Analysis of a High Rise Building Frame Considering Hybrid Shear Wall under Lateral Load Using ETABS

Saurabh Gupta[1] D.L. Sahu[2]
[1]Research Scholar [2]Assistant Professor
[1,2]Department of Civil Engineering
[1,2]Sam Global University, Raisen, Madhya Pradesh, India

Abstract — Shear walls are structural elements that protect structures from lateral loads such as wind and earthquakes. When the external walls of a building are insufficiently strong and stiff, shear walls are added to the interior to provide greater strength and stiffness. When the permissible span width ratio for the floor or roof diaphragm is exceeded, these shear walls are required. Shear walls are flexural members that are commonly used in high- and low-rise buildings to prevent total collapse due to seismic stresses. Here hybrid shear wall means a combination of shear wall and X bracing this research is focused towards presenting the behaviour of structure considering three different cases namely, structure with X bracing at corner, structure with shear wall at corner and structure with hybrid shear wall at corner. The structure was modelled and analyzed using analytical application ETABS v 2016. The parameters of comparison were Storey displacement, storey shear. Storey drift, storey stiffness and base shear.

Keywords: Hybrid Shear Wall, Response Spectrum Analysis, ShearWall, Seismic Forces

I. INTRODUCTION

To securely carry gravity and lateral loads, tall building design entails a conceptual design, approximation analysis, preliminary design, and optimization. The basic goal of all structural systems employed in the construction of structures is to effectively transfer gravitational loads. Dead load, active load, and snow load are the three most frequent loads caused by gravity. Buildings are also vulnerable to lateral loads induced by wind and seismic forces, in addition to these vertical loads. High stresses, sway movement, and vibration can all be caused by lateral loads. As a result, it's critical that the structure be strong enough to withstand vertical loads while still being stiff enough to withstand lateral stresses. High-rise buildings can be found all over the world. The structural design of high-rise buildings incorporates wind and earthquake dynamic calculations. Computer performance has improved dramatically in recent years, and practically all structural designers now utilise computer software for high-rise building structural design. In high-rise buildings susceptible to lateral wind and seismic stresses, shear walls are extremely critical. Wind, earthquake, and uneven settlement loads, along with the weight of the structure and its inhabitants, produce severe twisting (torsion) forces. These forces have the ability to literally tear (shear) a structure apart. The shape of a frame is maintained and rotation at the joints is prevented by connecting or installing a stiff wall inside it. It is provided, when the center of gravity of building area & loads acted on it differs by more than 30%. To bring the C.G. in range of 30% concrete wall is provided lateral forces may not increase much. Shear wall gives better response if it is provided at optimum location. The shear wall's goal is to look at the various ways that tall structures can be stabilised against the impacts of heavy horizontal wind and seismic loads.

The static and dynamic structural responses of high-rise buildings are influenced by the distributions of transverse shear stiffness and bending stiffness per storey. "At some point after the building's initial construction and occupation, making changes to the building's systems, or possibly the structure itself."

Wind and seismic forces acting on high-rise buildings become a significant design consideration. Tall building structural systems can be enhanced to regulate dynamic response by employing more appropriate structural elements such as shear walls and tube structures, as well as enhancing material qualities; the maximum height of concrete buildings has risen substantially in recent decades. Shear walls' edges are subjected to severe compressive and tensile stresses as a result of the massive overturning effects induced by horizontal Earthquake forces. Concrete at the wall end areas must be strengthened in a specific way to survive these load reversals without losing strength in order for shear walls to behave ductilely. Boundary elements are wall end sections with enhanced confinement. The boundary elements' specific restricting transverse reinforcement is comparable to that found in reinforced concrete frame columns. The thickness of the shear wall in these boundary elements is sometimes raised as well.

A shear wall is a structural element that resists lateral forces such as wind forces in a reinforced concrete framed construction. Shear walls are commonly employed in high-rise buildings that are subjected to lateral wind and earthquake stresses. Wind forces become more significant as a structure's height grows in reinforced concrete framed constructions. Horizontal movement or sway is restricted under codes of practise.

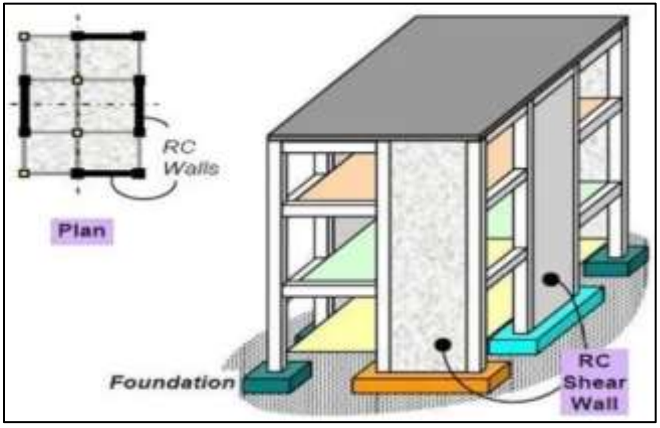


Fig. 1: Shear Wall

II. LITERATURE REVIEW:

Abhishek Sharma and Prince Sharma (2019) the objective of the research was to observe the non-linear analytical behaviour of coupling beams by using ETABs and to select appropriate section from conventional reinforced concrete coupling beams, steel link beams and composite steel – concrete coupling beams in a high seismic zone. A regular geometry for a commercial office building (G+20) Special Moment Resisting Frame (SMRF) with Coupled Shear Walls in the core situated in seismic Zone V having zone factor 0.36 and soil type medium stiff and Importance Factor (I) 1.5 was modelled by using ETABs 2015.

From the nonlinear static analysis it was clearly observed that coupling beams behaves as a shear dominated beams rather than flexure. The steel link coupling beams deformed in a more ductile way as compared to the RC coupling beams and composite steel-concrete coupling beams. Steel link beams shown adequate strength and ductility over concrete link beams and huge amount of shear is observed by the steel links beams. The shear controlled plastic hinges assigned to conventional RC beams was found in Collapse prevention state which is considered most damageable state in performance based design (PBD) whereas composite steel-concrete coupling beams remains in Life Safety (LS) and steel link beams performed enormous shear absorption but still plastic hinges formed gone to the Intermediate Occupancy (IO) which means core shear wall can be operated during seismic hazards and not in case of RC coupling beams. The elastic analysis of coupled shear walls can't be adopted because coupling beams undergoes large inelastic deformations in designing coupled shear walls. Braced coupled shear walls also can be a better option in high seismic zone as the diagonal braces distributed maximum axial forces from one wall pier to the joined wall pier by means diagonal braces.

AlshawabkehShorouq and Wu Li (2019) A "hybrid" concrete shear wall system was investigated in this study, which included mild steel reinforcement as well as posttensioned steel for flexural strength and inelastic energy dissipation. A logical parametric research was carried out to investigate the expected seismic behaviour of a concrete wall subjected to seismic loading in a series of prototype or model hybrid walls comprising post tensioned steel in precast concrete shear walls and cast-in-place concrete shear walls.

According to the findings, using mild steel in addition to post-tensioned steel in reinforcing the concrete shear wall improved the concrete shear wall's seismic resistance properties, notably in terms of reducing lateral displacement (i.e., dislocation) induced by earthquake loading.

III. OBJECTIVES:

In this study R.C.C. building is modelled, analyzed and designed. Design of shear wall by itself is a study of demand Vs capacity ratio adhered to the properties of shear wall sections. This can be generated by the mathematical model created in Etabs by considering the earthquake and wind forces.

1) Behavior study of 10 storey high rise RCC structure with X bracing, shear walls and hybrid shear wall is for seismic & wind loads.
2) The variation of storey drifts of the models to be investigated.
3) The variation of displacement has to be investigated.
4) It is necessary to perform both similar static analysis and response spectrum analysis.
5) Identify the response of three structural system for symmetrical structure.

IV. METHODOLOGY:

A. Steps of Modelling

Step 1 Reviewing research papers published by different authors in order to identify the scope of the research.

Step 2 Defining grid system data for x and y coordinates. In ETABS, X coordinates are defined on grid ID as A, B, C etc and Y coordinates as 1, 2, 3 etc. The Z direction defined the storey height.

Fig. 2: Grid System Data

Step 3 Defining structure object and applying simple storey data, here number of storey is G+10 with typical storey and bottom height is 3.2 m.

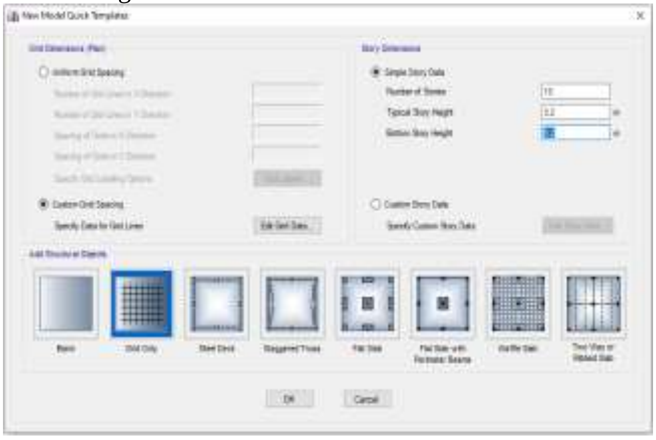


Fig. 3: Model Template

Step 3 This step defines the properties of material as here RCC structure is considered with X bracing, shear wall and hybrid shear wall.

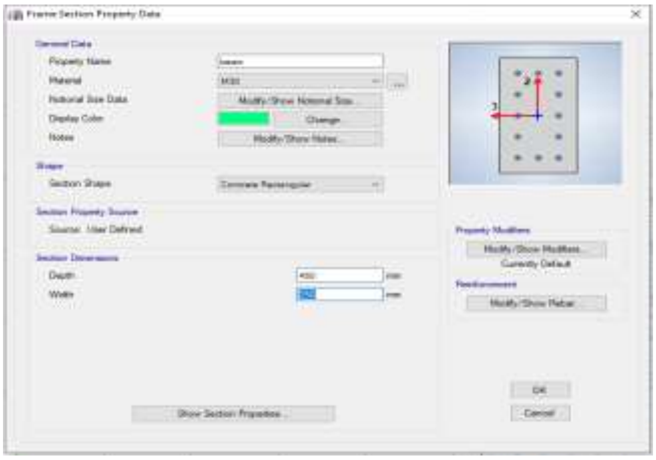
Material Name: M30
Material Type: Concrete
Directional Symmetry Type: Isotropic
● Specify Weight Density ○ Specify Mass Density
Weight per Unit Volume: 24.9926 kN/m³
Mass per Unit Volume: 2548.538 kg/m³
Modulus of Elasticity, E: 27386.13 MPa
Poisson's Ratio, U: 0.2
Coefficient of Thermal Expansion, A: 0.0000055 1/C
Shear Modulus, G: 11410.89 MPa

Fig. 4: Defining property of concrete (M30)

Material Name: Fe345
Material Type: Steel
Directional Symmetry Type: Isotropic
● Specify Weight Density ○ Specify Mass Density
Weight per Unit Volume: 76.9729 kN/m³
Mass per Unit Volume: 7849.047 kg/m³
Modulus of Elasticity, E: 210000 MPa
Poisson's Ratio, U: 0.3
Coefficient of Thermal Expansion, A: 0.0000117 1/C
Shear Modulus, G: 80769.23 MPa

Fig. 5: Defining properties of steel

Step 4 Defining section data for beam, column, slab, X bracing system and shear wall

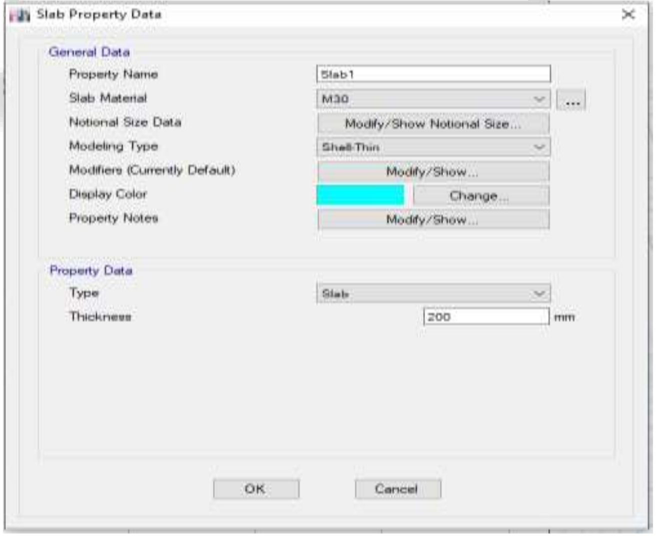


Property Name: beam
Material: M30
Section Shape: Concrete Rectangular
Source: User Defined

Fig. 6: Defining section properties for beam

Property Name: column
Material: M30
Section Shape: Concrete Rectangular
Source: User Defined

Fig. 7: Defining properties of column



Property Name: Slab1
Slab Material: M30
Modeling Type: Shell-Thin
Modifiers (Currently Default)
Type: Slab
Thickness: 200 mm

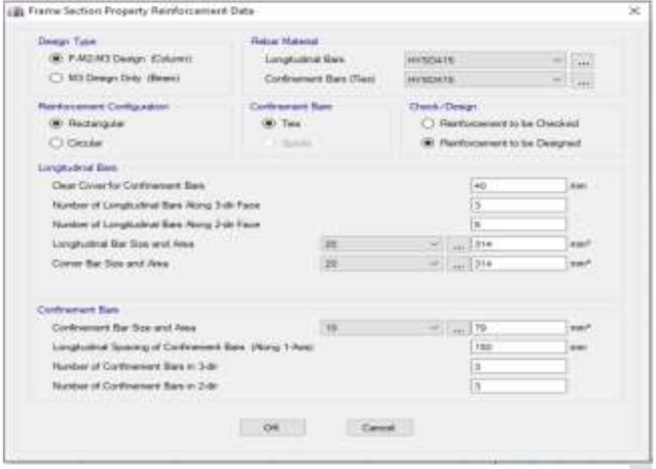
Fig. 8: Defining properties of slab

○ P-M2-M3 Design (Column)
● M3 Design Only (Beam)
Longitudinal Bars: HYSD415
Confinement Bars (Ties): HYSD415
Top Bars: 60 mm
Bottom Bars: 60 mm
Top Bars at I-End: 0 mm²
Top Bars at J-End: 0 mm²
Bottom Bars at I-End: 0 mm²
Bottom Bars at J-End: 0 mm²

Fig. 9: Defining section properties of reinforcement data

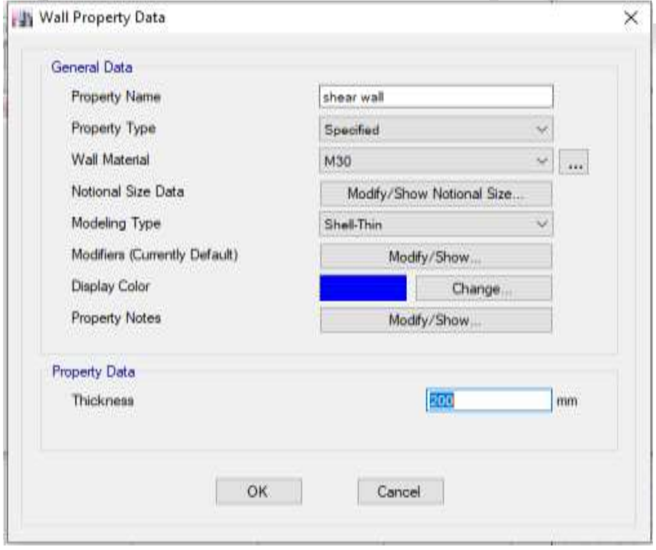
General Data
Property Name: bracing X type
Material: Fe345
Shape
Section Shape: Steel I/Wide Flange
Section Property Source
Source: User Defined
Section Dimensions
Total Depth: 400 mm
Top Flange Width: 250 mm
Top Flange Thickness: 25 mm
Web Thickness: 15 mm
Bottom Flange Width: 250 mm
Bottom Flange Thickness: 25 mm
Fillet Radius: 0 mm
Property Modifiers: Currently Default

Fig. 10: Defining section properties for X bracing system



Design Type
● P-M2-M3 Design (Column)
○ M3 Design Only (Beam)
Rebar Material
Longitudinal Bars: HYSD415
Confinement Bars (Ties): HYSD415
Reinforcement Configuration
● Rectangular
○ Circular
Confinement Bars
● Ties
○ Spirals
Check/Design
○ Reinforcement to be Checked
● Reinforcement to be Designed
Longitudinal Bars
Clear Cover for Confinement Bars: 40 mm
Number of Longitudinal Bars Along 3-dir Face: 3
Number of Longitudinal Bars Along 2-dir Face: 6
Longitudinal Bar Size and Area: 20, 314 mm²
Corner Bar Size and Area: 20, 314 mm²
Confinement Bars
Confinement Bar Size and Area: 10, 79 mm²
Longitudinal Spacing of Confinement Bars (Along 1-Axis): 150 mm
Number of Confinement Bars in 3-dir: 3
Number of Confinement Bars in 2-dir: 3

Fig. 11: Frame section property reinforcement data from design type and rebar material



General Data
Property Name: shear wall
Property Type: Specified
Wall Material: M30
Notional Size Data
Modeling Type: Shell-Thin
Modifiers (Currently Default)
Display Color
Property Notes
Property Data
Thickness: 200 mm

Fig. 12: Defining properties of shear wall

Step 5 Defining load pattern for dead, live and seismic

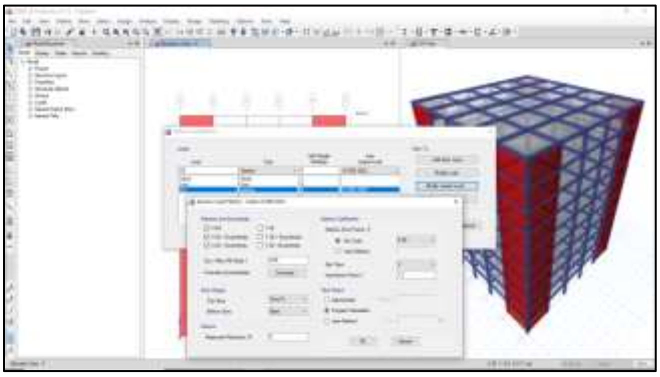
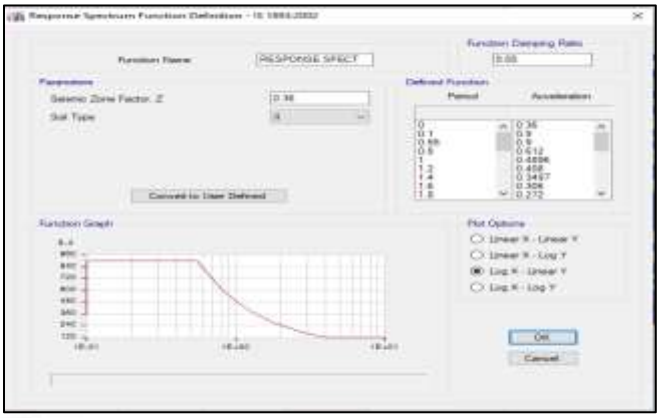


Fig. 13: Defining seismic load pattern as per IS 1893 part I 2016



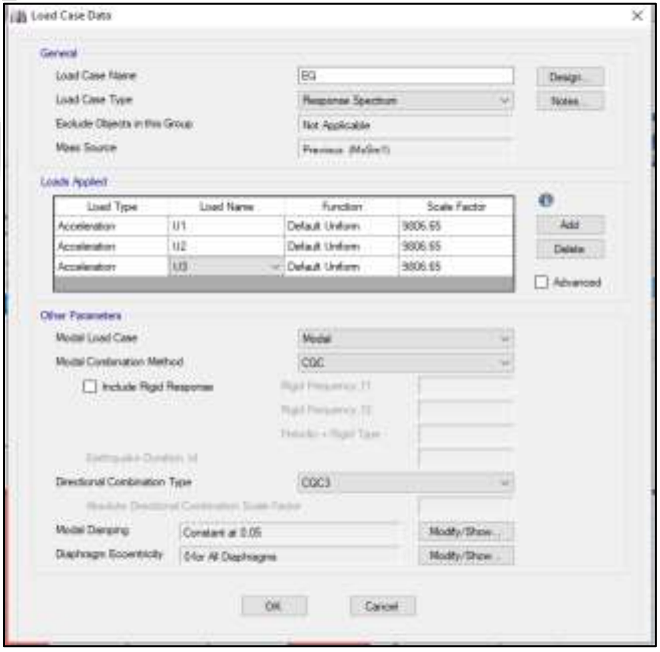
Function Name: RESPONSE SPECT
Function Damping Ratio: 0.05
Parameters
Seismic Zone Factor, Z: 0.36
Soil Type: II

Defined Function

Period	Acceleration
0	0.36
0.1	0.9
0.55	0.9
0.8	0.612
1	0.4896
1.2	0.408
1.4	0.3497
1.6	0.306
1.8	0.272

Plot Options
○ Linear X - Linear Y
○ Linear X - Log Y
● Log X - Linear Y
○ Log X - Log Y

Fig. 14: Defining response spectrum function



General
Load Case Name: EQ
Load Case Type: Response Spectrum
Exclude Objects in this Group: Not Applicable
Mass Source: Previous (MsSrc1)

Loads Applied

Load Type	Load Name	Function	Scale Factor
Acceleration	U1	Default Uniform	9806.65
Acceleration	U2	Default Uniform	9806.65
Acceleration	U3	Default Uniform	9806.65

☐ Advanced

Other Parameters
Modal Load Case: Modal
Modal Combination Method: CQC
☐ Include Rigid Response
Rigid Frequency, f1
Rigid Frequency, f2
Periodic + Rigid Type
Earthquake Duration, td
Directional Combination Type: CQC3
Absolute Directional Combination Scale Factor
Modal Damping: Constant at 0.05
Diaphragm Eccentricity: 0 for All Diaphragms

Fig. 15: Defining Load case data for Response Spectrum

Step 6 Analyzing the structure for displacement, drift and shear force

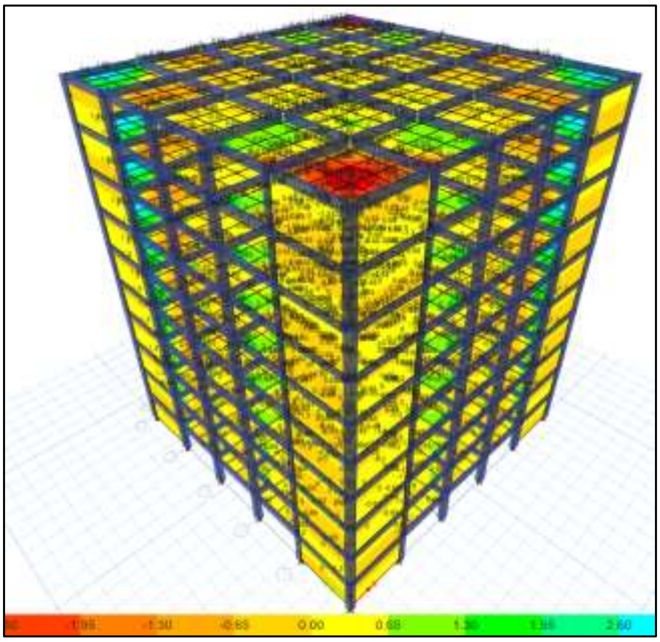


Fig. 16: Analyzing stress

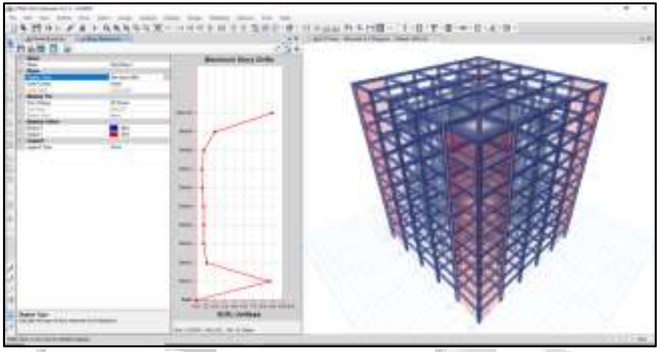


Fig. 17: Storey Drift

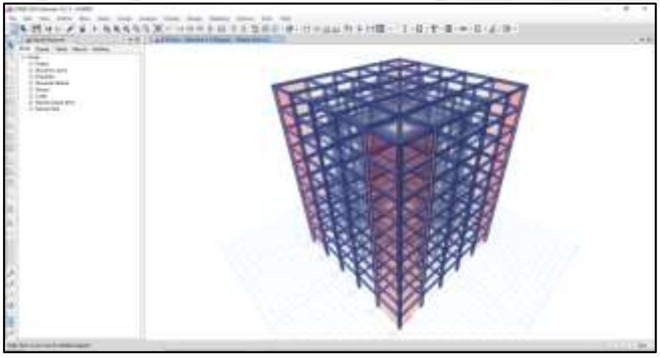


Fig. 18: Stress on Shear Wall

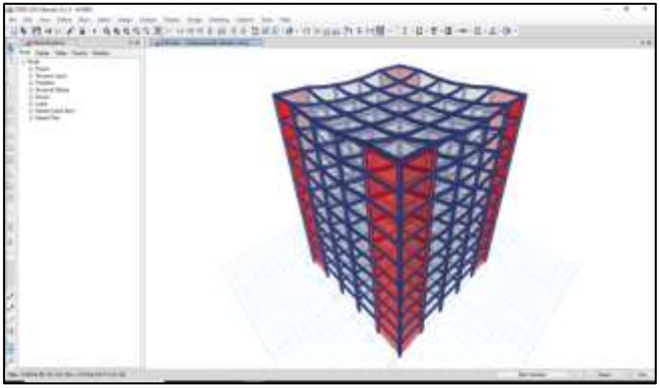


Fig. 19: Analysis of Displacement

Geometrical Description of Symmetrical Building	
Length in X-direction	25m
Length in Y-direction	25m
Floor to Floor Height	3m
Total Height of Building	30m
Slab Thickness	200mm
Wall Thickness	230mm
Shear wall Thickness	200mm
Column Size	450X450mm
Beam Size	450X250mm

Table 1: Geometrical Description of Symmetrical Building

V. ANALYSIS RESULT:

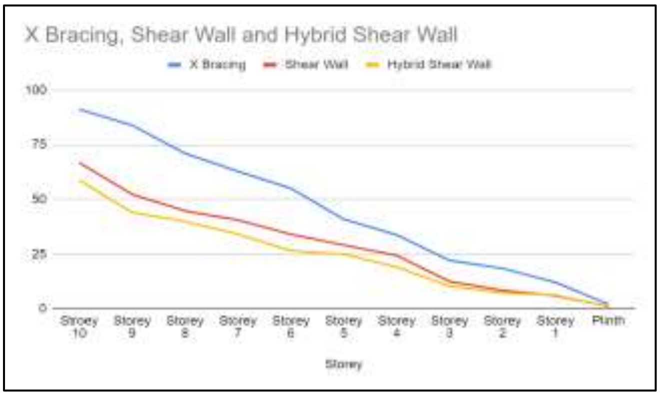


Fig. 20: Storey Displacement in mm

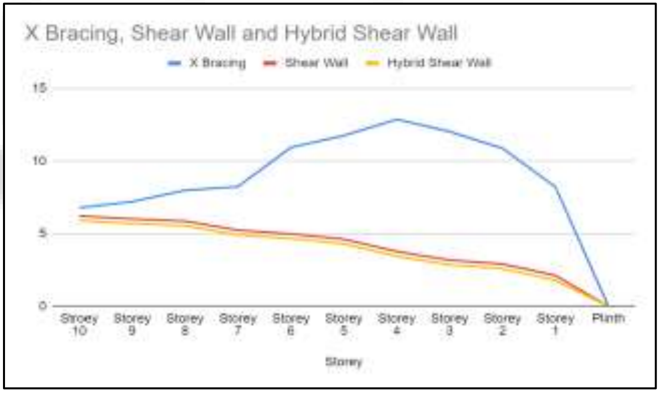


Fig. 21: Maximum Storey Drift

Fig. 22: Maximum Storey Shear in Kn

Fig. 23: Maximum Storey Stiffness

VI. CONCLUSION

This research is focused towards presenting the behaviour of structure considering three different cases namely, structure with X bracing at corner, structure with shear wall at corner and structure with hybrid shear wall at corner. The structure was modelled and analyzed using analytical application ETABS v 2016. The parameters of comparison were Storey displacement, storey shear. Storey drift, storey stiffness and base shear.

Storey displacement is the lateral displacement of the storey relative to the base. It is the total displacement of the storey with respect to the ground. Compared to X bracing and shear wall, the hybrid shear wall structure has lower displacement values.

Storey Drift is defined as the ratio of displacement of two consecutive floor to height of that floor. Compared to X bracing and shear structure, the hybrid Shear wall structure have lower Drift ratios. Storey drift of building is within the limit as clause no 7.11.1 of IS-1893 (Part-1):2016.

Storey shear factor is the ratio of the story shear force when story collapse occurs to the story shear force when total collapse occurs. Here the storey shear was minimum with structure with X bracing in comparison to other two cases.

Storey stiffness is estimated as the lateral force producing unit translational lateral deformation in that storey, with the bottom of the storey restrained from moving laterally, i.e., only translational motion of the bottom of the storey is restrained while it is free to rotate. Maximum storey stiffness was analyzed in structure with shear wall when compared to structure with x bracing and structure with hybrid shear wall.

VII. FUTURE SCOPE

Parameters of material consumption in terms of weight of steel, volume of concrete, time of construction and cost should be evaluated to outline and compare the economic efficiency of the structures.

In this study hybrid shear wall is considered as a combination of X bracing and shear wall , whereas hybrid shear wall was prepared using different materials such as using polymers to strengthen its capabilities.

This research is limited to seismic analysis and in future wind analysis can be further considered.

REFERENCES

[1] Saleem Malik Yarnal, Sagar S Allagi, Prashant M Topalakatti andArif Ahmed Mulla, [Non-Linear Analysis of Asymmetric Shear Wall with Openings], International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181, Vol. 4 Issue 08, August-2015.

[2] ThaveraWihardja and Iswandi Imran, [Seismic Behavior of Hybrid Coupled Wall System], Regional Conference in Civil Engineering (RCCE), The Third International Conference on Civil Engineering Research (ICCER), August 1st-2nd 2017.

[3] Zhangfeng Zhu and ZhengxingGuo, [Experiments on Hybrid Precast Concrete Shear Walls Emulating Monolithic Construction with Different Amounts of Posttensioned Strands and Different Debond Lengths of Grouted Reinforcements], Hindawi Publishing Corporation Advances in Materials Science and Engineering Volume 2016, Article ID 6802503, 13 pages.

[4] Sooria raj, [Feasibility Study on the Structural Behaviour of Hybrid Wood Steel Structures Using Finite Element Analysis], International Journal of Scientific & Engineering Research, Volume 7, Issue 5, May-2016, ISSN 2229-5518.

[5] Abhishek Sharma & Prince Sharma, [Seismic Performance Evaluation of Hybrid Coupled Shear Walls in High Rise Buildings], International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-8 Issue-8 June, 2019.

[6] AlshawabkehShorouq and Wu Li, [Hybrid Post-Tensioned Concrete Shear Walls Behavior Under Seismic Loads], International Journal of Scientific and Research Publications, Volume 9, Issue 5, May 2019, ISSN 2250-3153.

[7] SATYA NARAYANA REDDY Y, V MAHESH and SENTHIL KUMAR, [COMPARATIVE STUDY ON CONVENTIONAL, SHEAR WALL AND HYBRID STRUCTURES INDIFFERENT SEISMIC ZONES], International Journal of Advances in Mechanical and Civil Engineering, ISSN: 2394-2827, Volume-6, Issue-3, May-2019.

[8] Xu, L., Shen, X. and Shen, J., [Seismic Study of Hybrid Shear Wall], Tenth U.S. National Conference on Earthquake Engineering Frontiers of Earthquake Engineering July 21-25, 2014.

[9] Shuzhen Chen and M. Poongodi, [An exhaustive research and analysis on seismic performance of prefabricated concrete shear wall structure], ISSN PRINT 1392-8716, ISSN ONLINE 2538-8460, KAUNAS, LITHUANIA, 2020.

[10] NursiahChairunnisa, ImanSatyarno, Muslikh and AkhmadAminullah, [Analysis and Design of shear wall coupling beam using hybrid steel truss encased in reinforced mortar], Procedia Engineering 171 (2017) 940 – 947.

[11] Chong-fang Sun, Shu-ting Liang, Xiao-jun Zhu, Hu Li, Jian-min Guo, Gang Li, Ya-min Song and Dong-yue Wu, [Experimental Study and Numerical Simulation of

Precast Shear Wall with Rabbet-Unbonded Horizontal Connection], International Journal of Concrete Structures and Materials, 2020.

[12] NIMA USEFI, HAMID RONAGH, and MASOUD MOHAMMADI, [FINITE ELEMENT ANALYSIS OF HYBRID COLD FORMED STEEL SHEAR WALL PANELS], Streamlining Information Transfer between Construction and Structural Engineering, 2018.