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Comparative Study on Multi-Storey RC Frame with Shear Wall and Hexagrid System

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ABSTRACT

The past earthquakes in which many concrete structures are severely damaged have indicated the need for evaluating the seismic adequacy and economically adequate buildings. Hence the structures vulnerable to damage must be identified and an acceptable level of safety for such structures must be determined. To make such assessments, simplified linear-elastic methods of analysis are conducted. Thus, the structural engineering community has developed a new generation of design and seismic procedures and some of them incorporate performance based design of structures. Recent developments in the design of buildings in seismically active areas show that an elastic procedure commonly referred to as the response spectrum analysis is a viable method to assess and analyze buildings. The main focus of the present work is to carry out linear dynamic response spectrum analysis on a multi-storied RC building with Bare frame ,Shear wall and Hexagrid system of bracings. For this purpose RC frame is designed using ETABS V.13. The behavior of the structure is studied based on the maximum displacement, maximum drift, maximum storey shear and maximum overturning moment. The study includes the consideration of the effect of base shear and displacement for RC frames with and without Hexagrid bracings and with shear wall. Comparison is made for result parameters such as maximum storey displacement, maximum storey drift, maximum storey shear and maximum overturning moment between various models for zones-III and comparison is made for result parameters such as maximum storey displacement, maximum storey drift, maximum storey shear and maximum overturning moment between seismic zones of India (Zone-III) for different models. ETABS V13 was used for the purpose and the desired information was achieved.

KEYWORDS Hexagrid, storey drift, storey displacement, ETABS and storey shear.

1. Introduction

1.1 General

Tall building development has been rapidly increasing worldwide introducing new challenges that need to be met through engineering judgment. The structural systems today are undergoing a major evolution to address the ability of providing flexibility in the design and use of the building together with sustainability (Green) and cost-effective system. In modern tall buildings, lateral loads induced by earthquake are often resisted by a system of coupled shear walls and early tall buildings were steel frames with diagonal bracings of various configurations such as X, K, and Chevron. But when the building increases in height, the stiffness of the structure becomes more important. Hence in order to have high stiffness, maximize Eigen frequency for resisting dynamic responses and minimize mean compliance for static responses introduction of bracing beams between the shear walls and external columns is necessary. This provides sufficient lateral stiffness to the structure. Excessive drift due to lateral loads can be effectively controlled by using bracing systems which minimizes structural and non structural damage. Hence in the present case a new system i.e., Hexagrid system of bracing is introduced.

1.1. INTRODUCTION TO HEXA GRID SYSTEM OF BRACING

The design of tall and slender structures is controlled by three governing factors, strength (material capacity), stiffness (drift) and serviceability (motion perception and accelerations), produced by the action of lateral loading. The overall geometry of a building often dictates which factor governs the overall design. As a building becomes taller and more slender, drift considerations become more significant. Proportioning member efficiency based on maximum lateral displacement supersedes design based on allowable stress criteria. Next to the very common structural systems for lateral loads such as concrete cores, shear walls and rigid orthogonal frames, there are more possible options to ensure structural stability and stiffness. Some of these systems such as 'diagrids', 'tube constructions', and 'mega trussed frames' have been researched by numerous scientists. The appearance of hexagonal forms in nature gives away the possible potential of this structure. Most designs in nature are very efficient for their objective. So nature can only be copied in the structure and thereby the mechanics are understood. The lateral stiffness properties of a hexagrid have not yet received enough attention. A hexagrid is a hexagonal frame built up out of beam-like elements. It is as a variant of diagrid which has a triangular configuration of diagonal columns and horizontal beams. A lot of designs in nature with hexagonal features show the promising qualities of a hexagonal structure for example a honey comb. For simplicity, the grids are split up into small pieces. These pieces are called 'unit cells'.

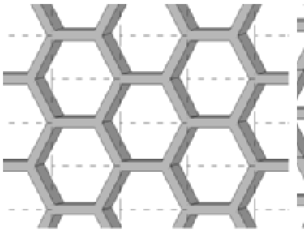

Fig 1.1 Hexagrid

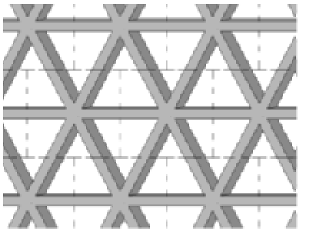

Fig 1.2 Diagrid

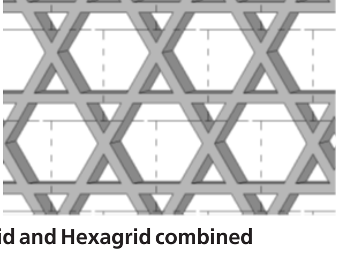

Fig 1.3 Diagrid and Hexagrid combined

2. SEISMIC DESIGN PHILOSOPHY

Seismic design philosophy may be summarized as follows

- When there is minor but frequent shaking, the main members of the building which carry the vertical and horizontal forces should not be damaged. However building parts that do not carry load may sustain repairable damage.

- When there is moderate but occasional shaking, the main members may sustain repairable damage, but the other parts of the building may be damaged such that they may even have to be replaced after the earthquake and
- Under strong but rare shaking, the main members may sustain severe (even irrepairable) damage, but the building should not collapse.

3. OBJECTIVES OF THE STUDY

The following are the main objectives of the present study

- To compare the maximum displacement, maximum story drift, maximum story shear, maximum overturning moments of RC bare frame and RC frame with shear wall and RC bare frame with shear wall and hexagrid system in various seismic zones of India.
- To compare various results like maximum displacement, maximum story drift, maximum story shear, maximum overturning moments for zone3 for RC bare frame, RC bare frame with shear wall and RC bare frame with shear wall and hexagrid system.

4. SEISMIC METHODS OF ANALYSIS

The analysis process can be categorized on the basis of three factors: the type of externally applied loads, the behavior of structure/ or structural materials and the type of structural model selected. Based on the type of external action and behavior of structure, the analysis can be further classified as

1. Linear static analysis
2. Non-linear static analysis
3. Non-linear dynamic analysis
4. Linear dynamic analysis

Linear static analysis or equivalent static analysis can be used for regular structures with limited height .Linear dynamic analysis can be performed by response spectrum method or by the elastic time history. The significant difference between linear static and linear dynamic analysis is the level of force and their distribution along the height of the structure. Non-linear static analysis is an improvement over linear static or dynamic analysis in the sense that it allows inelastic behavior of the structure and provides information on the strength, deformation and ductility of the structure. Non-linear static analysis can be performed by push over analysis. A non-linear dynamic analysis or in elastic time history analysis is the only method to describe the actual behavior of a structure during an earthquake.

5. METHODOLOGY

The general finite element package ETABS (version-2013.1.5) has been used for modeling and analysis. It is a versatile and user-friendly program that offers a wide scope of features like static and dynamic analysis, nonlinear dynamic analysis and nonlinear static pushover analysis, etc. These features and many more, make ETABS the state-of-the-art in structural analysis programs. Linear dynamic response spectrum analysis is a very powerful feature offered in the linear version of ETABS. Response Spectrum analysis is performed on both two and three dimensional structural models. ETABS can also perform response spectrum analysis for various zones and different soil types.

5.1. MODEL DISCRIPTION

In this study, a 30 storey bare RC building, 30 storey bare RC building with shear wall and a 30 storey bare RC building with shear wall and hexagrid system are considered. These models are analyzed by response spectrum method. Medium type of soil is considered for response spectrum analysis in this study. Different zones considered for response spectrum analysis are zone -III. A brief summary of the building is presented in the table 1.

Table 1 A brief summary of the building is presented in the table 1.

Type of structure	OMRF
Grade of concrete	M40
Grade of reinforcing steel	Fe500
Number of storeys	30
Building height	120 m
Grid data	7 X 7 Bay, 6m Spacing. Shear wall at the centre of the grid.
Beam size	300X600
Bracing size	300X300
Slab thickness	150
Shear wall thickness	600
Support condition	Fixed base

Column size: Square columns:

1000mm X 1000mm	First to Third Floor
900mm X 900mm	Fourth and Fifth Floor
800mm X 800mm	Sixth to Eighth floor
700mm X 700mm	Ninth to 12th Floor
600mm X 600mm	13th to 16th Floor
500mm X 500mm	17th to 30th Floor

Modeling cases:

Case 1: Bare frame
Case 2: Bare frame with shear wall.
Case 3: Bare frame with shear wall and hexagrid system

Analysis type:

Linear dynamic response spectrum analysis

Model types:

Type 1: Bare frame system (zone 3)
Type 2: Bare frame system with shear wall (zone 3)
Type 3: Bare frame with shear wall and Hexagrid system (zone 3)

5.2. Loading:

Types of loads: For the purpose of computing the maximum stresses in any structure or member of the structure, the following loads and load effects shall be taken into account, where applicable:

a). Dead Loads
b). Imposed Loads

Dead loads and imposed loads to be assumed in design shall be as specified in IS 875-1987(Part 1 & 2).

Super-imposed load on slab: At floor and roof levels: Floor finishes: 1 kN/m^2
Live load on slab: 4kN/m^2

5.3. Structural Modeling

The analytical model was created in such a way that the different structural components represent as accurately as possible the characteristics like mass, strength, stiffness and deformability of the structure. Non structural components were not modeled. The various primary structural components that were modeled are as follows:

(a) Beams and columns: Beams and columns were modeled as 3D frame elements.
(b) Beam-column joints: The beam-column joints were assumed to be rigid and were modeled by giving end-offsets to the frame elements. This was intended to get the bending moments at the face of the beams and columns.
(c) Foundation Modeling: The foundation was modeled based on the degree of fixity which is provided. The effect of soil structure interaction was ignored in the analysis.
(d) Slab Modeling (Modeling of joints): Slab is modeled as a rigid diaphragm. In rigid diaphragm case all the joints in the slab moves together as a single unit.

5.4. MODELLING AND ANALYSIS

Response spectrum analysis of Bare Frame with shear wall and Hexagrid system is carried out and the following 3D models are obtained as shown in Fig.1, Fig.2. &Fig.3.

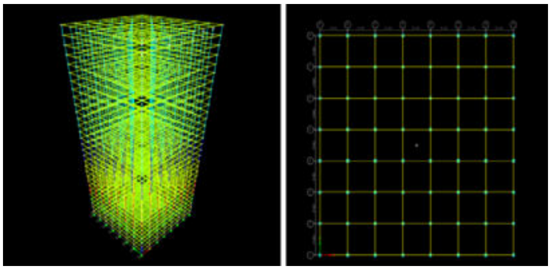

Fig 1: Model of RC bare frame

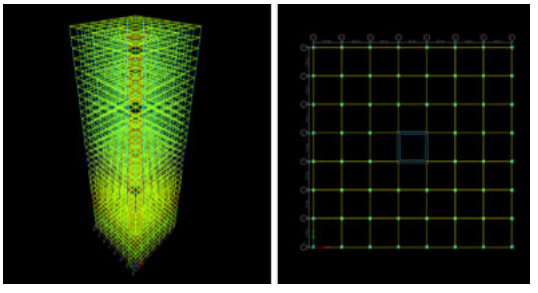

Fig 2: Model of RC bare frame with Shear wall

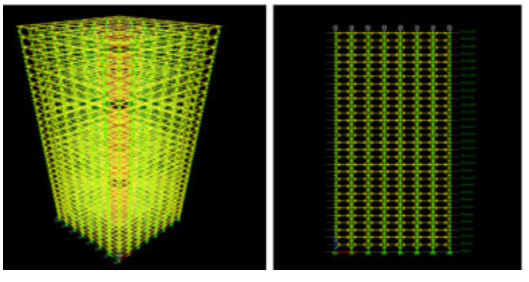

Fig.3 Model of RC bare frame with Shear wall and Hexagrid system

6. RESULTS AND DISCUSSION

The graphical re A brief summary of the building is presented in the table 1.presentation Response Spectrum Results for all cases in Zone 3

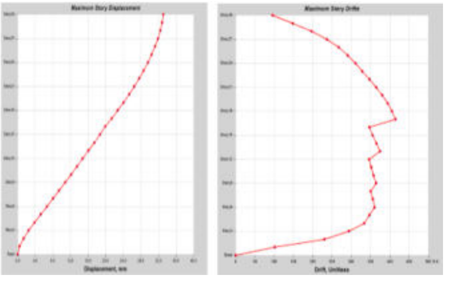

Fig.4 Displacement and Storey drift variation for Bare Frame

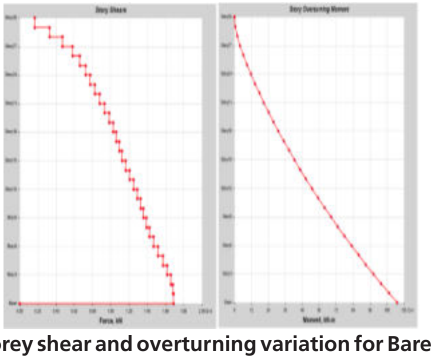

Fig.5 Storey shear and overturning variation for Bare frame

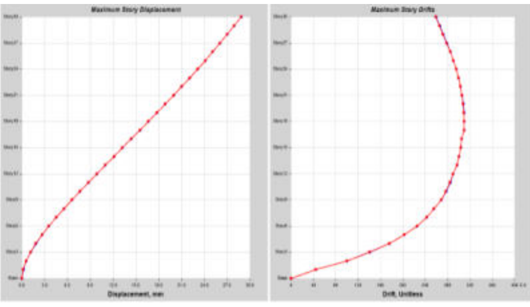

Fig.6 Displacement and Storey drift variation for Bare Frame with shear wall

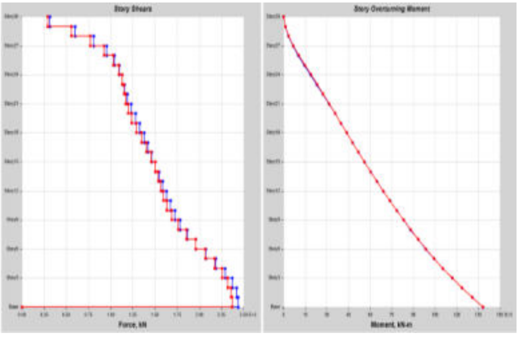

Fig.7 Storey shear and overturning variation for Bare frame with Shear wall

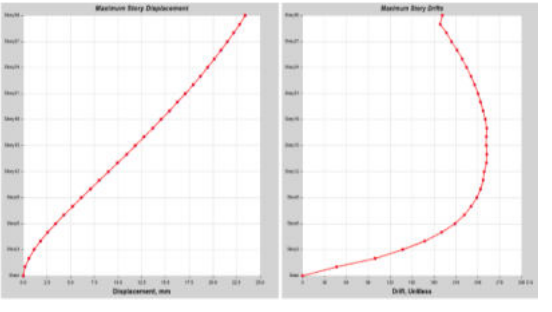

Fig.8 Displacement and Storey drift variation for Bare Frame with shear wall and hexagrid.

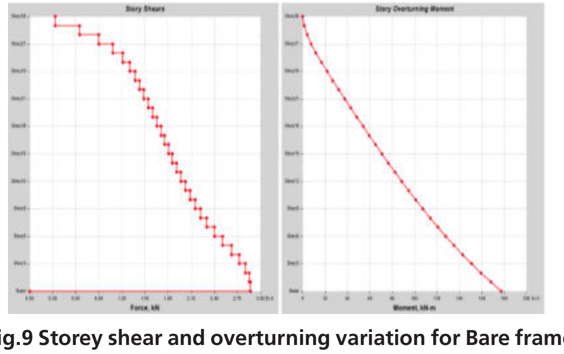

Fig.9 Storey shear and overturning variation for Bare frame with Shear wall and Hexagrid

DISCUSSION

1)Figures show that in zone 3 the model bare frame with shear wall and hexagrid system has least displacement of 23.4mm at the top story and least drift of 0.00025mm between story 15 and 18; and bare frame has highest displacement of 33.13mm and highest story drift of 0.00041mm between story 15 and 18.

2) Figures show that in zone 3 the model bare frame with shear wall and hexagrid system has highest shear of 2869.95kN at the base and highest overturning moment of 177220kNm at the base; and bare frame has least shear of 1689.64kN and least overturning moment of 115128 kNm at the base.

3) Storey drift in hexagrid system is found to be lesser than the storey drift of RC frame with shear wall and RC bare frame.

7. CONCLUSIONS

1. The base shear in RC bare frame is least compared to other two models as the mass of RC bare frame with shear wall and mass of RC bare frame with shear wall and hexagrid system is more than that of RC bare frame.

2. The displacement of bare frame is maximum , due to change in lateral stiffness and more compared to other two models. The displacement of bare frame with shear wall and bare frame with shear wall and hexagrid system are lower.

3. Shear wall whose width is same as bay width and height same as storey height are very effective in reducing the dynamic response of the structure.

4. The shear wall and hexagrid system, although do not interfere in the vertical load resisting system for the RC frame structures, they significantly affect the lateral load resisting system of the same due to its stiffness and mass.

5. As base shear depends on seismic weight of the building, the base shear of bare frame with shear wall and hexagrid system was found to be more compared to bare frame and bare frame with shear wall.

6. Drift values shows the effective behaviour of the structure when the hexagrid system of bracing is adopted.

7. The effect of RC bare frame with shear wall and hexagrid system of bracing is prominent for multi-storeyed buildings in high seismic zones.

8. As the number of storeys is increased the resistance of the structure to base force decreases and as a result displacement increases.

8. REFERENCE

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