IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 17, Issue 2 Ser. V (Mar - Apr 2020), PP 54-59
www.iosrjournals.org

Seismic Response of a Multi-storied RCC building with Framed and Shear wall Structure

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Abstract:
Background*: The design of a structure must satisfy three basic requirements which are stability, strength and serviceability. There are two other consideration that a sensible designer ought to bear in mind viz. economy and aesthetic. As the height of building increases lateral load due to wind and earthquake makes their presence felt increasingly. In fact, in very tall building the choice of a structural system is dictated by its economy in resisting lateral load rather than gravity loads. In short it can be said that gravity load resisting and lateral load resisting system are complementary and interactive. The vertical framing system resist the gravity loads and lateral loads from the floor system and transmit these effects to the foundation and to the ground through beams, column and walls. When the main function of a wall is to resist lateral load due to wind and earthquake is referred as shear wall which can have thickness from 125mm to 200mm or even more for high-rise buildings. In this paper seismic response of seismic RCC building has been judged to compare its effect with simple framed structure and with shear wall structure in terms of shear-force, moment and displacement including drift with the help of E-TABS software.*

Key Word: *Earthquake, Shear wall, Seismic, loads, high-rise, Drift, Shear force, displacement.*

Date of Submission: 16-04-2020 Date of Acceptance: 01-05-2020

I. Introduction

Ductile shear walls also called flexural walls which form part of the lateral load resistance system are vertical members cantilevering vertically from the foundation, design to resist lateral force on its own plane and are subjected to bending moment, shear and axial load. Unlike a beam a wall is a relatively thin and deep, and is subjected to substantial axial forces. The wall must be design as an axially loaded beam, capable of informing reversible plastic hinges with sufficient rotation capacity.

Their thickness can be as low as 150mm, or as high as 400mm in high rise buildings. Shear walls are usually provided along both length and width of buildings (Figure-1). 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 its very goodperformance in past earthquakes.

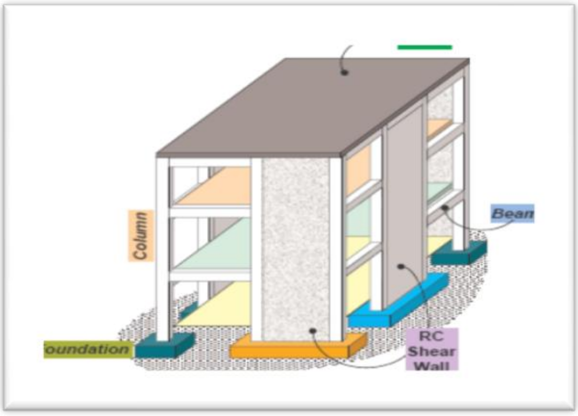

Figure 1: Multi-storey RCC building with shear wall.

Shear walls in high seismic regions require special detailing. However, in past earthquakes, even buildings with sufficient number of walls that were not specially detailed for seismic performance (but had enough well-distributed reinforcement) were saved from collapse. Shear wall buildings are a popular choice in many earthquake prone countries, like Chile, New Zealand and USA. Shear walls are easy to construct, because reinforcement detailing of walls is relatively straight-forward and therefore easily implemented at site. Shear walls are efficient, both in terms of construction cost and effectiveness in minimizing earthquake damage in structural and non- structural elements (like glass windows and building contents). Most RC buildings with shear walls also has columns. These columnsprimarilycarry gravity loads (*i.e.,* those due to self-weight and contents of building). Shear walls provide large strength and stiffness to buildings in the direction of their orientation, which significantly reduces lateral sway of the building and thereby reduces damage to structure and its contents.

II. Types of Structures

There are mainly three type of structures

1. Braced structures

In braced frames(figure-2) the lateral loads like wind earthquakeetc. are resistedby special arrangements like shear walls, shear trusses, bracing or special supports. Thus,the beam column frames are not subjected to horizontal loads. In other words, the sideswayor joint translation is not possible in column. The structure is called a braced structure andcolumns occurringin such structure is called the braced column.Theshear walls, shear trusses or bracing provided in the building must havestiffness to act as effective bracings. According to SP: 24 the bracing system mustprovide total stiffness equal to at least six times the sum of stiffnessof all the columns, withinthe storey.They may become uneconomical for larger height as shear walls are designedas vertical cantilevers from the ground.

2. Unbraced structures

An unbraced frame (Figure-2) where resistance to horizontal loads is provided bybending in the beam and column in that plane. In other words, the sideway or jointtranslation does occur in suchframes. These structures are called unbraced structures andthe columns occurring in such structures are called unbraced columns.

3. Dual structures

Dual structures are combination of the above two. The resistance to horizontalloads is provided by both, the bending in frames and by shear walls. The frames and shearwalls will resist horizontal forces in proportion to their relative stiffness. However, theframe should be designed to carry minimum 25% horizontal shear.

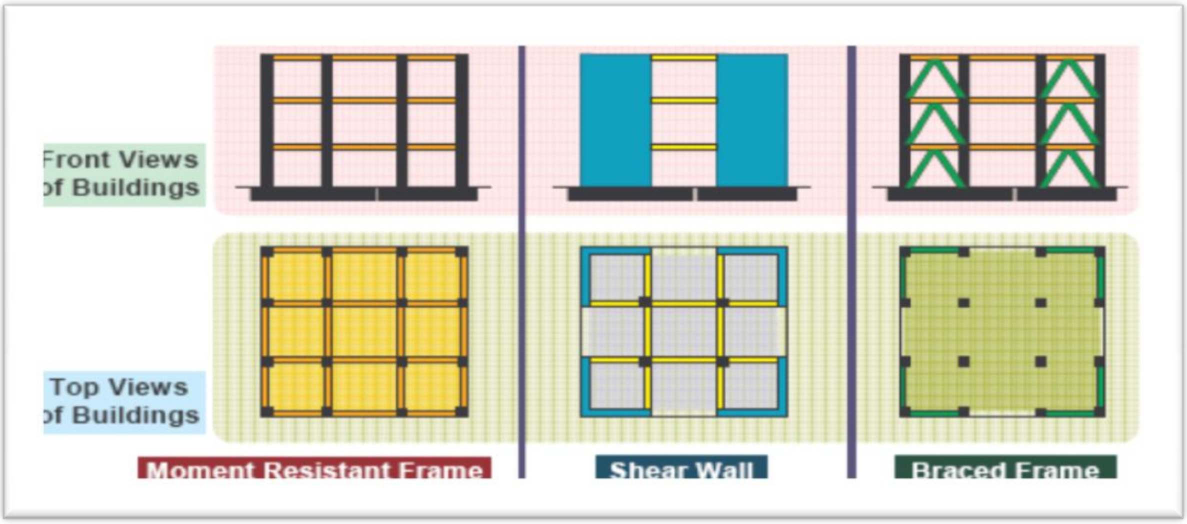

Figure 2: Types of structures

III. Types of Analysis

The analysis of any structure can be broadly classified as linear analysis or non-linear analysis. When only elastic behaviour of materials is considered, linear analysis methods suffice and provide desirable results, though formulation of P-delta may still be applied. On the other hand, when either geometric or material non-linearity is considered during structural modelling and analysis, non-linear analysis methods give best results. Geometric non-linearity concerns the P-Delta effects associated with application of external loading upon the displaced configuration of a structure. Whereas material non-linearity concerns inelastic structural response in

which the behaviour of a component, system, or connection deviates from the initial stiffness tangent characteristic of linear-elastic behaviour. Further, linear and non-linear methods may be dynamic or static. A few of the traditional analysis methods, and the relations between their attributes, are presented in figure-3.
Each of these analysis methods has benefits and limitations. An overview of each method is as follows:

- Strength-based analysis is a static-linear procedure in which structural components are specified with their elastic capacities exceeding the demands of loading conditions. Strength-based demand-capacity (D-C) ratios indicate the adequacy of each component. Strength-based analysis is the most simplified and least time-consuming analysis method because only the elastic stiffness properties are applied to the analytical model.

- Static-pushover analysis is a static-nonlinear procedure in which a structural system is subjected to a monotonic load which increases iteratively, through an ultimate condition, to indicate a range of elastic and inelastic performance. As a function of both strength and deformation, the resultant nonlinear force-deformation (F-D) relationship provides insight into ductility and limit-state behaviour. Deformation parameters may be translational or rotational. Pushover is most suitable for systems in which the fundamental mode dominates behaviour. When higher-order modes contribute, as with taller buildings, dynamic analysis is most effective.

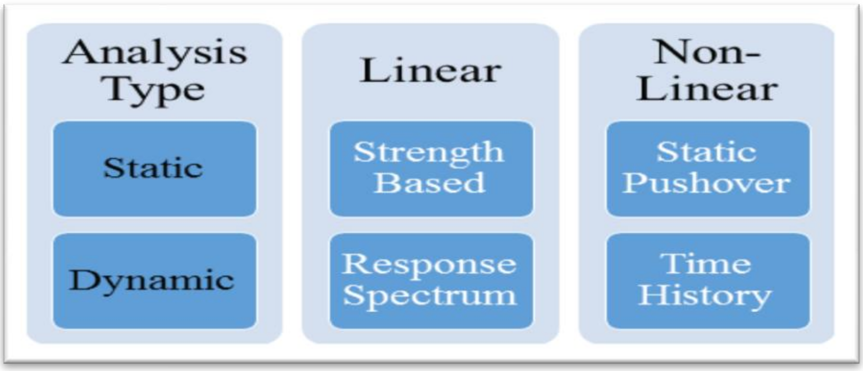

Figure 3: Types of analyses

- Response spectrum analysis methods are typically used for seismic analysis of structures. It calculates the maximum response values in each mode of the structure from a spectrum curve and then combines these responses using modal superposition. The input spectra might be for a smoothed spectrum like codes used to describe for a range of earthquakes or spectra for a specific earthquake. Spectra curves are plotted with period on the horizontal axis and acceleration on the vertical axis. It may consist of multiple curves for different levels of damping. A response spectrum analysis seeks to determine the likely maximum response of the structure when subjected to the pseudo acceleration of a response spectrum curve. Structures must remain essentially elastic since response-spectrum analysis is dependent upon the superposition of gravity and lateral effects.

- Time-history analysis is a dynamic-nonlinear technique which may involve either the FNA or the direct-integration method. FNA is a modal application, whereas with direct integration, the equations of motion are integrated at a series of time steps to characterize dynamic response and inelastic behaviour. Loading is time-dependent, and therefore suitable for the application of a ground-motion record. Time-history analysis may account for both material nonlinearity and P-Delta effects.

IV. Description of model and Data taken

A (G+5) storied building with shear wall and without shear wall is presented. Aplan of size 17.85mx10.5m has been selected. Which has been analyzed by E-TABS-2016

Table no. 1:

Live load	4.0kN/m2 at typical floor 1.5kN/m2 on terrace
Floor finish	1.0kN/m2
Terrace finish	1.0kN/m2

Water proofing	2.0kN/m2
Zone	IV
Earthquake load	As per IS-1893(Part1) -2002
Type of soil	Type II, Medium as per IS:1893
Building height	23.5m
Storey height	3.5m
Walls	External wall 0.200m, Internal wall 0.100m Shear wall 0.200 m
Column size	0.40 X 0.25 m2
Beam size	0.40X 0.20m2s
Thickness of shear wall	0.20m

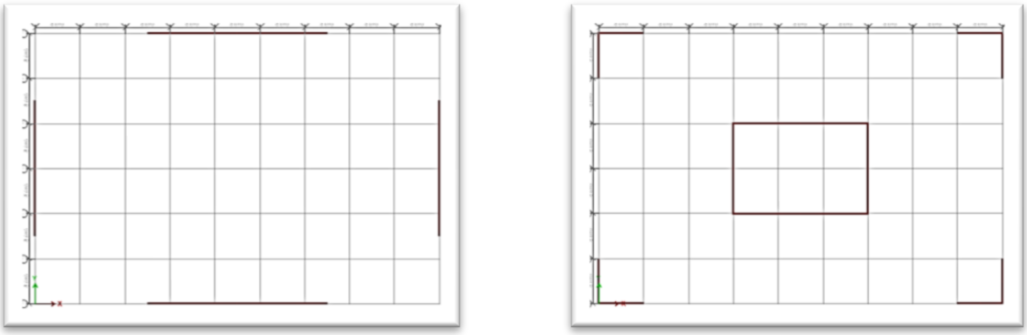

Figure 4: Plan view of different model

V. Result and Discussion

When structure has been analyzed without shear wall and with shear wall for different position the following results obtained which has been tabulated below for peripheral column only.

Table 2:Comparison of moment with shear wall and without shear wall

Storey Level	External Column				% variation in moment whenshear wall structure is considered
	Structure without shear wall		Structure with shear wall		
	Axial load (F_y) KN	Moment (M) KN-m	Axial load (F_y) KN	Moment (M) KN-m	
Terrace	72.33	29.88	91.30	33.32	+13.11
5th floor	220.90	42.71	220.88	30.31	-26.50
4th floor	365.11	48.77	366.78	34.15	-28.20
3rd floor	517.80	53.91	506.20	32.27	-35.44
2nd floor	673.89	50.50	641.12	29.11	-39.90
1st floor	830.50	49.11	772.10	25.67	-52.11

Table 3: Nodal Displacement (mm) without Shear wall and with shear wall

Structure without shear wall			Structure with shear wall		
Storey level	Displacement (mm)		Storey Level	Displacement (mm)	
	X-Axis	Z-Axis		X-Axis	Z-Axis
Terrace	52.11	89.22	Terrace	28.95	39.543
5th Floor	49.55	83.25	5th Floor	23.55	32.56
4th Floor	43.45	73.10	4th Floor	18.45	26.51
3rd Floor	34.53	58.87	3rd Floor	13.75	18.43
2nd Floor	24.43	42.11	2nd Floor	9.35	12.68
1st Floor	14.23	23.30	1st Floor	5.36	6.60
Plinth	4.42	7.43	Plinth	2.87	2.46
Foundation	0	0	Foundation	0	0

During analysis it is seen that there are no twisting effects on structure when shear walls are placed in symmetrical location in building and when walls are placed in unsymmetrical position then structure also getting twist due to generation of torsional moments. Hence it is better to place shear wall in symmetrical way rather than unsymmetrical.

From the above Table 2 it is also found that moment coming without shear wall are very much with respect to structure with shear wall. In the lower storey moments coming with shear wall is very less while in upper storey shear wall moment at terrace level is more than the moments coming without shear wall thus moments in upper storey of shear wall structure are higher in the moments of column in shear wall thus, needs additional reinforcement at this level.

According to Table 3 it is seen that in structure without shear the maximum displacement is at terrace level is 52.11 mm in X-axis and 89.22 mm in Z-axis where as in structure with shear wall the terrace level displacement has reduced to 28.95mm in X-axis and 39.54 mm in Z-axis. Thus, maximum percentage reduction in displacement when shear wall structure is considered is 43.95% in X-axis and 52.98% in Z-axis. It means that the overall displacement with shear wall can be reduced too much with respect to simple framed structure.

Table 4: Storey Drift(mm) without Shear wall and with shear wall

Structure without shear wall			Structure with shear wall		
Storey level	Storey Drift (mm)		Storey Level	Storey Drift (mm)	
	X-Axis	Z-Axis		X-Axis	Z-Axis
Terrace	3.60	5.92	Terrace	4.50	6.93
5th Floor	6.43	11.14	5th Floor	4.91	7.23
4th Floor	8.92	14.55	4th Floor	**5.52**	**7.50**
3rd Floor	10.21	16.86	3rd Floor	4.94	6.93
2nd Floor	**11.53**	**18.13**	2nd Floor	4.13	5.93
1st Floor	9.96	17.45	1st Floor	3.97	4.33
Plinth	3.56	6.33	Plinth	1.30	1.53
Foundation	0	0	Foundation	0	0

As per IS-code:1893-2016 it is stated that maximum drift due to earthquake between two successes floor should not be more than 0.004 times the difference in level of these floors, because in this building the floor height has been kept 3500mm thus, maximum permissible drift should not be more than 0.004 × 3500 which is 14mm only. From the Table-4 it is found that maximum drift coming out without shear wall is 18.13mm which is more than permissible limit thus, structure will be unsafe at this level, maximum drift with shear wall structure is coming at 4th floor is 7.50mm which is less than the permissible limit prescribed by the code, thus, this structure will also be safe in drift at any level with shear wall.In high-rise building drifting problem will be more and it will cause the damage of structure during earthquake hence shear wall system will be more effective. Like outrigger and any other system used according to conditions.

VI. Conclusion

From the above analysis it is very clear that the shear wall is very much effective in reducing the moments and displacement along with drift in any structure thus, it should be placed for multi-storey building or high-rise building to keep the structure safe.

The results also state that the placement of shear wall should be systematic rather than the asymmetrical location so that twisting effect of the building can be controlled due to torsional moment. Thus, placement of shear wall is also a way to have a most optimum shear wall configuration.

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