IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

ENHANCING STRUCTURE ASPECT USING STEEL PLATE SHEAR WALL PANELS IN STEEL BUILDING

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Abstract: This study evaluates the performance of the perforated stiffened steel plate shear wall system, a modern global system that is effective in high-rise buildings and provides economic benefits compared to previous systems. Steel plate shear walls are an important structural element in the design of buildings. They are used to provide lateral stability and resist seismic and wind forces. The study also examines the performance of steel buildings with unstiffened and stiffened steel plate shear walls, using diagonal, horizontal, vertical, and combination of horizontal and vertical stiffeners. The building studied is a steel moment resisting frame (G+20 and G+30) designed for gravity and seismic loading, using the Indian seismic code 1893:2016. The study uses response spectrum analysis and the ETABS 20 structural analysis software to evaluate storey drifts, base shear of the structure, top storey displacement, and storey stiffness. The results are obtained to evaluate the performance of the structures.

Index Terms – Modal analysis, Response spectrum analysis, out-of-plane buckling, pinching of their hysteretic curve.

I. INTRODUCTION

1.1 GENERAL

Steel plate shear wall (SPSW) is a lateral load resisting system which resists the horizontal storey shear of a building. In general, it consists of a steel plate wall, boundary columns and horizontal floor beams. Steel plate shear walls (SPSW) have several benefits over traditional concrete shear wall. Compared to reinforced concrete shear walls, SPWs are much lighter, which ultimately reduces the demand on columns and foundations, and reduces the seismic load. The steel infill panels in SPSW system can be either stiffened or unstiffened. Use of horizontal and vertical struts in stiffened SPSW systems can increase the capacity and therefore also reduce the section of horizontal beam and vertical column.

A properly designed steel plate shear wall has superior ductility, high initial stiffness, stable hysteresis loops, inherent redundancy, and good energy absorption capacity. These characteristics make the system attractive in high-risk seismic regions.

1.2 NEED OF THE WORK

The study "Enhancing Structure Aspect Using Steel Plate Shear Wall Panels in Steel Building" aims to investigate the use of steel plate shear wall panels as a seismic-resistant system for steel buildings. This type of system can provide high lateral stiffness, strength, and energy dissipation capacity, which are necessary to resist seismic forces and prevent building collapse during earthquakes.
The use of stiffeners and perforations in the steel plate shear wall panels is to enhance their performance by increasing their resistance to buckling and reducing their weight, respectively. The stiffeners can prevent the

steel plates from buckling under compressive loads, while the perforations can reduce the weight of the panels without significantly reducing their strength.

The study is important because earthquakes pose a significant threat to buildings, infrastructure, and human life in many parts of the world. The use of steel plate shear wall panels as a seismic-resistant system in steel buildings can help reduce the damage and loss of life caused by earthquakes. Additionally, the investigation of the use of stiffeners and perforations in the panels can help optimize their design and enhance their performance.

1.3 OBJECTIVE OF THE WORK

- To study the behavior of steel structures with and without steel plate shear wall panels under earthquake loads.
- To investigate the effect of different types of stiffeners (diagonal, horizontal, vertical, and H&V) on the behavior of steel plate shear wall panels.
- To analyze the effect of the percentage of openings (10% and 20%) in the steel plate shear wall panels on the behavior of the structure.
- To compare the stiffness, displacement, drift, and time period of the steel structures with and without steel plate shear wall panels.
- To determine the most efficient steel structure model in terms of seismic resistance and weight.

1.4 SCOPE OF THE WORK

- Under the current research, there is scope to find out the key parameters, and to investigate their likely effect on steel plate shear wall system by numerical modeling.
- Analytical study of structure in larger scale also provides the opportunity to propose some design recommendations.
- A design recommendation will be proposed to improve the capacity of SPSW system using stiffener as diagonal, horizontal, vertical and combination of horizontal and vertical lateral loading.

II. METHODOLOGY

2.1 GENERAL

There have been several studies conducted on the use of perforated steel plate shear walls with stiffeners as a means of improving earthquake resistance in buildings. These studies generally conclude that the use of perforated steel plate shear walls with stiffeners can improve the seismic performance of buildings by increasing their strength and stiffness, as well as reducing the potential for damage and collapse during an earthquake.

2.2 MODELLING ASSUMPTIONS

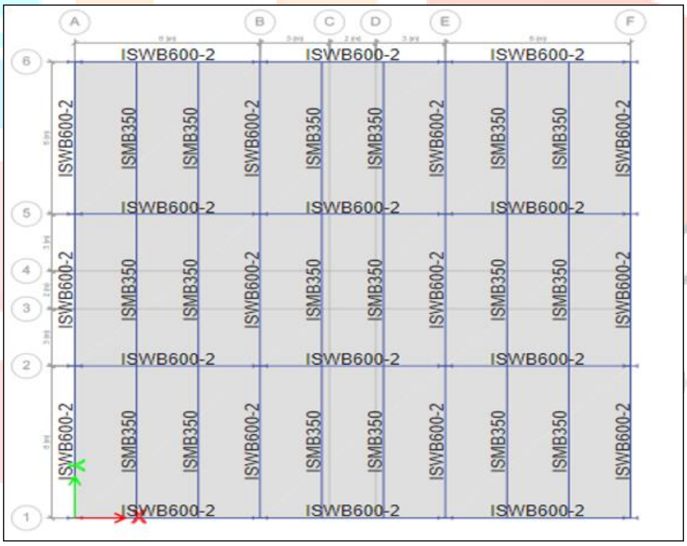
The base of all the building models is assigned as fixed at the base. All the floor diaphragms are assigned as rigid. The materialproperties for all the structural elements are kept same i.e., M30 and Fe345.

Table 2.1 Assumed preliminary data required for the analysis of the Frame

S. No	Variables	Data
1	Type of Structure	Moment resisting frame
2	Number of stories	20 & 30
3	Floor Height	3m
4	Live Load	4.0 KN/m2
5	SDL	2.0 KN/m2
6	Materials	Concrete M30 and reinforced with HYSD bars Fe(345)
7	Size of Column	ISMB 600
8	Size of Beams	ISWB 600-2 & ISMB350
9	Depth of slab	150 mm thick
10	Specific weight of RCC	25 KN/m2
11	Zone	V
12	Importance Factor	1.5
13	Response reduction Factor	5
14	Type of soil	Medium
15	Stiffeners	ISLC250
16	Steel Plate	6mm thick

2.3 STRUCTURAL SYSTEMS OF THE BUILDING

The foundation system consists of independent footings with a 3 m foundation depth.

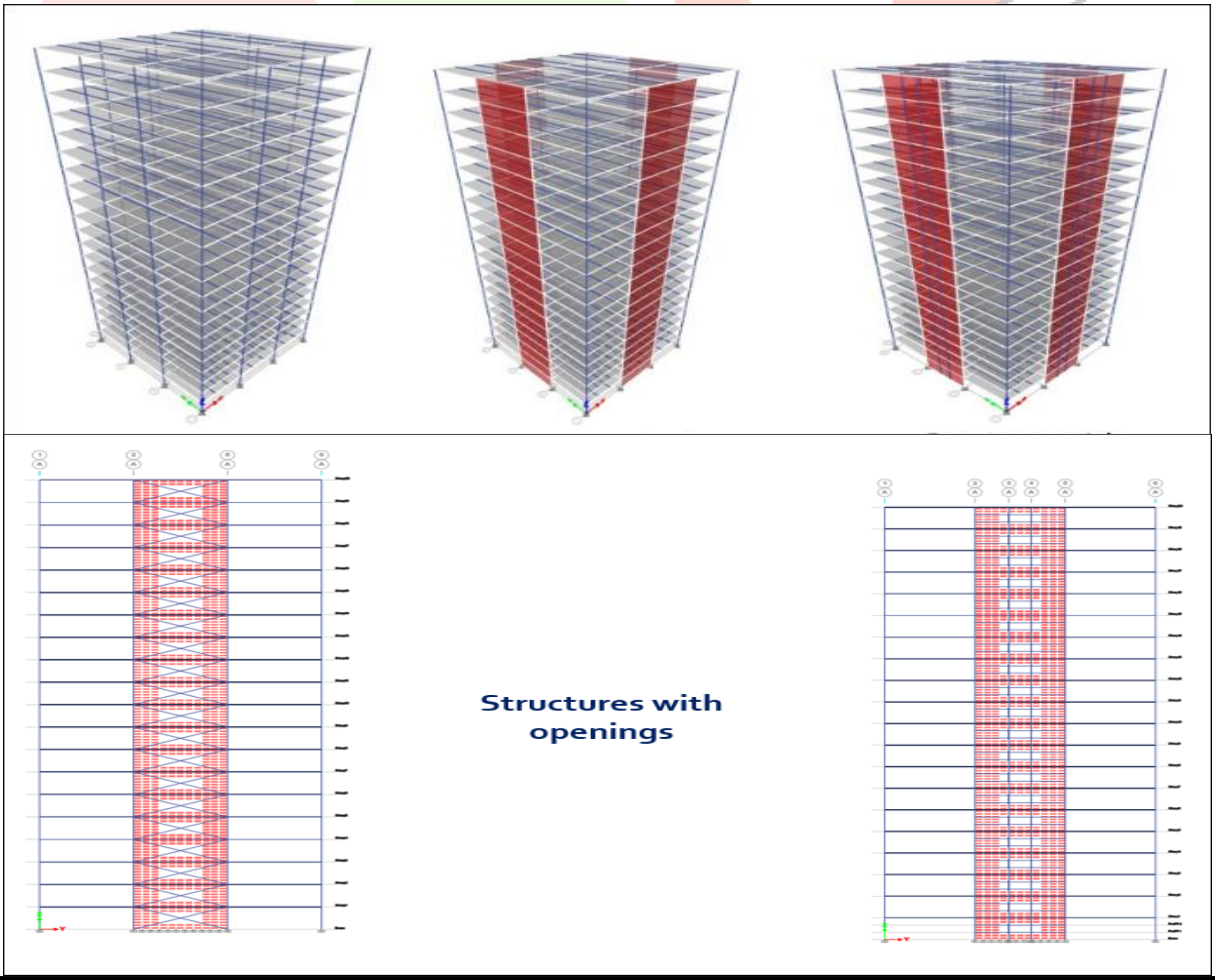


2.4 DATA COLLECTION

The building models are of 10,20 and 30 stories located in zone V.

TABLE 2.2 GENERAL DATA COLLECTION AND CONDITION ASSESSMENT OF BUILDING

S.No	Description	Information	Remark
1	Building Height: 20 storey and 30 storey		
2	Number of basements below ground	0	
3	Open ground storey	yes	
4	Special Hazards	no	
5	Type of building	Regular space frames	IS 1893:2016 Clause 7.1
6	Horizontal Floor System	Beams & Slabs	
7	Software Used	Etabs 20	

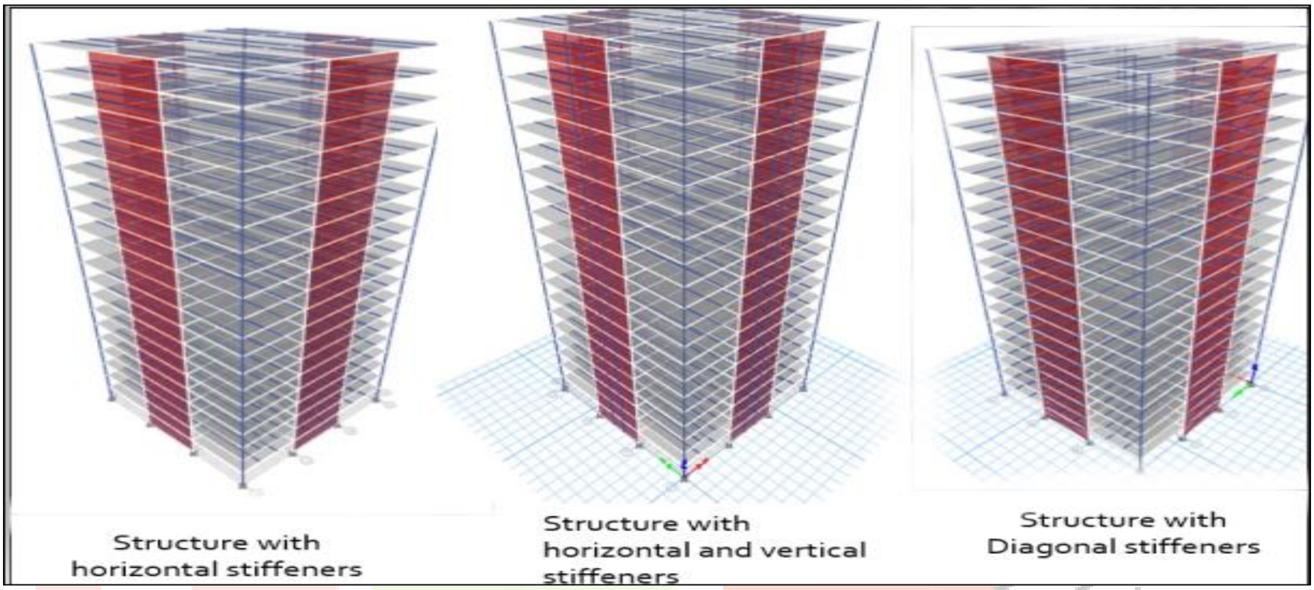


2.5 RESPONSE SPECTRUM ANALYSIS

- Response-spectrum analysis provides insight into dynamic behavior by measuring pseudo-spectral acceleration, velocity, or displacement as a function of structural period for a given and level of damping.
- The Design base shear obtained for dynamic analysis should not be less than the base shear obtained using the calculated time period, As ETABS takes the time period for response spectrum analysis from the modal analysis results we get less base shear for response spectrum case, to make it equal we multiply it by the scale factor.

III. RESULTS AND DISCUSSION

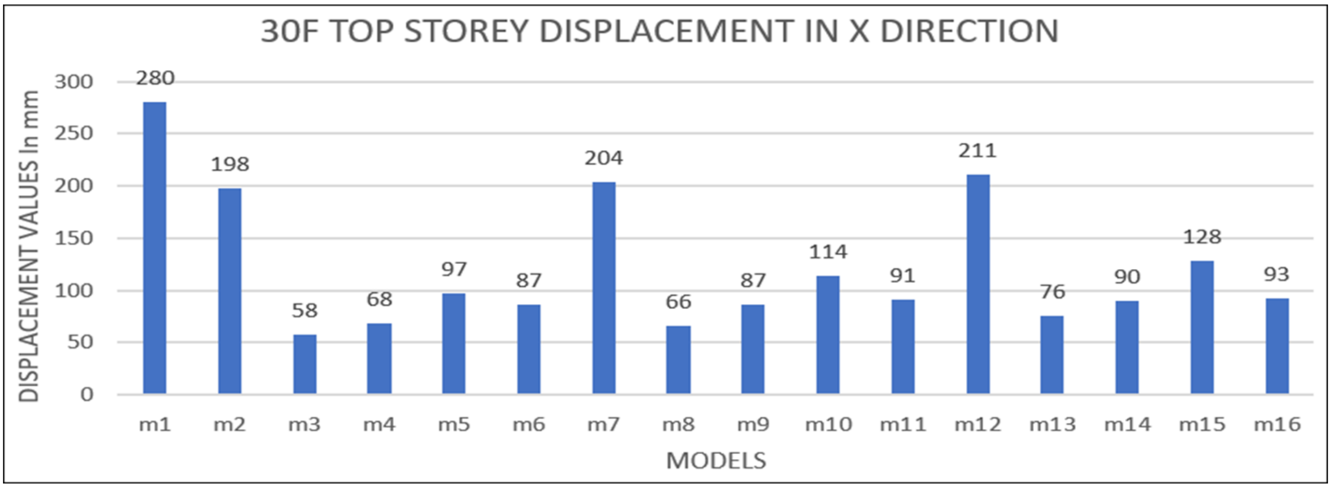
Below are the models.

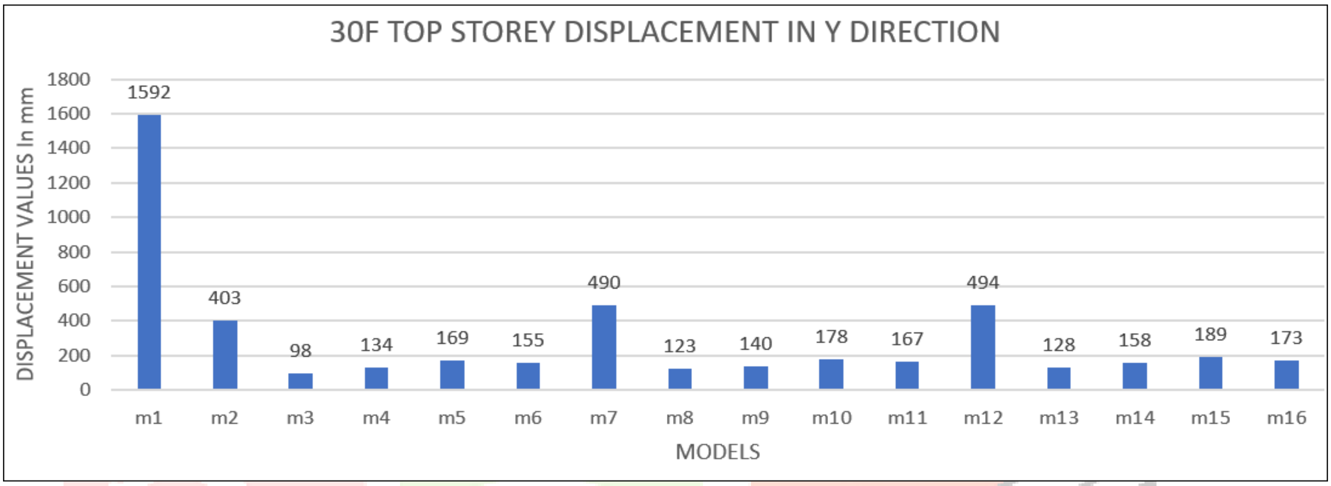


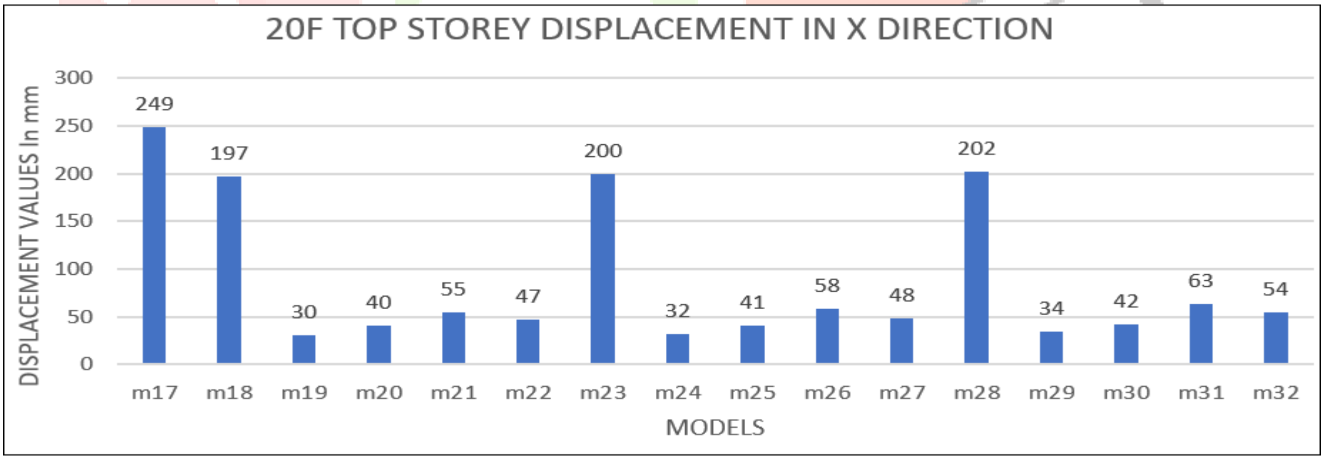
	30 Floor
m1	Structure without shear wall
m2	Structure with shear wall
m3	SPSW with Diagonal stiffener
m4	SPSW with Horizontal stiffener
m5	SPSW with Vertical stiffener
m6	SPSW with H&V stiffener
m7	Structure with shear wall having 10% opening
m8	SPSW with Diagonal stiffener having 10% opening
m9	SPSW with Horizontal stiffener having 10% opening
m10	SPSW with Vertical stiffener having 10% opening
m11	SPSW with H&V stiffener having 10% opening
m12	Structure with shear wall having 20% opening
m13	SPSW with Diagonal stiffener having 20% opening
m14	SPSW with Horizontal stiffener having 20% opening
m15	SPSW with Vertical stiffener having 20% opening
m16	SPSW with H&V stiffener having 20% opening

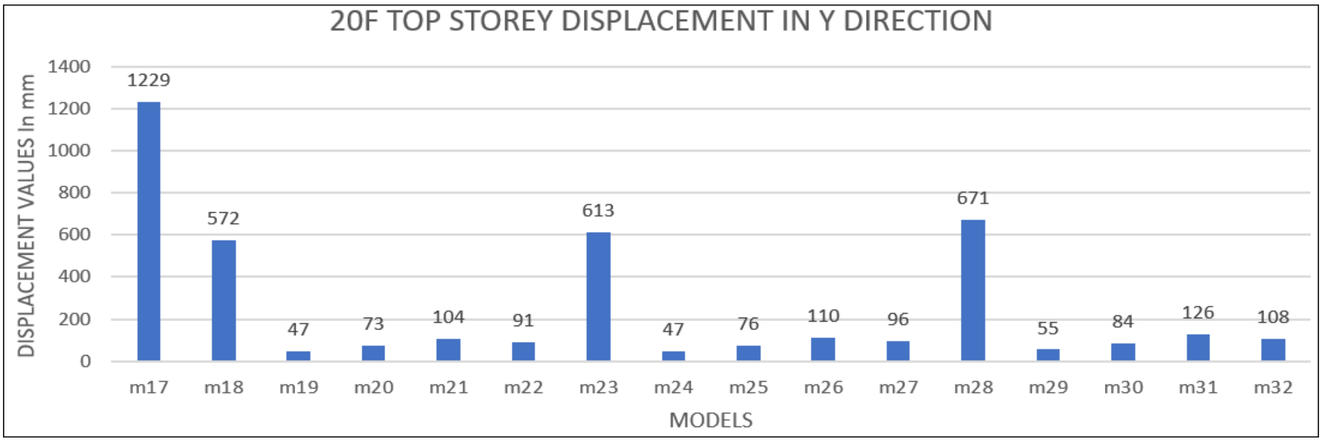
	20 Floor
m17	Structure without shear wall
m18	Structure with shear wall
m19	SPSW with Diagonal stiffener
m20	SPSW with Horizontal stiffener
m21	SPSW with Vertical stiffener
m22	SPSW with H&V stiffener
m23	Structure with shear wall having 10% opening
m24	SPSW with Diagonal stiffener having 10% opening
m25	SPSW with Horizontal stiffener having 10% opening
m26	SPSW with Vertical stiffener having 10% opening
m27	SPSW with H&V stiffener having 10% opening
m28	Structure with shear wall having 20% opening
m29	SPSW with Diagonal stiffener having 20% opening
m30	SPSW with Horizontal stiffener having 20% opening
m31	SPSW with Vertical stiffener having 20% opening
m32	SPSW with H&V stiffener having 20% opening

3.1 STOREY DISPLACEMENT:

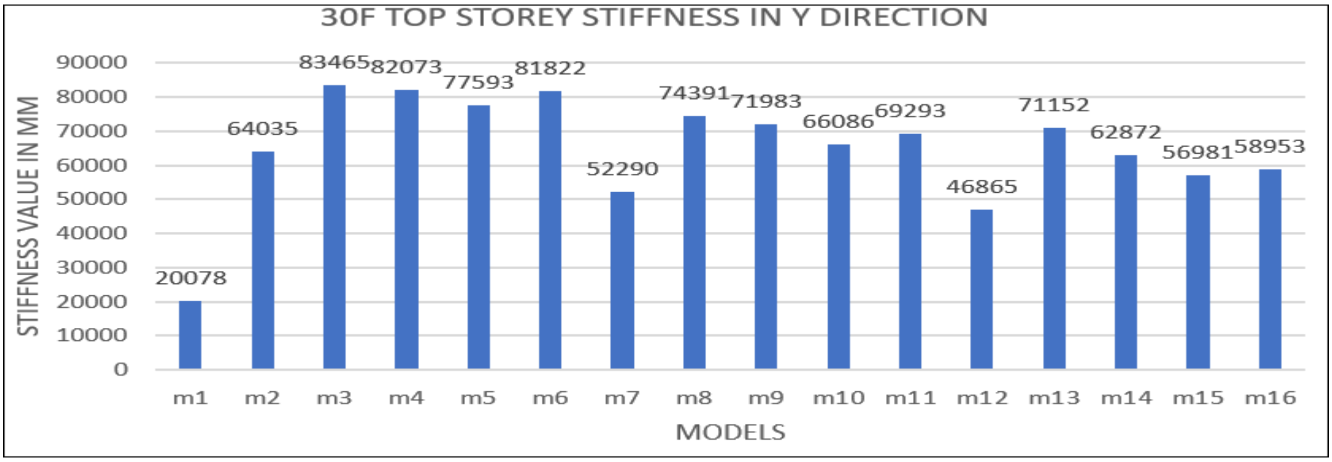


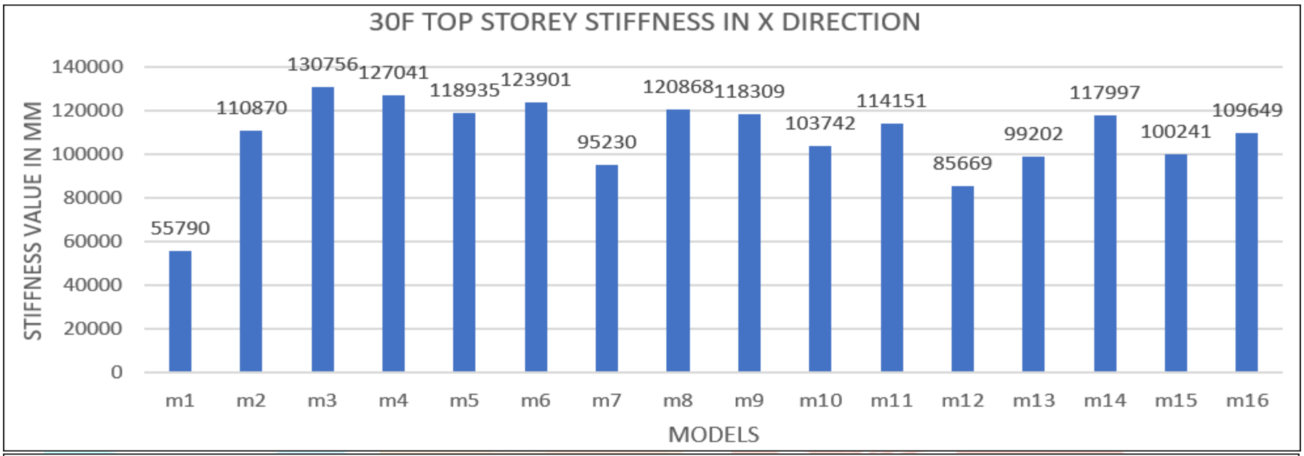


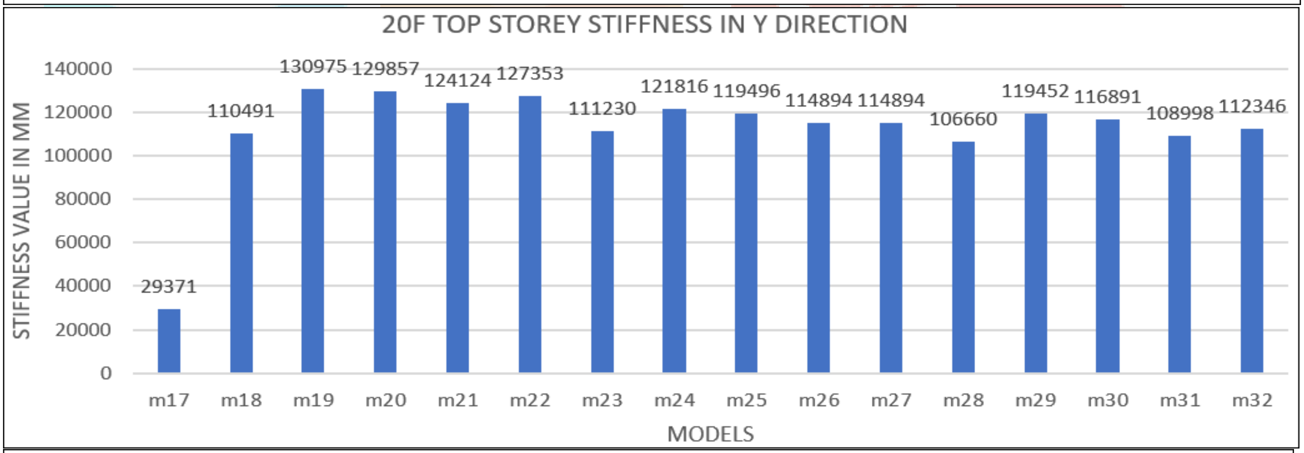


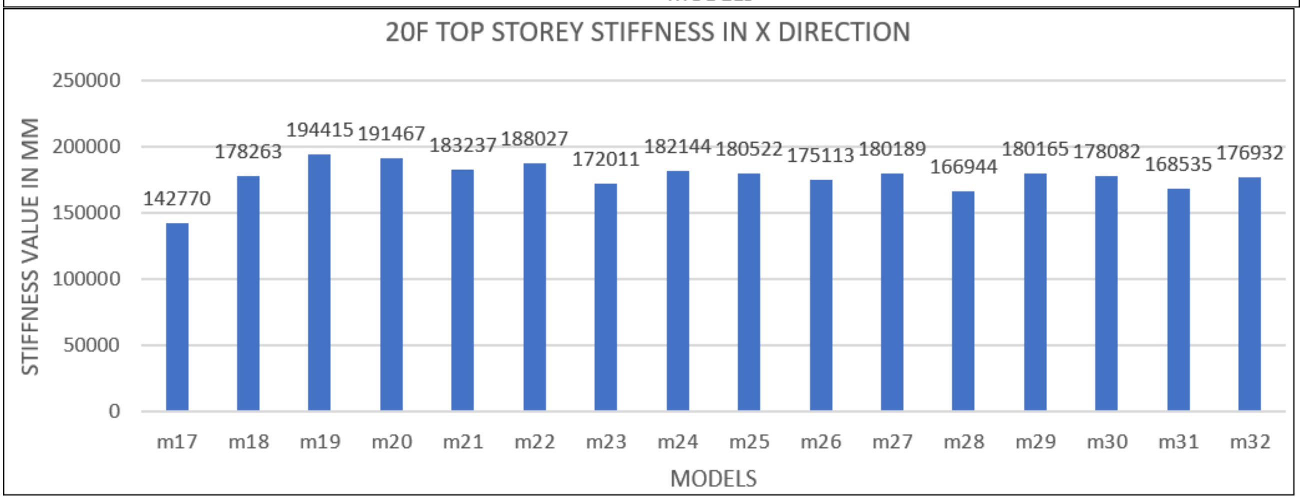


3.2 STOREY STIFFNESS:

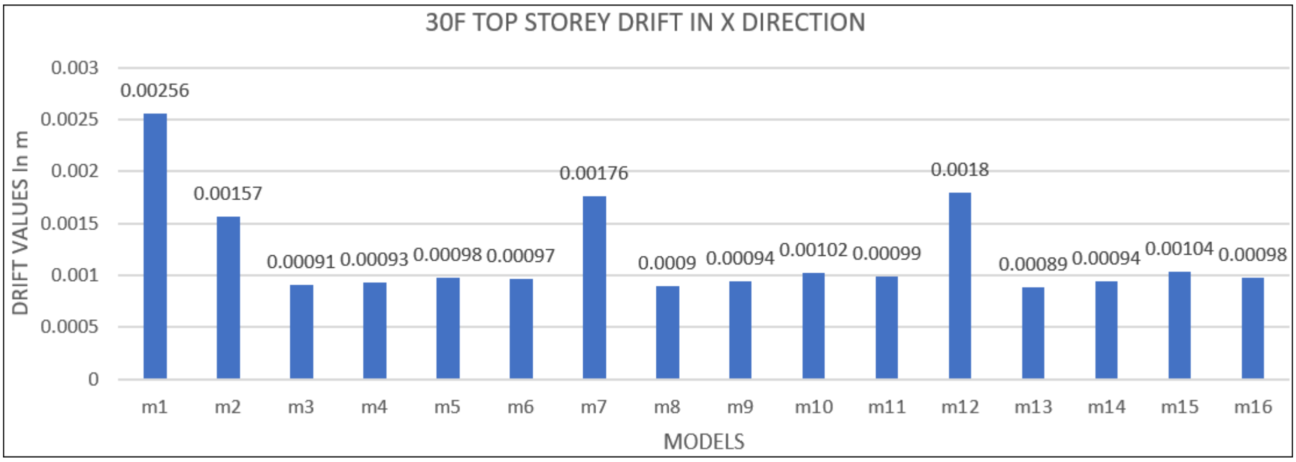


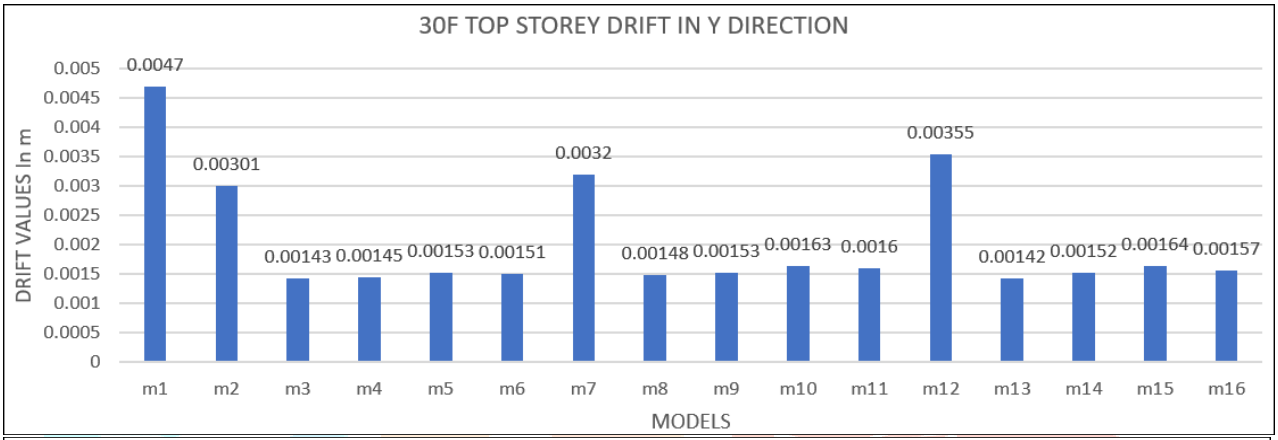


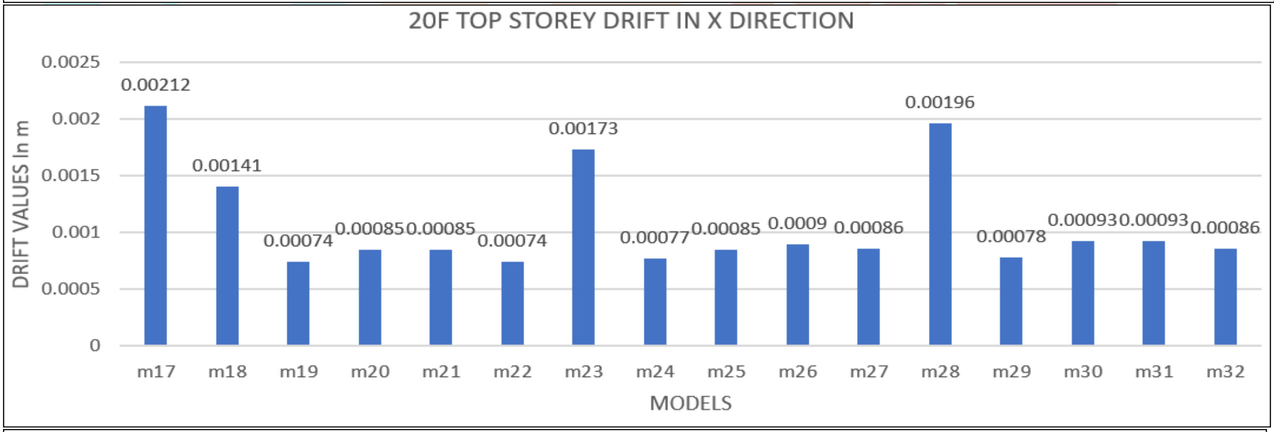


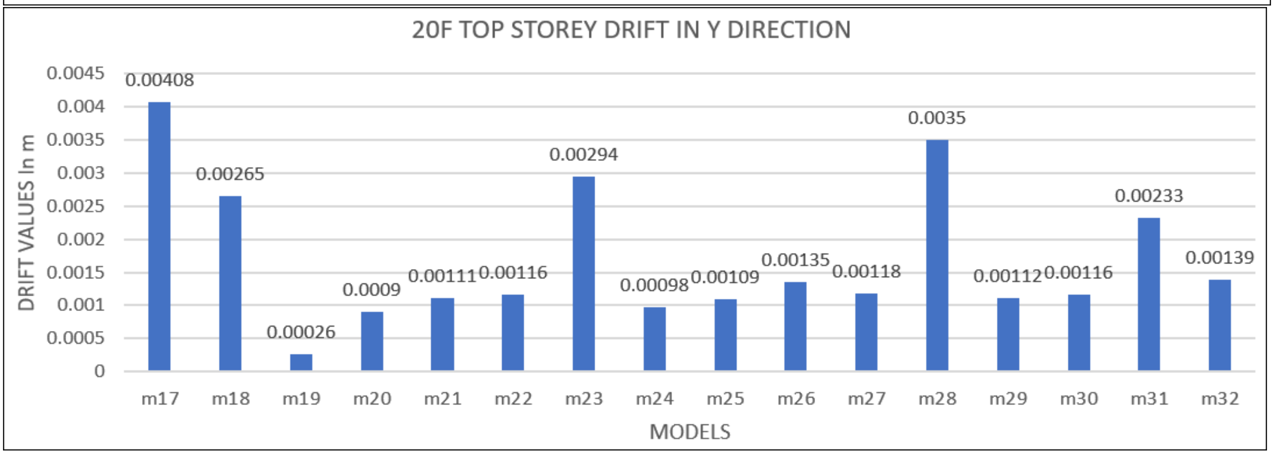


3.3 STOREY DRIFT:

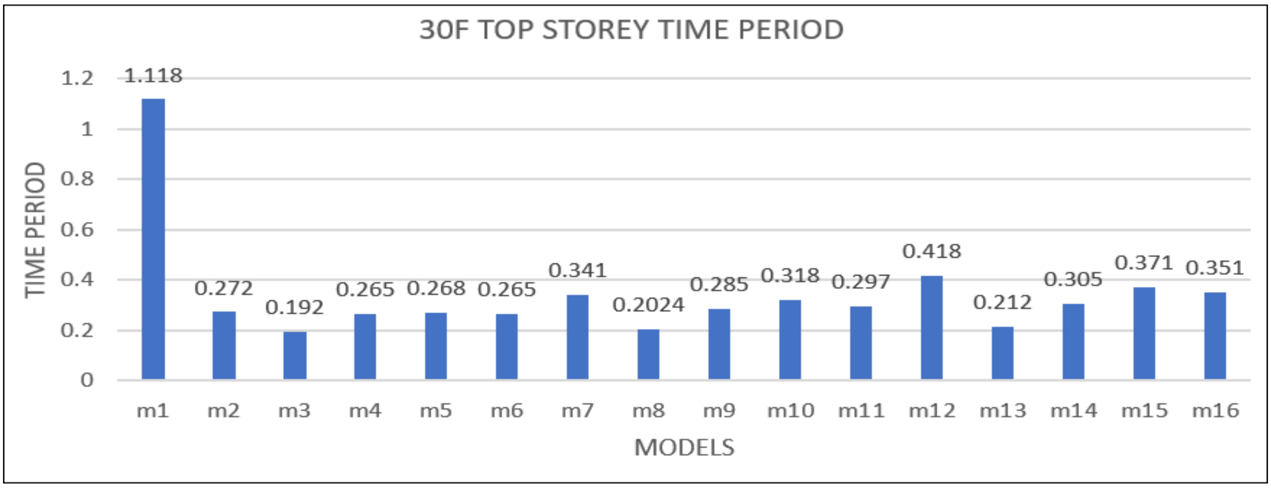


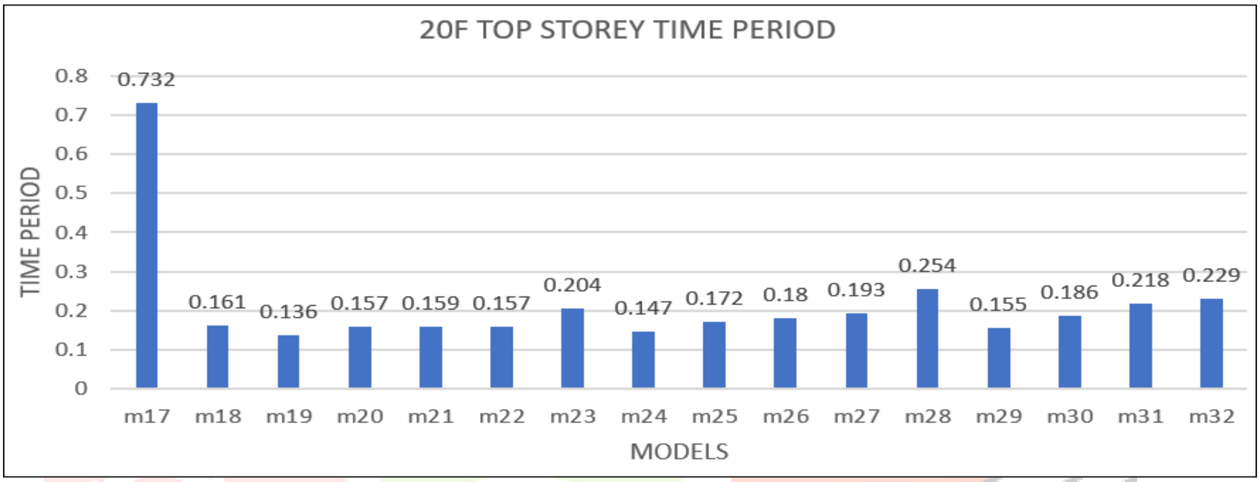






3.4 STOREY TIME PERIOD:





3.5 WEIGHT OF STRUCTURES:

30 Floor	
Minimum	**Maximum**
Structure with vertical stiffners having 20% opening	Structure with H&V stiffener without opening
7809.3332KN	85642.7187KN
20 Floor	
Minimum	**Maximum**
Structure with vertical stiffners having 20% opening	Structure with H&V stiffener without opening
55193.1962KN	57216.0632KN
10 Floor	
Minimum	**Maximum**
Structure with vertical stiffners having 20% opening	Structure with H&V stiffener without opening
27596.5981KN	28608.0316KN

3.6 DISCUSSION ON ABOVE RESULTS:

Displacement

As the height of the structure is 60m and 90m, the overall displacement shall be limited to H/500 (120mm) and (180mm).

The story displacement of Shear wall with diagonal stiffener is less compared to other structures and as opening increases the displacement is increasing.

Stiffness

Structure with shear wall have diagonal stiffener is observed to have more stiffness when compared with other models.

Drift:

IS 1893:2016 is the Indian Standard Code of Practice for "Criteria for Earthquake Resistant Design of Structures" and it specifies the maximum permissible story drift for earthquake-resistant design of buildings in India. As per Clause 7.11.1 of the code, the maximum permissible story drift in any story should not exceed 0.004 times the height of that story. This criterion is intended to ensure that the building can withstand the seismic forces generated during an earthquake without suffering excessive damage or collapse.

For 20 story permissible drift = 0.012m

For 30 story permissible drift = 0.012m

TIME PERIOD RESULTS:

The natural period of a structure is as per Clause 7.6.2 of IS 1893 2016 part1.

All the structure has a value nearby to the natural frequency of building hence safe

IV CONCLUSIONS

4.1 CONCLUSIONS

- In this study, the behavior of steel structures with and without steel plate shear wall (SPSW) panels under earthquake loads was investigated. The effects of different types of stiffeners (diagonal, horizontal, vertical, and H&V) on the behavior of SPSW panels and the influence of the percentage of openings (10% and 20%) in the panels were analyzed. The goal was to compare the stiffness, displacement, drift, and time period of the steel structures and determine the most efficient model in terms of seismic resistance and weight.
- The results demonstrated that the inclusion of SPSW panels in steel buildings significantly improved their performance. The stiffness of the structures increased significantly in both the x and y directions with the addition of SPSW panels, compared to the model without shear walls (m1, m17). Among the SPSW models, those with diagonal stiffeners exhibited the highest stiffness and least displacement (m3, m19), while the models without shear walls had the least stiffness and highest displacement (m1, m17).
- The displacement of the structures with SPSW panels remained within permissible limits, whereas the model without shear walls exceeded the limit. The models incorporating diagonal stiffeners (m3, m19) showed the least displacement, indicating their effectiveness in reducing structural movements.
- The natural period of the structures decreased in all models with SPSW panels compared to the model without shear walls. The model with diagonal stiffeners (m3, m19) displayed the shortest natural period, while the model without shear walls and no stiffeners had the longest natural period (m1, m17)
- All models satisfied the maximum permissible drift criterion, indicating their ability to withstand earthquake-induced forces.
- Considering the weight of the structures, it is an important parameter in the design process. The weight of the buildings increased with the addition of SPSW panels and stiffeners. However, the utilization of vertical stiffeners (m16, m32) with 20% openings demonstrated a reduction in weight compared to other models with similar configurations.
- Structures with opening were observed as safe and within limits, as per observation displacement increases with the increase percentage of opening and provision of 20% opening offered an economic structure.
- In summary, the use of steel plate shear wall panels with diagonal or vertical stiffeners (m13, m32, m29, m16) and 20% openings is recommended to enhance the structural aspects of steel buildings in terms of seismic resistance and weight. The results of this study can be useful for engineers and architects in designing earthquake-resistant steel buildings.

4.2 SCOPE FOR FURTHER STUDY

- Investigating the effects of irregularities in the geometry of the steel plate shear wall panels on the seismic behavior of the structure. For example, we could study the behavior of structures with non-rectangular panels, tapered panels, or panels with varying thickness.
- Studying the behavior of structures with different types of connections between the steel plate shear wall panels and the rest of the structure. For example, you could investigate the use of bolted versus welded connections, or the effects of using different types of bolts or welding techniques.
- Exploring the use of different types of materials in the construction of steel plate shear wall panels. For example, we could investigate the use of composite materials, or materials with different mechanical properties than the steel typically used in these types of panels.
- Studying the behavior of multi-story steel structures with shear walls and investigating the optimal placement and orientation of the walls to improve the overall seismic performance of the building.

V ACKNOWLEDGMENT

I would like to express my sincere and heartfelt gratitude to my beloved mentor **Mr. MD IMTIYAZ QURESHI**, Assistant Professor, Dept. of Civil Engineering, NSAKCET for his guidance. I am thankful for his guidance and active supervision at every stage of the thesis work. It is his immense patience and co-operation that has helped for the successful completion of this work.

I would also like to thank **Prof. Syed Farrukh Anwar**, Head of the Department of Civil Engineering, Nawab Shah Alam Khan College of Engineering and Technology, his strategic direction and oversight of this research, particularly in the early stages and his ongoing advice throughout the project.

I express my sincere thanks to **Prof. M. V. S. Sreedhar**, Chairman, Board of Studies, Civil Engineering Department, Osmania University, for his valuable support and advice for preparation of this report as per the format and facilitating viva-voce.

I express my sincere thanks to **Prof. P. RajaSekhar**, Professor and Head of Civil Engineering, Osmania University, for facilitating the conduct of viva-voce examination.

I am thankful to, Principal Prof. Sriram Venkatesh, University College of Engineering, Osmania University, Hyderabad for facilitating the conduct of viva-voce examination.

I am thankful to **Dr. Syed Abdul Sattar**, Principal of Nawab Shah Alam Khan College of Engineering and Technology for his constant zeal and supervision.

Many thanks also go to the teaching and non-teaching staff in the university and colleges. Finally, I acknowledge all those who have helped me directly or indirectly with the completion of my work.

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