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Seismic Response of Existing Reinforced Cement Concrete Structure after Addition of Cross Bracings

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ABSTRACT: *Structures in high seismic risk areas may be susceptible to severe damage in a major earthquake. For the variety of structures and possible deficiencies that arise, several retrofitting techniques can be considered. Bracing system is one of the retrofitting techniques and it provides an excellent approach for strengthening and stiffening existing building for lateral forces. Also, another potential advantage of this system is the comparatively small increase in mass associated with the retrofitting scheme since this is a great problem for several retrofitting techniques. Our ability to build seismically safe structures with adequate seismic resistance has increased significantly in the past few decades. Many reinforced concrete frame structures built in seismically active areas are expected to perform inadequately in a seismic event.*

Braced frames are known to be efficient structural systems for buildings under high lateral loads such as seismic or wind loadings. The fact that the lateral resistance of frame can be significantly improved by the addition of a bracing system has led to the idea of retrofitting seismically inadequate reinforced concrete frames with steel bracing system. Steel bracing systems have both practical and economical advantages. 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. Furthermore, if it is used in the structure, the minimum disruption of the building is obtained.

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I. INTRODUCTION

During earthquake motions, deformations take place across the elements of the load-bearing system as a result of the response of buildings to the ground motion. As a consequence of these deformations, internal forces develop across the elements of the load-bearing system and displacement behaviour appears across the building. The resultant displacement demand varies depending on the stiffness and mass of the building. In general, buildings with higher stiffness and lower mass have smaller horizontal displacements demands. On the contrary, displacement demands are to increase. On the other hand, each building has a specific displacement capacity. In other words, the amount of horizontal displacement that a building can afford without collapsing is limited. The purpose of strengthening methods is to ensure that the displacement demand of a building is to be kept below its displacement capacity. This can mainly be achieved by reducing expected displacement demand of the structure during the strong motion or improving the displacement capacity of the structure.The maintenance, rehabilitation and upgrading of structural members, is perhaps one of the most crucial problems in civil engineering applications. Moreover, a large number of structures constructed in the past using the older design codes in different parts of the world are structurally unsafe according to the new design codes. Since replacement of such deficient elements of structures incurs a huge amount of money and time, strengthening has become the acceptable way of improving their load carrying capacity and extending their service lives.

Recent earthquakes have shown the importance of rehabilitating seismically deficient structures to achieve an acceptable level of performance. This can be achieved by improving the strength, stiffness, and ductility of the existing structures. Significant advancements have been made in the research and development in this field. Many buildings have either collapsed or experienced different levels of damage during past earthquakes. Several investigations have been carried out on buildings that were damaged by earthquakes. Low-quality concrete, poor confinement of the end regions, weak column-strong beam behaviour, short column behaviour, inadequate splice lengths and improper hooks of the stirrups were some of the important structural deficiencies (Yakut et al., 2005). Most of those buildings were constructed before the introduction of modern building codes. They usually cannot provide the required ductility, lateral stiffness and strength, which are definitely lower than the limits imposed by the modern building codes (Kaplan etal., 2011). Due to low lateral stiffness and strength, vulnerable structures are subjected to large displacement demands, which cannot be met adequately as they have low ductility.

In the past, most of the reinforced concrete structures were designed primarily for gravity loads. They were also designed for lateral forces that may be much smaller than that prescribed by the current codes. Structures which have such kinds of deficiencies can be prevented from earthquake damages by proper rehabilitation. Therefore, seismic retrofitting has become an important and popular topic among researchers which is studied and applied to seismically deficient structures.

II. MODELLING &ANALYSIS OF BUILDING

The analysis of G+14 floors is carried out using STAAD V8i software for special moment resisting frame situated in zone 4.The RCC G+14 structure is analysed without bracings and with cross bracing structural system. Bending moments, shear forces, storey shears, storey drifts and axial forces are compared for both type of structural systems i.e. braced and unbraced structural system.

Table 1.MODELING DATA FOR BUILDING

Structure	SMRF
No. of stories	G+14
Type of building use	Residential
Young's modulus, E	$21.7x10^6 kN/m^2$
Grade of concrete	M25
Density of RCC	25 kN/m^3
Beam Size	0.3x0.5m
Column Size	0.5x0.5m
Dead Load Intensity	5 kN/m^2
Live Load Intensity	3.0 kN/m^2
Seismic Zone, Z	IV
Soil Type	Medium
Importance Factor, I	1
Response Reduction Factor, RF	5

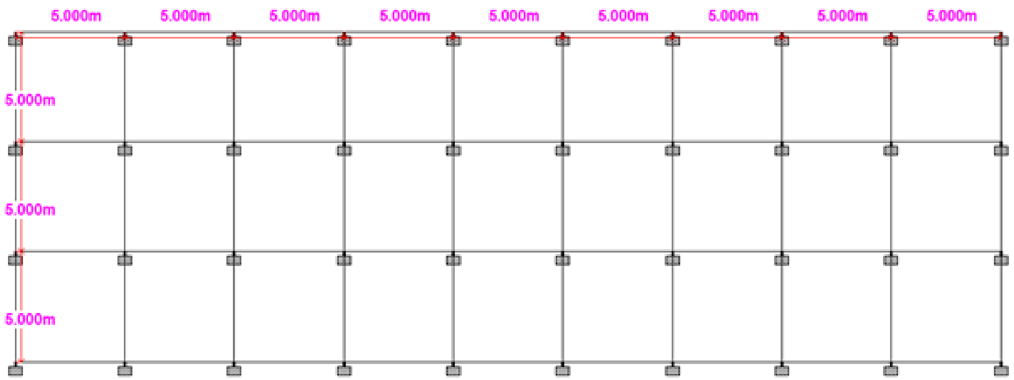

Fig. 1 Plan of a Structure

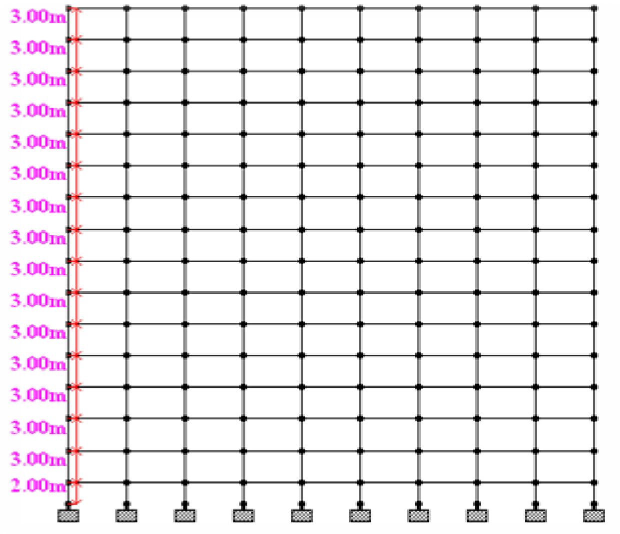

Fig. 2 Elevation of Unbraced Structure

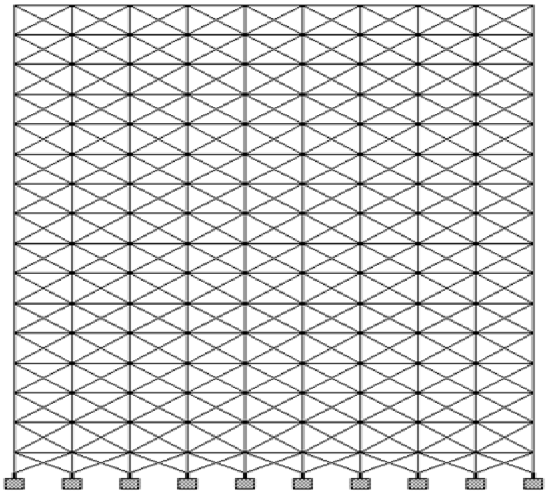

Fig. 3 Elevation of Cross Braced Structure

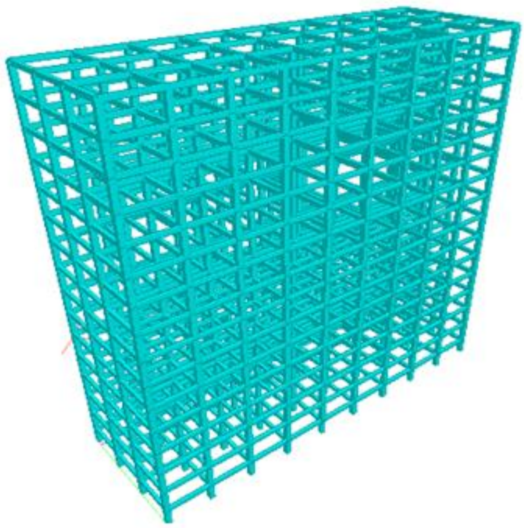

Fig. 4 Isometric View of Unbraced Structure

III. RESULTS

TABLE 2.MAXIMUM LATERAL DISPLACEMENT (MM) IN X DIRECTION

Level		
	Unbraced Structure	Cross Braced Structure
15	34.769	20.73
14	34.127	20.247
13	33.083	19.515
12	31.655	18.561
11	29.89	17.424
10	27.84	16.141
9	25.553	14.743
8	23.072	13.258
7	20.436	11.71
6	17.683	10.119
5	14.843	8.502
4	11.945	6.873
3	9.012	5.244
2	6.076	3.623
1	3.204	2.03
Ground	0.714	0.556
Base	0	0

TABLE 3. MAXIMUM LATERAL DISPLACEMENT (MM) IN Z DIRECTION

Level		
	Unbraced Structure	Cross Braced Structure
15	39.503	32.498
14	38.533	31.56
13	37.153	30.286
12	35.375	28.693
11	33.248	26.831
10	30.828	24.751
9	28.167	22.5
8	25.313	20.121
7	22.312	17.653
6	19.203	15.128
5	16.023	12.578
4	12.806	10.027
3	9.582	7.5
2	6.39	5.022
1	3.318	2.649
Ground	0.727	0.619
Base	0	0

TABLE 4. MAXIMUM AXIAL FORCE (KN) IN COLUMNS FOR DEAD AND LIVE LOAD

Level	Structure Type	
	Unbraced Structure	Cross Braced Structure
Base to Ground	3835.653	3780.03
Ground to 1st	3586.31	3533.598
1st to 2nd	3333.943	3284.542
2nd to 3rd	3084.579	3038.525
3rd to 4th	2837.964	2795.298
4th to 5th	2593.836	2554.596
5th to 6th	2351.94	2316.165
6th to 7th	2112.039	2079.76
7th to 8th	1873.903	1845.153
8th to 9th	1637.316	1612.122
9th to 10th	1402.07	1380.455
10th to 11th	1167.964	1149.947
11th to 12th	934.807	920.403
12th to 13th	702.415	691.632
13th to 14th	470.631	463.471
14th to 15th	239.589	236.05

TABLE 5. MAXIMUM AXIAL FORCE (KN) IN COLUMNS FOR SEISMIC LOAD IN X-DIRECTION

Level	Structure Type	
	Unbraced Structure	Cross Braced Structure
Base to Ground	245.812	442.261
Ground to 1st	230.48	397.099
1st to 2nd	208.474	344.074
2nd to 3rd	185.774	295.283
3rd to 4th	163.401	250.88
4th to 5th	141.598	208.106
5th to 6th	120.506	169.139
6th to 7th	100.281	133.149
7th to 8th	81.113	107.834
8th to 9th	63.229	88.483
9th to 10th	46.896	70.074
10th to 11th	32.424	52.918
11th to 12th	20.163	37.342
12th to 13th	10.507	23.69
13th to 14th	5.546	12.35
14th to 15th	2.521	4.154

TABLE 6. MAXIMUM AXIAL FORCE (KN) IN COLUMNS FOR SEISMIC LOAD IN Z-DIRECTION

Level	Structure Type	
	Unbraced Structure	Cross Braced Structure
Base to Ground	282.91	522.36
Ground to 1st	266.901	474.401
1st to 2nd	243.388	416.297
2nd to 3rd	218.59	361.211
3rd to 4th	193.814	309.216
4th to 5th	169.423	260.294
5th to 6th	145.611	214.512
6th to 7th	122.576	172.031
7th to 8th	100.547	133.112
8th to 9th	79.793	102.345
9th to 10th	60.627	81.154
10th to 11th	43.401	61.523
11th to 12th	28.512	43.785
12th to 13th	16.396	28.277
13th to 14th	7.5	15.363
14th to 15th	2.834	5.672

TABLE 7. MAXIMUM SHEAR FORCE (KN) IN COLUMNS FOR DEAD AND LIVE LOAD

Level	Structure Type	
	Unbraced Structure	Cross Braced Structure
Base to Ground	20.84	21.268
Ground to 1st	21.285	21.299
1st to 2nd	23.499	23.675
2nd to 3rd	25.865	26.204
3rd to 4th	27.956	28.44
4th to 5th	29.829	30.445
5th to 6th	31.503	32.237
6th to 7th	32.99	33.83
7th to 8th	34.3	35.233
8th to 9th	35.442	36.456
9th to 10th	36.421	37.503
10th to 11th	37.241	38.38
11th to 12th	37.892	39.076
12th to 13th	38.619	39.839
13th to 14th	39.018	40.291
14th to 15th	48.743	50.094

TABLE 8. MAXIMUM SHEAR FORCE (KN) IN COLUMNS FOR SEISMIC LOAD IN X-DIRECTION

Level	Structure Type	
	Unbraced Structure	Cross Braced Structure
Base to Ground	36.764	48.631
Ground to 1st	37.245	22.558
1st to 2nd	37.882	23.675
2nd to 3rd	38.015	22.693
3rd to 4th	37.872	22.793
4th to 5th	37.483	22.897
5th to 6th	36.797	22.919
6th to 7th	35.758	22.788
7th to 8th	34.313	22.44
8th to 9th	32.408	21.813
9th to 10th	29.987	20.837
10th to 11th	26.995	19.435
11th to 12th	23.371	17.505
12th to 13th	19.043	14.904
13th to 14th	14.023	11.544
14th to 15th	8.485	7.425

TABLE 9. MAXIMUM SHEAR FORCE (KN) IN COLUMNS FOR SEISMIC LOAD IN Z-DIRECTION

Level	Structure Type	
	Unbraced Structure	Cross Braced Structure
Base to Ground	37.344	47.029
Ground to 1st	38.996	34.989
1st to 2nd	40.957	36.847
2nd to 3rd	41.044	37.112
3rd to 4th	40.867	37.204
4th to 5th	40.377	37.062
5th to 6th	39.563	36.652
6th to 7th	38.37	35.901
7th to 8th	36.736	34.73
8th to 9th	34.6	33.06
9th to 10th	31.902	30.808
10th to 11th	28.579	27.889
11th to 12th	24.567	24.217
12th to 13th	19.836	19.735
13th to 14th	14.154	14.191
14th to 15th	8.781	8.814

TABLE 10. MAXIMUM BENDING MOMENT (KN-M) IN COLUMNS FOR DEAD AND LIVE LOAD

Level	Structure Type	
	Unbraced Structure	Cross Braced Structure
Base to Ground	28.513	28.363
Ground to 1st	32.741	32.715
1st to 2nd	36.479	36.606
2nd to 3rd	40.042	40.314
3rd to 4th	43.24	43.65
4th to 5th	46.12	46.661
5th to 6th	48.696	49.359
6th to 7th	50.984	51.759
7th to 8th	52.997	53.873
8th to 9th	54.748	55.712
9th to 10th	56.246	57.285
10th to 11th	57.502	58.602
11th to 12th	58.548	59.697
12th to 13th	59.296	60.466
13th to 14th	59.719	60.923
14th to 15th	97.627	99.433

TABLE 11. MAXIMUM BENDING MOMENT (KN-M) IN COLUMNS FOR SEISMIC LOAD IN X-DIRECTION

Level	Structure Type	
	Unbraced Structure	Cross Braced Structure
Base to Ground	63.126	68.364
Ground to 1st	63.697	38.282
1st to 2nd	58.305	34.743
2nd to 3rd	57.235	34.221
3rd to 4th	53.966	34.279
4th to 5th	56.612	34.385
5th to 6th	55.82	34.425
6th to 7th	54.534	34.362
7th to 8th	52.676	34.019
8th to 9th	50.167	33.303
9th to 10th	46.923	32.117
10th to 11th	42.863	30.354
11th to 12th	37.896	27.877
12th to 13th	31.882	24.469
13th to 14th	24.771	19.964
14th to 15th	16.694	14.334

TABLE 12. MAXIMUM BENDING MOMENT (KN-M) IN COLUMNS FOR SEISMIC LOAD IN Z-DIRECTION

Level	Structure Type	
	Unbraced Structure	Cross Braced Structure
Base to Ground	64.811	67.858
Ground to 1st	67.359	60.486
1st to 2nd	63.846	57.545
2nd to 3rd	62.309	56.497
3rd to 4th	61.556	56.242
4th to 5th	60.62	55.773
5th to 6th	59.704	55.063
6th to 7th	58.248	54.246
7th to 8th	56.172	52.853
8th to 9th	53.384	50.765
9th to 10th	49.79	47.859
10th to 11th	45.299	44.01
11th to 12th	39.803	39.075
12th to 13th	33.253	32.966
13th to 14th	25.003	25
14th to 15th	17.269	17.312

IV. DISCUSSION ON RESULTS

Table 2 & Table 3 show the maximum lateral displacement for seismic load in X & Z direction respectively at different storey levels. The lateral displacements of the structure for unbraced & cross braced structure systems are compared. The maximum lateral displacement at terrace level in X direction is 34.769mm& 20.73mm for unbraced &cross braced structural systems. Whereas the lateral displacement at the same storey level in Z direction for the above said structural systems are 39.503mm &32.498mm respectively. It has been noted that the lateral displacement is drastically reduced after the application of cross bracings system.

Table 4, Table 5 & Table 6 show the maximum axial force in columns for dead & live load, seismic load in X- direction and seismic load in Z direction respectively. The axial forces of the structure for unbraced and cross braced structural systems are compared. For dead & live load case, it has been observed that the axial force in the structure has been reduced after the application of the bracing system but the axial force values in the columns for the seismic loads are increased. The axial force for seismic load in X direction for unbraced structure at the base level is 245.812 kN which has been increased considerably to 442.261 kN, for cross braced, structural system.

Table 7, Table 8 & Table 9 show the shear forces at different stories for both the structural systems i.e. unbraced& cross braced structural systems for dead & live load, seismic load in X direction and seismic load in Z direction respectively. It can be seen that the shear force for column for dead & live load for unbraced and cross braced structural systems is almost the same, but there is a considerable change in the shear forces for seismic load in both the directions for unbraced & cross braced structural systems. It has been observed that maximum shear force for the unbraced structural system for seismic load at base level in X direction is 36.764 kN and it has been increased to 48.631 kN, for cross braced structural system.

Table 10, Table 11 & Table 12 show the maximum values of bending moments at different stories for both the structural systems i.e. unbraced& cross braced structural systems for dead & live load, seismic load in X and Z direction respectively. It can be seen that the bending moments for columns for dead & live load for unbraced and cross braced structural system is almost the same ,but there is a considerable change in the bending moments for seismic load in both the directions for unbraced & cross braced structural systems. It can be seen that the maximum bending moments for unbraced& cross braced structural system at base level is 63.126 kN-m& 68.364 kN-m.

V. CONCLUSION

After the analysis of the structure with both types of structural systems i.e. unbraced & cross braced structural systems, it has been concluded that the lateral displacement in the structure arises due to lateral load i.e. seismic load decreases substantially after introduction of cross bracing system. Cross bracing system reduces bending moments and shear forces in the columns. However axial force has been increased in the columns after the introduction of cross bracing system. The lateral load is transferred to the foundation through axial action only.

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BIOGRAPHY

Mohammed Nauman received his B.Tech. degree in Civil Engineering from Jamia Millia Islamia, New Delhi, India, in 2008 and the M.Tech degree in Earthquake Engineering from Jamia Millia Islamia, New Delhi, India, in 2013. Currently, he is a practicing structural engineer. His areas of designing are design of multistorey RCC and steel structures. His main area of interest is the retrofitting of the existing RCC and steel structures.

Dr. Nazrul Islam received has published more than 60 research papers in International journals and conferences along with the degrees like obtained his Bachelor's Degree in Civil Engineering from AMU Aligarh, India in the year 1984, Master's degree in Structures from IIT Roorkee, India (then known as University of Roorkee) in the year 1990. He has obtained his Ph.D. degree in Structures from IIT Delhi, India in the year 1998. Currently he is serving as a teaching faculty in Department of Civil Engineering, Faculty of Engineering and Technology, Jamia Millia Islamia, New Delhi, India

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