC ANALYSIS

The equivalent static analysis or linear static analysis is bit simple technique, which will substitute to the response spectrum method. In this work, the time period considered will be negligible and forces are applied in a linear format.

3.2 RESPONSE SPECTRUM ANALYSIS

Response spectrum analysis is a linear dynamic analysis. In the analysis the mode shapes and modal mass participation factors are considered in the analysis and hence it will be treated as practical. All the building or structures will not respond to earthquake out of its frequency of vibration. These frequencies of the structure are called as eigenvalues and the shape of each mode generates which is known as eigenvector. In general, starting 3 modes are important to consider. And as per code it should cover a factor of 90% of modal mass participation.

IV. MODELING OF STELL STRUCTURAL SYSTEM

Modelling of G+29 storey building is considered for the analysis in ETABS software. .

The structure considered here is a regular building with plan dimension of 42m x 42m with a bay length of 6m on both sides. In the present study, a G+29 storeys steel structure with bare frame, bracing system, diagrid system are considered. .

4.1 MATERIAL PROPERTY

The material considered for analysis RC is M-40 grade concrete and Fe-500 grade reinforcing steel:

Young's- Modulus - steel, Es = 2, 10,000 MPa

Young's - Modulus - concrete, EC =31622.7 MPa

Characteristic strength of concrete, fck = 40 MPa

Yield stress for steel, fy = 500 MPa

Table.3.1 Specification of models

Member	Specification
Beam	ISMB500
Column	Built up ISHB 450
Bracings	ISMB150

The above sections are assigned based on economical design depending on height of the building

4.2 MODEL GEOMETRY

The Building is 30-storied, seven bays along X-dir. and seven bays along Y- dir., Steel frame with properties as specified below. The floors are modelled as rigid deck slab section. The details of the model are given as follows:

Number of stories = 30

Number of bays along X Dir. = 7 Bay, Y-Dir. = 7 Bay

Storey height = 3.0 meters at Ground Floor,

Remaining Floors.

Bay width along X Dir.= 6 m, Y Dir. = 6 m.

V. TYPES OF MODELS FOR ANALYSIS

In the present work five models were considered and analyzed they are viz.
Model - 1- Bare frame - regular building
Model – 2-Bracins System.
Model - 2- Outrigger System.
Model- 4- Diagrid System.

5.1 MODELING

Figure .1 indicates the plan of the symmetrical structure. The figure.2 shows the elevation of the model

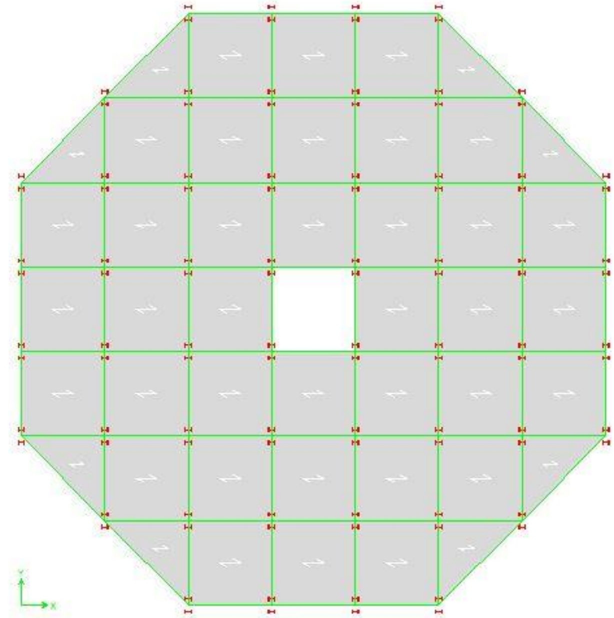

Fig. 1 Plan of the buildings

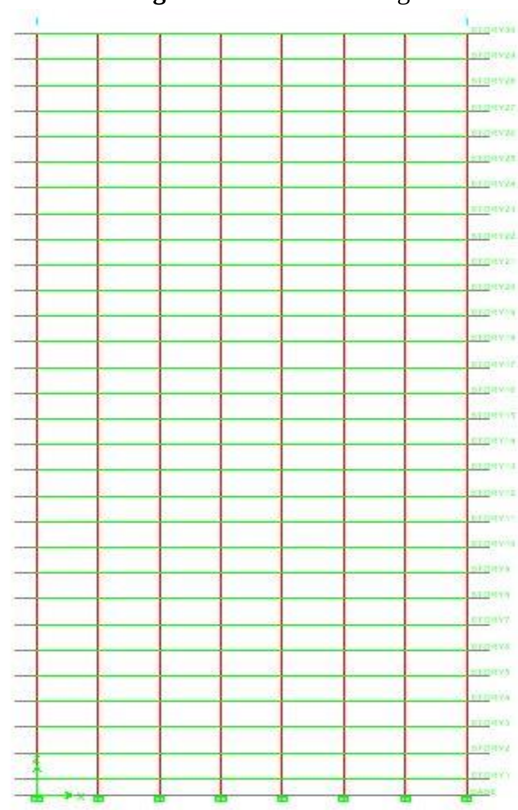

Fig. **2** Elevation View

VI. RESULTS

This chapter describes the results and discussion of the models analyzed in ETABS by linear analysis

Equivalent Static Analysis(ESA)

6.1 STOREY DISPLACEMENT

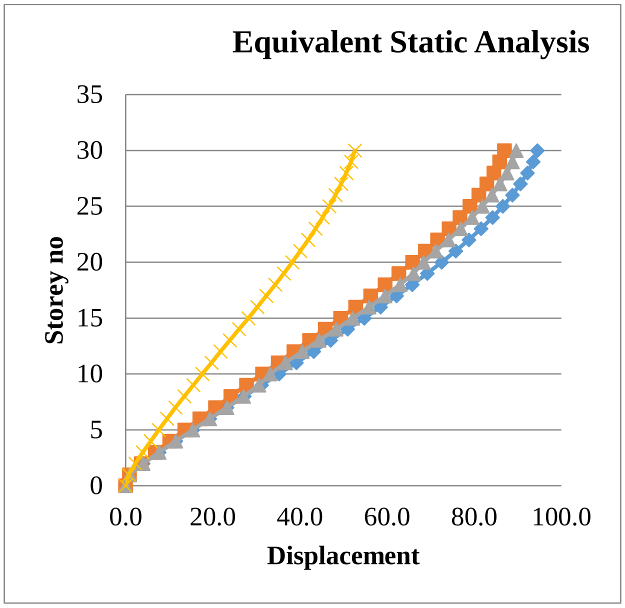

Fig. **3** Comparison of story v/s displacement for 30 storey different models in x-direction

The displacement in the conventional building seems to be high compared to all other structures. It is observed that the model-1 is maximum and module-4 displacement is minimum the percentage decrease in displacement from model-1 to module-2 is 8.042%, displacement from model-1 to module-3 is 5.185%, and from module-1 to module-4 is 44.33%.

6.2 STOREY DRIFT

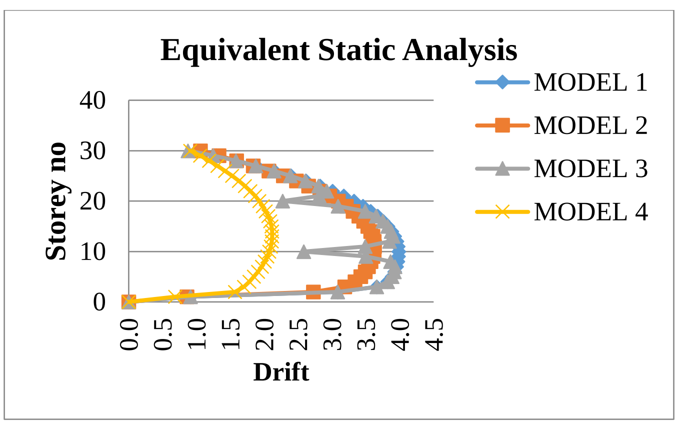

Fig. **4** Comparison of storey v/s storey drifts for 30 story different models in x-direction

The drift values are the difference in the displacement values. From the graphs, it is clear that the drift values are significantly less in the diagrid structure. The percentage decrease in the storey drift from model-1 to module-2 is 10%, from module-1 to module-3 is 2.5%, from module-1 to module-4 is 47.5%.

6.3 TIME PERIOD

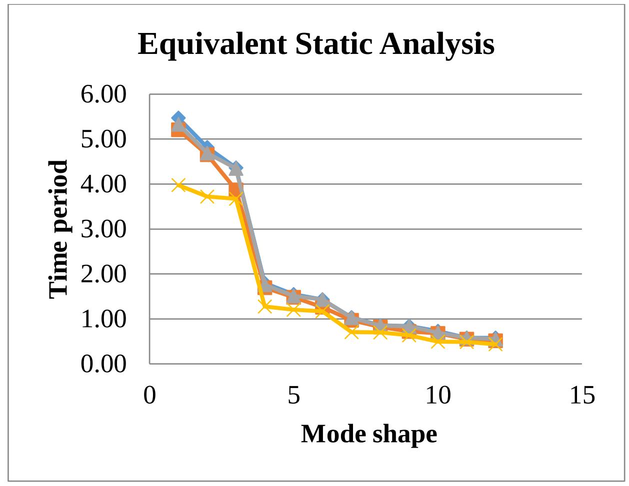

Fig. **5** Comparison of mode numbers v/s time period for 30 storey different models

Regular conventional model is having higher time period and hence the higher flexibility. The flexibility of the diagrid structure reduced in the time period due to lesser time period. The time period of models1, 2 and 3 are almost same due to same flexibility and however, the models 4 differs.

6.4 FREQUENCY

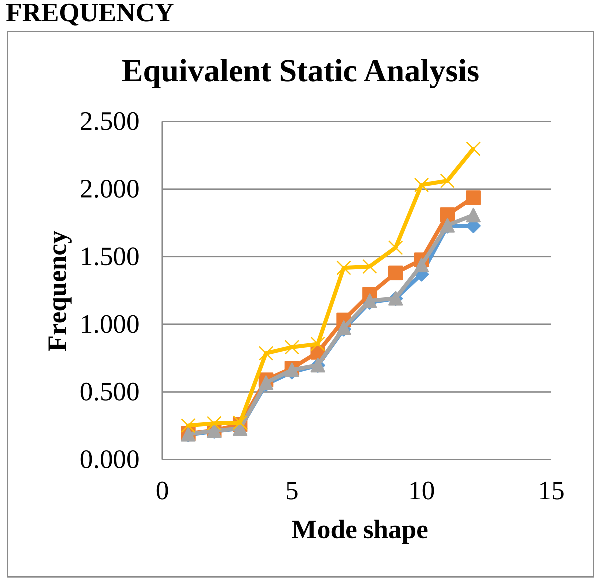

Fig. 6 Comparison of mode numbers v/s frequency for 30 storey different models

Since, the frequency is inversely dependent on the time period, the values are in line with time period values. However, the frequency will be more for diagrid model when compared to other models. The Regular model is having lesser frequency because of longer time period.

Response Spectrum Analysis(RSA)

6.1 STOREY DISPLACEMENT

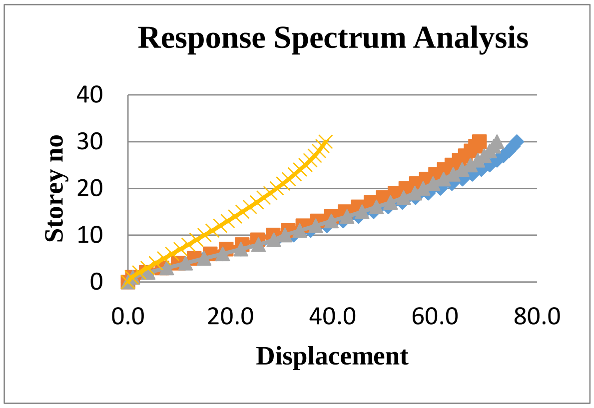

Fig. **7** Comparison of story v/s displacement for 30 storey different models in x-direction

The displacement in the conventional building seems to be high compared to all other structures. It is observed that the model-1 is maximum and module-4 displacement is minimum the percentage decrease in displacement from model-1 to module-2 is 9.6%, displacement from model-1 to module-3 is 3%, and from module-1 to module-4 is 49 %.

6.2 STOREY DRIFT

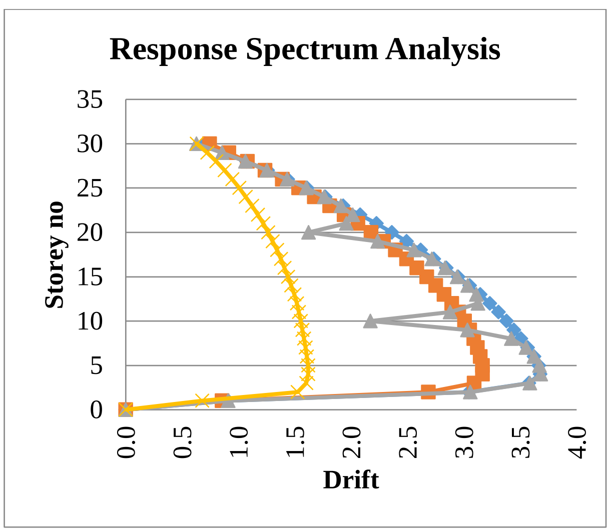

Fig. **8** Comparison of storey v/s storey drifts for 30 story different models in x-direction

The drift values are the difference in the displacement values. From the graphs, it is clear that the drift values are significantly less in the diagrid structure. The percentage decrease in the storey drift from model-1 to module-2 is 13.5%, from module-1 to module-3 is 2.7%, from module-1 to module-4 is 56.75%.

6.3 TIME PERIOD

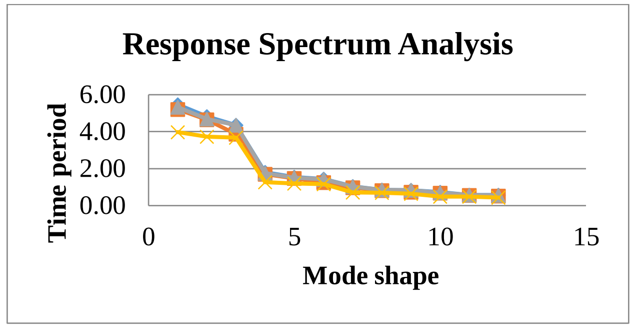

Fig. **9** Comparison of mode numbers v/s time period for 30 storey different models

Regular conventional model is having higher time period and hence the higher flexibility. The flexibility of the diagrid structure reduced in the time period due to lesser time period. The time period of models1, 2 and 3 are almost same due to same flexibility and however, the models 4 differs.

6.4 FREQUENCY

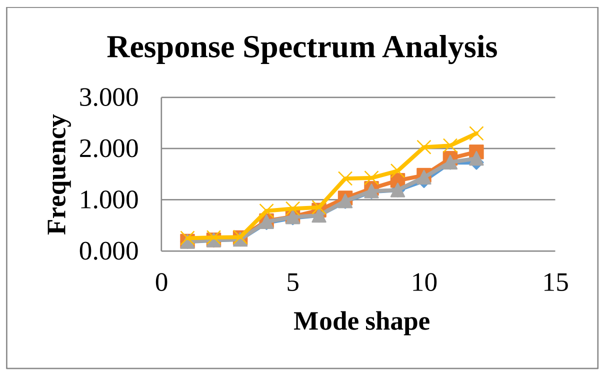

Fig. 10 Comparison of mode numbers v/s frequency for 30 storey different models

Since, the frequency is inversely dependent on the time period, the values are in line with time period values. However, the frequency will be more for diagrid model when compared to other models. The Regular model is having lesser frequency because of longer time period

VII. CONCLUSIONS

The following conclusions are being made by the results obtained from the present study:

1. The displacement of model 1, conventional structure is having higher displacement compared with all other models.

2. The model-1 exhibits a higher displacement of about 49% and more compared with diagrid structure.
3. The storey drift for model-1 is more comparison with the other modules.
4. The module -4 is found to be less having lesser drift between the stories.
5. The time period of the structure depends on its flexibility. From the results regular conventional building is having greater flexibility than other models. The diagrid model shows lesser time period due to its brittle behaviour. It is almost 50% reduction in comparison
6. There is no much difference in the base shear values between the models. Since all the models process similar load and height, the base shear parameter is not a matter of considerations.
7. The difference between equivalent static and response spectrum analysis is noticed from the results.
8. It is found that, Equivalent static giving higher displacement values than Response spectrum. However, the time period and base shear values will be not varying for different analysis.
9. The time period and base shear values will not vary for the type of analysis. Since it is depending on the building geometry and its dynamics.

Scope for Future Study

Further to the study, the project can be extended to the following research:

- To consider various other structures like tube structures, Belt truss system, Mega bracings etc.
- The soil structure interaction parameters can be included to check the realistic behaviour.
- The time history analysis can be conducted to assess the models in detail.

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