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Seismic Analysis of Concrete Structures with and without Bracings

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Abstract - 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 research, Dynamic Analysis by Response Spectrum Analysis is carried out with low-, mid- and high-rise concrete buildings with different types of bracing systems. Aim of study was to investigate and compare different results of seismic analysis of different types of structures with bracing systems and without bracing systems. For this purpose, G+4 Storey, G+12 Storey, G+16 Storey concrete building model are used with same configuration with different bracing systems such as X brace, V brace, Single diagonal edge brace. A commercial software ETABS2018 is used for analysis purpose. Results are obtained by considering the parameters like Base Shear, Displacement, Storey Drift of concrete Structures.

***Key Words*: Concrete Structure, Seismic load, Braced system, Braced framed structure, Response spectrum analysis, ETABS 2018**.

1. INTRODUCTION

Earthquake is the most dangerous phenomenon because of its unpredictability and massive devastation power. Earthquakes do not kill people; human lives and properties loss as a result of the demolition of structures. During strong earthquakes, building frames collapse, resulting in direct human loss. Various studies are carried out to determine the reason of collapse in various types of structures when they are subjected to strong seismic stimulation. Massive demolition of high-rise structures demonstrates that such an inquiry is urgently needed in emerging countries like India. People are drawn to high-rise constructions due to rapid urban population expansion, limited construction space, and high land costs. Previous earthquakes in India have demonstrated that not just non-engineered structures, but also engineered ones, must be designed to withstand seismic loads. By incorporating steel bracing into the structural system, structural response can be improved. 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.

1.1 BRACED FRAMED STRUCTURE

A braced frame is a type of structural system that is widely employed in structures that are subjected to lateral loads like wind and seismic pressure. A braced frame's members are usually built of structural steel, which can act in both tension and compression. Vertical loads are carried by the frame's beams and columns, while lateral loads are carried by the bracing system. Brace placement, on the other hand, might be troublesome since it can interfere with the façade's design and the placement of openings. Bracing has been expressed as an internal or external design feature in buildings with high-tech or post-modernist styles.

1.2 ADVANTAGES OF BRACED FRAMED STRUCTURE

1. Bracing minimizes 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.

1.3 OBJECTIVES

1. To study seismic behaviour of concrete structure with and without bracing.

2. Enhancing the Structural Stability of concrete structure during earthquake.

3. Comparative study of earthquake resistant Capacity of various Bracing Systems.

4. To recommend best suited bracing systems for concrete structure.

1.4 SCOPE OF THE STUDY

In this world of most the buildings are reinforced concrete structures, and some of them are designed for earthquake loads. And also, in reinforced concrete structures bracing system are very rarely used, so in this research Response Spectrum analysis of G+4, G+12, G+16 Storeyed reinforced concrete buildings with different type of steel bracing is carried out by using commercial software ETABS 2018, and different parameters such as Base Shear, Displacement and Storey Drift are compared.

2. MODELLING

For analysis purpose 3 types of buildings and 3 types of steel bracings are considered which are split into:

1. 4 Models of G+4 Storeyed building, one is without bracing and others are with X, V, Single edge diagonal bracings.

2. 4 Models of G+12 Storeyed building, one is without bracing and others are with X, V, Single edge diagonal bracings.

3. 4 Models of G+16 Storeyed building, one is without bracing and others are with X, V, Single edge diagonal bracings.

Different parameters such as Base shear, Story drift, Story stiffness are compared for these models. The overall plan dimension is 20mX20m. symmetric building has uniform storey height of 3m throughout. The building consist of 6 bays in both direction and steel braces are inserted in the first and last 2 bays.

3. MODEL DESCRIPTION

In this research, Response Spectrum Analysis was performed to study the behaviour of unbraced and braced frames. Analysis is carried out by using ETABS2018 software. Each building is designed using IS 1893:2016, IS 875(Part 3): 2015 and IS 456:2000. In the following Table 1. all the parameters of 12 buildings are same except the bracing type.

Table -1: Model Details

Sr no.	Parameter	Type/Value
1	Structure Type	Concrete Structure
2	Shape of Model	Square shape
3	Size of Model	20x20m
4	Number of Storey	G+4, G+12, G+16 Storey
5	Number of Models	12 Models
6	Floor to Floor height	3m
7	Slab Thickness	200mm
8	Grade of Concrete	M30
9	Grade of Steel	Fe415
10	Type of Bracing	X, V, Single diagonal Edge Bracing
11	Imposed Load	3 kN/m^2
12	Seismic zone	III
13	Zone Factor	0.16
14	Soil Condition	Type-II
15	Importance Factor	1.2
16	Response Reduction Factor	5
17	Damping Ratio	0.05

4. 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.

4.1 G+4 STOREY BUILDING MODELS

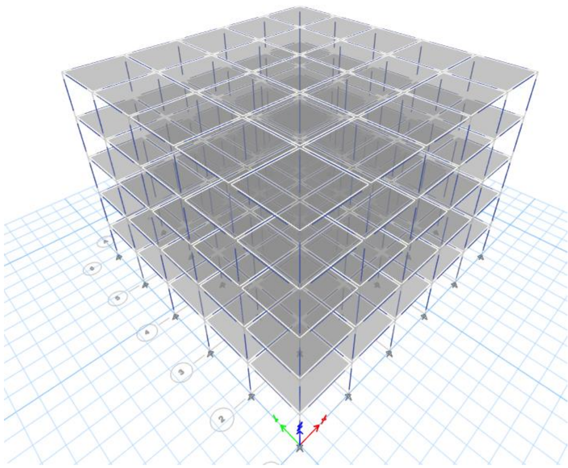

Fig 4.1 G+4 Storey model without bracing

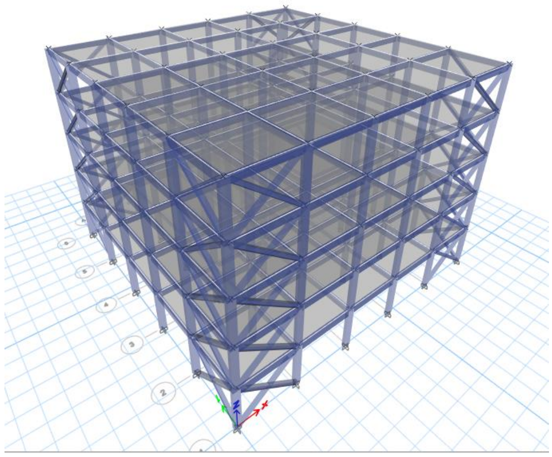

Fig 4.2: G+4 Storey model with X bracing

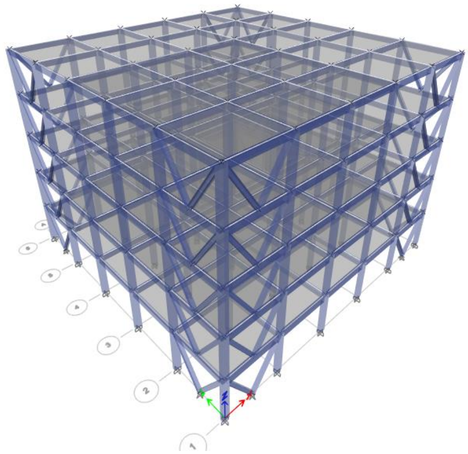

Fig 4.3: G+4 Storey with V bracing

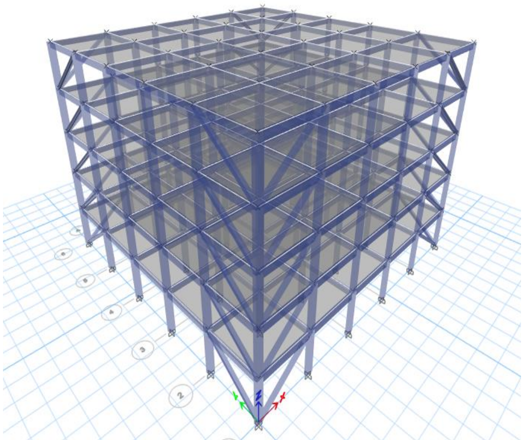

Fig 4.4: G+4 Storey model with
Single diagonal edge bracing

3D view of G+4 concrete frames 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 4 models. Bracings are provided in the end bays of frames in each direction.

4.2 G+4 STOREY BUILDING MODELS

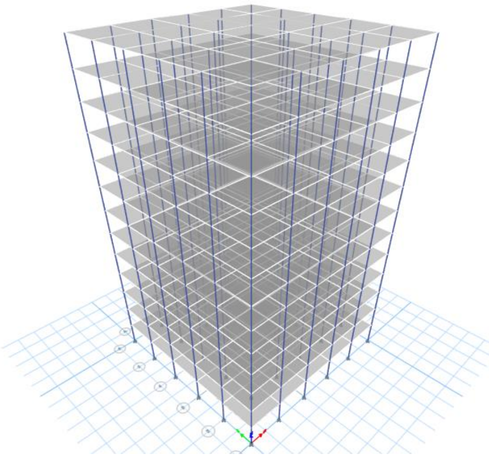

Fig 4.5: Storey model without bracing

3D view of G+12 concrete frames 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 4 models. Bracings are provided in the end bays of frames in each direction.

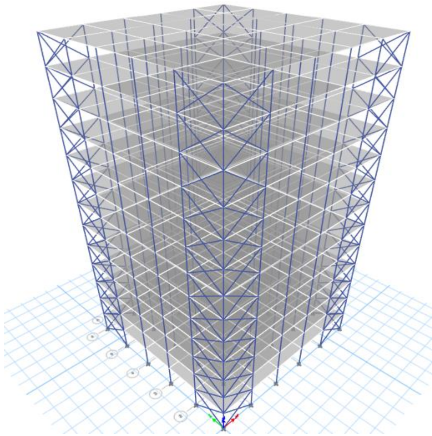

Fig 4.6: G+12 Storey model with X bracing

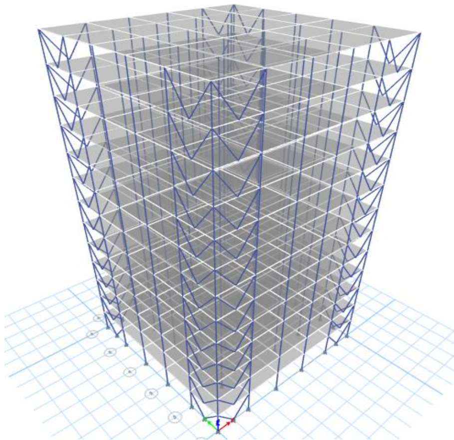

Fig 4.7: G+12 Storey with V bracing

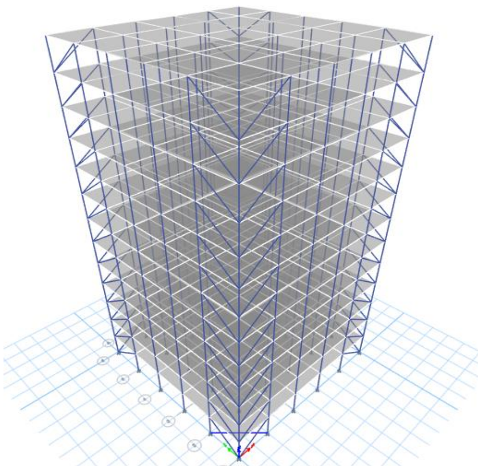

Fig 4.8: G+12 Storey model with Diagonal edge

bracing

4.3 G+16 storey Building Models

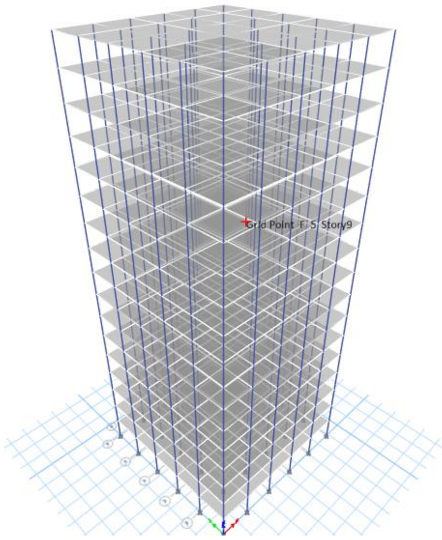

Fig 4.9: G+16 Storey model without bracing

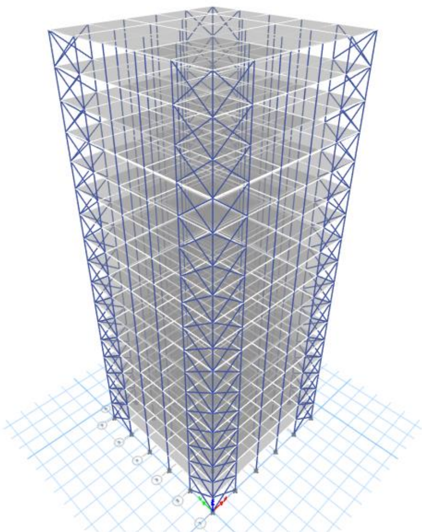

Fig 4.10: G+16 Storey model with X bracing

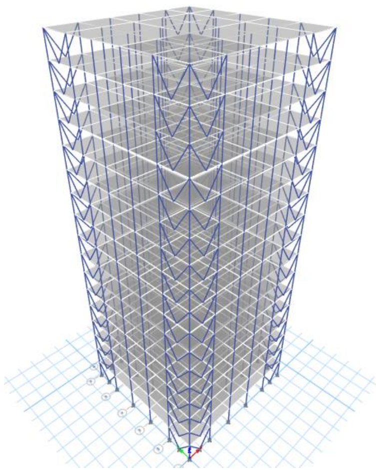

Fig 4.11: G+16 Storey with V bracing

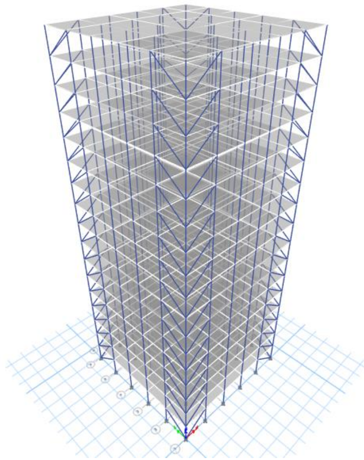

Fig 4.12: G+16 Storey model with Single Diagonal Edge bracing

3D view of G+16 concrete frames 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 4models. Bracings are provided in the end bays of frames in each direction.

After assigning the sectional properties to the concrete frame, 3D models were generated. After that Response Spectrum Analysis was performed to study the behaviour of unbraced and braced frames. Analysis is carried out by using ETABS2018 software. After analysis, we concluded that by increasing the lateral stiffness of the concrete frame, base shear of the frame will obviously increase. Here, the values of displacement, storey drift and base shear of 12 models are shown in graphical representation. Bracings change the stiffness of the moment resisting frames. Hence, it has a significant effect on the shear force and bending moment of columns as they take most of the lateral loading acting as a truss member i.e., they can take only tension or compression. The total base shear found out is smaller for smaller height building as compared to larger height. From the analysis output data, it is evident that at the same floor level the storey drift of larger height model is found to be greater than that of the smaller. Base shear of concrete frame with bracing systems increased as seismic weight of building is increased.

5. RESULTS AND DISCUSSIONS

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

5.1 RESPONSE SPECTRUM ANALYSIS RESULTS FOR G+4 STOREY BUILDING

1. Maximum Storey Displacement:

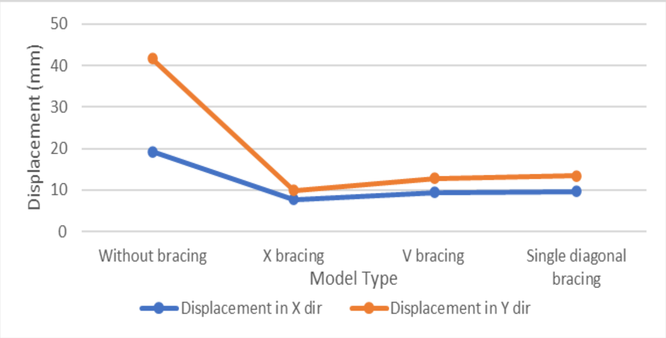

Fig 5.1: Maximum storey displacement in X, Y direction

It is observed that the storey displacement in the models with bracing is reduced compared to the displacement in the model without bracing. X bracing proved to be very effective than V and Diagonal bracing as displacement is reduced by a large amount i.e., in X direction it is 19.221mm for model without bracing and reduced to 7.704mm for model with X bracing.

2. Base Shear

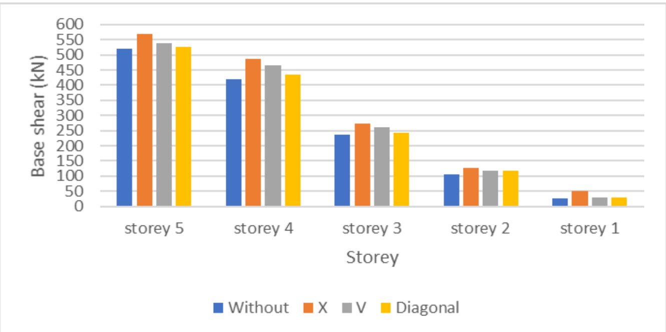

Fig 5.2: Base Shear results for G+4 storey building

It is observed that the base shear in X bracing system is more as compared to other diagonal, V bracing system. The base shear produced in X and Y direction is same because stiffness of building is same in both directions.

3. Storey Drift

The graphs of storey drift are given for X and Y direction for without and with different bracing systems

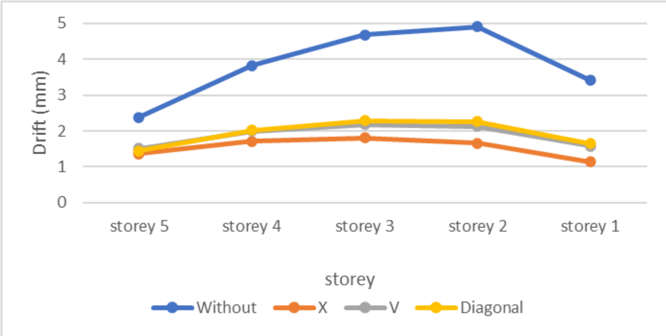

Fig 5.3: Storey drift for G+4 Storey model in X direction

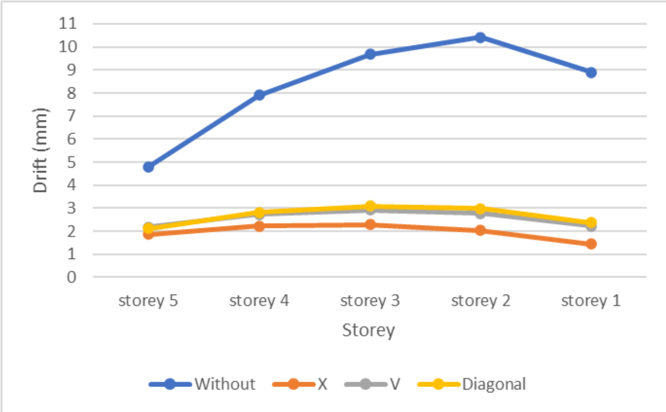

Fig 5.4: Storey drift for G+4 Storey model Y direction

It can be seen that minimum storey drift in both X and Y direction is in X bracing than other bracings. Maximum drift is observed in storey 2 i.e., 10.4mm for model without bracing and it is reduced to 2.02mm for X bracing, 2.7mm for V bracing and 2.9mm for diagonal bracing systems in X direction and same is the case for Y direction also. Other 2 bracing i.e., V and Diagonal are also proved to be effective.

5.2 RESPONSE SPECTRUM ANALYSIS RESULTS FOR G+12 STOREY BUILDING

1. Maximum Storey Displacement:

The maximum storey displacement observed is the last story of the model after the analysis is given in the graphical representation below:

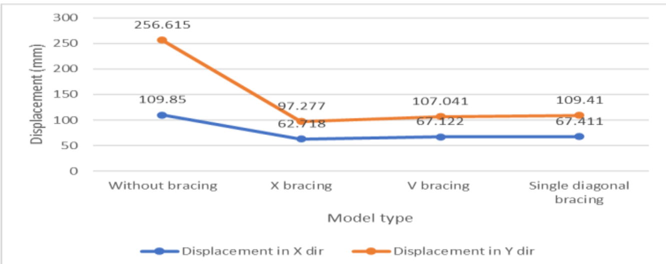

Fig 5.5 Storey displacement in X, Y direction

It is observed that the storey displacement in the models with bracing is reduced compared to the displacement in the model without bracing. X bracing proved to be very effective than V and Diagonal bracing as displacement is reduced by a large amount i.e., in X direction it is 109.85mm for model without bracing and reduced to 62.718mm for model with X bracing.

2. Base Shear

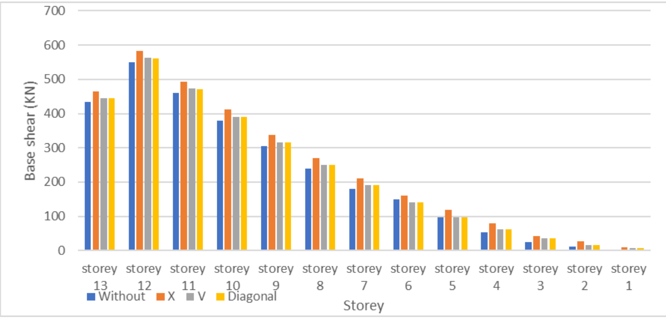

Fig 5.6: Base Shear results for G+12 storey building

It is observed that the base shear in X bracing system is more as compared to other diagonal, V bracing system. Base shear in models with V and Diagonal bracing is almost same. The base shear produced in X and Y direction is same because stiffness of building is same in both directions.

3. STOREY DRIFT

The graphs of storey drift are given for X and Y direction for without and with different bracing systems:

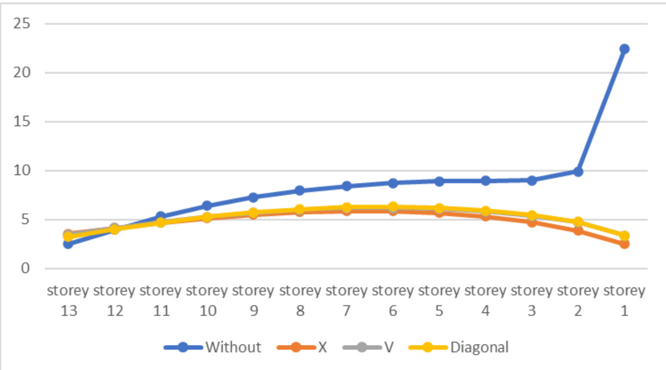

Fig 5.7: Storey drift for G+12 Storey model X direction

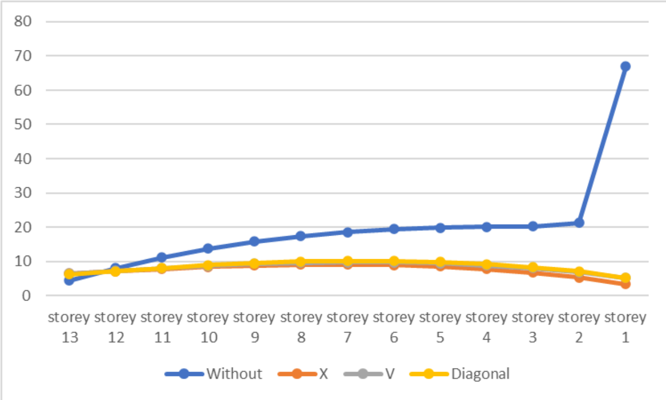

Fig 5.8: Storey drift for G+12 Storey model in Y direction

It can be seen that minimum storey drift in both X and Y direction is in X bracing than other bracings. Maximum drift is observed in storey 1 i.e., 22.447mm for model without bracing and it is reduced to 2.51mm for X bracing, 3.38mm for V bracing and 3.35mm for diagonal bracing systems in X direction and same is the case for Y direction also. Other 2 bracing i.e., V and Diagonal are also proved to be very effective.

5.3 RESPONSE SPECTRUM ANALYSIS RESULTS FOR G+16 STOREY BUILDING

1. Maximum Storey Displacement:

The maximum storey displacement observed is the last story of the model after the analysis is given in the graphical representation below:

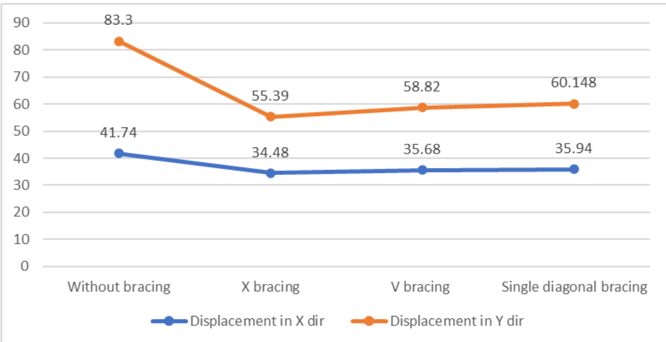

Fig 5.9: Maximum storey displacement in X, Y direction

It is observed that the storey displacement in the models with bracing is reduced compared to the displacement in the model without bracing. In this model the displacement reduced for models with bracing is almost same for all 3 bracing systems. A large decrease is observed in Y direction as displacement is 83.3mm for model without bracing and it is reduced to 55.39mm for model with X bracing.

2. BASE SHEAR

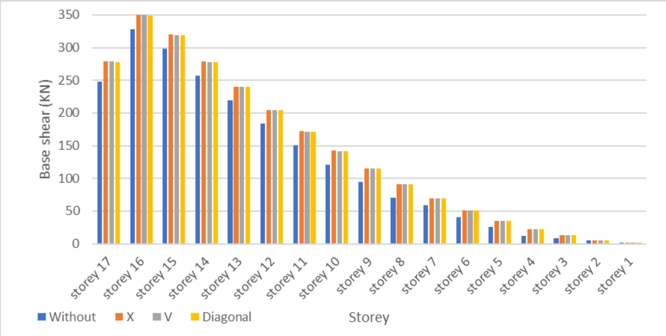

Fig 5.10: Base Shear results for G+16 storey building

It is observed that the base shear in models with bracing is increased compared to models without bracing. Base shear in models with X, V and Diagonal bracing is almost same. The base shear produced in X and Y direction is same because stiffness of building is same in both directions.

3. STOREY DRIFT

The graphs of storey drift are given for X and Y direction for without and with different bracing systems:

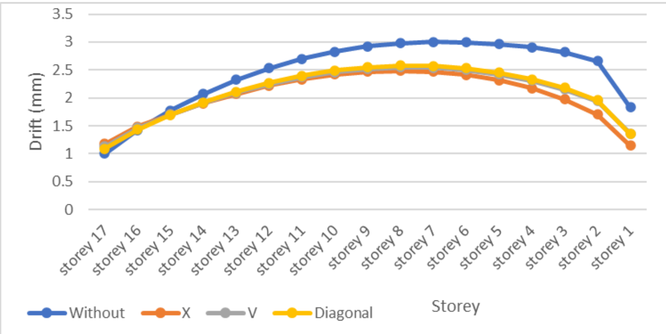

Fig 5.11: Storey drift for G+16 Storey model x direction

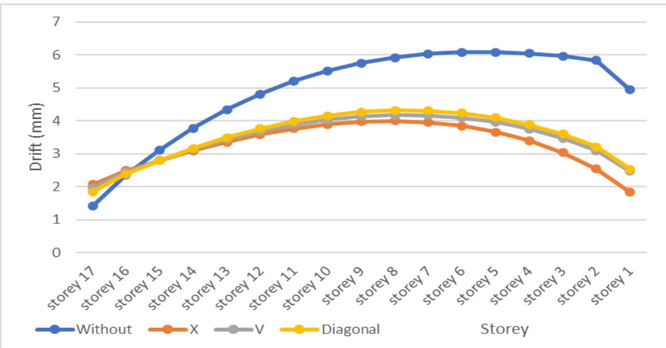

Fig 5.12: Storey drift for G+16 Storey model Y direction

It can be seen that minimum storey drift in both X and Y direction is in X bracing than other bracings. Maximum drift is observed in storey 6 i.e., 2.995mm for model without bracing and it is reduced to 2.41mm for X bracing, 2.49mm for V bracing and 2.53mm for diagonal bracing systems in X direction and same is the case for Y direction also. Other 2 bracing i.e., V and Diagonal are also proved to be very effective.

6. CONCLUSIONS

Response Spectrum Analysis is used in this study to determine which type of bracing is most suitable in resisting lateral deformation in a multistory RC framed building. The seismic analysis is carried out using the assumption that all of the structures are in seismic zone III. Based on the analysis, the following findings have been drawn:

1. Maximum storey displacement:

The maximum storey displacement of the model is reduced by X bracing is more than V and diagonal bracing. X bracing reduced the displacement by 59% in G+4 Storey, 43% in G+12 Storey, 17% in G+16 Storey models.

2. Base shear:

The increase in the base shear is almost same for all 3 types of bracing systems. The base shear is increased by 8.7% in G+4 Storey, 5.61% in G+12 Storey, 6.19% in G+16 Storey models. The increase in base shear for X and Y direction is same as stiffness is same for both directions.

3. Storey drift:

The decrease in storey drift is more in models with X bracing than models with V and diagonal bracing. In X direction Storey drift is decreased by 66.19% for G+4 Storey, 88.19% for G+12 Storey and 20% for G+16 Storey models and in Y direction it is decreased by 80.5% for G+4 Storey, 86.4% for G+12 Storey and 40% for G+16 Storey.

Following are the concluding remarks of the research work:

1. Steel bracings are proved effective and can be used as an alternative to the other strengthen or retrofitting techniques for the structures.
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 edge bracing also gave positive results but after comparing the results it is not a suitable bracing system for concrete structures compared to X and V bracing as the reduction in the displacement and drift is very less

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