Seismic Analysis of Multi-Storied Framed Structure With Different Types of Bracings As Per Indian Standard

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Abstract- *Bracing System has always been very effective in increasing the lateral stability of the building and provides stiffer to the structure and is efficient in safely transferring the loads.*

The present study has been done by comparing different types of bracing arrangements for a G+4 story RC structure located in zone III and is studied as per the Indian standard codes to see which type of bracing arrangement is better and up to how much efficient it is in resisting the effects of laterally acting loads, the results would comprise of the comparison of axial forces, shear forces, bending moments, deflection, base shear and storey shear.

Keywords- Bracing System, Multistory, Base Shear, Seismic, Lateral displacement.

I. INTRODUCTION

During an earthquake, deformations gets induced across the elements of a structure which result in reaction of structure to its movement at base level. The resultant movement requirement varies which is dependent on the stiffness coefficient and weight of the building. In general, structures with high stiffness coefficient and less weight have small drift demands. Thus every structure has a definite displacement capacity. The quantity of displacement which a structure can meet without failure is restricted to an amount. The aim of increasing its stability is to make sure that the requirement of a building is lower than its aptitude to displace. This can be done by reducing the lateral movement of the building.

The better way to reduce the lateral load of a building is to provide more stiffness at the outside surface thus maximizing the benefit of the building. To satisfy this, stiffness is a key part in designing of a building..

Bracing system is one of the most efficient and considerably low in cost method to laterally strengthen the frames in a structure against the earthquake loading. A braced structure contains of beams, girders and columns which stiffens the overall frame and reduced the lateral displacement and hence increasing its load carrying capacity which forms a frame to resist the horizontal forces as well.

A regular shaped building has been modelled and analyses is done for gravity and earthquake loads acting upon all the axis of bending of members. Similarly, building is provided by bracing in all direction along bending. Various different arrangements of bracing systems has been studied for the building.

II. LITERATURE SURVEY

A Rahimi et al. (2018) this papers aims at evaluating, through time history analyses, the behaviour of RC columns before and after retrofitting with steel X-bracing and examining possible complications, increased demands and side effects of such a retrofitting method. The effects on the level of column shear and axial force, as well as, column performance level and low cycle fatigue life are investigated.

Maryam Boostani et al. (2018) proposed bracing systems for earthquake resistant steel structures are introduced and studied through an experimental program and FEM (finite element method) numerical analysis. These proposed bracing systems called OGrid, by two types as the OGrid-I and the OGrid-H, are braced frames with circular braces connected to MRF (moment resisting frame) with joint connections. Linear and nonlinear behavior of the new OGrid bracing systems are studied and compared with X-bracing system. To achieve the linear and nonlinear behavior of models, response spectrum analysis and nonlinear static (pushover) analysis are used by FEM.

Se Woon Choi et al. (2016) presented a study proposes an FRP-bracing-based optimal seismic retrofit method for reinforced concrete (RC) frames with infill walls. This method minimizes the number of FRP bracings for the retrofit and maximizes the dissipated energy while satisfying constraints related to interstory drift and structural collapse.

Ashok R Mundhada et al. (2015) presented a comparative study for seismic performance of multistoried rc building with flat slab & grid slab comparing the axial forces in columns and displacement in X and Y direction while also comparing the base shear and story drift between the two.

Giovanni Maria Montuori et al. (2014) presented a methodology for establishing the need for a specific secondary bracing system (SBS) as a function of the diagrid geometry. Further, design criteria for secondary bracing systems are worked out and applied to some 90 story building models, characterized by perimeter diagrid structures with different module height and diagonal cross sections.

Nauman Mohammed et al. (2013) The objective of this paper is to evaluate the response of braced and unbraced structure subjected to seismic loads and to identify the suitable bracing system for resisting the seismic load efficiently.

III. SCOPE OF THE STUDY

On the basis of literature reviewed, it can be concluded that different bracing systems have been used to enhance the efficiency and performance of a building but no major efforts have been reported regarding the comparison of two or more type of bracing system arrangements for a structure.

The present study will include the comparison and analysis of a multistoried RC structure with four different cases of bracing arrangements and the results showing the comparison in the output when the structure is designed via IS 456:2000 as well as IS 1893:2016. The study is likely to encourage the uptake of bracing in construction of a building for lateral loads.

IV. OBJECTIVE OF THE STUDY

The present study aims at the following objectives:

1. To carry out the comparison, analysis and design of building with and without bracings at the outer periphery covered by columns along the sides only for the following data:

a) Building with no bracings.
b) Building with Diagonal bracings.
c) Building with Cross bracings.
d) Building with A-bracings.

2. To compare the following results of the above mentioned systems and their frames using IS456:2000 and IS1893(Part1):2016

a) Base Shear
b) Storey Shear
c) Axial Forces
d) Shear Forces
e) Bending Moments
f) Deflection

3. To evaluate and compare the stability of the structure subjected to gravity & seismic forces for the building with unbraced & braced frames.

V. PROBLEM STATEMENT

A RC building, located in ZONE III with medium soil condition is considered for the study purpose. In present work in order to compare, analyze and design the building for different cases of dead & live load and different combinations considering the seismic load in X, -X, Z, -Z directions for same load conditions covered by brick infill walls for different type of bracing arrangements.

For the residential RC building, structural parameters considered in this study are tabulated as follows:

Table5.1CommercialBuildingStructuralParameters

S.NO.	DESCRIPTION	DATA
1.	Structure	SMRF
2.	Nos.ofstorey	G+4
3.	Typeofbuildinguse	Commercial
4.	Grade ofconcrete	M-25
5.	Densityofconcrete	25KN/m^3
6.	BuildingSize	18mx30m
7.	BeamSize	0.3mx1m
8.	ColumnSize	0.6mx0.6m
9.	FloorHeight(H)	4m
10.	DeadLoadIntensity	3.125KN/m^2
11.	FloorFinishLoad	1.0KN/m^2
12.	LiveLoadIntensity	4 KN/m^2
13.	Seismiczone	III
14.	ImportanceFactor	1.5
15.	ResponseReductionFactor,Rf	5
16.	Bayspacing	6m

A TYPICAL Commercial building (G+4) with
L= 18m; W= 30m; H= 20m
Bay spacing 6m is considered.

METHODOLOGY & MODELLING APPROACH

5.1 Steps in Modeling

The major steps involved in the modeling are as follows:

1. Add nodes to form the required geometry.
2. Join these nodes to form beams and column elements.
3. Assign property to all the elements.
4. Assign support conditions (fixed) to columns at base.
5. Define primary load cases.
6. Assign all the loads to the elements as per the calculation done.
7. Assign definition to the seismic load.
8. Define load combinations.
9. Select required codes as per Indian Standards
10. Add perform analysis command and provide the load list to be used for analysis.
11. Add design command to all the structural elements to be designed.

A braced RC frame system which is displayed shown in Fig
The properties of building:
Number of bay along X-axis = 3,
Number of bay along Y-axis = 5,
Width of bay in X-direction = 6 m,
Bay width along Y-direction = 6 m
No. of floors= G+4
Total height of every storey = 4m.

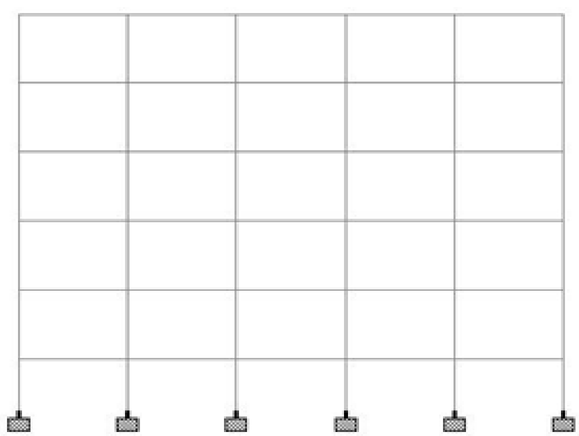

Fig.5.1Elevationofunbracedstructure

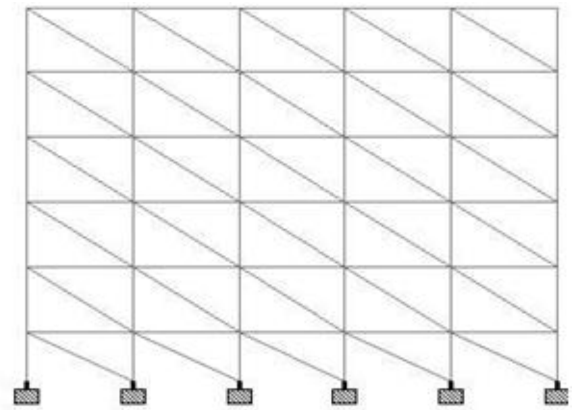

Fig.5.2Elevationofdiagonalbracedstructure

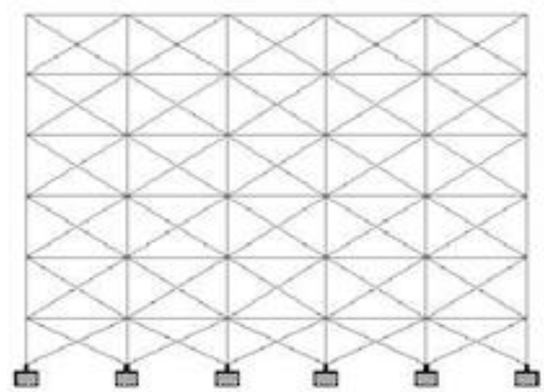

Fig.5.3Elevationofcrossbracedstructure

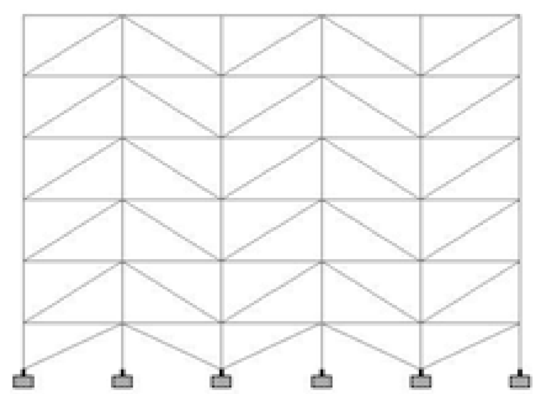

Fig.5.4ElevationofA-braced structure

VI. LOAD CONSIDERATIONS & COMBINATION

The primary load cases considered in the present study are:

a) [DL]
b) [LL]
c) Seismic Load In+X Direction[EQ+X]
d) Seismic Load In-X Direction[EQ-X]
e) Seismic Load In+Z Direction[EQ+Z]
f) Seismic Load In-Z Direction[EQ-Z]

Table6.1:Load Combinations

LIMITSTATE OFSERVICIBILITY
DL+LL
EQX
EQ(-X)
EQZ
EQ(-Z)
LIMITSTATEOFSTRENGTH
1.5DL+1.5LL
1.5DL+1.5EQX
1.5DL+1.5EQ(-X)
1.5DL+1.5EQZ
1.5DL+1.5EQ(-Z)
1.2DL+1.2LL+1.2EQX
1.2DL+1.2LL+1.2EQ(-X)
1.2DL+1.2LL+1.2EQZ
1.2DL+1.2LL+1.2EQ(-Z)
0.9DL+1.5EQX
0.9DL+1.5EQX(-X)
0.9DL+1.5EQZ
0.9DL+1.5EQX(-Z)

VII. RESULT & DISCUSSION

Table7.1: Maximum Axial Force for Columns (kN)-Dead Load and Live Load

FloorLvl.	StructureType			
	Unbraced	DiagonallyBraced	Cross Braced	ABraced
BasetoGround	3710	2580	3160	3780
Ground toFirst	3600	2460	2990	3510
First toSecond	2870	1950	2380	2720
SecondtoThird	2150	1470	1780	2010
Thirdto Fourth	1440	995.62	1200	1370
Fourthto Fifth	722.29	508.2	595	700

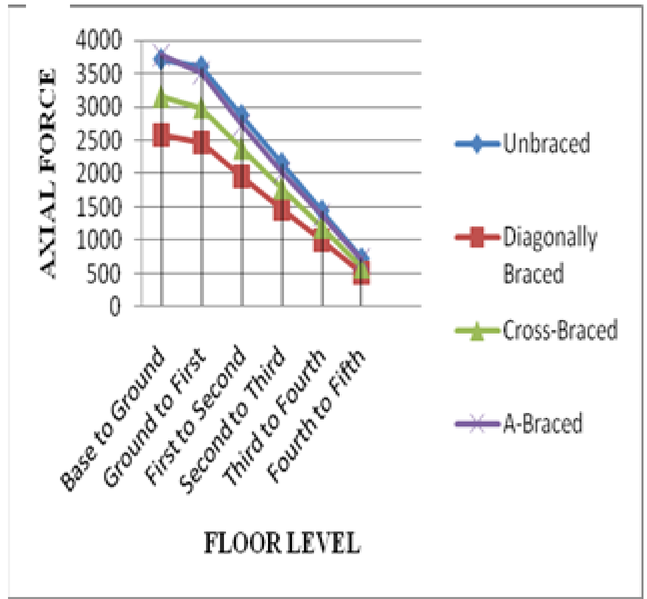

Fig. 7.1 Maximum Axial Force in Columns (kN) - Dead Load & Live Load

Table7.2: Maximum Axial Force for Columns (kN)-Dead Load and Live Load

FloorLvl.	StructureType			
	Unbraced	DiagonallyBraced	Cross Braced	ABraced
Baseto Ground	104.22	183.707	177.38	112.72
Ground toFirst	96.239	164.412	125.76	221.04
First toSecond	65.213	119.807	79.226	149.203
SecondtoThird	39.23	80.395	43.243	90.243
Thirdto Fourth	18.047	46.639	20.275	42.296
Fourthto Fifth	4.505	20.28	10.361	10.914

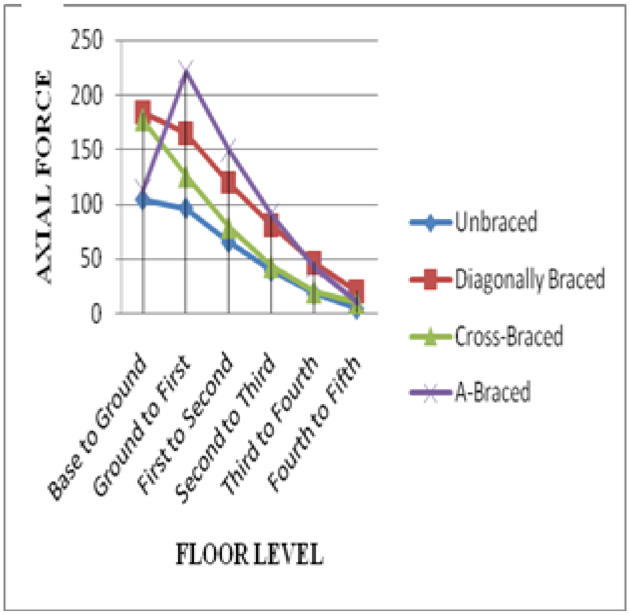

Fig. 7.2 Maximum Axial Force in Columns (kN) - Seismic Load along X- Direction

Table 7.3: Maximum Axial Force for Columns (kN) - Seismic Load along Z- Direction

FloorL vl.	StructureType			
	Unbraced	DiagonallyBraced	Cross Braced	ABraced
Baseto Ground	96.837	159.58	115.885	221.485
Ground toFirst	88.967	145.46	80.981	180.795
First toSecond	59.012	109.673	50.888	120.159
Secondt oThird	34.924	74.995	27.549	71.719
Thirdto Fourth	15.683	43.89	10.644	32.599
Fourtht oFifth	3.716	22.745	3.899	12.756

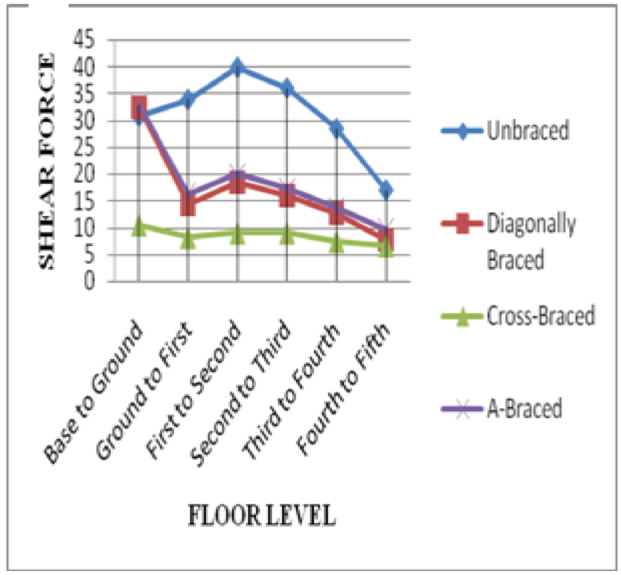

Fig. 7.3 Maximum Axial Force in Columns (kN) - Seismic Load along Z- Direction

Table 7.4: Maximum Shear Force (Fy) in Columns (kN) - Dead Load & Live Load

FloorL vl.	StructureType			
	Unbraced	DiagonallyBraced	Cross Braced	ABraced
Baseto Ground	10.466	3.765	4.612	4.256
Ground toFirst	26.553	26.238	26.442	26.648
First toSecond	58.602	58.23	58.221	58.789
Secondt oThird	52.942	52.978	52.781	53.244
Thirdto Fourth	58.397	58.302	58.09	58.602
Fourtht oFifth	24.084	24.155	24.188	24.532

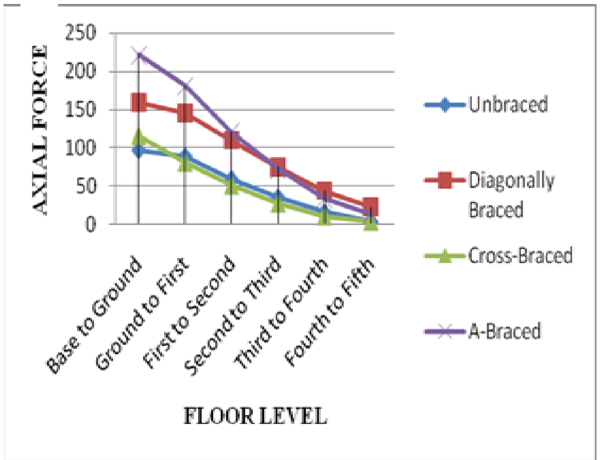

Fig. 7.4 Maximum Shear Force (Fy) in Columns (kN) - Dead Load & Live Load

Table 7.5: Maximum Shear Force (Fy) in Columns (kN) - Dead Load & Live Load

FloorL vl.	StructureType			
	Unbraced	DiagonallyBraced	Cross Braced	ABraced
Baseto Ground	30.784	32.364	10.423	32.878
Ground toFirst	33.853	14.367	8.167	16.286
First toSecond	39.858	18.409	8.936	20.019
Secondt oThird	35.988	15.884	8.973	17.21
Thirdto Fourth	28.425	12.649	7.424	13.593
Fourtht oFifth	16.982	7.699	6.632	9.622

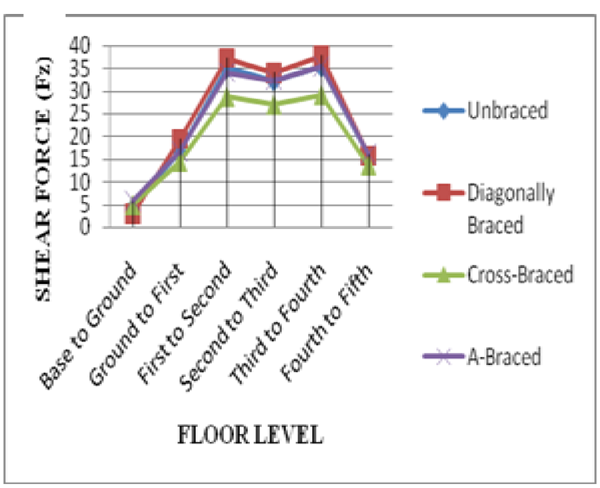

Fig. 7.5 Maximum Shear Force (Fy) in Columns (kN) - Seismic Load along X- Direction

Table 7.6: Maximum Shear Force (Fy) in Columns (kN) - Dead Load & Live Load

FloorL vl.	StructureType			
	Unbraced	DiagonallyBraced	Cross Braced	ABraced
Baseto Ground	0.422	1.345	0.355	0.744
Ground toFirst	2.639	2.242	0.596	1.429
First toSecond	5.563	2.812	1.078	2.806
Secondt oThird	3.473	2.305	1.119	2.223
Thirdto Fourth	2.557	1.896	1.102	2.192
Fourtht oFifth	1.36	2.209	0.927	2.379

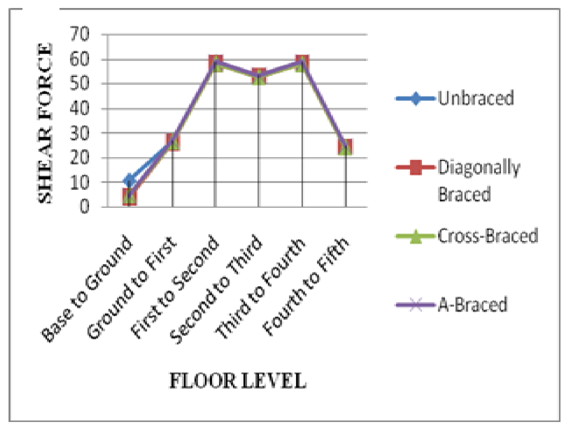

Fig. 7.6 Maximum Shear Force (Fy) in Columns (kN) - Seismic Load along Z- Direction

Table 7.7: Maximum Shear Force (Fz) in Columns (kN) - Dead Load & Live Load

FloorL vl.	StructureType			
	Unbraced	DiagonallyBraced	Cross Braced	ABraced
Baseto Ground	4.429	3.027	5.036	5.785
Ground toFirst	16.693	19.549	14.559	16.713
First toSecond	34.985	37.322	28.848	34.042
Secondt oThird	32.266	34.12	27.11	32.384
Thirdto Fourth	35.342	37.841	29.255	35.413
Fourtht oFifth	15.904	15.855	13.777	16.101

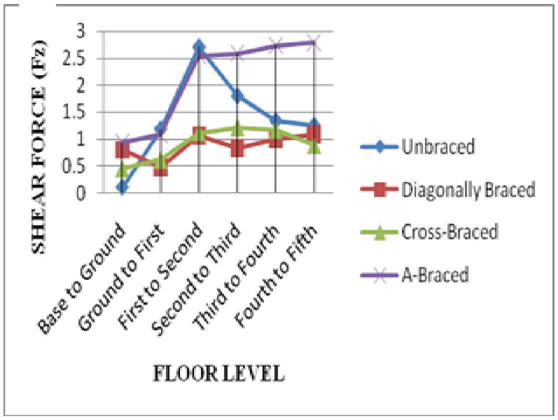

Fig. 7.7 Maximum Shear Force (Fz) in Columns (kN) – Dead Load & Live Load

Table 7.8: Maximum Shear Force (Fz) in Columns (kN) - Seismic Load along X-Direction

FloorL vl.	StructureType			
	Unbraced	DiagonallyBraced	Cross Braced	ABraced
Baseto Ground	0.102	0.808	0.444	0.927
Ground toFirst	1.184	0.478	0.606	1.084
First toSecond	2.714	1.071	1.116	2.541
Secondt oThird	1.799	0.836	1.212	2.583
Thirdto Fourth	1.339	1.005	1.164	2.734
Fourtht oFifth	1.251	1.094	0.883	2.791

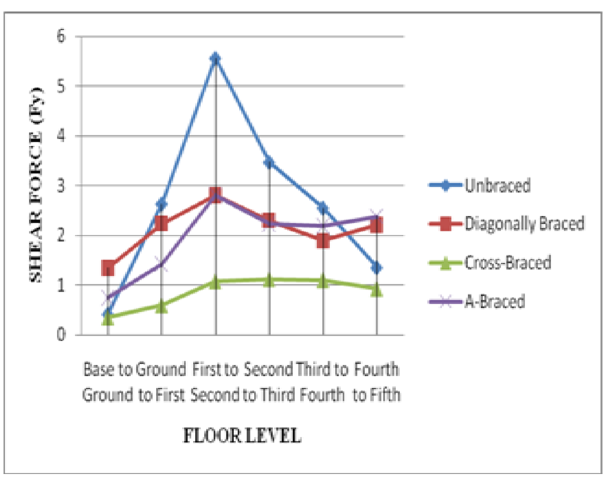

Fig. 7.8Maximum Shear Force (Fz) in Columns (kN) - Seismic Load along X- Direction

Table 7.9: Maximum Shear Force (Fz) in Columns (kN) - Seismic Load along Z-Direction

FloorL vl.	StructureType			
	Unbraced	DiagonallyBraced	Cross Braced	ABraced
Baseto Ground	31.177	15.175	3.894	29.062
Ground toFirst	35.425	6.204	2.98	14.961
First toSecond	37.668	6.116	3.319	17.747
Secondt oThird	33.895	5.276	2.973	15.378
Thirdto Fourth	27.18	4.542	2.42	12.589
Fourtht oFifth	16.915	3.443	2.148	8.171

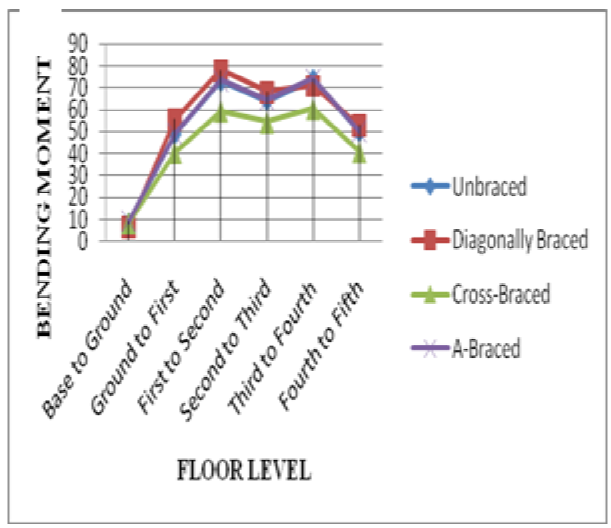

Fig. 7.9 Maximum Shear Force (Fz) in Columns (kN) - Seismic Load along Z- Direction

Table 7.10 Maximum Bending Moments In Columns (kNm)- Dead Load & Live Load

FloorL vl.	StructureType			
	Unbraced	DiagonallyBraced	Cross Braced	ABraced
Baseto Ground	8.216	6.245	8.023	9.059
Ground toFirst	49.011	55.565	40.33	49.038
First toSecond	73.157	78.11	59.385	73.228
Secondt oThird	64.468	68.258	54.267	64.704
Thirdto Fourth	74.06	71.187	60.424	74.167
Fourtht oFifth	50.105	52.896	40.649	50.34

Table 7.11 Maximum Bending Moments in Columns (kNm) - Seismic LoadalongX-Direction

FloorL vl.	StructureType			
	Unbraced	DiagonallyBraced	Cross Braced	ABraced
Baseto Ground	0.411	1.584	0.291	2.048
Ground toFirst	4.022	2.291	1.602	3.202
First toSecond	6.048	2.293	2.296	5.112
Secondt oThird	3.75	2.276	2.452	5.266
Thirdto Fourth	2.763	2.214	2.343	5.439
Fourtht oFifth	2.587	2.188	1.84	5.122

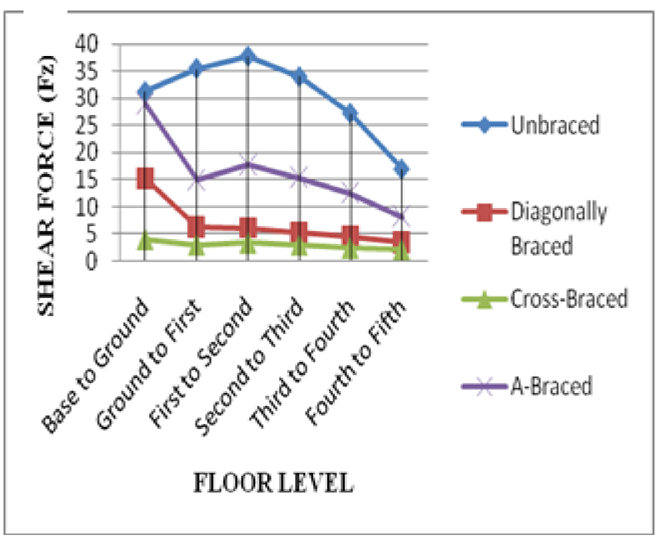

Fig. 7.10 Maximum Bending Moments In Columns (kNm) - Dead Load & Live Load

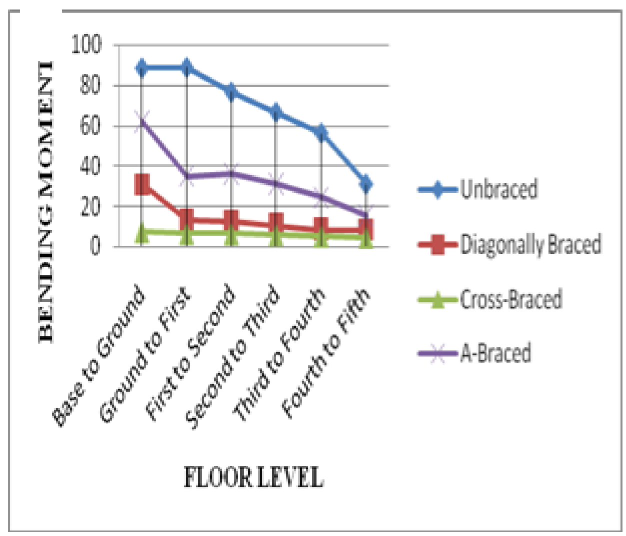

Fig. 7.11 Maximum Bending Moments in Columns (kNm) - Seismic Load along X-Direction

Table 7.12 Maximum Bending Moments in Columns (kNm) - Seismic Load along Z-Direction

FloorL vl.	StructureType			
	Unbraced	DiagonallyBraced	Cross Braced	ABraced
Baseto Ground	88.451	30.892	7.624	62.139
Ground toFirst	88.732	13.142	6.685	35.034
First toSecond	76.474	12.477	6.551	36.18
SecondtoThird	66.557	10.82	5.956	31.14
Thirdto Fourth	56.262	8.718	5.329	24.43
FourthtoFifth	31.017	8.444	4.67	15.172

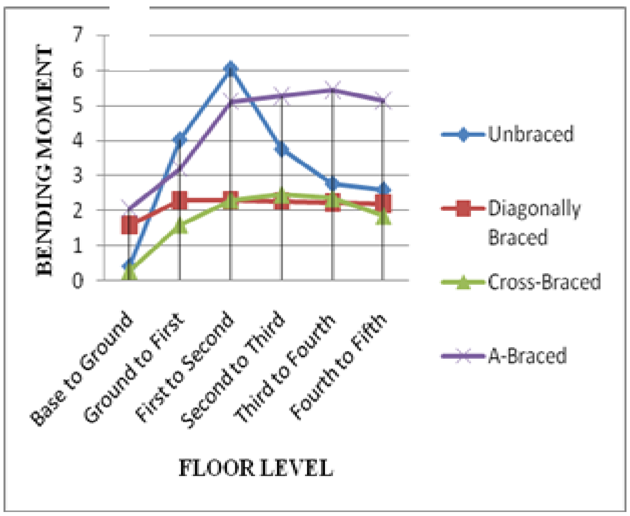

Fig. 7.12 Graph For Maximum Bending Moments (kNm) in Column - Seismic Load along Z Direction.

Table 7.13 Maximum Lateral Displacement (mm) along X-Direction

FloorL vl.	StructureType			
	Unbraced	DiagonallyBraced	Cross Braced	ABraced
5	8.03	6.449	2.989	5.378
4	7.36	5.52	2.528	4.738
3	6.26	4.247	1.337	3.815
2	4.88	2.894	1.337	2.779
1	3.39	1.583	.402	1.7
Ground	1.13	0.302	0.258	0.769
Base	0	0	0	0

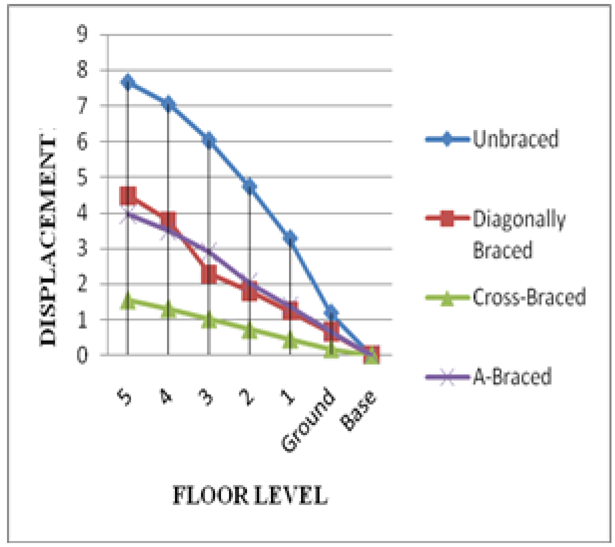

Fig. 7.13 Graphfor Maximum Bending Moments (kNm) in Column - Seismic Load along Z Direction.

Table 7.14 Maximum Lateral Displacement (mm) along X-Direction

FloorL vl.	StructureType			
	Unbraced	DiagonallyBraced	Cross Braced	ABraced
5	7.67	4.481	1.556	3.959
4	7.05	3.778	1.317	3.499
3	6.03	2.281	1.024	2.895
2	4.74	1.794	0.727	2.025
1	3.28	1.249	0.453	1.374
Ground	1.18	0.648	0.171	0.665
Base	0	0	0	0

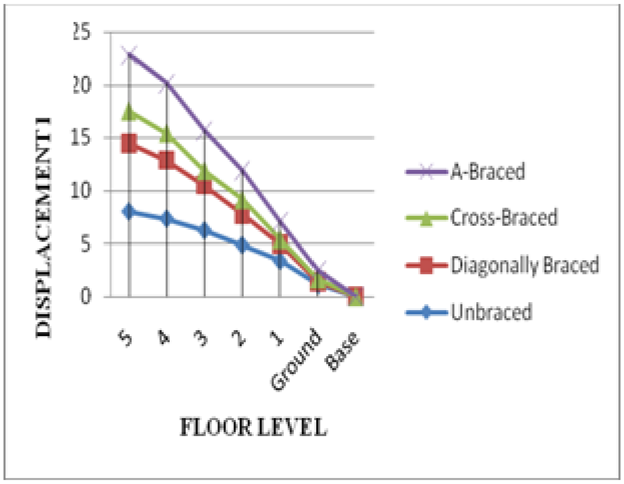

Fig. 7.14 Maximum Lateral Displacement(mm) along Z-Direction

VIII. CONCLUSION

For Base Shear and Storey Shear:

Storey shear does not vary much in all the cases, The storey shear has been calculated from the base shear which are 2801.268 kN, 2814.36 kN and 2827.46 kN for unbraced, diagonal & A-braced and cross braced structure respectively.

For Axial Forces:

The forces for different brace arrangement have been compared. In case of dead and live load, it is seen that axial force had been came down after the introduction of the braces and the axial acting force of the columns for earthquake loads increase. The axial force for earthquake load in X range for unbraced type of structure system at the lowest level is 104.22 kN which increases to 183.707 kN, 177.38 kN, 112.72 kN for diagonal braced, cross braced and structure with A-bracings respectively. The most increase in force is seen in diagonal bracing system

For Shear Force (Fy):

The force (Fy) for column in case of dead load and live load in case of unbraced and other types of bracing arrangements is somewhat same, also there is some change in the values of shear force (Fy) for earthquake load in X and Z direction for unbraced and different types of braced structural systems. The most force for the unbraced system for seismic load at bottom in X range is 30.784 kN and gets increased to 32.36 kN and 32.878 kN, for diagonal braced and A-braced respectively and reduced to 10.423 kN for cross bracing. It is reduced to 16.982 kN for unbraced system and 7.699 kN, 6.632 kN and 9.622 kN for diagonal bracing, cross bracing and A-bracing structure respectively at top floor.

For Shear Force(Fz):

The force(Fz) for column in case of dead load and live load in case of unbraced system and various types of braced systems is nearly the equal, but some change in the shear force (Fz) for earthquake load in all the axises for unbraced and various types of braced structurs. It is seen that the maximum limit of shear force (Fz) for unbraced structure for earthquake load at bottom in X-axis is 0.102 kN and it increase to 0.808 kN, 0.444 kN and 0.4927 kN , for diagonal braced, cross braced and A-bracing respectively. It has been increased to 1.251 kN for unbraced, 1.094 kN, 0.883 kN and2.791 kN for diagonal braced, cross braced and A-braced structure respectively at terrace level.

For Bending Moments:

It is visible that moments of columns for dead load and live load for unbraced and various other arrangements of bracing style system does not very much. It also the most moments for unbraced, diagonal braced, cross braced and A-braced system at bottom level is 8.216 kN-m, 6.245 kN-m, 8.023 kN-m and 9.059 kN-m respectively. It’s been increased to 50.105 kN-m,52.896 kN-m, 40.649 kN-m and 50.34 kN-m respectively for system of unbraced, diagonal braced, cross braced and A-braced structure at top most level respectively.

In case of seismic load in Z direction for system of unbraced and various other kinds of bracing system, maximum bending moments for is for unbraced structure which is 88.451 kN-m at base level and 30.892 kN-m, 7.624 kN-m and 62.139 kN-m for diagonal braced, crossly braced and A-braced structure, respectively. It had comedown to 31.017 kN-m, 8.444 kN-m, 4.67 kN-m and 15.172 kN-m respectively forum braced, diagonal braced, cross braced system and A-braced system of structure at top most level.

For Deflection:

The displacements in the system for different braces arrangements are computed. The maximum displacement at top level along X-axis is 8.03 mm, 6.449 mm, 2.989 mm and 5.378 mm for unbraced, diagonal braced, cross braced and A-braced systems. Thus the displacement at the same floor in Z-axis for the above building are 7.67 mm, 4.481 mm, 1.556 mm and 3.959 mm. It is to be seen that the lateral displacement is highly reduced after the implementation of cross type bracing arrangement system. Maximum reduction in displacement of structure is seen after the implementation of crossed type bracing arrangement.

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