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The Effect of Edge Beams in The Static and Dynamic Seismic Analysis of High-Rise Building Structures

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ABSTRACT
The demand of high-rise building increases widely in many crowded cities as New York and east Asia and many other cities of high economic value as Dubai. The high increase in building height is accompanied with an increase of drift and maximum displacements for the structures subjected to seismic and wind load as well. In this study the moment resisting frame and shear wall and a combination of both are studied for the effect of seismic loading. The location of the moment resisting frames and the shear walls is an important parameter in this study. The edge beams for the building structures is used to decrease the maximum displacements and drift for the high-rise structures. A static and dynamic analysis using commercial software are used to monitor the main parameters studied. A comparison between the static and dynamic analysis is done according to the ASCE-7-10 and design according to the ACI 318-14. The study pointed that the maximum displacements and drift is more critical in the static analysis and the edge beams used in the model cases studied, showed a great reduction in drift and maximum displacement as well. The study also monitored that the shear wall length is a major factor in resisting lateral loading and decreasing the drift and displacement especially if the wall is of one unit length in the direction of loading. Dividing the wall length in the direction of loading affects much in resisting the drift and displacements. This study focuses on the high benefit of using edge beams in high-rise concrete structures.

Keywords: *edge beams, drift, moment resisting frame, shear walls, lateral seismic loading.*

1. Introduction

The increase of the high-rise buildings all over the world led the author to study the behavior of seismic loading on medium and high-rise concrete structures.
A Thirty storeys building concrete structures is studied using different systems cases as moment resisting frame, shear wall and dual system of moment resisting frame and shear wall.
The edge beams for the building structures is used to decrease the maximum displacements and drift for the high-rise structures [1]. A static and dynamic analysis using ETABS software [2] are used to monitor for the main parameters studied. The maximum displacements and drift were checked with in the allowable range. The study was done according to the ASCE-7-10 [3] and the ACI 318-14 [4].
Recently many research papers studied different types of systems of high-rise concrete building structures [5-12]
Singh et al [13-14], in there study carried out on a five and a ten storied buildings with identical plan. Maximum inter-storey drifts of the buildings at collapse have been compared with the limiting value of maximum inter-storey drifts corresponding to gravity shear ratio, given in literature. It is found that most of the buildings analyzed here are collapsing at an inter-storey drifts lower than that prescribed in literature.
Keskar. Rautn [15], In the present work, a G+9 multistoried commercial building having flat slab with and without shear wall and has been analyzed. Comparative study of these structures are analyzed on the parameters like base period, base shear, storey drift and storey displacements. As compared to the conventional frame structure model and flat slab with shear wall model behavior is better than flat slab without shear wall model.
Medasana, Chintada[16], studied and compared the seismic performance of Thirty storeys high-rise buildings with conventional beam slabs, flat slabs and alternate flat –beam slab
Story drift in buildings with flat slab construction is significantly more as compared to beam slab building. The drift values of alternate flat slab –beam slab

buildings lies in between the two structures but somewhat nearer to the beam slab building. (due to rigidity of the beam slab structure).As a result of high drift ratios in flat slab building, additional moments are developed and columns of such buildings should be designed by considering additional moment caused by the drift.

The primary function of edge beams lies in their contribution to the lateral stability of high-rise structures. By forming a stiff perimeter ring around the building, they resist wind loads and earthquake forces that could cause lateral sway or even collapse. Edge beams act as horizontal trusses, transferring lateral loads to the core and columns, effectively reducing the bending stresses on the main structure. This enhanced stability allows architects to design taller and slender buildings, pushing the boundaries of architectural expression.

Edge beams not only bolster lateral stability but also play a crucial role in distributing gravity loads throughout the structure. They act as transfer beams, receiving loads from floor slabs and transmitting them to the columns and core. This efficient load distribution helps optimize the design of other structural elements, reducing material requirements and minimizing overall construction costs. Additionally, edge beams help mitigate stress concentrations in the main structure by providing additional support and stiffness at critical points.

The influence of edge beams extends beyond their purely structural contributions. They can be instrumental in shaping the architectural aesthetics of high-rise buildings. By creating clean lines and defined edges, edge beams can add visual interest and sophistication to the façade. They can also provide a platform for incorporating architectural features like sunshades, balconies, and decorative elements. Moreover, edge beams can enhance the functionality of the building by offering additional space for mechanical and electrical systems, potentially improving space utilization and efficiency.

2. Research Significance

The presented study is the key solution of the most effective factor in the analysis and design of high-rise concrete structures which is the maximum displacements and drift. The edge marginal beam for the high-rise buildings is the magic solution to decrease much the displacements and drift for the high-rise structures. The research was done using 3 types of edge beams (300x800), (300x1000) and (300x1200) although the latest one was given in this study for it had the best enhancement and decrease for both displacements and drift and assure the studied concrete structures to be permitted to the code.

3. Buildings Models Geometry

The plan dimensions is of 28 meters x 20 meters, which is four spans of 7 meters in y direction and four spans of 5 meters in x direction as shown in Figures (1a)and (1b).

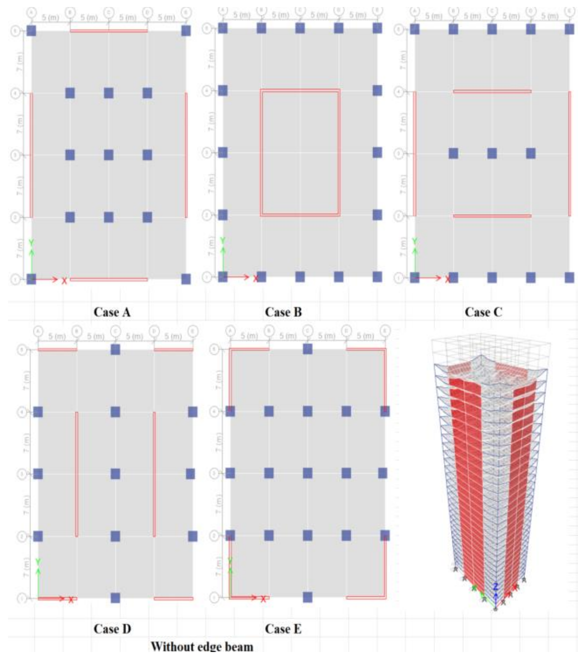

Figure (1a) different cases of shear walls location without edge beams.

Case A is 10 meters length double shear wall in the outer edge of the building in x direction and 14 meters in y direction. Although in case B the same dimensions of shear walls in x and y direction but in the inner edge. Case C is the same dimension of shear walls but the shear walls in x direction in the x direction is an inner walls and outer edge shear walls in y direction.

Case D the shear walls in y direction is an inner walls and the shear walls in x direction s have same dimensions but divided into 4 walls of less inertia.

Case E all the shear walls in x and y directions are in the outer edge and divided into 4 walls in each direction.

Using edge beams with all cases models will affects much the behavior of such concrete structures and behaves as a moment resisting frame in cooperation with the considered shear wall taken to be dealt as a dual system to overcome the lateral loading.

For a true comparison study procedure for the behavior of all model cases the response factor R will be kept constant, although it is well known to be taken according to the ASCE-7-10 standards of the building system.

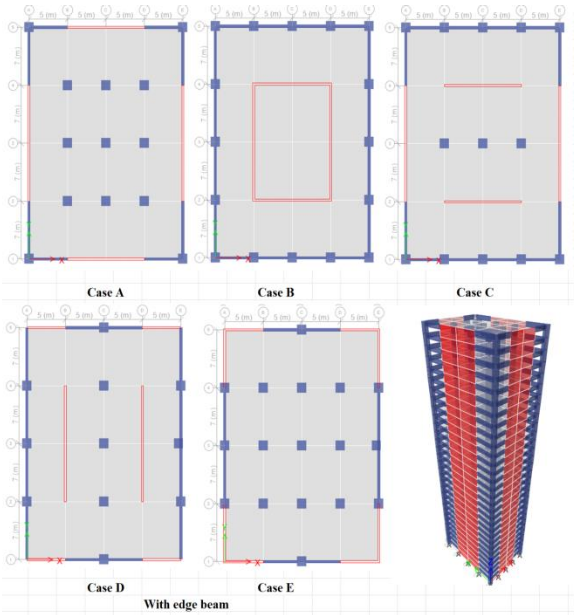

Figure (1b) different cases of shear walls location with edge beams.

3.1 Materials and Methods

Thirty storeys building of 3.0 meters floor height, The dimensions of the building is constant according to the model case, but the total building area=560m^2 as shown in Figure 1.The material compressive strength of concrete and the yield of steel are Fc'=27.5 MPa and Fy=415MPa respectively , Column size is 1200 ×1200 mm^2,constant for all height of the model used, Beam size :800 x300 and 1000 x 300 also 1200 ×300 mm^2 as an edge beam for the residential Building and compared with the cases of models without edge beams.

3.2 Loading Conditions

Typical dead loads consist of (a) the self-weight of the slabs, considering the 200-mm slab thickness. (b) floor finish load of 1.5 kN/m^2, (c) wall load of 2.5 kN/m^2; (d) live load of 3 kN/m^2, (e) earthquake loads as per ASCE 7-10, Seismic Zone 3 in USA, Seismic Design Category D, Zip code 98122 and site class D,(f) with a response modification factor of 5, system over strength of 3 and deflection amplitude of 4.5; (g) importance factor of 1; and (h) damping of 5% and 90 mode shapes.

4. Analysis of The Results

The most important parameters in the behavior of high-rise building structures is the maximum displacement and drift for the seismic loading, Figure 2 showed that the maximum displacement in x direction is clear in cases D and E of least shear wall dimension in x direction and the Figure pointed well the usage of edge beam as it reduced the maximum displacement for all cases especially D and E by nearly more than one third the maximum displacement occurred without using the edge beam.

The next Figure (2) showed that the model case B of the inner shears in both directions monitored the least displacement and drift as well in Figure 3. Case D and E showed the most displacements and drift for the case of divided 4 shear walls in x direction outer edge walls. (Case E have more columns to resist in x direction thus have less displacements).

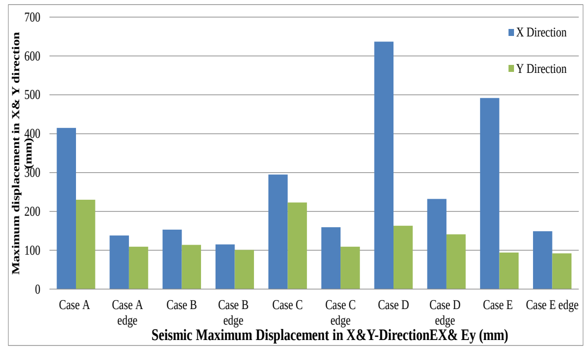

Figure (2) Maximum displacement in x and y direction for seismic static loading.

The maximum displacements in y direction is in the cases A and C where the shear walls are outer edge.

Figure 3 presents all model cases with and without marginal edge beam used and it is recognized that the maximum drift behaved as well as the maximum displacement of the building structure as shown in Figure 3. Also the two extreme cases D and E have drift more than all others cases as discussed before. The drift calculated in the two cases were not permitted values by the ASCE7-10 code in drift although using the edge beam decreased much the drift within the allowable range permitted by the code.

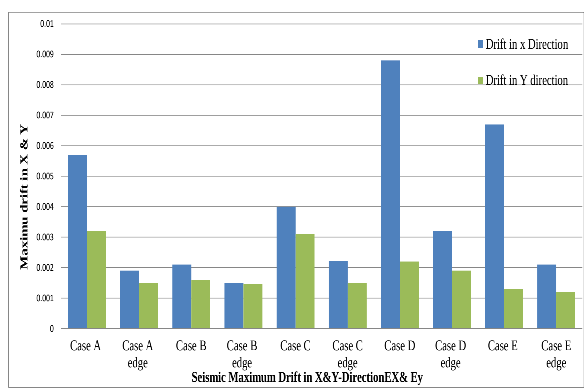

Figure (3) Maximum drift in x and y direction for seismic static loading.

All the other models having drift values permitted by the code and also decreased much when using the edge beam as given in the Figure.

The stiffness and inertia for the shear walls and moment resisting frame played the major role in the behavior of high-rise buildings and the maximum displacement and drift calculated.

The base shear in both directions x and y are calculated for all model cases as shown in Figure 4, The base shear is nearly similar in both directions for the plan dimensions used although it is a bit more in y direction.

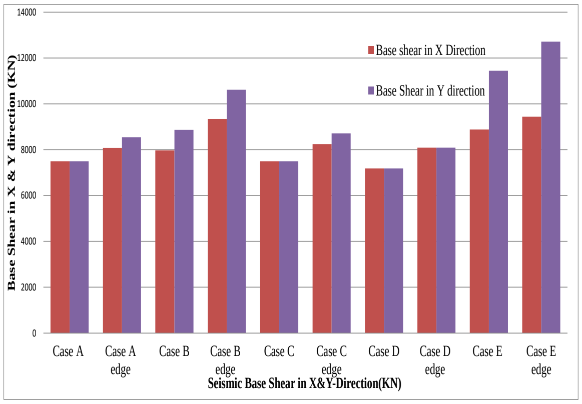

Figure (4) Maximum Base shear in x and y direction for seismic static loading.

Case E with and without edge beam monitored the most base shear for all models and also increased in the y direction.

Using edge beam increases the base shear in both directions.

The time period in all cases are nearly the same 2 sec. for using 30 storey building structures for all model cases and the difference shown in the Figure (5) is due to the system used and the shear wall dimensions and location although it is well shown that the time period in x direction is more than y direction with small values.

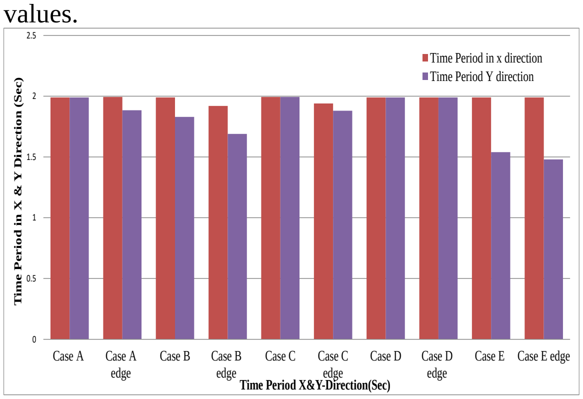

Figure (5) Time period in x and y direction for seismic static loading.

The maximum displacement in x and y direction was monitored in all cases subjected to lateral seismic static and dynamic loading, the values in Figure 6 and Figure 7 showed that the static displacements are more critical than the dynamic in all model cases especially after taking the scale factor for dynamic loading to account for constant base shear in both static and dynamic models.

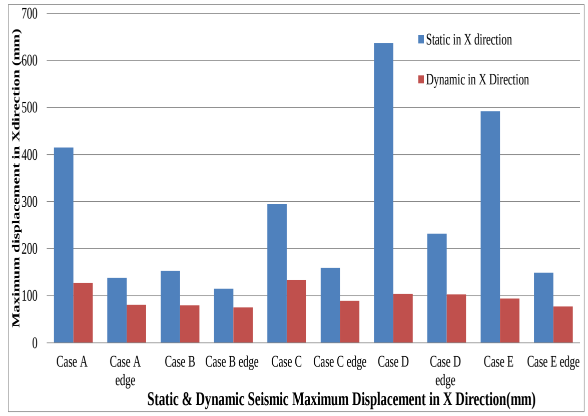

Figure (6) Maximum displacement in x direction for seismic static & dynamic loading.

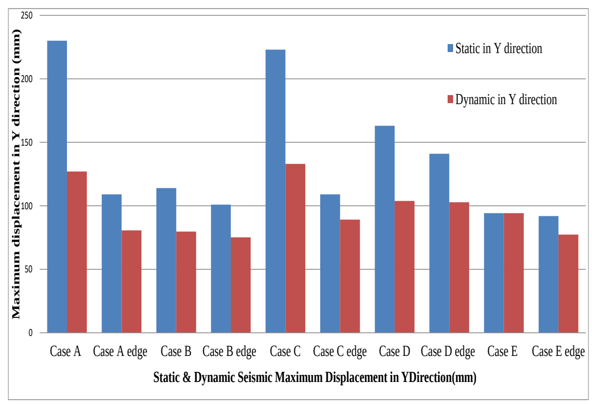

Figure (7) Maximum displacement in y direction for seismic static & dynamic loading.

The maximum drift in x and y reported in the Figure 8 and Figure 9 for both static and dynamic loading showed an increase in drift for static than dynamic but the variation is not great. Although the case D and E also reported a high increase between static and dynamic in x direction and cases A and c in y direction.

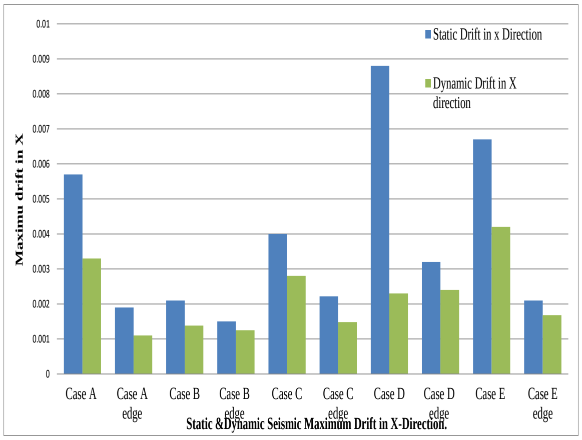

Figure (8) Maximum drift in x direction for seismic static & dynamic loading.

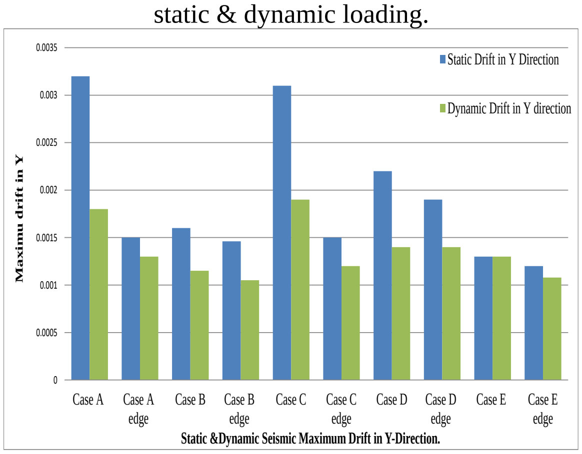

Figure (9) Maximum drift in y direction for seismic static & dynamic loading.

Studying the dynamic loading as well , the maximum displacement for all cases studied were given in the next Figure 10, which also gave the same behavior for the static case but of less values. The scale factor taken for all dynamic model was between 3 and 4.5 to assure the same base shear for static and dynamic analysis. These values are reasonable for the system used either moment resisting frame or shear wall or both.

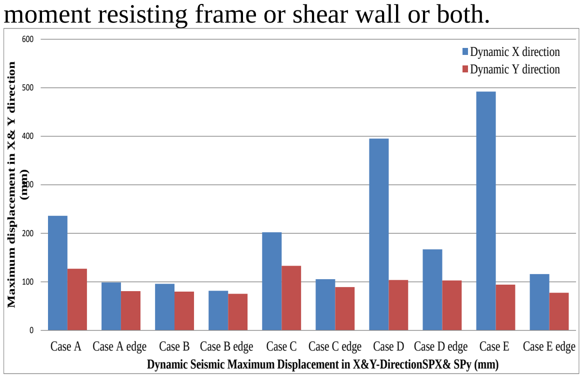

Figure (10) Maximum displacement in x & y direction for seismic dynamic loading.

Figure(11) showed the drift in both directions for all cases subjected to dynamic loading and the behavior of drift is similar to the displacements in the previous Figure to assure the bond between maximum displacement and drift in high-rise buildings.
Studying all model cases,

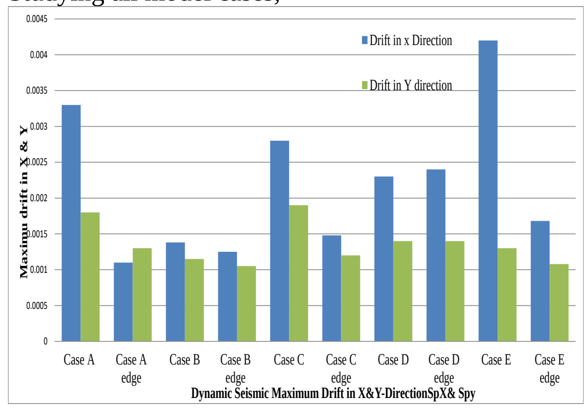

Figure (11) Maximum drift in x & y direction for seismic dynamic loading.

Case A.(with and without edge marginal beam).

The edge beam decreased the maximum displacements in static lateral seismic loading by 67% in x direction and 52 % in the y direction as shown in Figure (12) and Table 2. Although, in the dynamic analysis the edge beam decreased the maximum displacement by 58% in x direction and 37% in y direction.

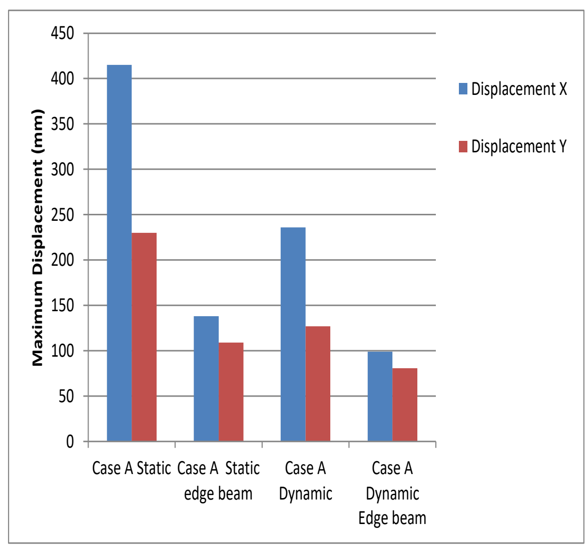

Figure (12) Maximum displacement in case (A) subjected to static and dynamic loading

Case B.(with and without edge marginal beam).

The edge beam decreased the maximum displacements in static lateral seismic loading by 24%

in x direction and 11 % in the y direction as shown in Figure (13) and Table 2. These percentage of decrease is much less than the case A for the shear walls in model A is in the outer edge with the edge beam although model B the shear walls are in the inner core of the building as shown in Figure (1).

.Although in the dynamic analysis the edge beam decreased the maximum displacement by 15% in x direction and 6% in y direction.

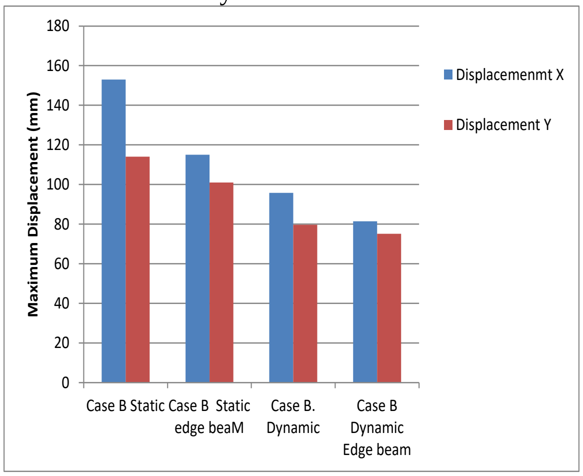

Figure (13) Maximum displacement in case (B) subjected to static and dynamic loading.

Case C (with and Without edge marginal beam)

The edge beam decreased the maximum displacements in static lateral seismic loading by 46% in x direction and 51 % in the y direction as shown in Figure (14) and Table 2. Although, in the dynamic analysis the edge beam decreased the maximum displacement by 48% in x direction and 33% in y direction.

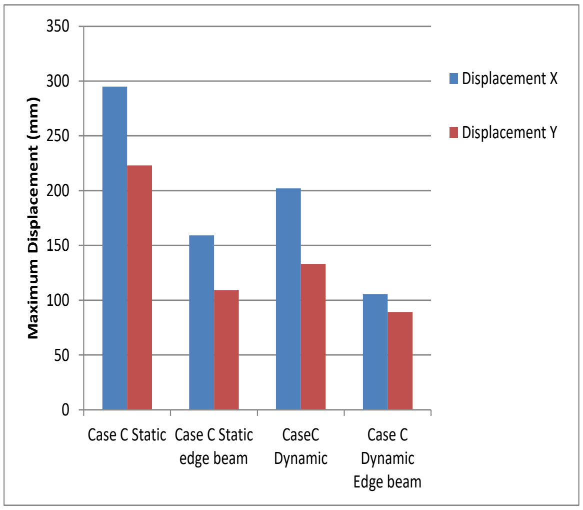

Figure (14) Maximum displacement in case (C) subjected to static and dynamic loading.

Case D (with and Without edge marginal beam)

The edge beam decreased the maximum displacements in static lateral seismic loading by 63% in x direction and 13 % in the y direction as shown in Figure (15) and Table 2. Although, in the dynamic analysis the edge beam decreased the maximum displacement by 57% in x direction and 0.9% in y direction.

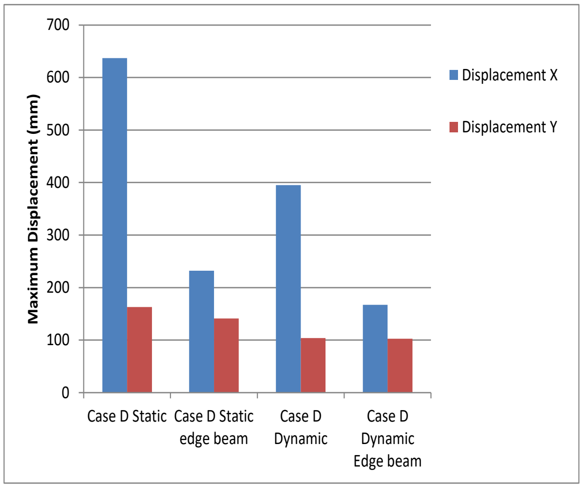

Figure (15) Maximum displacement in case (D) subjected to static and dynamic loading.

The wide variation of displacements in x and y directions is most in model case D for the shear walls in y directions is in the inner and of greater dimensions and inertia although the x direction we have outer shear walls and divided into 4 instead of 2 walls in x direction. It is well recognized that the case E in Figure (16) have more columns that made the variation to be limited.

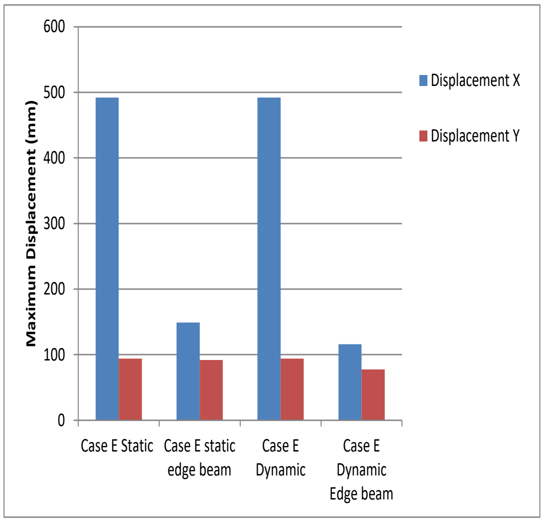

Figure (16) Maximum displacement in case (E) subjected to static and dynamic loading.

Case E (with and Without edge marginal beam)

The edge beam decreased the maximum displacements in static lateral seismic loading by 70% in x direction and 2.5 % in the y direction as shown in Figure (16) and Table 2. Although, in the dynamic analysis the edge beam decreased the maximum displacement by 76% in x direction and 17% in y direction.

In order to complete a full view of the behavior of high-rise buildings in different model cases with and without marginal edge beam, a comparison is made for the drift due to seismic load calculated for all models. The reduction of the maximum storey drift and displacements is given in the previous Table 2.

Table 1: Displacements and Story drift and base shear for all model cases

Analysis Type	Model	Displacements		Story Drift		Base Shear (KN)
		X (mm)	Y (mm)	X (mm)	Y (mm)	
Static (ELF)	Case A	415	230	0.0057	0.0032	7500
	Case B	253	114	0.0021	0.0016	7972
	Case C	195	223	0.004	0.0031	7500
	Case D	637	236	0.0088	0.0022	7185
	Case E	492	94.2	0.0067	0.0013	11443
Dynamic (RS)	Case A	236	127	0.0033	0.0018	7500
	Case B	95.8	79.7	0.00138	0.00115	7972
	Case C	202	133	0.0028	0.0019	7500
	Case D	395	103.8	0.0023	0.0014	7185
	Case E	492	94.2	0.00168	0.0013	11443
Static (ELF) Edge beams	Case A	138	109	0.0019	0.0015	8076
	Case B	115	101	0.0015	0.00146	9341
	Case C	159.2	109	0.00222	0.0015	8246
	Case D	232	141	0.0032	0.0019	8086
	Case E	149	91.9	0.0021	0.0012	9,440.00
Dynamic (RS) Edge beams	Case A	98.8	80.7	0.0011	0.0013	8076
	Case B	81.4	75.15	0.00138	0.00105	9341
	Case C	105.4	89.12	0.00148	0.0012	8246
	Case D	167	102.8	0.0024	0.0014	8086
	Case E	116	77.4	0.00108	0.00108	9440

Table 2: Reduction of Displacements and Story drift using edge beams

Percentage of reduction (%) using the edge beams					
Analysis Type	Model	Displacements		Story Drift	
		X (mm)	Y (mm)	X (mm)	Y (mm)
Static (ELF)	Case A	0.66747	0.526087	0.666667	0.53125
	Case B	0.545455	0.114035	0.285714	0.0875
	Case C	0.18359	0.511211	0.445	0.516129
	Case D	0.635793	0.402542	0.636364	0.136364
	Case E	0.697154	0.024416	0.686567	0.076923
Dynamic (RS)	Case A	0.581356	0.364567	0.666667	0.277778
	Case B	0.150313	0.057089	0	0.086957
	Case C	0.478218	0.329925	0.471429	0.368421
	Case D	0.577215	0.009634	-0.04348	0
	Case E	0.764228	0.178344	0.357738	0.17

5. Summary and Conclusions

In conclusion, edge beams, often unassuming yet vital components, play a multifaceted role in shaping the structural integrity and performance of high-rise concrete structures. Their influence on lateral stability, load distribution, stress mitigation, and architectural aesthetics makes them essential elements in the design and construction of these towering incredibles. By recognizing and appreciating the diverse contributions of edge beams, engineers and architects can continue to push the boundaries of high-rise construction.

The performance of seismic loading in high-rise concrete buildings structures monitored that the drift and displacements are the most effective parameters that increases much with the increase of the numbers of floors and height of the building. The system used is the main factor of resisting lateral loading. In this study introducing marginal edge beam with the system used enhanced much the decrease of drift and displacements in the studied system.

1-The stiffness and inertia for the shear walls and moment resisting frame played the major role in the behavior of high-rise buildings and the maximum displacement and drift calculated, as the length and location are taken in the studied models.

2-The maximum displacement in x and y direction was monitored in all cases subjected to lateral seismic static and dynamic loading, the values showed that the static displacements are more critical than the dynamic in all model cases.

3-The base shear for dynamic analysis is nearly about 3 to 4.5 times the base shear for the static analysis in the systems of moment resisting frame or shear wall or both.

4-The edge beam decreased the maximum displacements in static and dynamic lateral seismic loading by (12-76 %) and Table 2 illustrated these values.

5-The usage of marginal edge beam enhanced the model to resist drift by great extent and shifted the model D and E from being unsafe drift to be within the permitted code range.

6-The model of the inner shear walls in both directions showed the least displacement and drift as well and the outer divided shear walls. showed the most displacements and drift.

7-In choosing the system for high-rise concrete building structures it is advisable to take inner shear walls than the outer edge ones and use the outer edge beam than the inner beams to reduce the maximum displacements and drift.

8-The use of edge beam increases the base shear in the direction of the edge beam.

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