International Journal of Research
Available at https://edupediapublications.org/journals
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 07
March 2018

Seismic Performance of Reinforced Concrete Structures Using Shear Walls

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Abstract:

With the rapid growth of urban population and economic activities in several regions around the world, the demand of the building has increased in the past few decades. Scarcity of land makes the horizontal development restricted. Hence most of the designers for the construction use vertical development. One of the major obstacles for vertical development of building is lateral loads due to wind and earthquake. India is basically divided into four seismic Zones –II, III, IV, V. Zone II ,III may be considered as little and moderately prone to earthquake whereas IV and V may be considered as severe and extreme severe zones. Hence the structures in zones IV, V has to be made earthquake resistant. The structure can be made earthquake resistant by the provision of a shear wall in the structure. In the present work, a 10 and 15 storied structures situated in seismic zone V were analyzed in ETABS using Seismic Coefficient method and the parameters such as lateral storey displacements, storey drifts, Bending moments were studied. The structures are then equipped with shear walls of different configurations such as L, Core, rectangle and channel shape and observed the efficient configuration for the effective reduction in seismic response. It has been observed that the lateral roof displacements reduced largely to an amount of 84%, lateral storey drifts up to 85% and bending moments in columns up to 88% in a 10 storied structure and the maximum reduction in seismic response is observed in structure provided with L shape shear wall at the four corners of the building.

Keywords

BendingMoments,.LateralRoof displacements, Storey drifts, shear walls, Seismic response.

1. Introduction

An earthquake is a sudden and transient motion of the earth's surface. India has been divided into four seismic zones II, III, IV, V in which zone IV and V were regarded as severe and extreme severe zones in the country. When the structure is constructed in zone IV and V, for the safety of the structure, large cross sections have to be provided for the structural member which is not an economical and conservative design. A shear wall is very effective in resisting the lateral loads when subjected to earthquake loading. In the present work, structures of varying floor levels (10 and 15) were considered and seismic analysis is performed using seismic coefficient method. Later the bare frame structures are equipped with shear wall in different configurations such as L shape, core, rectangle and channel shape and observed the reduction in seismic response. The parameters considered were lateral storey displacements, storey drifts, bending moments in beams and columns were considered.

2. Literature Review

P. S. Kumbhare and A. C.Saoji (2012) investigated that Shear wall is one of the most commonly used lateral load resisting in high rise building. Shear wall has high in plane stiffness and strength which can be used to simultaneously resist large horizontal load and support gravity load. The work is to study the effect of seismic loading on placement of shear wall in medium rise building at different alternative location. The residential medium rise building is analyzed for earthquake force by considering two type of structural system. i.e., Frame system and Dual system. Effectiveness of shear wall has been studied with the help of four different models. Model one is bare frame structural system and other four models are dual type structural system. Analysis is carried out by using standard package ETAB. The comparison of these models for different parameters like Shear force, Bending Moment, Displacement, Storey Drift and Story Shear has been presented by replacing column with shear wall.

RavikanthChittiprolu and Ramancharla Pradeep Kumar (2014) investigated that the usefulness of shear walls in the structural planning of multi-story buildings has long been recognized. When walls are situated in advantageous positions in a building, they can be very efficient in resisting lateral loads originating from wind or earthquakes. Reinforced concrete framed buildings

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 07
March 2018

are adequate for resisting both vertical and horizontal loads acting on them. Extensive research has been done in the design and analysis of shear wall in high-rise buildings. However, significance of shear wall in high-rise irregular structures is not much discussed in literature. A study on an irregular high-rise building with shear wall and without shear wall was studied to understand the lateral loads, story drifts and torsion effects. From the results it is inferred that shear walls are more resistant to lateral loads in an irregular structure.

P. P. Chandurkar and Dr. P. S. Pajgade (2013) investigated that in the seismic design of buildings, reinforced concrete structural walls, or shear walls, act as major earthquake resisting members. Structural walls provide an efficient bracing system and offer great potential for lateral load resistance. The properties of these seismic shear walls dominate the response of the buildings, and therefore, it is important to evaluate the seismic response of the walls appropriately. In the work, main focus is to determine the solution for shear wall location in multi-storey building. Effectiveness of shear wall has been studied with the help of four different models. Model one is bare frame structural system and other three models are dual type structural system. An earthquake load is applied to a building of ten stories located in zone II, zone III, zone IV and zone V. Parameters like Lateral displacement, story drift and total cost required for ground floor are calculated in both the cases replacing column with shear wall.

3. Models considered for study

Model 1: 10 storied bare frame structure
Model 2: 10 storied structure with shear wall at core
Model 3: 10 storied structure with shear wall with channel.
Model 4: 10 storied structure with rectangular shape shear wall.
Model 5: 10 storied structure with shear wall in corners in L-shape.
Model 6: 15 storied bare frame structure
Model 7: 15 storied structure with shear wall at core.
Model 8: 15 storied structure with shear wall with channel shape.
Model 9: 15 storied structure with rectangular shape shear wall in exterior frames
Model 10:15 storied structure with shear wall in the corners in - L shape

4. Specifications of the structures

The specifications for a 10 and 15 storied structure are as follows.

Specifications	**10Storey**	**15 storey**
Column size	0.3 m x 0.6m	0.45m x 0.75m
Beam size	0.3 m x 0.45 m	0.3 m x 0.45 m
Slab thickness	0.15m	0.15m
Thickness of exterior wall	230mm	230mm
thickness of interior wall	115mm	115mm
Thickness of shear wall	230mm	230mm
Grade of concrete for columns	M-25	M-25
Grade of concrete for beams and slabs	M-20	M-20
Grade of steel	Fe-415	Fe-415
Unit weight of concrete	25kN/ m^3	25kN/ m^3
Unit weight of brick	19kN/ m^3	19kN/ m^3
Live load	3kN/m^2	3kN/m^2
Floor finish	1kN/m^2	1kN/m^2
No. of bays in X direction	5	5
No. of bays in X direction	8	8

5. Seismic Loading

Seismic analysis has been carried out using seismic coefficient method. The structures are assumed to be located in extreme seismic zone (V) with the following seismic parameters:
Zone factor = 0.36
Importance factor = 1.0
Response reduction factor = 5.0
As per the provisions of IS-1893:2002 the seismic load is taken as following:
The full dead load and partial amount of live load has to be taken as seismic load. Since the live load considered in the study is 3 kN/m^2, the amount of live load to be considered in seismic analysis is 0.25x3=0.75 kN/m^2.

6. Model Analysis

The following figures illustrates the floor plan three dimensional views of bare frames and structures with shear wall configurations.

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 07
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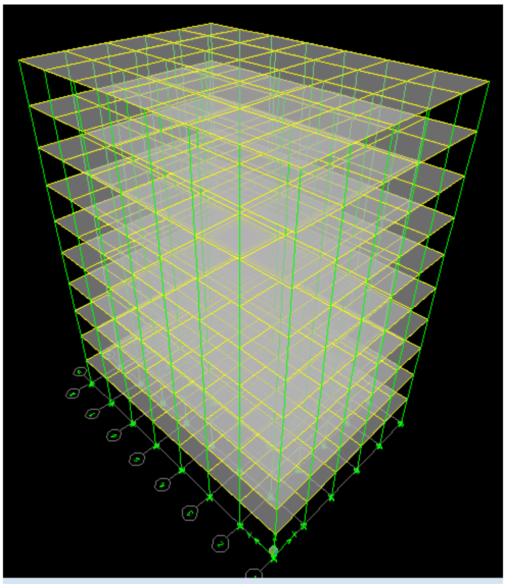

Figure 1. 3-Dimensional View of bare framed structure

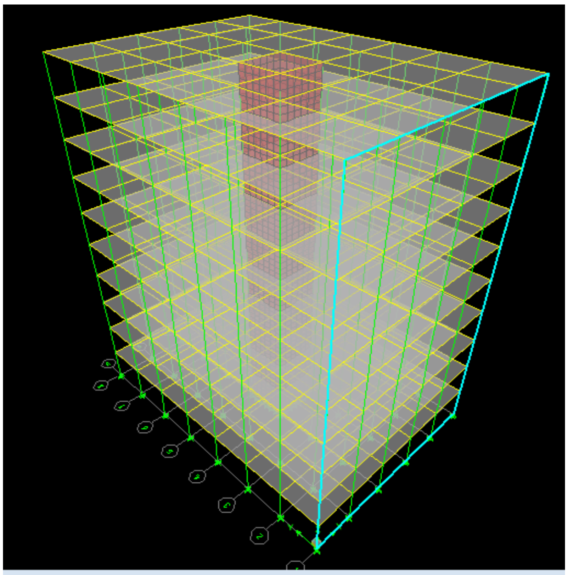

Figure 3. 3-Dimensional View of 10 storied structure with Core shear wall

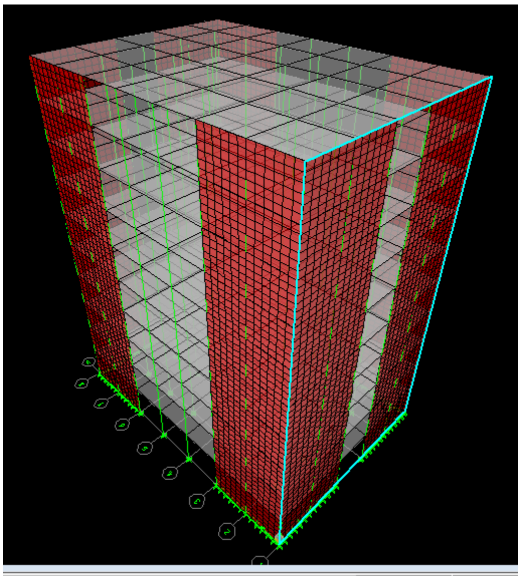

Figure 2. 3-Dimensional View of 10 storied structure with L shape shear wall

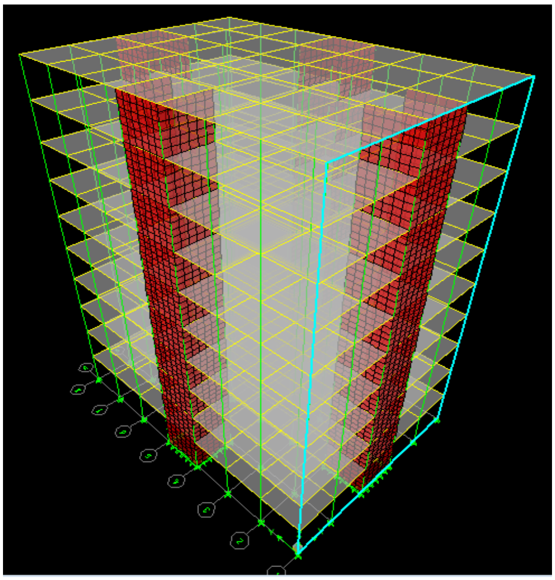

Figure 4. 3-Dimensional View of 10 storied structure with Channel shear wall

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 07
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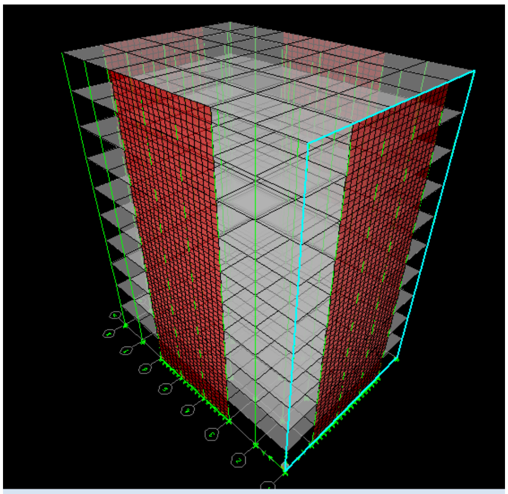

Figure 5 3-Dimensional View of 10 storied structure with Channel shear wall

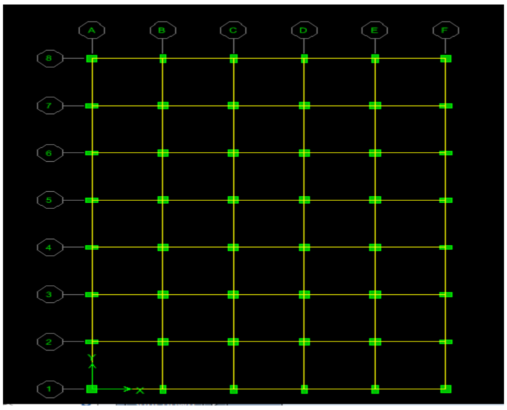

Figure6. Plan view of 10 and 15 storied structure

7. Results

a)Lateral storey displacements

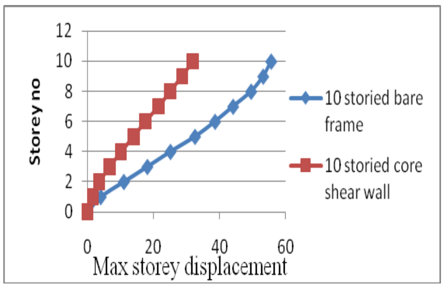

Figure 7. storey displacement for a 10 storied bare frame and with core shear wall

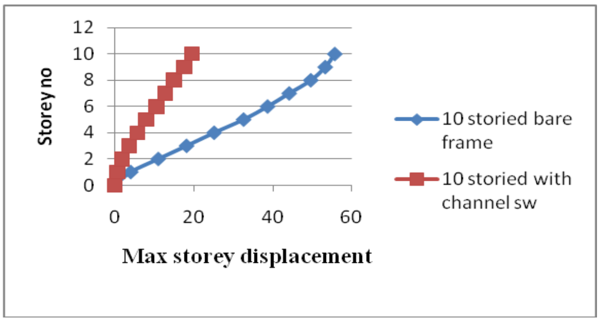

Figure 8. storey displacement for a 10 storied bare frame and with channel shear wall

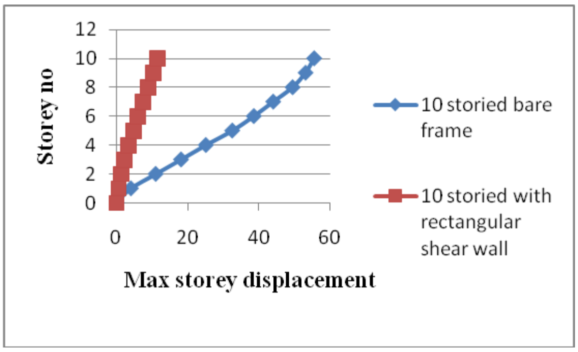

Figure 9.storey displacement for a 10 storied bare frame and with rectangular shear wall

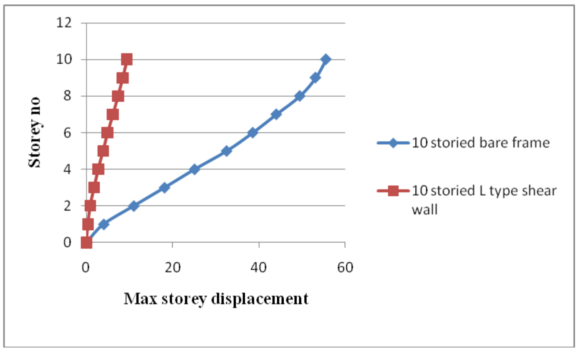

Figure10. storey displacement for a 10 storied bare frame and with L shear wall

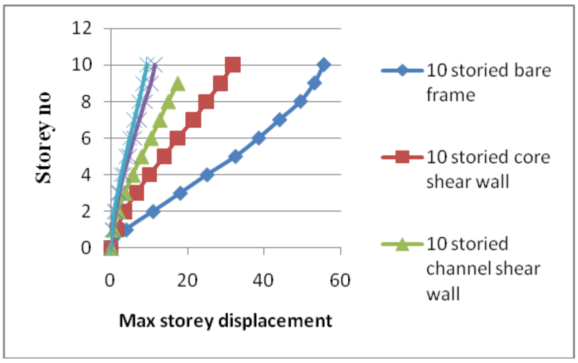

Figure11. storey displacement for a 10 storied bare frame and with all shear walls.

Figures 7 to 11 shows the comparison graphs for lateral roof displacements for bare frame and with multiple shear wall orientations. From figure 6, it can be observed that the maximum displacement of 55.54mm reduced to 31.8mm when modeled with a core shear wall, 19.51mm when modeled with a channel shear wall, 11.48mm when modeled with a rectangular shear wall in exterior frames and 9.38mm when modeled with L shape shear wall at the four corners of the building. Maximum reduction in lateral roof displacement is observed when modeled with L shape shear wall at the four corners of the building.

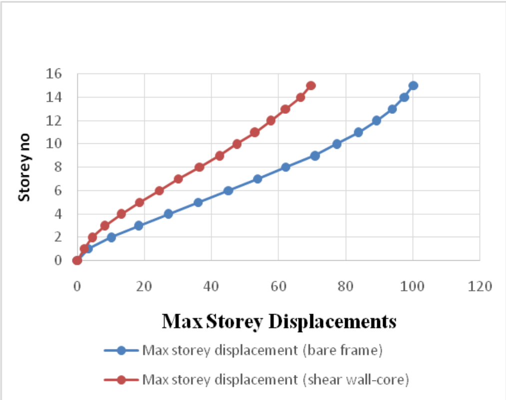

Figure 12. storey displacement for a 15 storied bare frame and with core shear wall

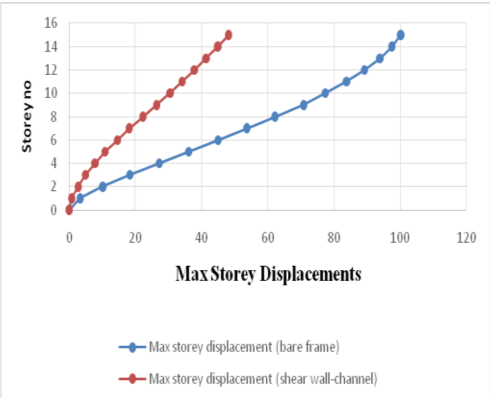

Figure 13. storey displacement for a 15 storied bare frame and with channel shear wall

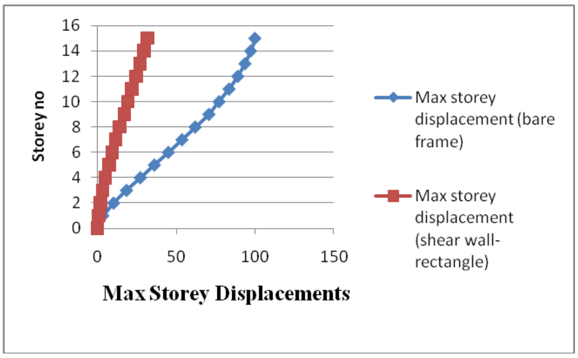

Figure 14. storey displacement for a 15 storied bare frame and with rectangle shear wall

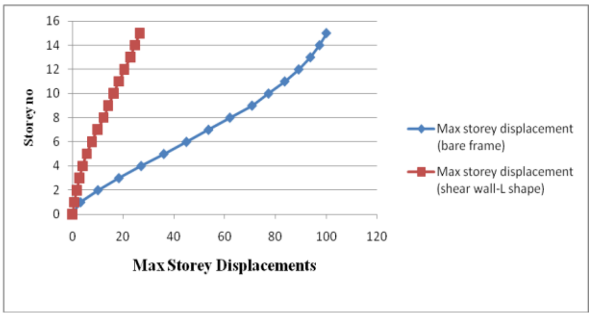

Figure 15. storey displacement for a 15 storied bare frame and with L shear wall

Figures 12 to 15 shows the comparison graphs for lateral roof displacements for bare frame and with multiple shear wall orientations. From figure 11, it can be observed that the maximum displacement of 100.08mm reduced to 69.6mm when modeled with a core shear wall, 48.1mm when modeled with a channel shear wall, 31.9mm when modeled with a rectangular shear wall in exterior frames and 26.6mm when modeled with L shape shear wall at the four corners of the building. Maximum reduction in lateral roof displacement is observed when modeled with L shape shear wall at the four corners of the building.

b) Storey drifts

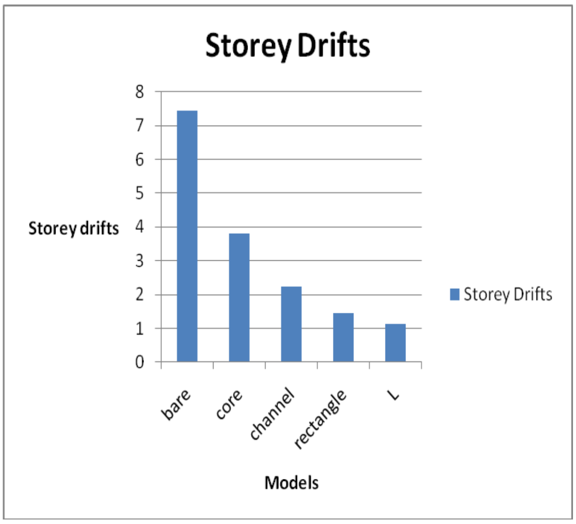

Figure 16. Storey drift for a 10 storied structure with and without shear wall

From figure 16, it can be observed that the maximum storey drift of 7.44 mm has occurred in 5th storey in a bare frame structure and the storey drifts reduced to 3.82 mm, 2.23 mm, 1.44 mm and 1.13 mm, when the structure is equipped with a core shear wall, channel type shear wall, rectangular shape and L-shape. Hence, it can be observed that maximum reduction in storey drift has occurred when the structure is equipped with L-shape shear wall.

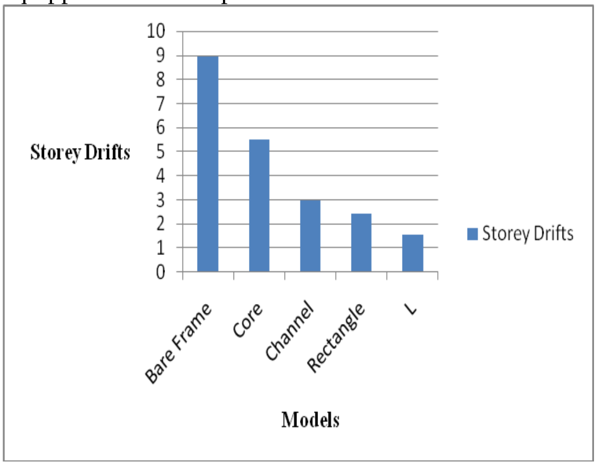

Figure 17. Storey drift for a 10 storied structure with and without shear wall

From figure 17, it can be observed that the maximum storey drift of 8.94 mm has occurred in 5th storey in a bare frame structure and the storey drifts reduced to 5.51 mm, 2.99 mm, 2.44 mm and 1.55 mm, when the structure is equipped with a core shear wall, channel type shear wall, rectangular shape and L-shape. Hence, it can be observed that maximum reduction in storey drift has occurred when the structure is equipped with L-shape shear wall.

b) Bending Moments

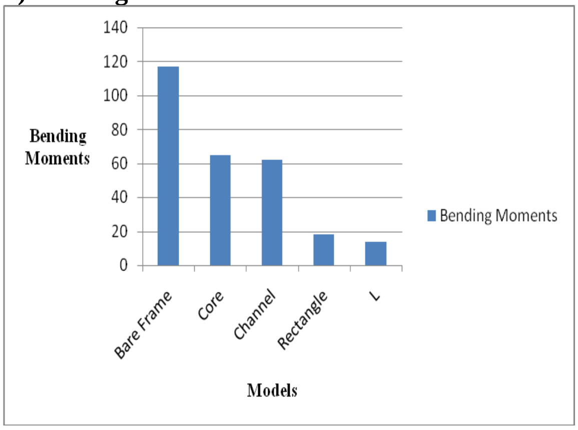

Figure 18. Bending Moments for a 10 storied structure with and without structure

From figure 18, it can be observed that the maximum Bending Moment of 117 kN-m has occurred in a bare frame structure and the Bending Moments reduced to 64.96 kN-m, 62.15 kN-m, 18 kN-m and 13.84 kN-m, when the structure is equipped with a core shear wall, channel type shear wall, rectangular shape and L-shape. Hence, it can be observed that maximum reduction in Bending Moment has occurred when the structure is equipped with L-shape shear wall.

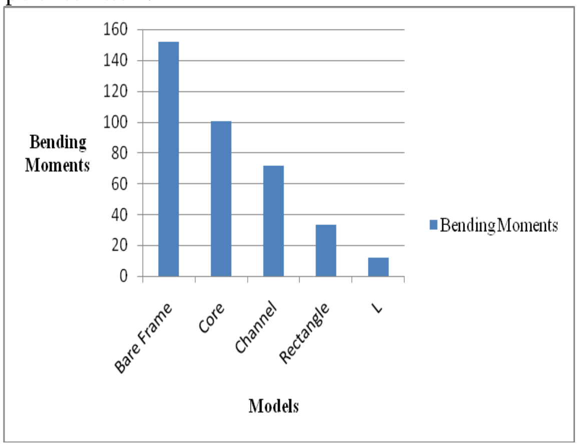

Figure 19. Bending Moments for a 15 storied structure with and without structure

From the above graph, it can be observed that the maximum Bending Moment of 152 kN-m has occurred in a bare frame structure and the Bending Moments reduced to 100.10 kN-m, 71.80 kN-m, 32.93 kN-m and 12.10 kN-m, when the structure is equipped with a core shear wall, channel type shear wall, rectangular shape and L-shape. Hence, it can be observed that maximum reduction in Bending Moment has occurred when the structure is equipped with L-shape shear wall.

8. Conclusions

On the basis of results obtained, the following conclusions were drawn.

1. Shear wall is very effective in reducing the seismic response of a structure.
2. The lateral roof displacements in a 10 storied structure decreased largely to an extent of 43%, 65%, 80%, 84% respectively when the structure is equipped with a core shear wall, channel shear wall, rectangular shape shear wall and L shape shear wall.
3. The lateral roof displacements in a 15 storied structure decreased largely to an extent of 30%, 52%, 69%,74% respectively when the structure is equipped with a core shear wall, channel shear wall, rectangular shape shear wall and L shape shear wall.
4. The lateral storey drifts in a 10 storied structure decreased largely to an extent of 49%, 70%, 81%, 85% respectively when the structure is equipped with a core shear wall, channel shear wall, rectangular shape shear wall and L shape shear wall.
5. The lateral storey drifts in a 15 storied structure decreased largely to an extent of 39%, 67%, 73%, 83% respectively when the structure is equipped with a core shear wall, channel shear wall, rectangular shape shear wall and L shape shear wall.
6. The maximum Bending Moments in the columns in a 10 storied structure is 117kNm which reduced to 45%,47%,85%,88% respectively when the structure is equipped with a core shear wall, channel shear wall, rectangular shape shear wall and L shape shear wall.
7. The maximum Bending Moments in the columns in a 15 storied structure is 152kNm which reduced to 34%, 53%, 78%, 91% respectively when the structure is equipped with a core shear wall, channel shear wall, rectangular shape shear wall and L shape shear wall.
8. Out of all the possible configurations of shear wall, L shaped shear wall at the four corners of the building is considered to be most effective in reducing seismic response.
9. Because of reduced bending moments in the structures, the cross sections of the structural members can be reduced which leads to lesser reinforcement which results in a conservative and economical design.

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