Seismic Analysis of Floating Column & Transfer Girder with & without Bracings

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Abstract - *Floating Columns are those which starts from an intermediate floor level instead of foundation level to meet the requirement of open storey. The beam on which floating column rests is called as Transfer Girder. This Assembly of floating column and transfer girder creates many problems in a structure. Hence it should be carefully studied, analyzed and designed. Bracings in concrete structures are used because it can withstand lateral loads due to an earthquake, wind etc. It is one of the best methods for lateral load resisting systems. Concrete-framed high-rise buildings are becoming more common in major cities. Engineers have turned to braced concrete framed structures as a cost-effective way to resist seismic loads. In this report, Dynamic Analysis by Response Spectrum Analysis is carried out with G+12 Building having floating columns with different types of bracing systems.*

Key Words*: *Analysis methods, Braced framed structure, Braced system, Concrete Structure, ETABS 2019, Floating Column, Response spectrum analysis, Seismic load, Single diagonal edge bracing, Transfer Girder, V bracing, X bracing,

1.INTRODUCTION

Earthquake is the most dangerous phenomenon because of its unpredictability and massive devastation power. Depending on the zone in which the particular site is located, treatment is required. Earthquakes in the recent past have raised a number of concerns and pushed us to consider disaster management. To avoid failure or reduce property loss, it is now necessary to think about a structure from the planning stage to the construction stage. So, as a result, studying the seismic reaction of these buildings in the elastic range is critical.

A column is a vertical member which is supposed to be starting from foundation level and transferring the load to the ground. Now a days, in the metro cities, Population is increasing and hence more space is required to provide maximum amenities to the residents living in a structure. But due to the lesser space available, it is a common practice to provide all these amenities inside a structure only. These may include provision of parking system (Stilt Parking, Stack Parking, Puzzle Parking, Basement Parking), Commercial Offices, Shops, Auditorium, Conference Hall etc. In these units, lesser number of columns are expected from the Architects.

To comply the needs of large open space, without or with the minimal use of columns, Floating Columns were introduced. Floating Columns are those which starts from an intermediate floor level instead of foundation level to meet the requirement of open storey. The beam on which floating column rests is called as Transfer Girder.

This Assembly of floating column and transfer girder creates many problems in a structure. Hence it should be carefully studied, analyzed and designed.

Though floating columns have to be discouraged, there are many projects in which they are adopted, especially above the ground floor, where transfer girders are employed, so that more open space is available in the Ground Floor. In the earthquake zones, the transfer girders which are employed have to be designed and detailed properly with care. If there are no lateral loads, the design and detailing is not difficult.

1.1 ADVANTAGES OF FLOATING COLUMN

1. Floating columns are mainly used to fulfil the architectural requirements of a structure.

2. Plan on Each Floor can be varied as per requirement.

3. They are very useful when the lower floor has a large span hall having rooms on its upper floors such as hotels, offices, shops, auditorium etc.

1.2 DISADVANTAGES OF FLOATING COLUMN

1. Increase storey displacement in buildings.

2. They Attract seismic forces extensively.

3. There is no continuity with the above and below floors making it vulnerable.

4. Joints of floating column have to bear large amount of shear force and moment due to sudden coming of earthquake. This may cause crack and damage at the joints.

1.3 NEED OF BRACINGS

Reinforced concrete structures have become more common in India in recent years. Horizontal members (beams and slabs) and vertical members (columns and walls) make up a conventional RC structure, which is supported by ground-level foundations. A RC frame is a structure made up of RC columns and connecting beams. The RC frame helps to withstand seismic forces. Earthquake shaking causes inertia forces in the structure, which are proportional to the mass of the structure. Because the majority of the building's mass is concentrated on the floor levels, earthquake-induced inertia forces are concentrated there. These pressures move down through slabs to the beams, beams to the columns and walls, and finally to the foundations, where they are diffused to the earth. The columns and walls of the lower storey encounter larger earthquake generated forces as the inertia forces accrue downward from the top of the building, and are thus intended to be stronger than the storey above.

Structural response can be increased in the structures by introducing steel bracing in the structural system. There are 'n' number of possibilities to arrange steel bracings, such as cross bracings X', diagonal bracing 'D', and 'V' type bracing, Knee bracing and New O-grid bracing.

The reaction of braced frames is researched extensively in various disciplines of structural engineering. Because of their external load carrying capabilities, these buildings have attracted a lot of attention from researchers. Inter storey drift must be managed in order to avoid damage to structural and non-structural elements, hence the concrete construction must be strong and stiff.

1.4 DIFFERENT TYPES OF BRACINGS

Following are several types of bracings adopted:

(i) Single Diagonal Edge Bracing

(ii) Cross-bracing or X bracings

(iii) K-Bracing

(iv) V-Bracing

(v) O-Grid Bracing

1.5 ADVANTAGE OF BRACED STRUCTURES

1. It reduces lateral storey displacement, storey drift, axial force, and bending moment in columns to a significant extent.

2. Braced frames withstand wind and seismic stresses better than non-braced structures.

3. It is inexpensive, simple to erect, and straightforward to design to provide the needed strength and stiffness.

4. The reduction in lateral displacement is a significant benefit. In this situation, concentric (X) bracing is more effective than eccentric (V) bracing.

1.6 OBJECTIVES

1. To Study Seismic behavior of Floating Column and Transfer Girder system with & without bracings in Seismic zone II, III, IV, V.

2. To compare various seismic parameters in Structure in Seismic zones II, III, IV, V.

3. To decide suitability of above system in Seismic zones II, III, IV, V.

1.7 SCOPE OF STUDY

The floating column and transfer girder captures various problems in structure like Higher time period, creation of soft storey, various irregularities like Mass irregularity, Stiffness irregularity, Torsional irregularity etc. Hence this system needs to be carefully studied, analyzed and designed to avoid collapse of structure and loss of lives under seismic events. So, in this project, G+12 storey building with & without bracings will be analyzed in seismic zones II, III, IV, V by using ETABS 19.0.2 version. Under the seismic analysis, Equivalent static method and Response Spectrum method will be used to compare various parameters like base shear, storey drift, time periods, irregularities etc. After comparing the results, the suitability of this system will be decided in the various seismic zones.

2. MODELLING

For analysis purpose, 16 different models are prepared as follows

1. 4 models of G+12 Storey building, one with floating column and transfer girder & without bracing and others with X, V & Single edge diagonal bracing in seismic zone-II.

2. 4 models of G+12 Storey building, one with floating column and transfer girder & without bracing and others with X, V & Single edge diagonal bracing in seismic zone-III

3. 4 models of G+12 Storey building, one with floating column and transfer girder & without bracing and others with X, V & Single edge diagonal bracing in seismic zone-IV

4. 4 models of G+12 Storey building, one with floating column and transfer girder & without bracing and others with X, V & Single edge diagonal bracing in seismic zone-V

Different parameter such as Base shear, Storey Drift Ratio, Modal Participating Mass Ratio are compared for these models. The overall plan dimension is 40mx40m. Ground floor height of the building is 4.2m and typical floor height is 3m.

3. MODEL DESCRIPTION

In this research, Response Spectrum Analysis was performed to study the behavior of floating column and transfer girder with and without bracings. Analysis is carried out by using ETABS 2019 software. Each building is designed using IS 1893:2016, IS 13920:2016 and IS 456:2000. In the following Table, all the parameters of 4 buildings are same except the seismic zone.

Table 1: Model details

Sr. no.	Parameter	Type/Value
1.	Structure Type	RCC Structure
2.	No. of Storey	G+12
3.	No. of models	16
4.	Ground floor height	4.2 m
5.	Typical floor height	3 m
6.	Grade of Concrete	M30
7.	Grade of Steel	Fe500
8.	Floor Finish	1.5 kN/m^2
9.	Live load	2 kN/m^2
10.	Wall Thickness (Internal & External)	150 mm
11.	Wall Type	AAC Blocks
12.	Wall Density	10 kN/m^3
13.	Soil Type	Type-I
14.	Importance Factor	1
15.	Response Reduction Factor	5
16.	Damping Ratio	0.05
17.	Type of bracing	X, V, Single diagonal Edge Bracing
18.	Size of Beam	300mm X 600mm
19.	Size of girder beam	1000mm X 1250mm
20.	Size of columns	500mm X 500mm
21.	Size of floating columns	500mm X 500mm

4. PLAN & 3D VIEW OF MODELS IN ETABS

Following are the 3D pictures of all 12 models with and without bracing which are used for the research work in ETABS.

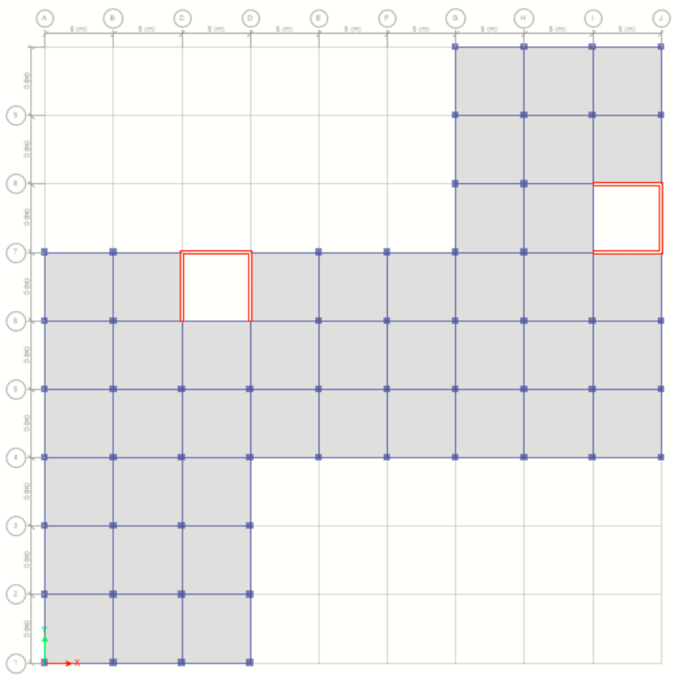


Fig. 4.1 Plan for all frames

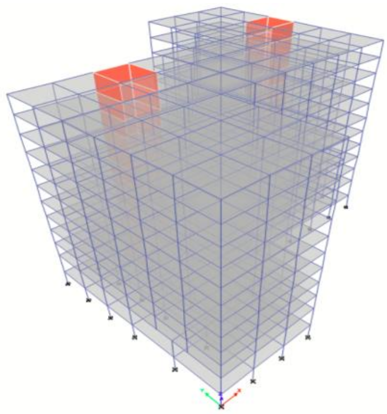


Fig. 4.2 Model-A,E,I,M without Bracing in seismic zone-II, III, IV, V

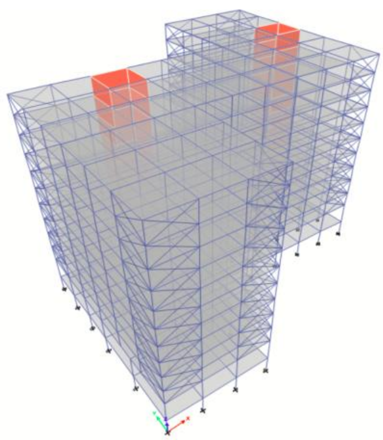


Fig. 4.3 Model-B,F,J,N with X-Bracing in seismic zone-II, III, IV, V

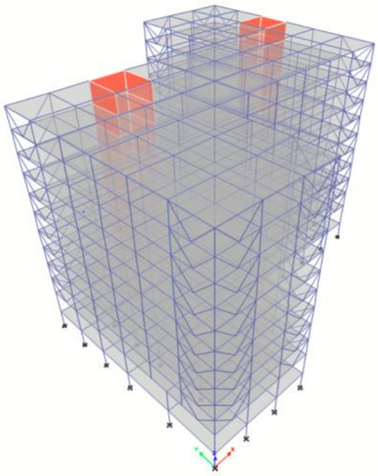


Fig. 4.4 Model-C,G,K,O with V-Bracing in seismic zone-II, III, IV, V

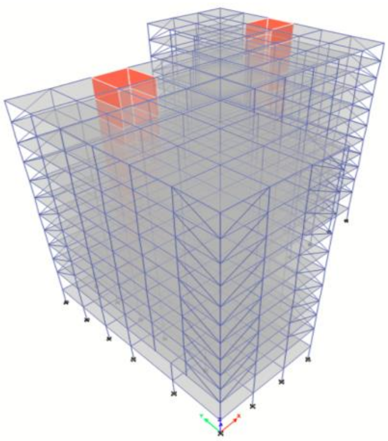


Fig. 4.5 Model-D,H,L,P with Single Diagonal Bracing in seismic zone-II, III, IV, V

3D view of G+12 concrete frames with floating column & transfer girder, without bracing and with X bracing, V bracing and single diagonal bracing are represented in these figures. These models are used for the response spectrum analysis. Section properties are same for all 16 models. Bracings are provided in the end bays of frames in each direction.

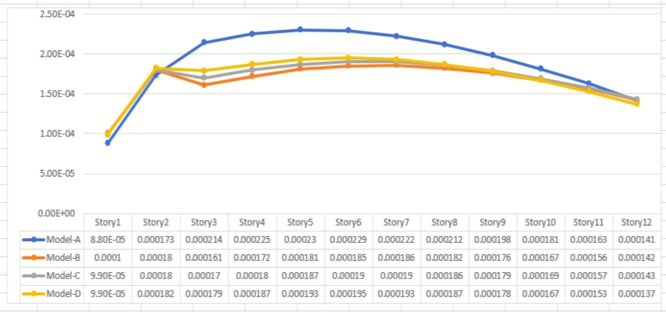
After assigning the sectional properties to the frame, 3D models were generated. After that Response Spectrum Analysis was performed to study the behavior of structure. Analysis is carried out by using ETABS 2019 software. After analysis, it was concluded that different bracing system helps to decrease torsion in 1st natural mode. Also, it is observed that base shear decreases by significant amount when bracings are provided. Bracing system also helps to reduce the storey drift in irregular building.

5. RESULTS AND DISCUSSION

Response spectrum analysis was carried out to evaluate the performance of RCC building with floating column and transfer girder with & without bracings under the action of lateral forces. After the response spectrum analysis, following results were obtained and are represented in tabular and graphical format and compared.

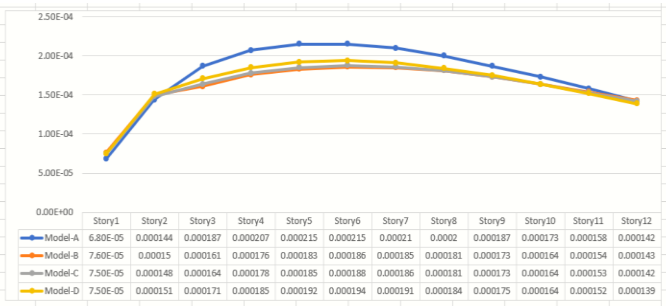
5.1 INTER-STOREY DRIFT RATIO

5.1.1 FOR SEISMIC ZONE-II



	Story1	Story2	Story3	Story4	Story5	Story6	Story7	Story8	Story9	Story10	Story11	Story12
Model-A	8.80E-05	0.000173	0.000214	0.000225	0.00023	0.000229	0.000222	0.000212	0.000198	0.000181	0.000163	0.000141
Model-B	0.0001	0.00018	0.000161	0.000172	0.000181	0.000185	0.000186	0.000182	0.000176	0.000167	0.000156	0.000142
Model-C	9.90E-05	0.00018	0.00017	0.00018	0.000187	0.00019	0.00019	0.000186	0.000179	0.000169	0.000157	0.000143
Model-D	9.90E-05	0.000182	0.000179	0.000187	0.000193	0.000195	0.000193	0.000187	0.000178	0.000167	0.000153	0.000137

Fig.5.1 Inter-storey drift ratio in X-Direction for models in seismic zone-II

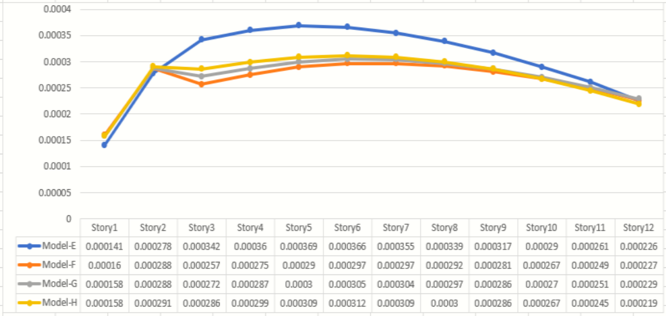


	Story1	Story2	Story3	Story4	Story5	Story6	Story7	Story8	Story9	Story10	Story11	Story12
Model-A	6.80E-05	0.000144	0.000187	0.000207	0.000215	0.000215	0.00021	0.0002	0.000187	0.000173	0.000158	0.000142
Model-B	7.60E-05	0.00015	0.000161	0.000176	0.000183	0.000186	0.000185	0.000181	0.000173	0.000164	0.000154	0.000143
Model-C	7.50E-05	0.000148	0.000164	0.000178	0.000185	0.000188	0.000186	0.000181	0.000173	0.000164	0.000153	0.000142
Model-D	7.50E-05	0.000151	0.000171	0.000185	0.000192	0.000194	0.000191	0.000184	0.000175	0.000164	0.000152	0.000139

Fig.5.2 Inter-storey drift ratio in Y-Direction for models in seismic zone-II

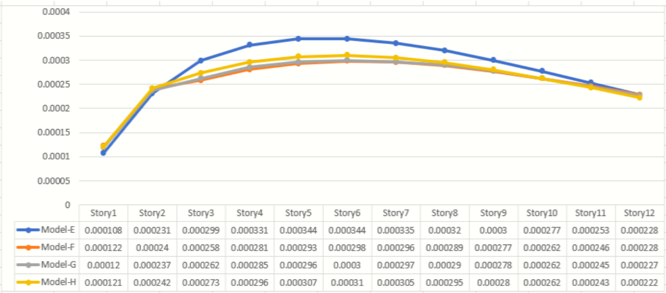
In Seismic zone-II, maximum drift ratio in X-Direction is 0.00023 without bracings whereas after providing the bracings, drift ratio reduces to 0.000181 in case of X-Bracing. In Y-Direction, maximum drift ratio without bracings is 0.000215 which reduces to 0.000183 after bracings are introduced. Hence, X-bracing is proved to be the most effective in these cases.

5.1.2 FOR SEISMIC ZONE-III



	Story1	Story2	Story3	Story4	Story5	Story6	Story7	Story8	Story9	Story10	Story11	Story12
Model-E	0.000141	0.000278	0.000342	0.00036	0.000369	0.000366	0.000355	0.000339	0.000317	0.00029	0.000261	0.000226
Model-F	0.00016	0.000288	0.000257	0.000275	0.00029	0.000297	0.000297	0.000292	0.000281	0.000267	0.000249	0.000227
Model-G	0.000158	0.000288	0.000272	0.000287	0.0003	0.000305	0.000304	0.000297	0.000286	0.00027	0.000251	0.000229
Model-H	0.000158	0.000291	0.000286	0.000299	0.000309	0.000312	0.000309	0.0003	0.000286	0.000267	0.000245	0.000219

Fig.5.3 Inter-storey drift ratio in X-Direction for models in seismic zone-III

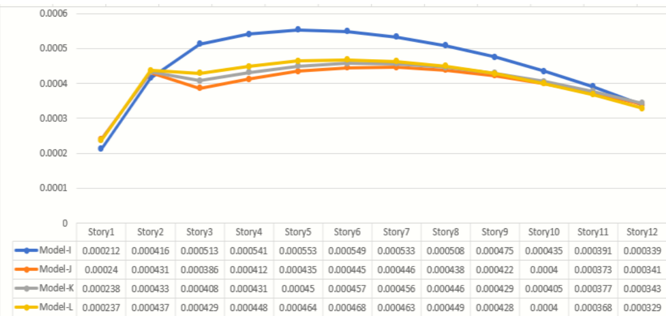


	Story1	Story2	Story3	Story4	Story5	Story6	Story7	Story8	Story9	Story10	Story11	Story12
Model-E	0.000108	0.000231	0.000299	0.000331	0.000344	0.000344	0.000335	0.00032	0.0003	0.000277	0.000253	0.000228
Model-F	0.000122	0.00024	0.000258	0.000281	0.000293	0.000298	0.000296	0.000289	0.000277	0.000262	0.000246	0.000228
Model-G	0.00012	0.000237	0.000262	0.000285	0.000296	0.0003	0.000297	0.00029	0.000278	0.000262	0.000245	0.000227
Model-H	0.000121	0.000242	0.000273	0.000296	0.000307	0.00031	0.000305	0.000295	0.00028	0.000262	0.000243	0.000222

Fig.5.4 Inter-storey drift ratio in Y-Direction for models in seismic zone-III

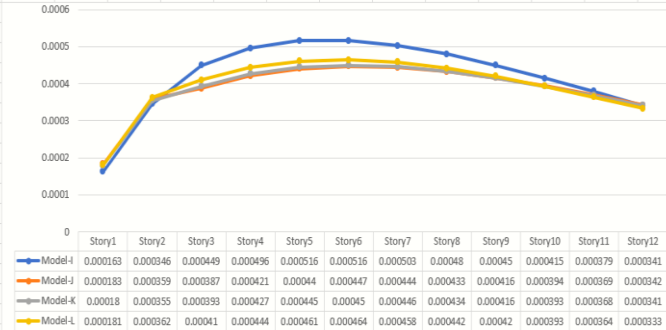
In Seismic zone-III, maximum drift ratio in X-Direction is 0.000369 without bracings whereas after providing the bracings, drift ratio reduces to 0.00029 in case of X-Bracing. In Y-Direction, maximum drift ratio without bracings is 0.000344 which reduces to 0.000293 after bracings are introduced. Hence, X-bracing is proved to be again effective in this case.

5.1.3 FOR SEISMIC ZONE-IV



	Story1	Story2	Story3	Story4	Story5	Story6	Story7	Story8	Story9	Story10	Story11	Story12
Model-I	0.000212	0.000416	0.000513	0.000541	0.000553	0.000549	0.000533	0.000508	0.000475	0.000435	0.000391	0.000339
Model-J	0.00024	0.000431	0.000386	0.000412	0.000435	0.000445	0.000446	0.000438	0.000422	0.0004	0.000373	0.000341
Model-K	0.000238	0.000433	0.000408	0.000431	0.00045	0.000457	0.000456	0.000446	0.000429	0.000405	0.000377	0.000343
Model-L	0.000237	0.000437	0.000429	0.000448	0.000464	0.000468	0.000463	0.000449	0.000428	0.0004	0.000368	0.000329

Fig.5.5 Inter-storey drift ratio in X-Direction for models in seismic zone-IV

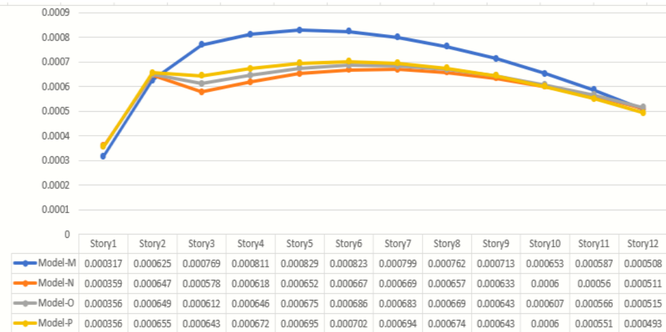


	Story1	Story2	Story3	Story4	Story5	Story6	Story7	Story8	Story9	Story10	Story11	Story12
Model-I	0.000163	0.000346	0.000449	0.000496	0.000516	0.000516	0.000503	0.00048	0.00045	0.000415	0.000379	0.000341
Model-J	0.000183	0.000359	0.000387	0.000421	0.00044	0.000447	0.000444	0.000433	0.000416	0.000394	0.000369	0.000342
Model-K	0.00018	0.000355	0.000393	0.000427	0.000445	0.00045	0.000446	0.000434	0.000416	0.000393	0.000368	0.000341
Model-L	0.000181	0.000362	0.00041	0.000444	0.000461	0.000464	0.000458	0.000442	0.00042	0.000393	0.000364	0.000333

Fig.5.6 Inter-storey drift ratio in Y-Direction for models in seismic zone-IV

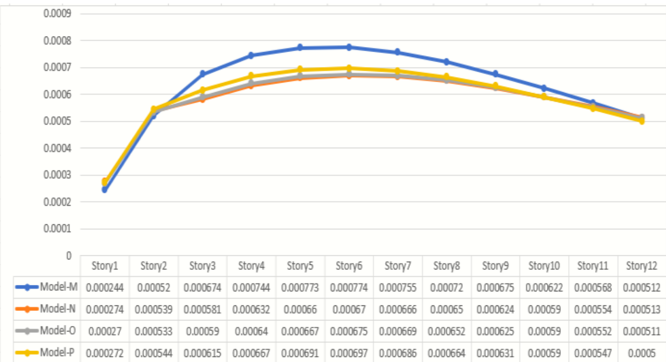
As observed in table, in Seismic zone-IV, maximum drift ratio in X-Direction is 0.000553 without bracings whereas after providing the bracings, drift ratio reduces to 0.000435 in case of X-Bracing. Also, In Y-Direction, maximum drift ratio without bracings is 0.000516 which reduces to 0.000447 after bracings are introduced. Hence, X-bracing is proved to be again effective in this case.

5.1.4 FOR SEISMIC ZONE-V



	Story1	Story2	Story3	Story4	Story5	Story6	Story7	Story8	Story9	Story10	Story11	Story12
Model-M	0.000317	0.000625	0.000769	0.000811	0.000829	0.000823	0.000799	0.000762	0.000713	0.000653	0.000587	0.000508
Model-N	0.000359	0.000647	0.000578	0.000618	0.000652	0.000667	0.000669	0.000657	0.000633	0.0006	0.00056	0.000511
Model-O	0.000356	0.000649	0.000612	0.000646	0.000675	0.000686	0.000683	0.000669	0.000643	0.000607	0.000566	0.000515
Model-P	0.000356	0.000655	0.000643	0.000672	0.000695	0.000702	0.000694	0.000674	0.000643	0.0006	0.000551	0.000493

Fig.5.7 Inter-storey drift ratio in X-Direction for models in seismic zone-V



	Story1	Story2	Story3	Story4	Story5	Story6	Story7	Story8	Story9	Story10	Story11	Story12
Model-M	0.000244	0.00052	0.000674	0.000744	0.000773	0.000774	0.000755	0.00072	0.000675	0.000622	0.000568	0.000512
Model-N	0.000274	0.000539	0.000581	0.000632	0.00066	0.00067	0.000666	0.00065	0.000624	0.00059	0.000554	0.000513
Model-O	0.00027	0.000533	0.00059	0.00064	0.000667	0.000675	0.000669	0.000652	0.000625	0.00059	0.000552	0.000511
Model-P	0.000272	0.000544	0.000615	0.000667	0.000691	0.000697	0.000686	0.000664	0.000631	0.00059	0.000547	0.0005

Fig.5.8 Inter-storey drift ratio in X-Direction for models in seismic zone-V

As observed in table, in Seismic zone-V, maximum drift ratio in X-Direction is 0.000829 without bracings whereas after providing the bracings, drift ratio reduces to 0.000652 in case of X-Bracing. Also, In Y-Direction, maximum drift ratio without bracings is 0.000773 which reduces to 0.00066 after bracings are introduced. Hence, X-bracing is useful in all the seismic zones to reduce the drift ratio.

5.2 BASE SHEAR

5.2.1 FOR SEISMIC ZONE-II

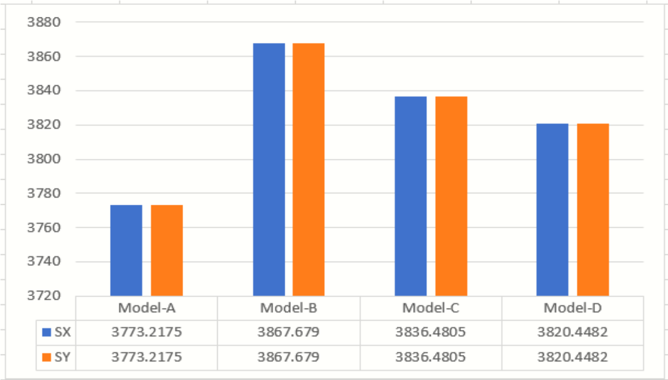


Fig.5.9 Base shear Comparison for models in seismic zone-II

As observed in graph, it can be observed that base shear for the model without bracing system is 3773.2175 kN for X & Y-Direction which increases to maximum value of 3867.679 kN in case of X-Bracing.

5.2.2 FOR SEISMIC ZONE-III

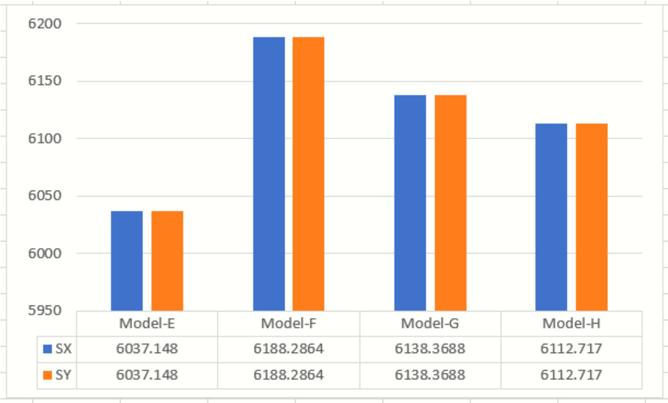


Fig.5.10 Base shear Comparison for models in seismic zone-III

It can be observed from analysis that base shear for unbraced floating column structure experience a base shear of 6037.148 kN; and for braced system, this value increases to 6188.2864 kN in case of X-Bracing.

5.2.3 FOR SEISMIC ZONE-IV

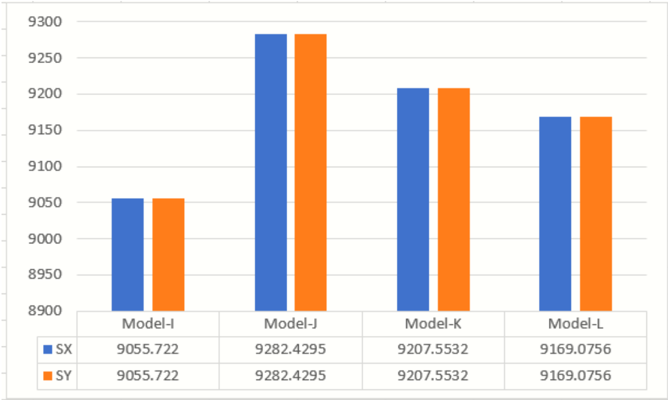


Fig.5.11 Base shear Comparison for models in seismic zone-IV

In seismic zone-IV, the base shear for unbraced structure is 9055.722 kN. After the provision of bracing, the base shear increases to 9282.4295 kN. Hence, the maximum base shear is observed in X-Bracing system.

5.2.4 FOR SEISMIC ZONE-V

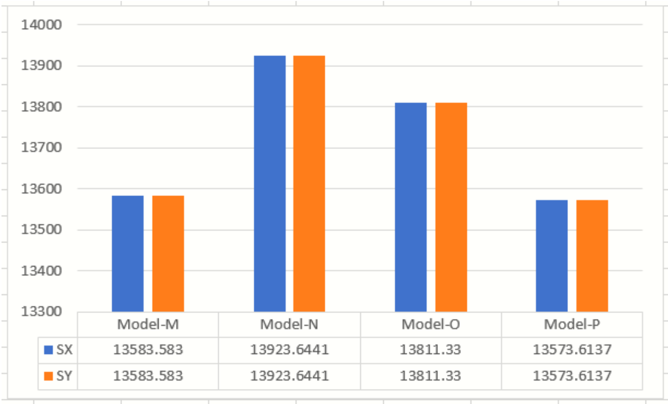


Fig.5.12 Base shear Comparison for models in seismic zone-V

In seismic zone-V, the base shear for unbraced structure is 13583.583 kN. After the provision of bracing, the base shear increases to 13823.6441 kN. Hence, the maximum base shear is observed in X-Bracing system in every seismic zone.

5.3 MODAL PARTICIPATING MASS RATIO

5.3.1 FOR SEISMIC ZONE-II

From the analysis, it was observed that slight torsion is present in first mode for the building without bracings (17.46%). After the bracing is provided, torsion is almost removed in 1st mode(2.76%) (reduced by maximum in X-bracing system).

5.3.2 FOR SEISMIC ZONE-III, IV, V

In Seismic zone-III, IV, V, 21.71% mass is participating in twisting action in 1st mode which means torsion is present in 1st mode in the building not having any bracing. But after the bracings are provided, torsion reduces to 12.16% which means it becomes translational mode. Here also, X-Bracing is proved to be the most effective.

6. CONCLUSIONS

Response Spectrum Analysis is used to study the behavior of floating column – transfer girder system with & without different types of bracings in a multistorey RCC framed structure in seismic zone II ,III ,IV, V. Based on the analysis, following findings have been drawn:

a) Base shear:

From fig. 5.9, 5.10, 5.11 & 5.12, it is clear that Base shear unbraced structure is 3773.2175 kN, 6037.148 kN, 9055.722 kN, 13583.583 in seismic zone II, III, IV, V respectively. For braced frame structure, the base shear increases to 3867.679 kN, 6188.2864 kN, 9282.4295 kN, 13923.6441 kN respectively for seismic zone-II, III, IV, V. This indicates rigidity of the structures improves when various types of bracings are provided specially for irregular structures.

b) Storey Drift:

From fig. 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, it can be observed that Storey drift ratio is found to be maximum at nearly mid-height of the structure having the values 0.00023, 0.000369, 0.000553, 0.000829 in X-Direction in seismic zone-II ,III, IV, V respectively when it is unbraced. When the bracings are provided, the storey drift ratio value decreases to 0.000172, 0.00029, 0.000435, 0.000652 in X-Direction in seismic zone-II ,III, IV, V respectively. This indicates drift of the structures decreases considerably when various types of bracings are provided.

c) Modal participating Mass ratio:

As per IS:1893-2016, torsion should not be allowed in first 2 fundamental modes of oscillation. From the analysis, it is observed that torsion is present in 1st fundamental mode of vibration having the values 0.1746, 0.2171, 0.2171, 0.2171 in seismic zone-II, III, IV, V when bracings are not provided. After the inclusion of various types of bracings, it can be observed that torsion is removed from 1st fundamental mode having the values 0.0276, 0.1216, 0.1216, 0.1216 in seismic zone-II,III,IV,V respectively. In addition to this, X-bracing is proved to be the most effective in every seismic zone as there is very negligible torsion in the first 2 fundamental modes of vibration.

Following are the concluding remark of the research work:

1. In every Seismic zone, sometimes even low-rise structures face severe problem, sometimes leading to its total collapse, use of floating column and transfer girder should be avoided; although provision of bracing can be adopted to control drift, to achieve translational modes in first 2 fundamental mode of vibration.
2. With the application of bracing, the lateral drifts are significantly reduced, and based on these findings, the ideal concentric system to use would be the X braced system, which had the best overall performance.
3. Building with X type of bracing is found to be most effective under the action of lateral loads and it is the most suitable type of bracing to increase the seismic performance of the concrete structures.
4. The V type bracing also gave better results in displacement and storey drift when compared to other models.
5. The single diagonal bracing not proved that efficient as compared to X & V-Bracings as the reduction in the displacement and drift is very less.

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