Analysis of Various RCC Lateral Force Resisting Systems and their Comparison using ETABS

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Abstract- The tumor of population with a quicker frequency has imposed an unadorned effect on land which is resulting in its shortage and thereby swelling the land cost making it unaffordable for an average person. Due to this, the FAR (Floor Area Ratio) in big cities is increasing. This has enforced mankind to go for high rise structures. But, as the height of a structure increases, the effect of lateral forces increases with it. Lateral force resisting system plays an important role in the multistoried buildings which are situated in high seismic zones. Lateral force resisting system reduces the lateral forces acting during the earthquake and increases the stiffness of the structure. To make the structure earthquake resistant, the provision of lateral force resisting system is essential. There are various types of lateral force resisting systems like shear wall, braced core, shear core, outrigger with belt system, coupled shear wall, bracings etc. The scope of this paper is confined to RCC structures only. In this paper, the emphasis is given on the structures having lateral force resisting system. This study pointed to compare these systems and ranking all in terms of their efficiency. Static and dynamic analysis has been carried out and results have been compared. Cost evaluation has also been carried out. Several books and IS codes has been referred to obtain the results up to maximum accuracy.

Keywords: Braced core, Coupled shear wall, Outrigger with belt, Shear core, Shear wall, Etabs.

I. INTRODUCTION

Due to the mounting demand of high rise structures, it has become indispensable for the Structure engineers to build a structure which can withstand lateral forces acting on it. Mainly, two types of lateral forces acts on a high-rise building. One is seismic force and another one is wind force. Generally, seismic force is more dominant. Wind force is considered when the height of building surpasses twice the dimension normal to which wind is acting. So, when there forces together acts on a structure, high shear forces and bending moments coins in structure elements causing their failure. The advance in civil engineering has already found the key to deal with this problem. Various types of resisting systems have been introduced which can resist these forces and safely transfer them to the soil. Resisting systems in steel structures are different from those of RCC structures. The primary purpose of all kinds of structural systems used in the building type of structures is to transfer gravity loads effectively. The most common loads resulting from the effect of gravity are dead load, live load and snow load. Besides these vertical loads, buildings are also subjected to lateral loads caused by wind, blasting or earthquake. Lateral loads can develop high stresses, produce sway movement or cause vibration. Therefore, it is very important for the structure to have sufficient strength against vertical loads together with adequate stiffness to resist lateral forces The types of systems for withstanding lateral forces used in this paper are braced core, coupled shear wall, outrigger with belt, shear core, shear wall, bracings at periphery. Proper study is carried out to find the effective size of components like, column, bracings etc. The most optimum position and parameters are found comparing the results given by Etabs. For example, outrigger is placed at three different positions, i.e., at top and one-fourth height of structure, at top and middle height of the structure and at top and three-fourth height of the structure. The most effective was evaluated based on analytical results. Then this result is compared with rest of the systems. After comparing all the results, these systems have been ranked according to terms of their effectiveness.

II. LITERATURE REVIEW

A number of researched have been introduced for different types of Lateral force resisting systems. The researches explain behavior of lateral systems. Alex Coull and Otto Lau.W.H (2011) studied the effect of outrigger system with belt at various positions of the building. Linear and nonlinear analysis are done. The paper concluded that the displacement is lowest when outrigger is provided at middle. Harries, et al (2004) presented the parametric study of coupled shear wall behavior. Positions of coupled shear wall are varied and span to depth ratio of coupling beam is also varied. The paper concluded that span to depth ratio of coupling beam should generally be 2.0 – 4.0. Murali Krishna and E Arunakanthi (2010) varied the position of shear wall and analysed the results in Etabs. Shear walls are usually provided along both length and width of buildings, Shear walls are like vertically-oriented wide beams that carry earthquake loads downwards to the foundation. Properly designed and detailed buildings with shear walls have shown very good performance in past earthquakes. Shear walls in high seismic regions require special detailing. However, in past earthquakes, even buildings with sufficient amount of walls that were not specially detailed for seismic performance. The paper concluded that shear wall is most effective at corners of the building. Esmaili et al. presented the effect of RC shear wall system on a 56 storey building. The paper showed the seismic behavior of shear wall.

III. OBJECTIVE

The main objectives of the present study are as follows:

1. Study on Linear static analysis of various lateral force resisting systems and comparing the results (displacement, storey drift and stiffness) with the conventional structure.
2. Study on Linear dynamic analysis (Response spectrum) of various lateral force resisting systems and comparing the results (displacement, storey drift and stiffness) with static results.
3. Evaluation of all systems used and their comparison.
4. Ranking all the systems in terms of effectiveness.

IV. METHODOLOGY

E-TABS software is used to develop 3D model and to carry out the analysis. The lateral loads to be applied on the buildings are based on the Indian standards. The methodology includes:

1. A 30 storey building is modelled in Etabs. The plan view is shown in Fig. 1 and 3-D view in Fig. 2. The details of the structure are shown in Table 1.
2. Six types of resisting systems were used i.e., braced core, shear core, shear wall, coupled shear wall, outrigger system with belt and bracing at periphery system.
3. The size of the bracings, columns and beams were calculated from SP-16, knowing the forces acting on them given by Etabs.
4. Coupled shear wall is positioned at 3 different positions and it came out to be most effective at position shown in Fig. 3
5. Similarly, the position of outrigger is varied i.e., at top and one-fourth height of building, at top and middle height of the building and at top and three-fourth height of the building. It came it out to be most effective when provided at top and middle height. (Fig 4).
6. The most effective position of shear wall is shown in Fig. 5

7. In bracing system, 4 different types of bracings are used at periphery i.e., eccentrically forward, eccentrically backward, V-type, inverted V-type. Inverted V-type came out to be most effective one (Fig. 6).
8. Static earthquake load and wind load by Force coefficient method is applied and results are obtained for load combination which produced the maximum effect i.e., 1.5 (DL + EQ). These results are compared.
9. Dynamic analysis is done to see the variation is results obtained by Static analysis.
10. Cost evaluation is done.
11. At last, systems are ranked according to their effectiveness.

Table 1

Contents	**Description**
No of stories	30 (3m each)
Grade of concrete	M 35
Size of beam	300mmx450mm
Size of column	700mmx700mm
Thickness of slab	150mm
Live load	4kN/m^2(Commercial)
Floor finish	1.5kN/m^2
Location	Delhi
Terrain category	4
Structure class	C
Zone factor (Z)	0.24
Importance factor (I)	1
Response reduction factor (R)	5

I. MODELLING

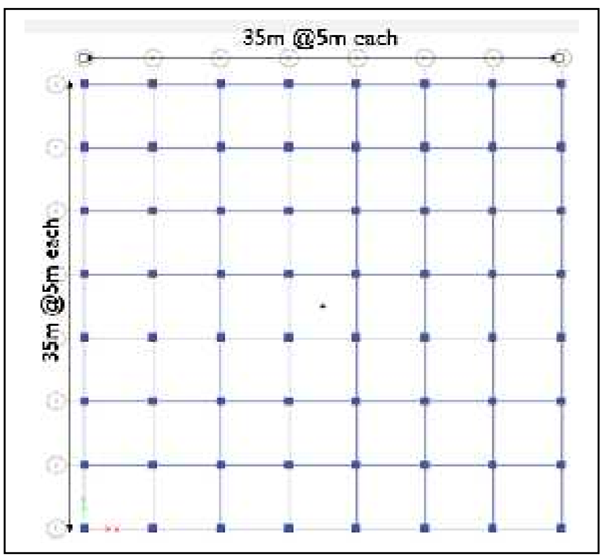

Fig. 1: Plan view

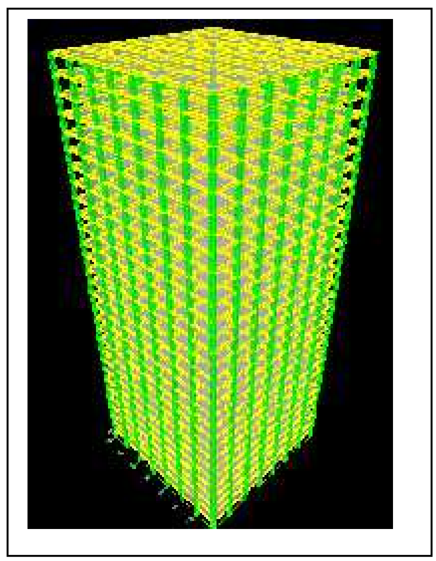

Fig. 2: 3-D view

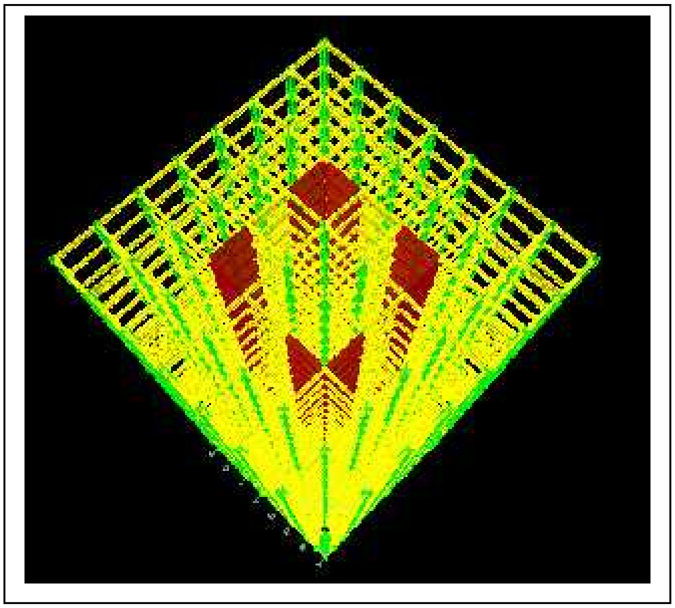

Fig. 3 Coupled shear wall at most effective position

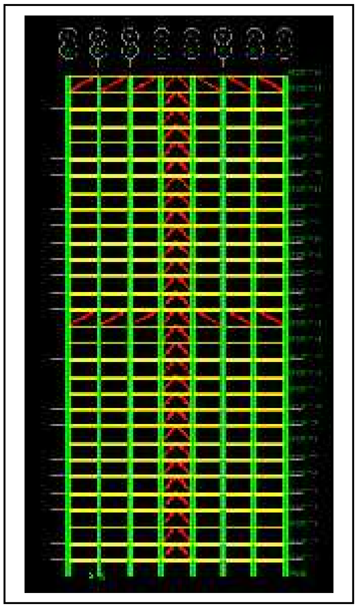

Fig. 4 Outrigger system with belt

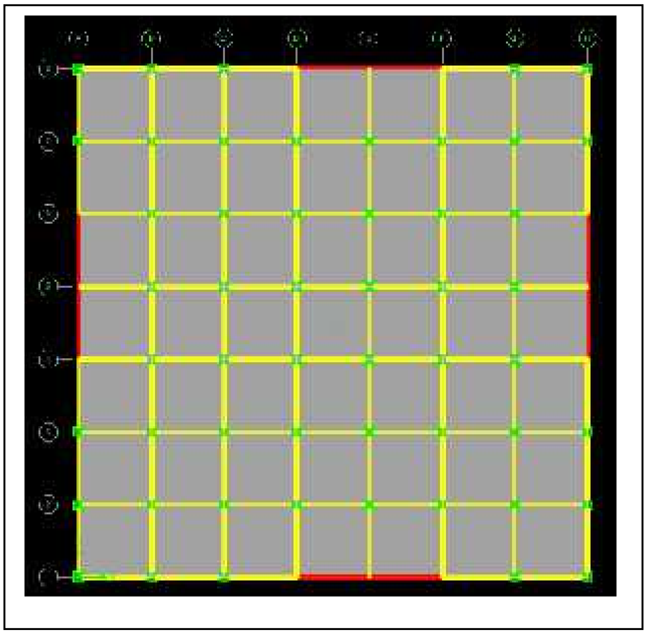

Fig. 5 Shear wall at most effective position

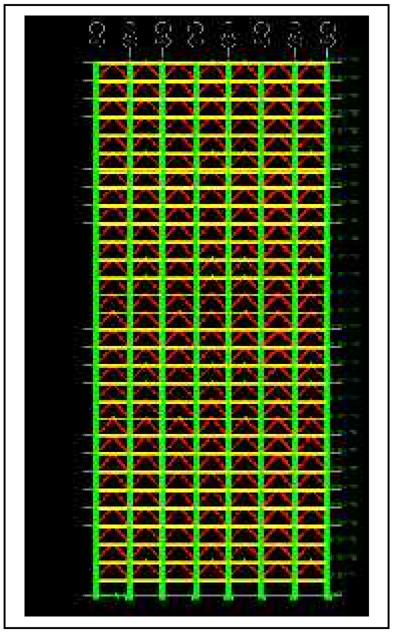

Fig. 6 Inverted V-type bracing

II. RESULTS AND DISCUSSIONS

Displacement due to static analysis is shown in Fig. 7 and due to dynamic analysis is shown in Fig. 8. The results have been taken for the load combination which produced the maximum effect, i.e. 1.5 (DL + EQ). In the dynamic analysis, SRSS method has been used. The base shear obtained by dynamic analysis is scaled to base shear obtained by static analysis according to IS: 1893 (2002). In dynamic analysis, displacement from same load combination have been extracted. Displacement of the Inverted v-type bracing at periphery structure came out to be least among all and braced core to be the maximum. Coupled shear wall showed less displacement then shear wall.

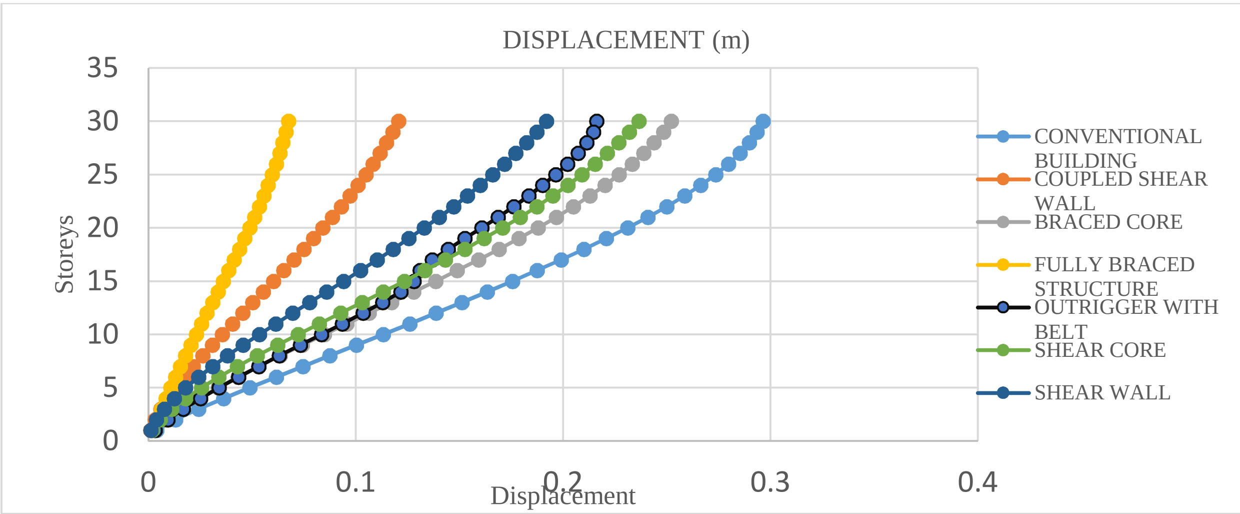

Fig. 7 Static results

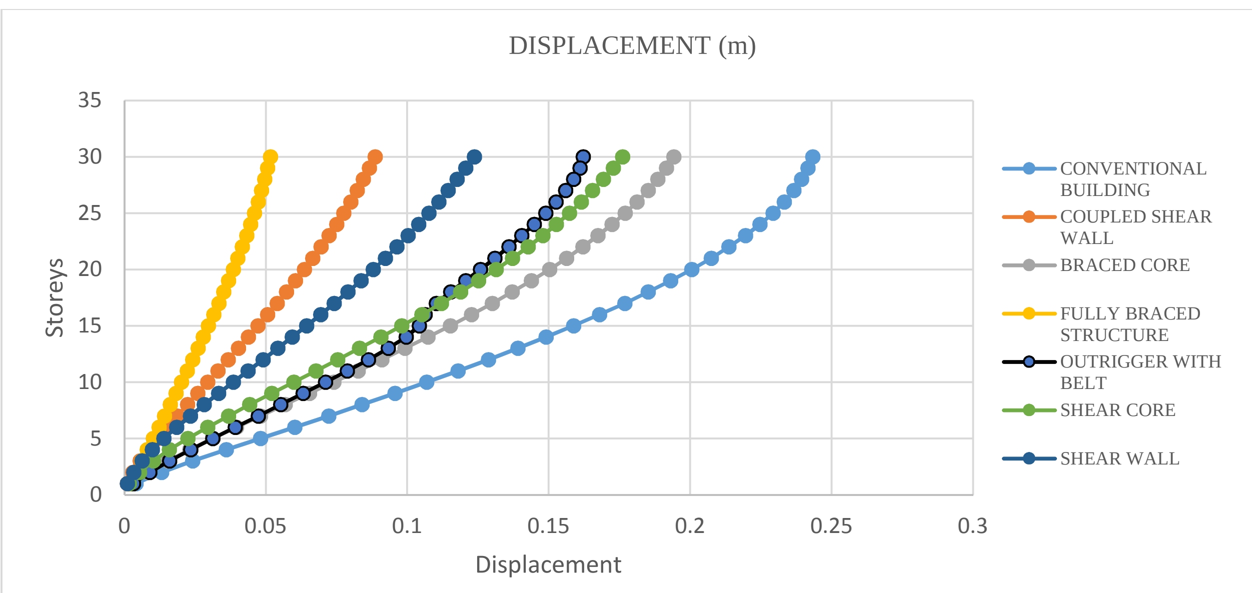

Fig. 8 Dynamic results

The results obtained from static analysis are compared with those obtained by dynamic analysis and a considerable fall in displacement is noticed in displacement in case of dynamic analysis. Fig. 9 shows results for coupled shear wall where the displacement dropped by 32mm at topmost storey. Fig. 10 shows results for braced core where displacement dropped by 58mm. Fig. 11 for bracing at periphery and drop noticed is 16mm. Similarly, Fig. 12, Fig. 13 and Fig. 14 shows results for outrigger, shear core and shear wall respectively and drop is 54mm, 60.5mm and 68.3mm. Highest drop in displacement have been observed for shear wall.

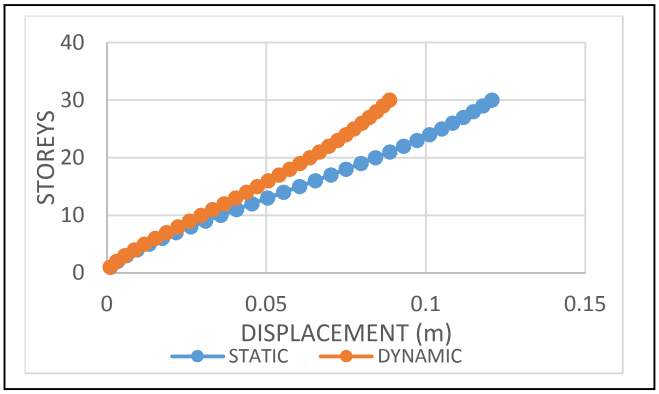

Fig. 9 Displacement for Coupled shear wall

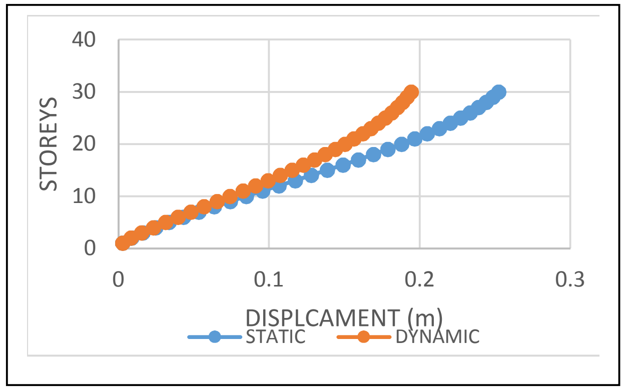

Fig. 10 Displacement for braced core

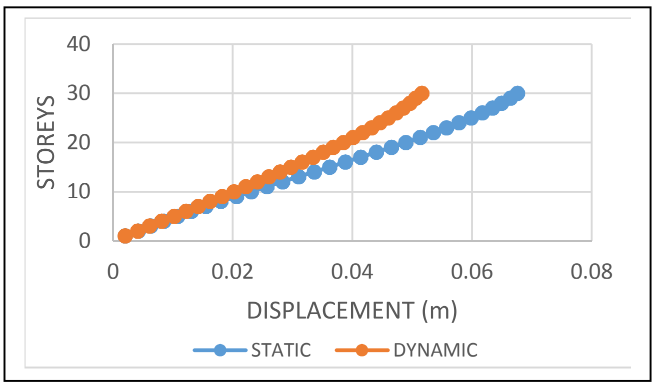

Fig. 11 Displacement for Inverted V-type bracing

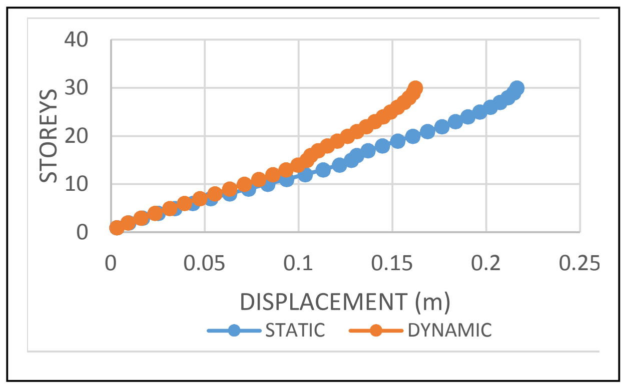

Fig. 12 Displacement for Outrigger system

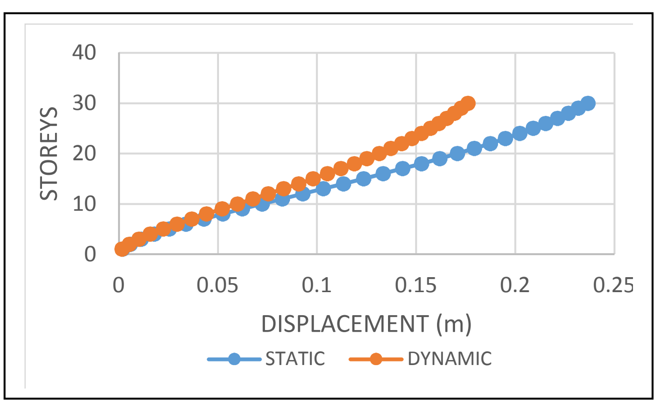

Fig. 13 Displacement for Shear core

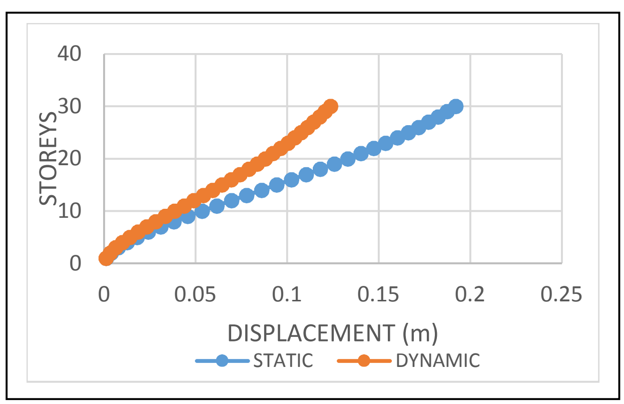

Fig. 14 Displacement for Shear wall

Percentage decrease in placement for all the systems is shown in TABLE 2. The ranking of all the structures have been done on this basis only. Cost evaluation is shown in Fig. 15. Volume of each component of structure is calculated and multiplied by the rate of M35 concrete. Percentage of steel is assumed in each building element like for column its 3%, which gives the quantity of steel used and cost is calculated. Cost of bricks and bracings is also calculated. Percentage increase in cost is shown in TABLE 3.

Table 2.

	Building with coupled shear wall	**Building with Braced core**	**Building with inverted V-type bracing**	**Building with outrigger and belt**	**Building with shear core**	**Building with shear wall**
% decrease in Displacement	63.73%	19.37%	78.46%	28.3%	27.3%	43.3%

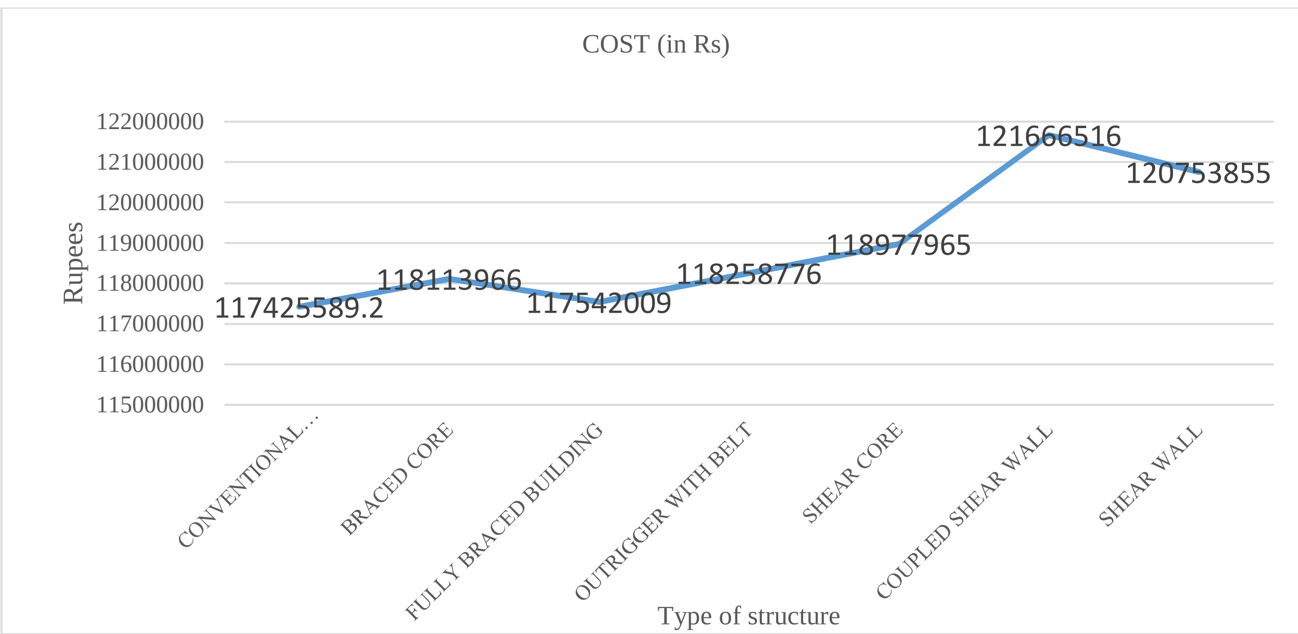

Fig. 15 Cost Evaluation

Table 3.

	Building with coupled shear wall	**Building with Braced core**	**Building with inverted V-type bracing**	**Building with outrigger and belt**	**Building with shear core**	**Building with shear wall**
%increase in cost	3.48%	0.58%	0.1%	0.70%	1.304%	2.76%

III. CONCLUSION

1. Outrigger is most effective when belt is provided at top and at middle position.
2. Shear wall is most effective when provided at the middle periphery. As shown in Fig. 5
3. Coupled shear wall is most effective at position shown in Fig. 3
4. When bracing is to be used at periphery, Inverted V-type is the most effective one.
5. Building with bracings at periphery came out to be the most effective one in terms of both effectiveness and cost.
6. Structures with shear wall are costlier then rest of the systems
7. Ranking of all systems in terms of their effectiveness in decreasing order:
    i. Building with Inverted V-type bracing at periphery
    ii. Building with coupled shear wall
    iii. Building with shear wall
    iv. Building with outrigger system with belt
    v. Building with shear core
    vi. Building with braced core.

IV. REFERENCES

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