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Comparative Analysis between Different Commonly used Lateral Load Resisting Systems in Reinforced Concrete Buildings

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Abstract- The concept of tall structures is not new to the world, yet the trend of high-rise construction started in the nineteenth century. High-rise or multi-storey buildings are being constructed either to cater for a growing population or as a landmark to boost a country's name and get recognition. Any structure, to be reliable and durable, must be designed to withstand gravity, wind, earthquakes, equipment and snow loads, to be able to resist high or low temperatures, and to assimilate vibrations and absorb noises. This has brought more challenges for the engineers to cater both gravity loads as well as lateral loads. Earlier buildings were designed for the gravity loads but now, because of height and seismic zone, the engineers have taken care of lateral loads due to earthquake and wind forces. Seismic zone plays an important role in the earthquake resistant design of building structures because the zone factor changes as the seismic intensity changes from low to very severe. In present research we have used square grid of 12m in each direction of 4m bay in each direction in seismic zone 5.Software used is Staad proV8i select series 5 and the work has been carried out for the different cases with lateral load resisting systems like Shear wall, Bracing, Moment Resisting Frames and check their efficiency by comparing nodal displacements, relative displacement of beams, maximum moments and shear forces in beams and thereby predicting their efficiency.

Keywords: bare frame, bracings, shear walls, lateral load resisting systems, seismic zone.

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I. Introduction

Buildings are subjected to two types of load (i) Vertical load due to gravity, and (ii) Lateral load due to earthquake and wind. The structural system of the building has to cater for both the types of load. The structural system of a building may also be visualized as consisting of two components (i) Horizontal framing system, consisting of slabs and beams, which is primarily responsible for transfer of vertical load to the vertical framing system and (ii) Vertical framing system, consisting of beams and columns, which is primarily responsible for transfer of lateral load to foundation. However the two components work in conjunction with each other. The old practice before 1960s had been to design buildings primarily for vertical loading and to check the adequacy of the structure for safety against lateral loads in a cursory manner. It has been established now that the design of a multi-storey building is governed by lateral loads and it should be prime concern of the designer to provide adequately safe structure against lateral loads. Further, the old buildings were having substantial non-structural masonry walls, partitions and connected staircase. These provided a significant safety margin against lateral loading. The modern buildings are having light curtain walls, lightweight flexible partitions along with high strength concrete and steel reinforcement. This reduces the safety margins provided by non-structural components. A number of structural systems have been developed in the last century for optimal transfer of lateral load. The ideal design is that in which no premium is there for lateral load i.e. the stress due to lateral loads is accommodated within the 33% increase in the permissible stresses. This design may not be possible but our aim is to reduce the premium as far as possible.

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II. Lateral Load Resisting Structural Systems

A number of structural systems to cater the varying architectural needs are available in steel as well as concrete. Nowadays, computers are widely used for analysis of structures, as computers and software are cheaply available. For proper design of structure an understanding of the behavior of the structural system is necessary. Otherwise, the designer is bound to make mistakes in the modeling of the structure and may have erroneous designs, whatever sophisticated software he may be using. The understanding of the behavior is also necessary for the executing engineer, so that he can understand the critical actions in the structure and can take special precautions in the construction. The following sections present an overview of the behavior of various structural systems under lateral loading.

a) Framed structures

The frames derive their lateral load resistance from the rigidity of connections between beams and columns. The behaviour of frames is straightforward and their computer modeling is simple. A number of softwares are available for analysis of frame structures.

The frames are infilled by masonry panels for the purpose of partition. These partitions are considered to be non-structural and their contribution to lateral load resistance is generally ignored. The behaviour of these panels is complex. These act as diagonal bracing members before failing and falling apart from the frame. In many cases, under severe shaking due to earthquake, these fail and fall apart before the frame is subjected to the ultimate load and that is why their contribution in lateral load resistance is not considered. However, presence of masonry panels alters the dynamic characteristics of frames and the behaviour is particularly complex when the ground storey of the frame buildings does not have masonry infills for the purpose of parking. Such buildings behave as soft ground storey. There is a sudden change in the stiffness of the building at the first floor level. This increases the storey drift and ductility demand of the ground storey tremendously and may lead to failure of the ground storey due to insufficient ductility. In such situation a safe approach to design the buildings with open ground storey for parking purpose is to increase the stiffness and ductility of the ground storey by bigger sections of beams and columns and closely spaced stirrups. In case of RC frame buildings, the floor slabs are usually casted monolithically with the frames. The floor slabs are quite rigid in their plane and are responsible for distribution of lateral load among the various frames. This action should be properly modeled in the space frame model. The modeling is particularly important in buildings having large differences in lateral stiffness of various lateral load resisting components and asymmetric buildings.

b) Shear wall structures

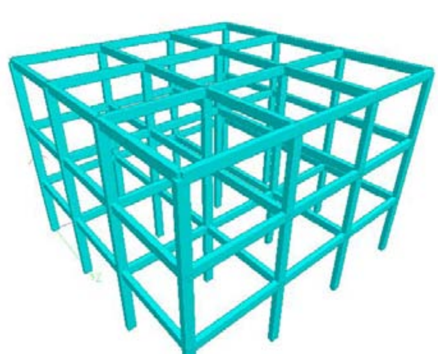
Shear wall is a slender vertical cantilever resisting the lateral load with or without frames. The behaviour of a shear wall is opposite to what its name suggests. A shear wall primarily resists the lateral load in flexure with very little shear deformations. The deformation of a shear wall is different than that of a frame. Therefore, when used in conjunction with frame, shear wall results in complex interaction with the resultant lateral load on the shear wall and frame varying in a complex manner along the height.

c) Braced frame system

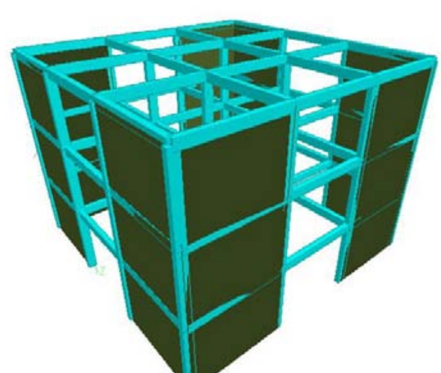
In braced frames the lateral resistance of the structure is provided by diagonal members that together with the beams form the web of the vertical truss with the columns acting as chords. Because the horizontal shear on the building is resisted by the horizontal components of the axial tensile and compressive actions in the web members, bracing systems are highly efficient in resisting lateral loads. Bracing is generally regarded as an exclusive steel system but nowadays steel bracings are also used in reinforced concrete frames. The efficiency of bracing in being able to produce a laterally very stiff structure for a minimum of additional material makes it an economical structural form for any height of building, up to the very tallest. An additional advantage of fully triangulated bracing is that the beams usually participate only minimally in the lateral bracing action. A major disadvantage of diagonal bracing is that it obstructs the internal planning and the location of windows and doors. For this reason braced bents are usually incorporated internally along wall and partition lines and especially around elevator, stair, and service shafts. More recently external larger scale bracing extending over many stories and bays has been used to produce not only highly efficient structures but aesthetically attractive buildings. Braces are of two types, concentric and eccentric. Concentric braces connect at the beam column intersection, whereas eccentric braces connect to the beam at some distance away from the beam column intersection. These structures with braced frames increase the lateral strength and also the stiffness of the structural system and hence reduce the drift.

III. Cases of Study

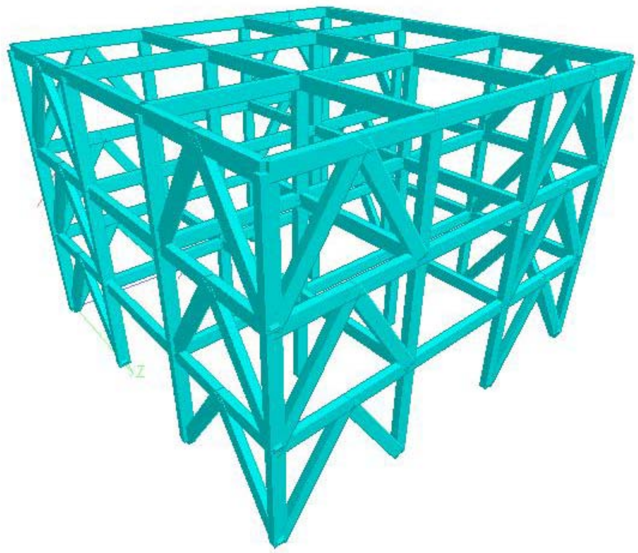
1] Case 1: Bare Frame
2] Case 2: Shear Wall at Corners
3] Case 3: Bracings at Corners



Case 1 : Bare Frame (Mrf)



Case 2 : Shear Wall at Corners



Case 3 : Bracing at Corners

a) Study parameters

a) Type of building: Multi Storied Building.
b) Zone: V
c) Type of soil: Medium
d) Plan of the Building: 12X12
e) Each Bay Size: 4m
f) Height of Building: 9m
g) Floor to floor height: 3mts.
h) Beams: 0.2mX0.35m
i) Columns: 0.2mX0.35m
j) Shear Wall thickness: 0.2m.
k) Live load: 2kN/m2.
l) Dead load of external wall as UDL: 12kN/m
m) Dead load of internal wall as UDL: 6kN/m
n) Damping ratio: 0.05%.

IV. Objectives of Study

Comparing maximum nodal displacements, maximum relative displacement of beams reactions, vertical reactions, maximum bending moments, maximum shear forces, displaced profiles.

V. Results

Table1: Maximum nodal displacement comparison between three lateral load resisting systems

	RESULTANT DISPLACEMENT (mm)		
	MRF	SHEAR WALL	BRACED TYPES
Max X	5.893	3.731	4.209
Min X	3.612	2.391	2.384
Max Y	6.895	0.257	0.213
Min Y	6.201	4.628	3.426
Max Z	6.895	2.803	3.103
Min Z	6.895	2.803	3.103
Max rX	5.408	0.907	2.253
Min rX	5.408	0.681	2.253
Max rY	3.001	3.569	3.238
Min rY	3.001	3.570	3.238
Max rZ	3.871	1.319	2.869
Min rZ	5.893	3.731	4.209
Max Rst	6.895	4.629	4.743

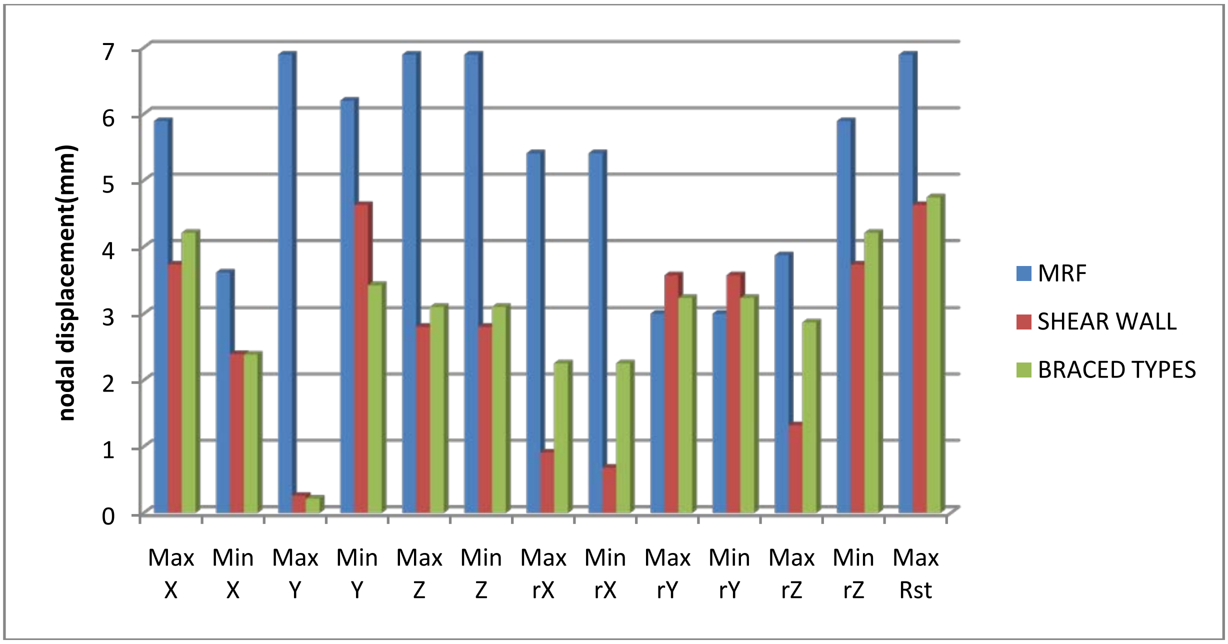


Fig. 1 : Graphical representation of maximum nodal displacement

Table 2 : Comparison of positive maximum beam moments between three lateral load resisting systems (only 10 beams compared)

Beam	L/C	MRF		SHEAR WALL		BRACED	
		Max My(kNm)	Max Mz(kNm)	Max My(kNm)	Max Mz(knm	Max My(kNm	Max Mz(knm
1	ELX+	0.078	6.209	0.506	0.054	0.755	0.224
	DL	0.001	26.334	0.062	26.301	0.254	16.625
	1.5(DL+LL ELX+)	0.116	54.021	0.716	44.814	1.578	27.728
2	ELX+	0.05	5.569	0.054	0.910	0.259	0.893
	DL		25.142		24.970		23.145
	1.5(DL+LL+ELX+)	0.075	51.116	0.001	43.843	0.086	40.60
3	ELX+	0.064	6.995	0.264	0.164	0.479	0.029
	DL	0.001	26.334	0.066	26.357	0.490	16.154
	1.5(DL+LL+ELX+)	0.097	44.405	0.524	44.747	1.689	26.738
4	ELX+	0.183		1.152	44.186	0.058	0.372
	DL	0.001		0.075		0.616	1.442
	1.5(DL+LL+ELX+)	0.274	51.041	1.607	44.186	1.047	2.230
5	ELX+	0.120	5.073	0.191	1.092	0.018	0.514
	DL		24.76		24.826	4.419	4.571
	1.5(DL+LL+ELX+)	0.179	49.708	0.214	43.844	8.579	7.698
6	ELX+	0.151	6.003	0.625	0.074	0.039	0.514
	DL	0.001	25.330	0.081	26.001	4.408	2.208
	1.5(DL+LL+ELX+)	0.227	47.142	1.090	44.325	8.678	4.711
7	ELX+	0.267	2.629	1.750	0.047	0.031	0.372
	DL	0.003	26.82		27.132	0.675	1.032
	1.5(DL+LL+ELX+)	0.405	49.427	2.565	45.838	0.960	2.206

8	ELX+	0.176	2.388	0.555	0.949	0.603	4.285
	DL		25.42	0.195	25.008	0.187	25.037
	1.5(DL+LL+ELX+)	0.264	46.794	1.155	43.962	1.265	54.127
9	ELX+	0.220	3.099	1.102	0.224	0.329	3.850
	DL	0.003	26.828		27.157	0.014	23.886
	1.5(DL+LL+ELX+)	0.326	41.539	1.210	46.549	0.519	51.65
10	ELX+	0.001	6.798	0.007	0.340	0.465	4.856
	DL	5.808	8.572	2.481	5.215	0.196	25.402
	1.5(DL+LL+ELX+)	9.967	9.824	4.224	8.851	0.489	44.043

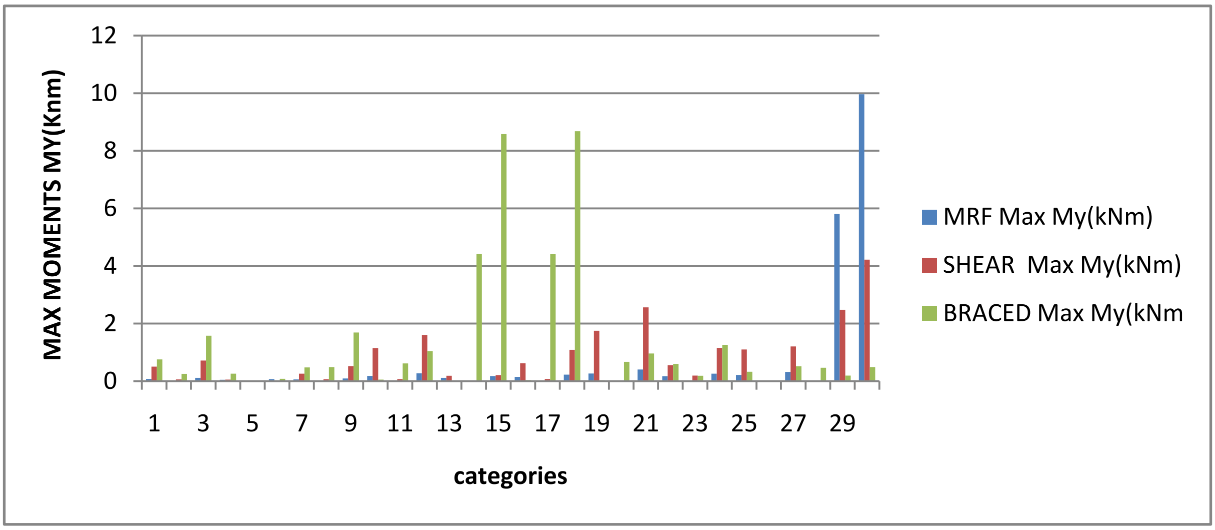


Fig. 2 : Comparison of positive maximum beam moments along vertical direction

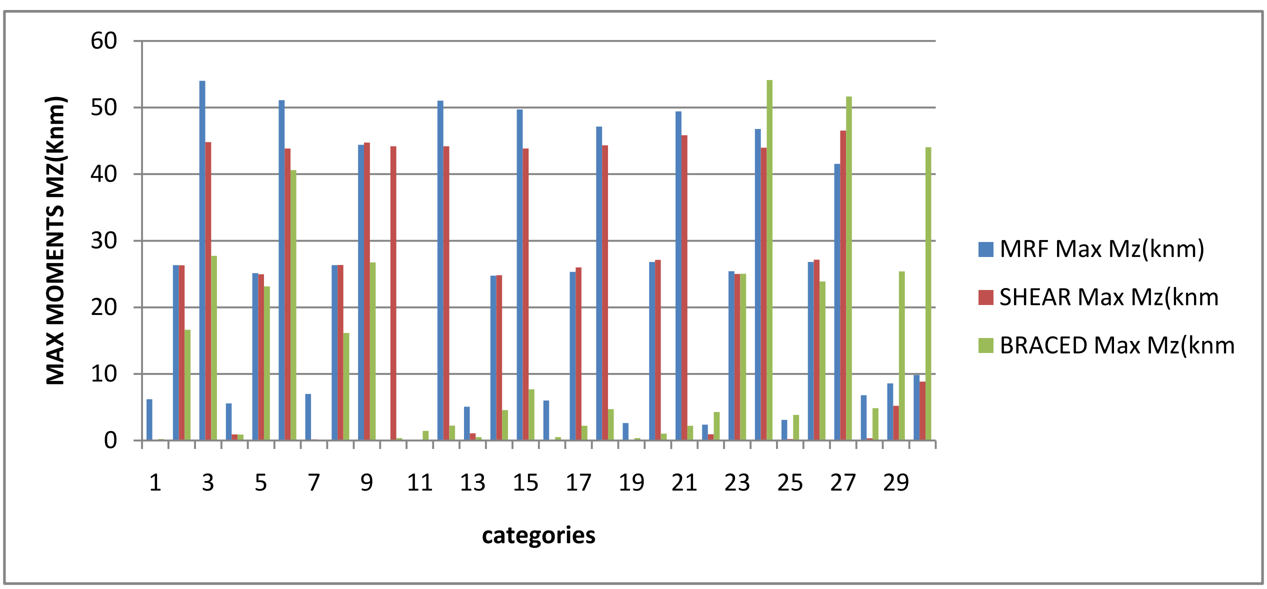


Fig. 3 : Comparison of positive maximum beam moments along horizontal direction

Table 3 : Comparison of positive maximum shear forces between three lateral load resisting systems (only 10 beams compared)

Beam	Load cases	MRF		SHEAR WALL		BRACED	
		Max FZ(kNm)	Max FY(kNm)	Max FZ(kNm)	Max FY(kNm)	Max FZ(kNm)	Max FY(kNm)
1	ELX+						
	DL		33.683	0.020	34.080		5.095
	1.5(DL+LL ELX+)		51.298		56.799		7.613
2	ELX+						
	DL		35.299	0.002	35.297		35.285
	1.5(DL+LL+ELX+)		54.711		58.263		58.258
3	ELX+						
	DL	0.001	36.914		36.563		8.088
	1.5(DL+LL+ELX+)		56.695		61.012		13.001
4	ELX+						
	DL		34.540	0.035	34.335	0.03	0.121
	1.5(DL+LL+ELX+)		53.471		57.303	0.582	
5	ELX+						0.264
	DL		35.299	0.009	35.302	2.209	
	1.5(DL+LL+ELX+)		55.143		58.135	4.289	
6	ELX+					0.019	0.264
	DL		36.057		36.249	2.203	2.249
	1.5(DL+LL+ELX+)		55.847		60.555	4.337	4.395
7	ELX+				0.067		0.121
	DL	0.001	32.798		33.296	0.381	0.769
	1.5(DL+LL+ELX+)		52.608		55.628	0.552	1.385
8	ELX+						
	DL		35.299		35.298		29.814
	1.5(DL+LL+ELX+)		57.175		58.225		52.913
9	ELX+				0.0698		
	DL		37.799		37.330		31.245
	1.5(DL+LL+ELX+)		60.992		62.521		55.980
10	ELX+		3.344		0.125		
	DL	2.9		1.246		0.075	32.959
	1.5(DL+LL+ELX+)						58.392

Table 4 : Comparison of maximum relative displacement of beams for single beam

BEAM	L/C	MRF	SHEAR	BRACED
1	ELX +	0.144	0.058	0.039
	ELX -	0.144	0.058	0.039
	ELX +	0.006	0.037	0.014
	ELX -	0.006	0.037	0.014
	DL	1.032	0.935	0.085
	LL	0.149	0.135	0.006
	WLX +	0.088	0.023	0.032
	WLX -	0.086	0.022	0.021
	WLX +	0.016	0.027	0.011
	WLX -	0.016	0.026	0.016
	1.5(DL+LL+ELX+)	1.862	1.617	0.185
	1.5(DL+LL+ELX -)	1.818	1.608	0.151

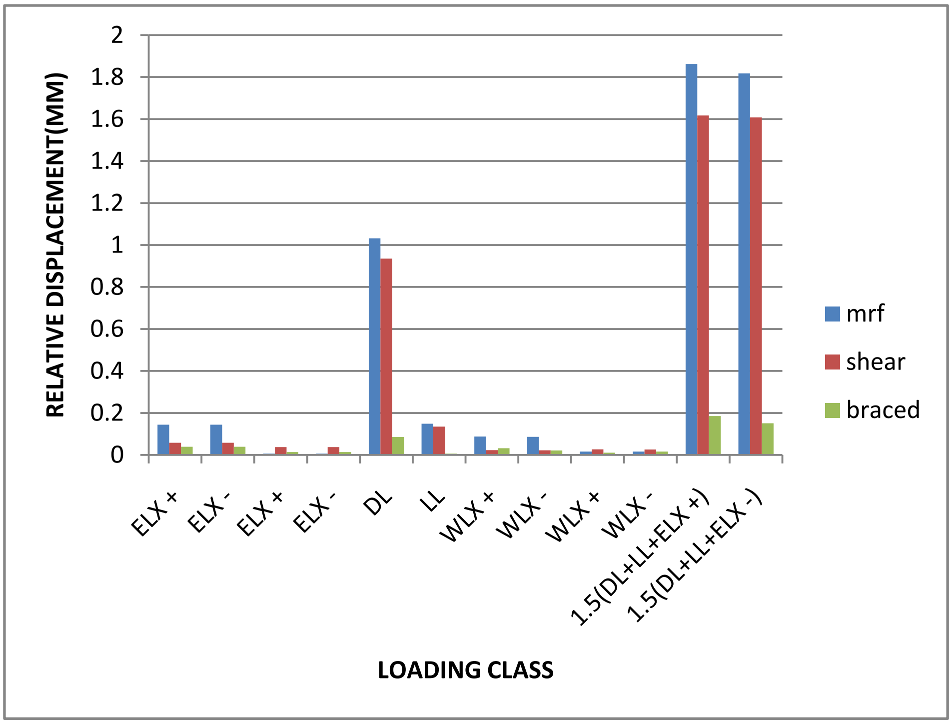


Fig. 4 : Comparison of maximum relative displacement for single beam

Table 5 : Comparison of reaction summary

	MRF		SHEAR		BRACED	
	FY vertical	MY vertical	FY vertical	MY vertical	FY vertical	MY vertical
MAX FX	-1.172	0.011	871	-0.032	818.046	-0.843
MAX FY	759.429	-0.017	971.502	-0.346	899.904	-0.423
MAX FZ	542.445	-0.041	971.502	-0.346	871.568	-0.127
MAX MX	-2.590	-0.013	970.063	0.342	751.819	0.380
MAX MY	344.128	0.076	804.164	0.631	790.893	0.929
MAX MZ	574.406	-0.026	579.191	0.159	4.9	-0.856

VI. Conclusions

From the above study of comparison between three common lateral load resisting systems, the following results have been obtained:

1. The nodal displacement both translational and rotational for Shear wall was least among all the three lateral load resisting systems.
2. Bending moment was comparatively lesser in Bracing lateral load resisting system than Shear wall and Moment Resisting Frame.
3. Shear force in beams was found least in Bracing lateral load resisting system as compared to Shear wall and Moment Resisting Frame.
4. Relative displacement was found comparatively lesser in Bracing lateral load resisting system than Shear wall and Moment Resisting Frame.
5. Base reactions were higher in Shear and Bracing lateral load resisting systems than Moment resisting frames.

VII. Conclusion

Bracing type of lateral load resisting system is most effective in reducing displacements and forces in the members and is economical way of increasing the lateral stiffness of the building.

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