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BEHAVIOUR AND MODEL OF EARTHQUAKE RESISTANT STRUCTURE USING STEEL BRACING

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Abstract:

Most of the RCC buildings were failed in the past due to lateral load. Bracing systems are one of the lateral load resisting system which has got structural importance specially in reinforced concrete buildings. Different bracing systems are efficient enough for seismic responses. The steel bracings are usually installed between existing vertical members. The purpose of the study of seismic response of a building is to design and build a structure in which the damage to the structure and its structure component by earthquake is minimized. The use of steel bracing systems for strengthening or retrofitting seismically inadequate reinforced concrete frames is a viable solution for enhancing earthquake resistance. 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 (RC) buildings rehabilitated using concentric steel bracing is investigated. The building is analyzed for different load combinations as per IS 1893:2002.

Key Words: RCC frame, Bracing, Earthquake & SAP2000.

Introduction:

In earthquake design the building has to go through regular motion at its base, which leads to inertia force in the building that consecutively causes stresses. India has experienced number of earthquakes that caused large damage to residential and industrial structure. For earthquake resistant design the normal building should be able to resist minor, moderate, sever shaking. In the circumstances of the building, simple shape configuration building transfer the earthquake force in the direct path to the base while in complex shape building the load transferring path is indirect which leads to generation of stresses at the corners. Seismic Analysis is a subset of structural analysis and is the calculation of the response of a building structure to earthquakes. It is part of the process of structural design, earthquake engineering or structural assessment and retrofit in regions where earthquakes are prevalent. In order to make multi-storey structures stronger and stiffer, which are more susceptible to earthquake and wind forces, the cross sections of the member increases from top to bottom this makes the structure uneconomical owing to safety of structure .The behavior of the buildings during earthquake depends not only on the size of the members and amount of reinforcement, but to a great extent on the placing and detailing of the reinforcement. Therefore, it is necessary to provide special mechanism that to improve lateral stability of the structure. There are various types of bracing systems like X bracing, V bracing, inverted V bracing, K bracing, diagonal bracing and so on.

Modeling:

Plan: The analysis of G+9 floors is carried out using SAP2000 software for special moment resisting frame situated in zone IV. The RCC G+9 structure is analysed without bracings and with cross bracings system. Lateral displacements, axial forces, bending moments, and shear forces is compared for all type of structural systems i.e. braced and unbraced structural.

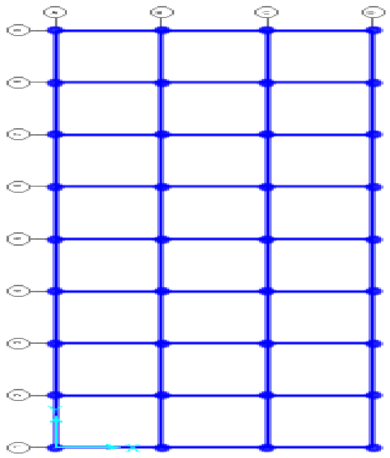

Figure 1: Plan

Table1: Model Data of Building

Structure	OMRF(ordinary moment resisting frame)
No. of stories	G+10
Storey height	3.00 m
Type of building use	Residential

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Foundation type	Isolated footing
Seismic zone	IV
Material properties	
Young's modulus of M_{20} concrete, E	22.36 x 10^6 kN/m^2
Grade of concrete	M_{20}
Grade of steel	Fe415
Density of reinforced concrete	25 kN/m^2
Modulus of elasticity of brick masonry	3.25 x 10^6 kN/m^2
Density of brick masonry	19.20 kN/m^3
Member properties	
Thickness of slab	0.125 m
Beam size	0.25 m x 0.7 m
Column size	0.3 m x 0.5m
Thickness of wall	0.23m
Dead load intensities	
Floor finishes	1.4 kN/m^2
Live load intensities	
Roof and floor	1.6 kN/m^2
Earthquake LL on slab as per Cl. 7.3.1 and 7.3.2 of IS 1893(part 1)-2002	
Roof	0 kN/m^2
Floor	2.5 x 3.0 = 0.75 kN/m^2

Table 2: Description of Plan

No of stories	10
Type of building use	Residential
Grade of concrete	M20
Zone	IV
Zone Factor	0.24
Importance Factor, I	1
Response Reduction Factor, RF	3
Values from IS 1893	

RCC Building Without Bracings: Selected plan area is rectangular and of size 48 x 18 m and divided into 24 strip of size 6 X 6 m. The potential advantage of bracing system is the comparatively small increase in mass associated with the retrofitting scheme since this is a great problem for several retrofitting techniques. The application of steel bracings is faster to execute. The steel bracings are usually installed between existing vertical members.

RCC Building With Cross or X Bracing: Fig is a multi-storied building modeled as per the above plan. The dimension of columns and beams are 0.3 m x 0.5m, 0.25 m x 0.7 m respectively. The bracing system used in this case is Steel inclined member with cross section dimensions 150X150X10 mm. The bracings are provided diagonally in both ways between two floors such that cross each other to form an X bracing. A braced bent consists of usual columns and girders whose primary purpose is to support the gravity loading, and diagonal bracing members that are connected so that total set of members forms a vertical cantilever truss to resist the horizontal forces.

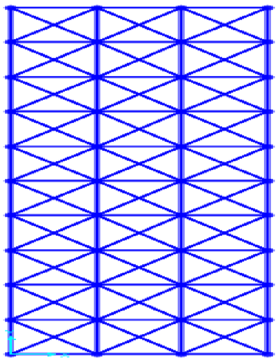

Figure 2: RC Building With Cross Bracing

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Results and Discussion:

Lateral Displacements: The lateral displacements of unbraced building for the cases of dead and live load for seismic analysis in all the three directions are presented in Table 1. The results are compared with that of buildings with various types of 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.

Table 3: Maximum lateral displacement in mm. in X direction for zone IV

Floor level	Lateral displacement(mm)	
	Without bracing	X bracing
10th floor	184	75
9th floor	166	70
8th floor	150	63.45
7th floor	134.48	56.74
6th floor	97.43	47.55
5th floor	125.50	38.30
4th floor	97.43	36.20
3rd floor	65.14	24.18
2nd floor	48.23	13.16
1st floor	29.24	11.15
Ground floor	18.16	7.8

Maximum Axial Forces, Shear Forces and Bending Moments in Columns: The maximum axial, shear forces and bending moments in columns of the building frame without bracing, for dead and live load analysis and for seismic analysis is presented. The results are compared with that of building frames with various types of bracings. The results in all the three directions are obtained. It is seen that the maximum axial forces are increased for buildings with bracings compared to that of the building without bracings. Further, while bracings 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 to retrofit in reinforced concrete frame using concentric steel bracings. It seen that the bending moment values are smaller for the buildings with X types of bracing.

Table 4: Maximum axial forces in column for zone IV (kN)

Floor level	Axial forces(kN)	
	X bracing	Without bracing
10th floor	98	100
9th floor	109	122
8th floor	120.10	140
7th floor	138.50	160.24
6th floor	200.01	250.38
5th floor	238.43	294.6
4th floor	293.07	350
3rd floor	340.34	300.35
2nd floor	391.54	350.94
1st floor	412.15	390.15
Ground floor	422.92	400.46

Table 5: Maximum shear forces in column for zone IV (kN)

Floor level	Shear forces(kN)	
	X bracing	Without bracing
10th floor	19.03	25.52
9th floor	22.65	31.94
8th floor	29.50	37.60
7th floor	31.30	45.30
6th floor	42.55	53.46
5th floor	42.78	64.70
4th floor	43	69.86
3rd floor	44	75
2nd floor	45.31	83
1st floor	41.27	95.53
Ground floor	50.50	91.50

Table 7: Maximum bending moments in column for zone IV (kNm)

Floor level	Bending moments(kNm)	
	X bracing	Without bracing

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10th floor	123.54	135.22
9th floor	117.35	123.39
8th floor	96.95	110.33
7th floor	78.09	115.51
6th floor	77	120.15
5th floor	76	150.83
4th floor	75.40	173.97
3rd floor	75.17	181.44
2nd floor	74	183.75
1st floor	73.74	191.36
Ground floor	165.32	200.84

Analysis of Three, Six, and Nine Storied Building: From the results obtained for four storied building frame, it is observed that the X 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 strengthening of multi storied buildings. For the analysis of three, six and nine storied building frames; X type of bracing system is considered. These buildings are analyzed for earthquake zone IV. The lateral displacement is obtained for these structures, for the seismic load case only. The percentage reduction in lateral displacements is found out for increase in the number of stories. It is observed that the X bracing system reduce the displacements considerably.

Comparison of Results for Displacement: Comparing the results obtained for maximum lateral displacement in X and Z direction for G+3, G+6,and G+9 storied buildings, it can be found that the X type bracing system reduce the lateral displacement considerably. The displacements in X direction for G+3, G+6, and G+9 storied buildings are presented in Table 5 for the various categories of models for zone IV. The variation of displacements for the braced frame in comparison to that of unbraced frame is presented.

Table 8: Maximum displacements in X direction (mm)

No. of Stories	Maximum displacements (mm)	
	X bracing	without bracing
3 stories	47.53	16.16
6 stories	102.62	40.68
9 stories	150.16	63.39

Deformed Shapes of Braced and Unbraced Building:

Figure 3: Deformed shape of unbraced building

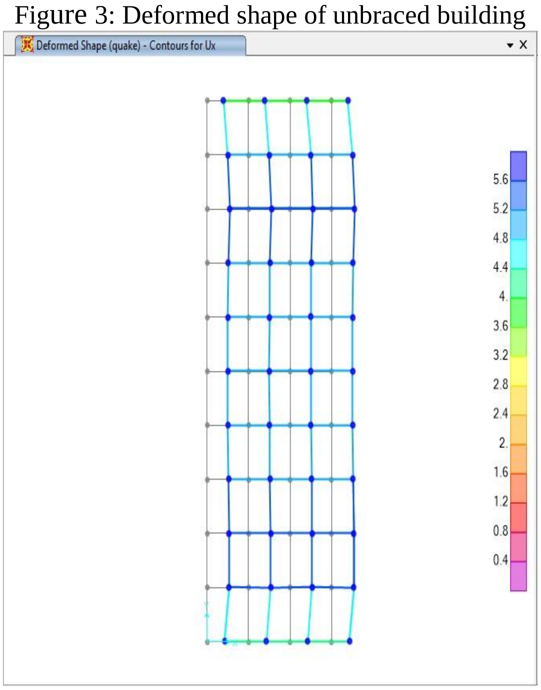
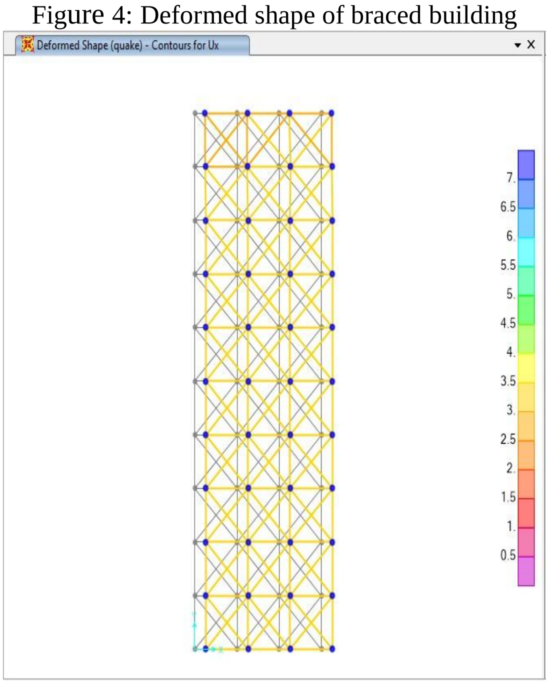


Figure 4: Deformed shape of braced building



Conclusions

The following conclusions are drawn based on present study.

- ✓ The concept of using steel bracing is one of the advantageous concepts which can be used to strengthen or retrofit the existing structures.
- ✓ Steel bracings can be used as an alternative to the other strengthening or retrofitting techniques available as the total weight on the existing building will not change significantly.

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- ✓ Steel bracings reduce flexure and shear demands on beams and columns and transfer the lateral loads through axial load mechanism.
- ✓ The lateral displacements of the building studied are reduced by the use of X type of bracing systems.
- ✓ The building frames with X bracing system will have minimum possible bending moments in comparison to other types of bracing systems.

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