Comparative Seismic Performance of MRF, Dual System & Shear Wall in RC Buildings

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Abstract— Behavior of multi-storey buildings subjected to different loadings specifically earthquake loads is always a subject of interest for structural engineers. With the increased frequency of earthquakes and more awareness about the design requirements and codal provisions it is extremely important to study the behavior of the structure with different structural frame configurations and their suitability. Moment resisting frames (MRF), dual system and shear wall dominated systems are three basic and widely used load resisting systems for medium high rise buildings. In this study the seismic performance of all the three systems is compared to find out strength and weakness of each system. A RC building is modelled using STAAD PRO software with different possible configurations for the three systems. The parameters considered for the comparison are inter- storey drift, storey shear, total displacement and time period. It is concluded that shear wall dominated system shows better performance than the other two systems under seismic loading.

Key words: MRF, Dual System, Shear wall, Comparison

I. Introduction

Reinforced Concrete (RC) is a common building material which has been used to construct high rise buildings for several decades. Different RC building shapes can be achieved using advanced molds. In case of RC buildings, shear walls are used to increase the resistance for all loads types of gravity and lateral loads, seismic loads that act on the structure during it's design life. Placing of shear wall at the optimal position in the buildings is essential to achieve sustainable and resilient building performance under both daily and extreme load conditions. Earthquakes are one of the most hazardous natural disasters that attacks human and cause large damages especially in regions where defined as high-seismic zones. Therefore, designing and analyzing structures to resist seismic attack is very much essential.

A. Shear wall system

Seismic performance of RC buildings mostly depends on the building configurations and the number of floors of the buildings. There are many factors affecting seismic performance of the buildings such as building stiffness, strength, and ductility. The stiffness of a building can be increased by adding shear walls. By adding shear walls, the buildings lateral displacement is reduced providing more stability to the building.

B. Dual system

A dual system is a structural system in which an essentially complete frame provides support for gravity loads. The resistance to lateral loads is provided by a specially detailed moment-resisting frame and shear walls or braced frames. In case of dual system, both shear walls and frames participate in resisting the lateral loads resulting from earthquakes or wind or storms. This system is considered to be a good solution for medium rise buildings as it gives benefit of both MRF and shear wall.

C. Moment Resisting Frame (MRF) system

Moment-resisting frames are rectilinear assemblages of beams and columns, with the beams rigidly connected to the columns. The lateral forces are mainly resisted by rigid frame action which means bending moment and shear force are developed in the RC frame members and joints. By virtue of the rigid beam-column connections, a moment frame cannot displace laterally without bending the beams or columns depending on the geometry of the connection. The primary source of lateral stiffness and strength for the entire frame is therefore bending rigidity and strength of the frame members.

II. Methodology of Work

The methodology worked out to achieve the mentioned objectives is as follows:

- Modelling of the selected building in STAAD pro. V8i Software.
- Twenty four models with different structural configurations, keeping the plan same were prepared and studied.
- Retrieve the four parameters i.e. storey drift, storey shear, time period, displacement of structure from the software.
- The comparative graphs of each parameter will be presented.

III. STRUCTURAL RESPONSE

The behavior of a building during an earthquake is a vibration problem. If the base of a structure is suddenly moved the lower portion of a building tends to vibrate, but the upper part of the structure will not respond instantaneously, but will lag because of inertial resistance and flexibility of structure. Building collapse is caused due to these inertia forces. Because earthquake ground motion is three-dimensional, the structure, in general, deforms in a three dimensional manner.

Generally inertia forces generated by the horizontal components of ground motion require greater consideration for seismic design since adequate resistance to vertical seismic loads is usually provided by the member capacities required for gravity load design.

For doing the analysis and to derive seismic forces, their distribution to various levels along height of the building and to various lateral load resisting elements, it depends on the height of the building, severity of the seismic zone in which the building is located and on the classification of the building as regular or irregular.

IV. EQUIVALENT STATIC METHOD

Base shear calculation (seismic) - The total lateral force or seismic base shear for design (V_B) along any principal direction is determined by equation no. 1,

$$V_B = A_h W \quad (1)$$

Where,
A_h = Design horizontal acceleration value, using the fundamental natural period, T, in the considered direction of vibration
W = Seismic weight of the building.

The design horizontal seismic coefficient Ah for a structure is determined by the expression no. 2,

$$A_h = \frac{ZIS_a}{2Rg} \quad (2)$$

Where,
Z = Zone factor
I = Importance factor
R = Response reduction factor
Sa/g = Average response acceleration coefficient

For any structure with T:5:0.1s, the value of A_h will not be taken less than Z/2 whatever be the value of 1/R. In eqn. no.2, Z is the zone factor given in Table 2 of IS 1893 for the maximum considered earthquake (MCE).

I is the importance factor given in Table 6, pg.no. 18 of IS 1893-2002, and depends upon the functional use of the structure, the hazardous consequences of its failure, post- earthquake functional needs historical value, or economic importance.

Sa/g is the response acceleration coefficient as given by Fig. 2 of IS 1893 for 5 per cent damping based on appropriate natural periods.

A. Seismic weight calculation

The seismic weight of the entire/whole building is the sum of the seismic weights of all the floors. The seismic weight of each floor is its full dead load plus the appropriate amount of imposed load that may reasonably be expected to be attached to the structure at the time of earthquake shaking. It includes the weight of permanent and movable/ flexible partitions, permanent equipment, a part of the live load, etc.

B. Fundamental natural period calculation

For a moment resisting frame building without brick infill panels, T_a may be estimated by the empirical expression,

$$T_a = 0.075h^{0.75} \text{ -}$$

For RC frame building

For all other buildings, including moment-resisting frame buildings with brick infill panels, Ta may be estimated by the empirical expression no. 3,

$$T_a = \frac{0.09\,h}{\sqrt{d}} \quad (3)$$

C. Distribution of design force calculation

Vertical distribution of base shear to different floor levels. The design base shear (VB) is distributed along the height of the building as per the following expression

$$Q_i = V_B \frac{W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2} \quad (4)$$

Where,
Qi = Design lateral force at floor i,
wi = Seismic weight of floor i,
hi = Height of floor i measured from base

V. MATHEMATICAL MODEL

A residential building of P + 9 storey is selected for the study. All the three systems are modelled for four no. of configurations under each system. Thus total twenty for models are prepared, analysed and compared. Specifications used for STAAD model are as follows,

Sr. No	Parameters	Dimensions/Type
1	Plan dimension	14.7 x 13.5 m
2	Number of stories	P+9
3	Total height of building	30m
4	Height of each storey	3m
5	Column size	230 X 650 mm
6	Beam size	230 x 550 mm
7	Grade of concrete	M20
8	Frame type	SMRF
9	Soil type	Hard soil
10	Live load	2 KN/M^2
11	Floor finish	1 KN/ M^2
12	Inner wall	150 mm
13	Outer wall	150 mm
14	Slab thickness	125mm
15	Unit weights of Concrete	25 KN/M^3
16	Unit weights of brick work	19 KN/M^3
17	Shear wall thickness	200mm ,150 mm

Table 1: Model Specifications

A. Basic arrangement of three systems

Type A - It is the first system considered for analysis. The MRF system is modelled with four different arrangements with the details listed in table II below. Strong column weak beam ideology is followed.

The typical layout shown in fig. 1 indicates option 2 from the table II.

Type name	Option no.	Description
A	1	Column orientation as per Arch. Requirement
A	2	All square columns
A	3	Column orientation parallel to Y axis in plan
A	4	Column orientation parallel to X axis in plan

Table 2: Type A Details

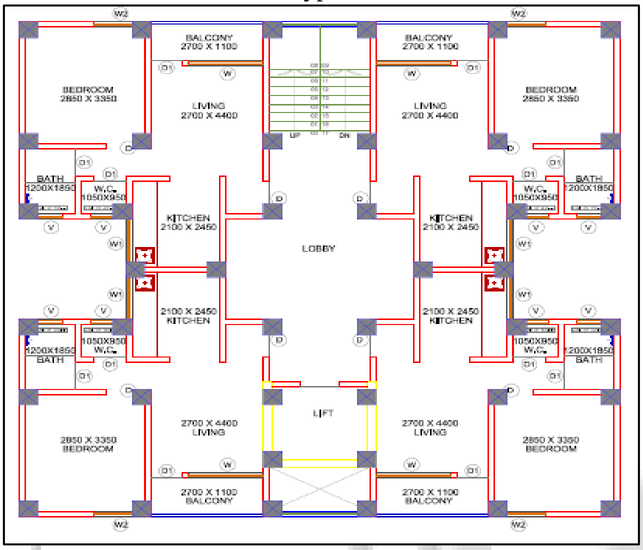


Fig. 1: Type A Typical layout

Type B – The second system is dual system. In this MRF system is added with shear wall at specific locations in order to improve lateral load resisting capacity of building.

With all other parameters same only different location are chose for shear walls and four options are created.

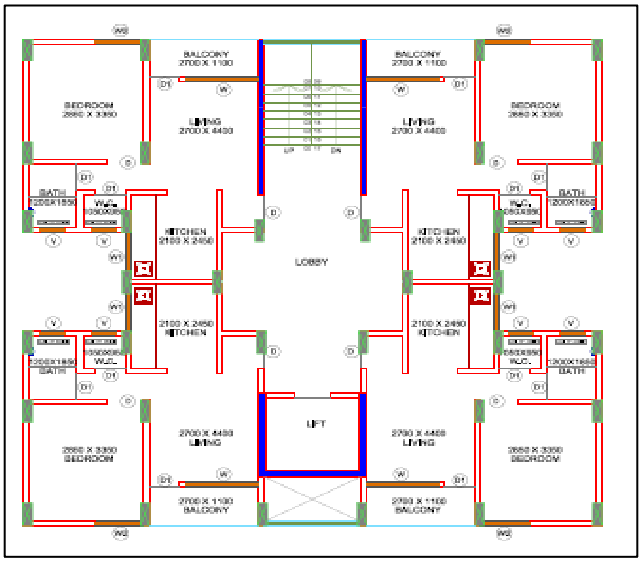
The thickness of shear wall considered in this case is 150mm. The typical layout shown in fig. 2 indicates option 1 from the table III.

Type name	Option no.	Description
B	1	Shear walls for lift and stair
B	2	Shear walls at external periphery and lift
B	3	Shear walls for lift and internal walls
B	4	Shear walls for lift, staircase and lobby

Table 3: Type B Details

Type C - This is the third type of system considered in analysis. Here, it is all shear wall dominated building. In this case four options are created depending upon wall thickness and on the basis of transfer structure.

Two thicknesses of shear walls are considered i.e.150mm and 200mm. The typical layout shown in fig.3 is for option 2 from table IV.



Type name	Option no.	Description
C	1	All walls are 200mm thk. Shear walls
C	2	All walls are 150mm thk. Shear walls
C	3	200mm thk. Shear walls with transfer slab
C	4	150mm thk. Shear walls with transfer slab

Table 5: Type C Details

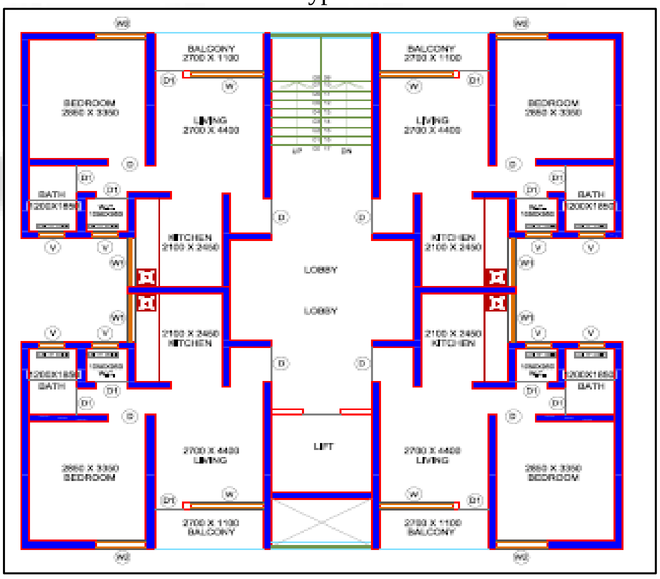


Fig. 3: Type C Typical layout

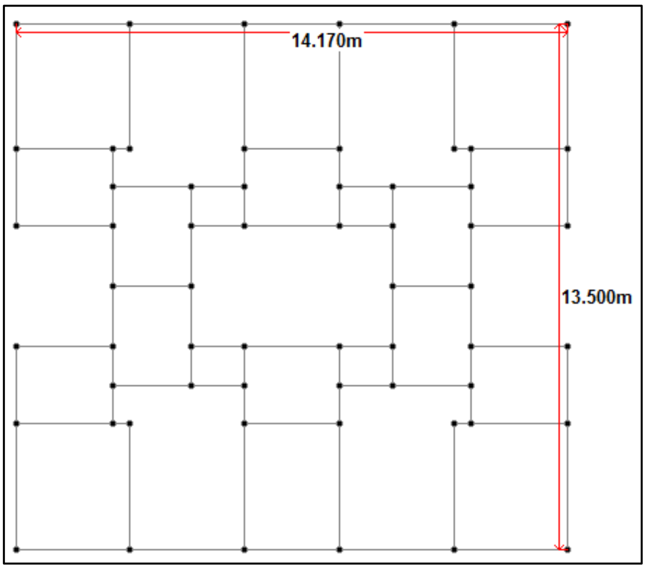


Fig. 4: Typical plan in STAAD

VI. RESULTS

The deflected shapes from the STAAD analysis results are shown in the figs. below. As it can be clearly seen from the above figs., displacement in case of shear wall dominated system is very less as compared to the other systems.

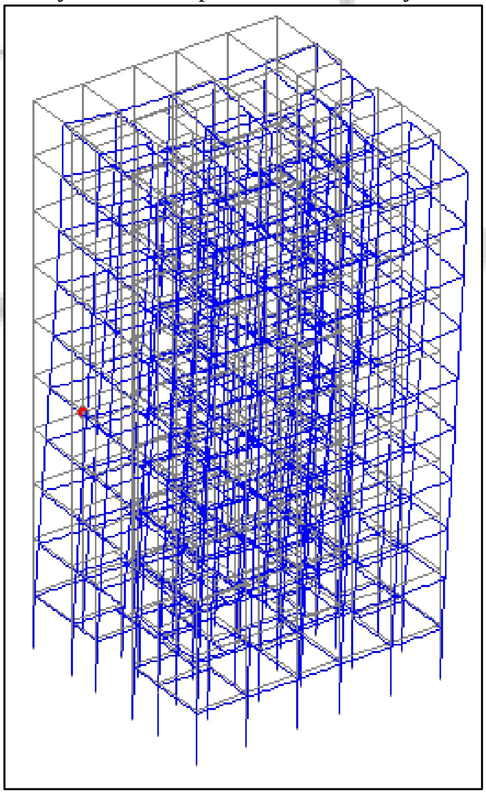


Fig. 5: Type A deflected shape

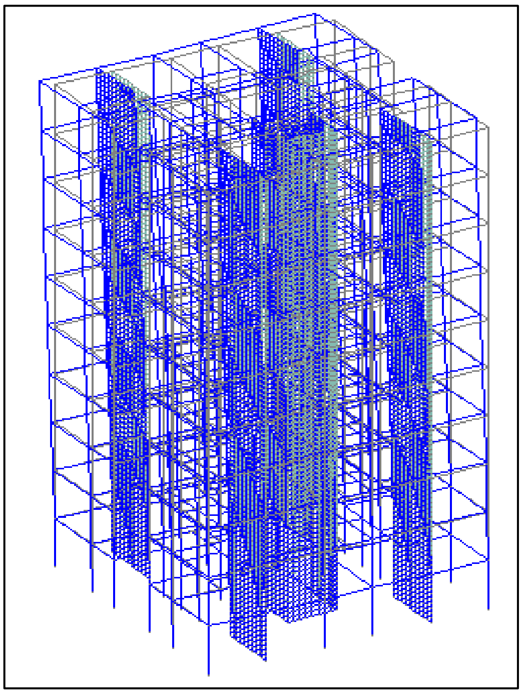


Fig. 6: Type B deflected shape

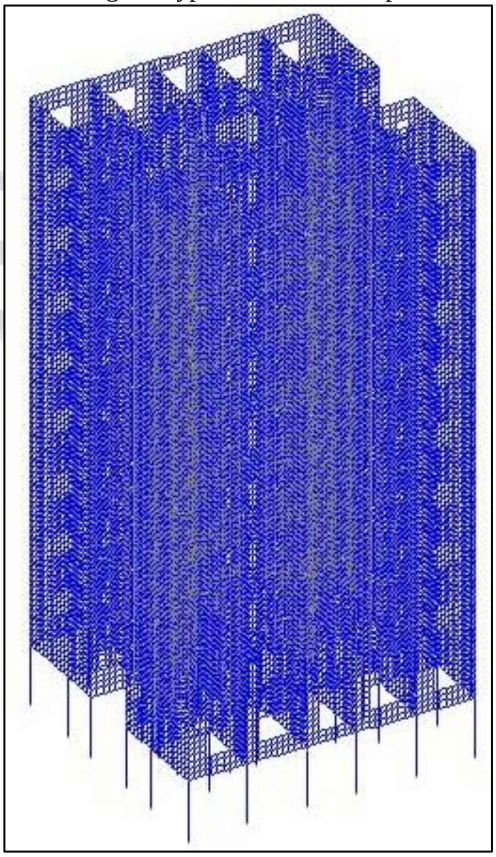


Fig. 7: Type C deflected shape

The graphical comparative representation of the results for the three systems with the four parameters are as follows.

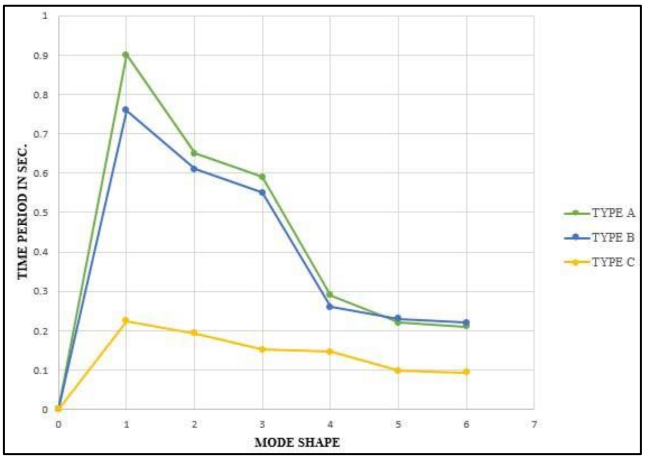


Fig. 8: Mode shape vs Time period

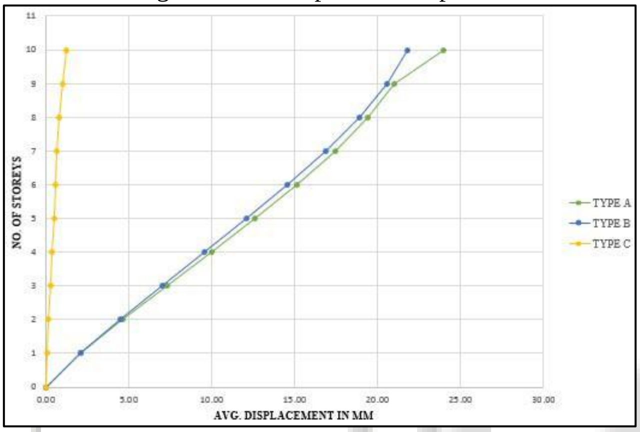


Fig. 9: Avg. displacement vs No. of storeys

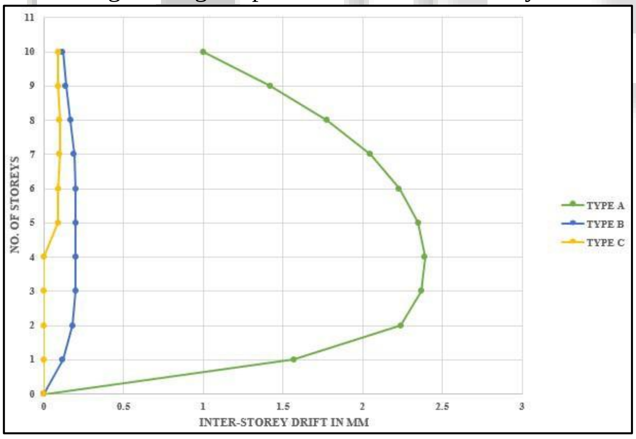


Fig. 10: Inter-storey drift vs No. of storeys

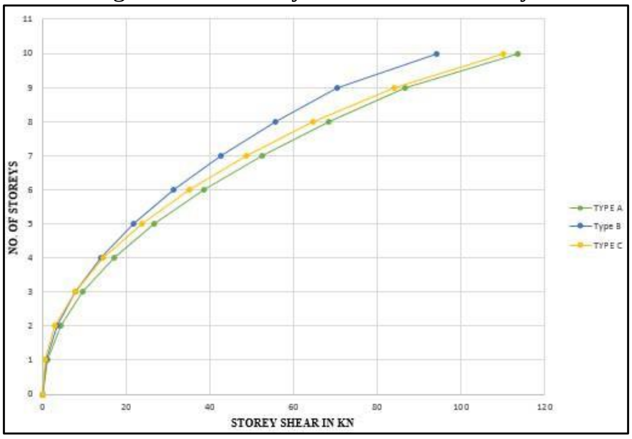


Fig. 11: Storey shear vs No. of storeys

System	Base shear in KN		Displacement in mm		Storey drift in mm	
	Max. value	% Difference	Max. value	% Difference	Max. value	% Difference
MRF	418.48	0%	24	0%	2.39	0%
Dual	341.55	18.38%	21.81	9%	0.2	92%
Shear wall	392.54	6.20%	1.25	95%	0.1	96%

Table 5: Comparison of Three Systems

VII. OBSERVATION & CONCLUSION

All the systems were compared on the basis of Time period, base shear, inter- storey drift & total displacement. The observations are as follows.

1) In case of MRF structure, storey drift & base shear are more than dual system. Total displacement is also on higher side in MRF system.
2) In case of dual system, base shear is the lowest, however total displacement and storey drift are more than in shear wall system.
3) Location of shear wall plays important role in dual system. Shear walls at periphery portion of building gives better results.
4) Global torsion is reduced in dual system. MRF systems have slightly more tendency for torsion.
5) Under earthquake forces due to overturning moments shear walls experience high compressive & tensile stresses. Thus to ensure shear wall behaves in ductile way end regions of walls will required special confirming reinforcement.
6) Shear wall dominated system have very less displacement and inter-storey drift which results into less flexural stresses. Axial tension and axial compression are the dominating forces.
7) From above observations we can conclude that shear wall dominated system performs better when subjected to seismic loads compared to MRF and dual system. This system also can prove economical as the flexural stresses are less so optimization in use of concrete and reinforcement is possible.

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