Analytical Study on Seismic Performance of Hybrid (DUAL) Structural System Subjected To Earthquake

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Abstract: *Steel braced frame is one of the structural systems used to resist earthquake loads in multi-storeyed buildings. Many existing reinforced concrete(RC) buildings can be retrofitted to overcome deficiencies, to resist seismic loads at the same time steel bracings can be incorporated with RC frames which in combine can be called as dual system to resist lateral force in the new buildings. Steel bracing is economical, easy to erect, occupies less space and has flexibility to design for meeting the required strength and stiffness. In the present study, the seismic performance of reinforced concrete buildings using concentric steel bracing is investigated. The bracings are provided at peripheral columns. A six, twelve and eighteen storied buildings are analysed for seismic zone V as per IS 1893: 2002 using SAP 2000 software. Response spectrum analysis is performed for the buildings. For getting eigen values and eigen vectors the MathCAD Prime software is used. And hence storey shear and base shear are computed. The seismic performance of the building is evaluated in terms of storey drifts.*

I. INTRODUCTION

This paper presents a study of three dimensional elastic behaviour of medium rise and high rise buildings having combination of rigid frame and vertical steel bracings which combine can be called as dual system. In present the parameters taken for analysis are displacements, reinforcement demands of frame members, moments, drift pattern for different types of bracing systems .As the height of the structure increases, effect of lateral load becomes more and more predominant and additional structure materials are required to resist it.

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Steel bracing of RC frames has received some attention in recent years both as retrofitting to increase shear capacity of the existing building and as a shear resisting element in seismic design of new buildings. The direct bracing of RC frames has received more attention since it is less costly, and can be used not for retrofitting but also as viable alternative to RC shear walls at pre –construction design level.

II. DUAL SYSTEM

In present contest many buildings are provided with more than one type of seismic resisting systems. Usually in these days structures are designed in such a way that it lateral force resistance is provided by frames and shear walls, frames and infill and frames and bracings. This combined system can be said as dual system.
Dual system may combine the advantages of the constituent elements. Ductile frames ,interacting with steel bracings , can provide a significant amount of energy dissipation when required particularly in upper stories of the building .On other hand as result of large stiffness of frame ,good story drift during earthquake can be achieved.
Despite the attractiveness and prevalence of dual system, it is only recently that research effort has been directed toward the developing relevant seismic design methodologies. This paper involves the analytical studies of proposed new apartment building, using dynamic analysis and the overall response of braced frame.

III. RC STRUCTURES WITH STEEL BRACINGS

Steel bracing is a highly efficient and economical method of resisting horizontal forces in a frame structure. Bracing has been used to stabilize laterally, the majority of the world's tallest building structures as well as one of the major retrofit measures. Bracing is efficient because the diagonals work in axial stress and therefore call for minimum member sizes in providing stiffness and strength against horizontal shear. A number of researchers have investigated various techniques such as infilling walls, adding walls to existing columns, encasing columns, and adding steel bracing to improve the strength and/or ductility of existing buildings and new buildings
Bracing system improves the seismic performance of the frame by increasing its lateral stiffness and capacity. Through the addition of the bracing system, load could be transferred out of the frame and into the braces, bypassing the weak columns. Steel braced frames are efficient structural systems for buildings subjected to seismic or wind lateral loadings. Therefore, the use of steel bracing systems for both retrofitting as well as in newly constructed reinforced concrete frames with adequate lateral resistance is attractive.

IV. TYPES OF BRACINGS

There are two types of bracing systems, Concentric Bracing System and Eccentric Bracing System.

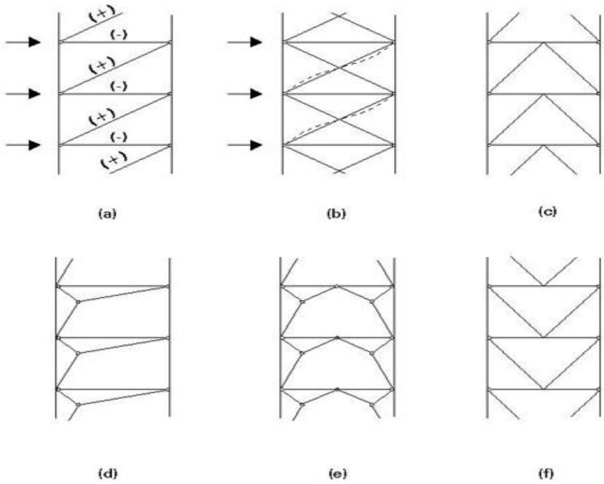

Fig. 1 Type of bracings

The steel braces are usually placed in vertically aligned spans. This system allows obtaining a great increase of stiffness with a minimal added weight, and so it is very effective for structure for which the poor lateral stiffness is the main problem. The concentric bracings increase the lateral stiffness of the frame, thus increasing the natural frequency and also usually decreasing the lateral drift. However, increase in the stiffness may attract a larger inertia force due to earthquake. Further, while the bracing decrease the bending moments and shear forces in columns, they increase the axial compression in the columns to which they are connected. Since reinforced concrete columns are strong in compression, it may not pose a problem in RC frame using concentric steel bracings.

Eccentric Bracings reduce the lateral stiffness of the system and improve the energy dissipation capacity. Due to eccentric connection of the braces to beams, the lateral stiffness of the system depends upon the flexural stiffness of the beams and columns, thus reducing the lateral stiffness of the frame. The vertical component of the bracing forces due to earthquake causes lateral concentrated load on the beams at the point of connection of the eccentric bracings.

V. MODELING

The SAP2000 software is utilized to create 3D model and carry out the analysis. The buildings are modelled as a series of load resisting elements. The dead load, live load and
lateral loads to be applied on the buildings are based on the Indian standards. The study is performed for seismic zone V as per IS 1893:2002. The buildings adopted consist of reinforced concrete and brick masonry elements. The frames are assumed to be firmly fixed at the bottom and the soil–structure interaction is neglected.

The six, twelve, and eighteen storied buildings are analysed for zone V without bracing and with diagonal and X type bracings at peripheral columns only.

MODEL DATA OF BUILDING

Structure OMRF	
Plan dimension:	16.229m*11.275m
No. of stories	G + 5, G+11 and G+18
Storey height	3.148 m
Type of building use	Apartment

Material Properties

Young's modulus of M20 concrete, E	22.36 x 10 6 KN/m^2
Grade of concrete	M20
Grade of steel	Fe 415
Density of reinforced concrete	25 KN/ m^3
Density of brick masonry	19.20 KN/ m^3

Member Properties

Thickness of slab	0.125 m.
Thickness of wall	0.23 m.
Dead Load Intensities	
Floor finishes	1.0 KN/ m^2
Live Load Intensities	
Floor	2.0 KN/ m^2

Roof	1.5 KN/ m^2
Floor 0.25 x 3.0	0.75kN/ m^2
Seismic Zone	V
Zone factor, Z	0.36
Importance factor, I	1.00
Response reduction factor, R	5.00

Table 1 Dimension of Beam and Column

Structure	Slab depth	Beam size (m)	Column size(m)
(G+5)	0.125	0.25*0.35	0.45*0.45
(G+11)	0.125	0.30*0.45	0.60*0.60
(G+17)	0.125	0.35*0.50	0.70*0.70

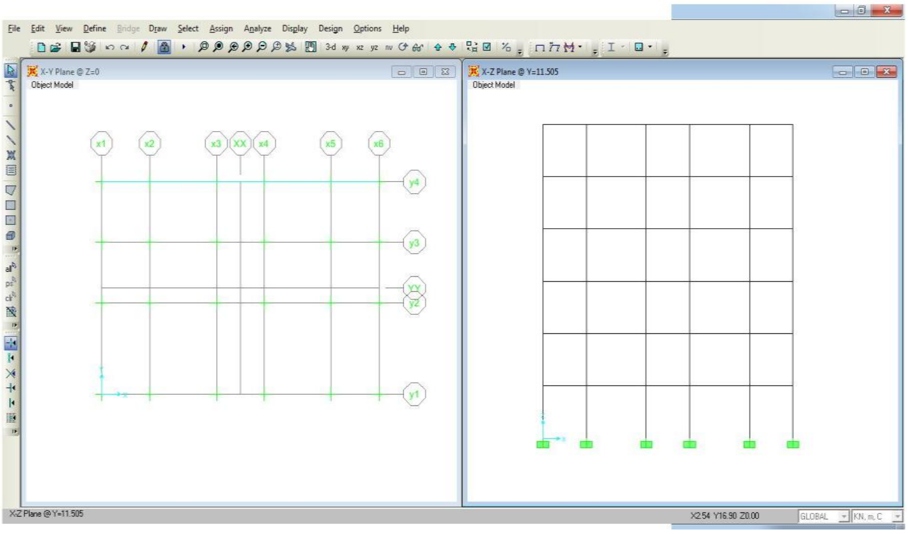

Fig. 2 Plan and elevation of six storey building

VI. RESULTS

Lateral displacements

The lateral displacements of non braced building for the cases of dead live and earthquake load for seismic analysis in all the three directions are presented in Table. The results are compared with that of buildings with various types of concentric bracings. It is observed that the maximum lateral displacements are reduced due to the presence of bracings. It is observed that the lateral displacements are reduced to the largest extent for X type of bracing systems then diagonal one.

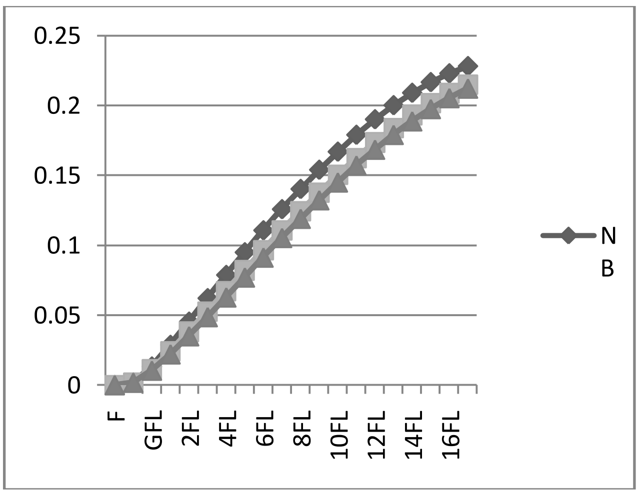

Fig. 3 Lateral deformation curves in X direction (18-Storey)

From the results obtained from building frame, it is observed that among concentric bracing system the X intersection type of bracing system is the most effective type of bracing system which can reduce the lateral displacements and moments in the structures. Therefore, the X type of bracing system can be used for seismic minimizing part of multi storied buildings. For all analysis of six twelve and eighteen storied building frames; X type of bracing system is considered. These buildings are analyzed for earthquake zone V. The lateral displacement is obtained for these structures, for the seismic load along with load combinations. The percentage reduction in lateral displacements is found out for increase in the number of stories. It is observed that the X bracing system reduces the displacements considerably than diagonal one.

Table 2 Maximum bending moment (KNm) for column for zone V

Floor level		Seismic Load		
	NODE	NB	DB	XB
GFL	1	699.24	472.68	396.27
1FL	2	440.20	326.87	273.35
2FL	3	347.93	218.77	180.11
3FL	4	302.25	184.85	150.63
4FL	5	272.38	155.40	123.46
5FL	6	248.79	134.11	104.11
6FL	7	228.86	133.78	89.78
7FL	8	211.04	125.34	79.61
8FL	9	194.45	117.48	72.59
9FL	10	178.17	110.55	67.38
10FL	11	160.99	104.58	62.80
11FL	12	142.01	72.62	58.57
12FL	13	120.38	64.99	54.50
13FL	14	95.81	57.80	50.97
14FL	16	152.29	81.31	64.37
15FL	17	127.90	66.83	51.87
16FL	18	107.93	68.16	60.99
17FL	19	91.20	118.60	109.48

Table 3. Inter storey drift (mm) for 18 storey building for zone V

Non Brace				D- Brace			X-Brace	
X		Y		X	Y		X	Y
FDN	0.00	0.00		0.00	0.00		0.00	0.00
BASE	3.633	0.183		0.595	0.207		0.464	0.199
GFL	4.905	1.170		3.014	0.943		2.870	0.830
1FL	5.273	1.607		4.081	1.277		3.734	1.109
2FL	5.334	1.745		4.448	1.373		4.140	1.203
3FL	5.272	1.771		4.611	1.408		4.375	1.255
4FL	5.149	1.750		4.673	1.416		4.506	1.284
5FL	4.988	1.708		4.668	1.408		4.558	1.297
6FL	4.800	1.654		4.612	1.389		4.548	1.296
7FL	4.590	1.594		4.513	1.361		4.487	1.284
8FL	4.360	1.529		4.379	1.325		4.382	1.262
9FL	4.108	1.460		4.214	1.281		4.241	1.232
10FL	3.831	1.386		4.020	1.231		4.068	1.193
11FL	3.527	1.304		3.799	1.172		3.866	1.146
12FL	3.190	1.214		3.549	1.104		3.637	1.090
13FL	2.820	1.111		3.272	1.027		3.382	1.026
14FL	2.418	0.996		2.900	0.940		3.104	0.953
15FL	2.003	0.868		2.550	0.900		2.808	0.869
16FL	1.634	0.735		2.297	0.739		2.501	0.785
17FL	1.634	0.616		1.963	0.641		2.185	0.697

Table 4 Percent of reinforcement for 18 storeys

Column	Floor	Reinforcement (%)		
		NB	DB	XB
1	GF	3.99	2.59	2.18
2	1FL	3.03	1.79	1.52
3	2FL	2.46	1.46	1.34
4	3FL	1.87	1.19	1.13
5	4FL	1.41	0.96	0.90
6	5FL	0.91	0.80	0.80
7	6FL	0.80	0.80	0.80
8	7FL	0.80	0.80	0.80
9	8FL	0.80	0.80	0.80
10	9FL	0.80	0.80	0.80
11	10FL	0.80	0.80	0.80
12	11FL	0.80	0.80	0.80
13	12FL	0.80	0.80	0.80
14	13FL	0.80	0.80	0.80
15	14FL	0.80	0.80	0.80
16	15FL	0.80	0.80	0.80
17	16FL	0.80	0.80	0.80
18	17FL	0.80	0.80	0.80

VII. CONCLUSION

- Based on the observation made from analysis of the example buildings, various conclusions may be drawn.
- Stiffness: The bracings in bare frame increases the overall stiffness of the structure Hence performance of braced frame is much better than bare frame.
- Lateral displacement: The lateral displacement in bare frame is more in comparison to the frame with bracings .The bracings prevent the excessive damage in non structural elements. The percent reduced in lateral displacement between DB and XB is from 15% to 8%, similarly in 12 storey frame it reduces by 8% to 9% and so on in 18 storeys.
- Member forces: Significant reduction in moment in case of frame with bracings in comparison to bare frame .Moment reduced by
- 40% to 60% in 6 storey, 20 %to 30% in 12 storey and 35% to 45% in 18 storeys. So comparatively in XB the reduction of member force is higher.
- Reinforcement detailing: Significant reduction in reinforcement demand by the frame members other than the one associated with bracings. The bare frame steel demand is nearly 4% in 18 storey which is not practically possible so it is reduced to 2.58% with (DB) and 2.18% with (XB) similarly in 12 storeys and 6 storey it is reduced as shown in table above.
- Inter storey drift: The performance of frame with bracings is better and within the limit.
- The inter-storey drift is very important parameter in analysis and design of buildings. If the inter-storey drift values at each floor level reach their maximum allowable limits, then the roof displacement will reach undesirable values.
- Maximum ISD for frame without bracings is in storey just above the GF between 2nd and 3rd storey, it is because the frame structure deflects in shear configuration where the rate of change of deflection goes on reducing with height.
- For frame with bracings maximum ISD is found at height nearly to 30%-40% height of the building .Deflection pattern is of flexure shape at lower heights in which rate of deflection increase and follows the shear configuration in upper heights.
- This means the bracings governs flexural deflection, so it is desirable.

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