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Unveiling the Resilience: Performance of Circular High-Rise Concrete Buildings under Lateral Loading using ring beams and bracing systems

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ABSTRACT
The ever-evolving architectural landscape has welcomed the emergence of circular high-rise concrete buildings as elegant and efficient solutions. Yet, their unique geometry poses critical questions regarding their performance under lateral loading, such as wind and earthquakes. This research delves into the intricacies of their behavior, analyzing their strengths, limitations, and potential failure modes when subjected to these forces. Through theoretical analysis, experimental testing, and numerical simulations, this paper aims to unveil the resilience of circular high-rise concrete buildings under lateral loading, providing valuable insights into their safe and optimal design. High-rise concrete buildings face unique challenges due to their susceptibility to lateral loads such as wind and seismic activity. Ring beams, horizontal structural elements encircling the building perimeter, play a crucial role in enhancing the overall performance of these structures. This research paper investigates the influence of ring beams and bracing systems on the structural behavior of high-rise concrete buildings, focusing on their impact on stiffness, strength, stability, and overall performance under seismic loading conditions. The study was performed using linear static analysis and nonlinear static of pushover analysis. The study pointed out some major guidelines in choosing the right system, For the residential buildings in the moderate zones the system of shear walls is sufficient, however, the moderate zone to high zone using a ring beam system in circular buildings is the best alternative in the analysis and design, although in high zones choosing the bracing system will be the best solution, also in the highest seismic zones areas the bracing system of X-type and two spans acts as a restrained two bay frame, which will decrease much the drift and maximum displacement into the permitted range.

Keywords: *Circular, Shear wall, Ring beams Seismic loading, Pushover, Bracing system.*

1. Introduction

The rapid advancement of construction technology has led to a burgeoning demand for high-rise buildings. These structures, while aesthetically pleasing and space-efficient, are inherently susceptible to lateral loads from wind and earthquakes. To ensure the safety and integrity of these buildings, engineers employ various strategies, including the strategic placement of ring beams.
Circular high-rise concrete buildings offer several advantages over traditional rectangular structures, including panoramic views, improved seismic performance, and efficient material utilization. However, their cylindrical shape presents unique challenges in ensuring their stability under lateral loads. Understanding their response to these forces is paramount for safe and sustainable design. This paper addresses this knowledge gap by providing a comprehensive analysis of their behavior under earthquake loads, contributing to the advancement of high-rise construction technology. Four major cities in the United States of America were chosen due to their high seismic area zones Las Vegas, Seattle, Los Angeles, and Berkeley in Western California. The concrete circular building structure was subjected to seismic load according to the ASCE 07-2022 and IBC 2003 and using finite element software as ETABS to solve the analysis of the twenty-five floors tower using static and dynamic analysis methods. The Analysis was done starting from the less seismic effect zone (Las Vegas) to the highest zones (Western California). The Permitted value of Drift according to the ASCE 07-2022 code was checked for all models in this research. Then a pushover analysis was done to represent the true performance of the various systems used.

Ring Beam Systems are some common structral engineering principles given in many references as Building Codes and Standards: These often implicitly or explicitly refer to the benefits of continuous structural elements like ring beams. Examples include the IBC (International Building Code) and seismic design standards like ASCE 7-22. Also, Anil K. Chopra [1] discussed the importance of structural continuity, stiffness, and energy dissipation in seismic performance, concepts directly related to the functions of ring beams.
These common facts are:

Increase Stiffness: By forming a continuous horizontal band around the building core, ring beams enhance the overall stiffness of the structure. This translates to reduced lateral deflections under wind and seismic loads, improving the building's resistance to sway and ensuring occupant comfort.
Improve Strength: Ring beams act as load-bearing elements, distributing vertical loads from slabs and columns more efficiently throughout the structure. This reduces stress concentrations on individual columns and walls, contributing to the overall strength and load-carrying capacity of the building.
Enhance Stability: By connecting columns and shear walls around the perimeter, ring beams create a rigid diaphragm that resists torsional forces induced by wind and seismic activity. This enhanced stability ensures the building's overall equilibrium and prevents potential twisting under lateral loads.
Provide Confinement: Ring beams confine concrete around columns and shear walls, improving their compressive strength and ductility. This confinement becomes particularly crucial in seismic zones, where structures experience cyclic loading and require superior energy absorption capabilities.

During earthquakes, ring beams work in conjunction with shear walls and columns to absorb and dissipate seismic energy. Their presence reduces inter-story drift, minimizes damage to structural components, and improves the overall seismic performance of the building. Three types of ring beams diameters were studied to decrease the effect of seismic stress and overall displacements and drift. These beams were taken as 300x800 and 300x1000 and affected the results, especially in Seattle city. Although in Los Angeles using the ring beams was not permitted by the code, thus the system used was the bracing system in two bays in each direction as shown in the next figure. In studying the seismic load for structure concrete buildings in western California of the highest seismic zones the use of a bracing system was the key solution for resisting this high seismic force.

While most research examines earthquake response in rectangular or square structures, several studies highlight the unique advantages of circular buildings:
Core Walls and Stiffness: Studies by [2-16] emphasized the critical role of core walls and maintaining a stiff perimeter in circular buildings for resisting lateral forces (wind and earthquakes).
Shape Advantages:

Zankar [17] suggested a circular shape offers inherent protection against large-scale earthquake and temperature issues for residential structures. Sazzad and Azad [18] observed that the distribution of seismic forces is influenced by a building's shape and stiffness, impacting the maximum earthquake-induced displacement. Ul-Alam et al. [19, 22] Circular buildings, according to reports, exhibit several distinct structural characteristics: They tend to experience greater story displacement and drift, which necessitates meticulous design attention. Also their circular form provides enhanced resistance to overturning moments at the foundation, and demonstrate a higher capacity to withstand base shear forces. These buildings In comparison to their square counterparts, circular buildings generally possess lower overall stiffness.

Reduced Lateral Drift: Research by Manohar et al. [20] and Mahure et al. [21] suggested that circular and elliptical shapes experience less lateral drift compared to rectangular structures, with circular being the most efficient. Joint Displacement: Mahure et al. [21] also found that circular shapes exhibit the best performance in terms of joint displacement due to earthquake loads.

This paper outlined a theoretical framework for analyzing high-rise concrete buildings with a circular shape subjected to lateral loads. This framework leverages established mechanics principles while considering the unique features of circular geometry, such as:

- Absence of corners
- Presence of a central shear walls.

The framework will involve developing analytical models for various scenarios. These models aim to predict:

- Internal forces within the structure
- Maximum displacements and drift
- Base shear forces
- Overall building stiffness

2. Research Significance

This research focused on a crucial aspect of high-rise concrete building design: minimizing maximum displacement and drift during earthquakes. The circular building section allowed for exploring two lateral load resistance systems:

- Ring Beam System: This system will be studied for three different circular radii.
- Bracing System: This system will be evaluated using various bracing types (X and V) and configurations (one-bay and two-bay).

The study aims to establish guidelines for selecting the most suitable system based on factors like:

- Seismic zone (low, moderate and high)
- Building type (residential and commercial)

Here's a potential takeaway:

- For moderate seismic zones, shear walls might suffice for residential buildings.
- In moderate to high seismic zones, circular buildings with ring beam systems offered a promising alternative.
- For high seismic zones, bracing systems (particularly X-type, two-bay configuration) were likely the best solution.

This approach can significantly reduce drift and displacement, keeping them within permitted limits for high-rise buildings in earthquake-prone areas.

3. Buildings Models Geometry

The twenty-five floors circular building structure of plan dimensions of three circles of 5,10 and 15 meters radius and two cantilever slabs of 3 meters in two directions only as shown in figures (1) and (2). The three ring beams were studied beam 1 of radius 15 meters, beam 2 of radius 10 meters, and also beam 3 of small circle of 5.0 meters radius.The automatic mesh option was taken for floors and walls as 1.25 m maximum mesh size.The boundary conditions for the building structure was restrained in X,Y and Z directions for the columns and fixed shear walls.

Although the bracing systems were studied in two different directions X & Y and for different bracing types X- and V-type. The Bracing systems were used to restrain the building towards lateral loading either using the system in one bay and replicating to the next or in two bay spans.

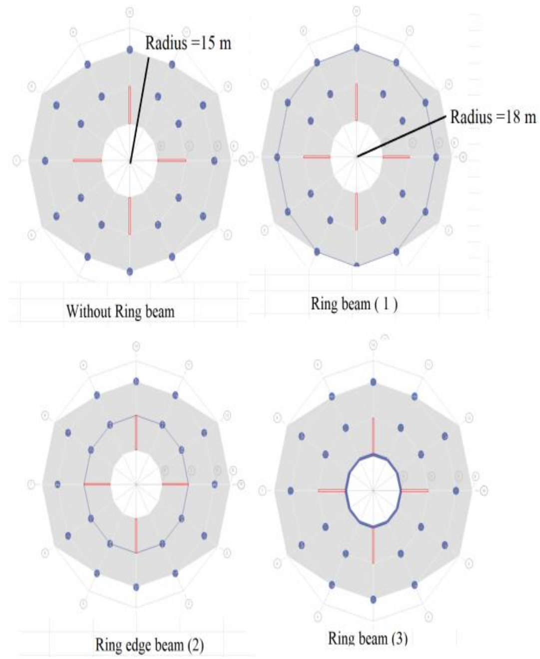

Figure (1) Geometry of the models

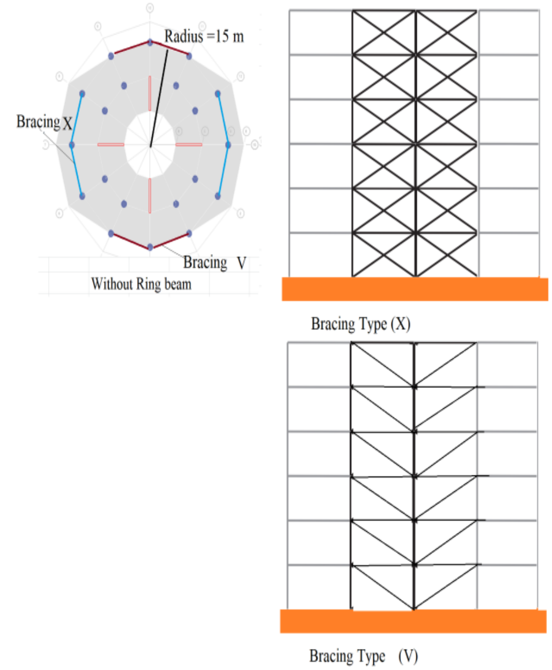

Figure (2) Bracing system in the models

3.1 Materials and Methods

Twenty five storeys residential circular building of 3.0 meters floor height, The dimensions of the building is constant according to the model case., The material compressive strength of concrete and the yield of steel are Fc'=27.5 MPa and Fy=415MPa , respectively. Circular Column size was of diameter 1000 mm, constant for all height of the model used. Beams size were 800 x300 and 1000 x 300 as a ring beams in some models . Plastic hinges were modelled in beams as deformations ductile (moment M_3) and the columns were modelled as deformations ductile controlled (fiber P-M_2-M_3) although the shear walls were modelled using (fiber P-M_3).

3.2 Loading Conditions

Typical dead loads consist of (a) the self-weight of the slabs, considering the 300-mm slab thickness. (b) floor finish load of 2 kN/m^2, (c) wall load of 2 kN/m^2, (d) live load of 3 kN/m^2, (e) earthquake loads as per ASCE 7-22, Seismic Design Category C and D, Zip code 89110,98122,9009 and 94704 and site class D, (f) with a response modification factor of 5, system over strength of 2.5 and deflection amplitude of 4.5; (g) importance factor of 1. and (h) damping of 5% and 75 mode shapes.

The seismic design category wasaccording to the ASCE 7-22[2].

Table 1: Materials specification and dimensions for members

Structure	Shear Wall-Column
Number of Storey	25
Type of building used	Residential
Storey Height	3 m
Grade of Concrete	fcu=27.5MPa
Grade of Steel	Fy=415 MPa
Youngs Modulus of Concrete	24855 MPa
Density of Concrete	*25* kN/m^3
Slab Thickness	300 mm
Beam Dimensions	300x800 and 300x1000
Column Dimensions	Diameter1000 mm
Bracing section dimmensions	300x300 & 500x500 mm^2
Floor Cover+wall load	4 kN/m^2
Live Load	3 kN/m^2
Seismic Zone	All
Importance Factor	1
Response reduction	depends on system
Site Class	D

Table 2: Different seismic zones according to Zip code

Seismic Zones UBC 97	2B	3	4	4 =0.4g
Zip code	89110	98122	90009	94704
City	Las Vegas	Seattle	Los Angeles	Western California
Sa	0.499	1.34	1.673	2.281
S1	0.164	0.5222	0.6148	0.945
SDS	0.46	0.89	1.1	1.52
SD1	0.23	0.52	0.61	0.945
Seismic Design Category	C	D	D	D & E

4. Numerical Simulations.

Finite element analysis (FEA) models using ETABS software was developed to further delve into the -linear static and dynamic behavior of circular high-rise concrete buildings under lateral loading. These models incorporate detailed representations of the geometry, material properties, and connection characteristics, including the non-linear constitutive behavior of concrete and steel. Parametric studies were conducted to analyze the influence of design variables, such as ring beam and bracing radius and dimensions, seismic zones, on the overall performance of the buildings under seismic lateral loading.

5. Analysis of The Results

The most important parameters in the behavior of high rise building structures was the maximum displacement and drift for the seismic loading, Figure 3 showed that the maximum displacements using different ring beam radius.

We will start analyzing the results from the lower seismic zone to the highest seismic zone of Zip code 89110 (Las Vegas). The maximum displacements per floor is plotted in Figure (3), where it is well recognized that using ring beam system well improved the stiffness and decreased the displacements as given in figure, and the depth of the beam also plays an important role as two beams where used in two different models (300 x 800) beam and (300 x1000) beam. Also three other ring beams models were studied as shown in Figure (1), beam 1, beam 2 and beam 3, each ring beam have a different radius, 5 meters, 10 meters and 15 meters, respectively.

Beam 1 and beam 2 decreased much the displacements although beam 3 had the least effect in the displacements due to it's location and small radius compared to the other two reinforced concrete beams.

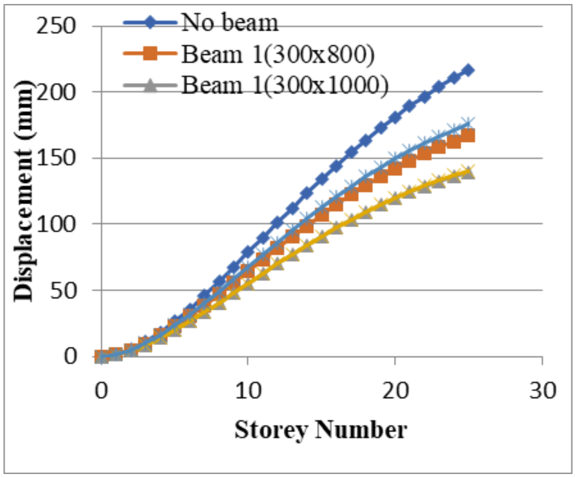

Figure (3) Displacements for the tower using different ring beams and bracing

Drift was the most important issue in the performance of high rise building concrete structures subjected to seismic loading and figure (4) assured that all systems models studied were permitted through out the ASCE code and the least values where monitored in beam 1 and beam 2 of dimensions (300 x1000). In this case all the solutions were presented and permitted, so the least beam of (300 x 800) Beam1 is recommended for this seismic zone area.

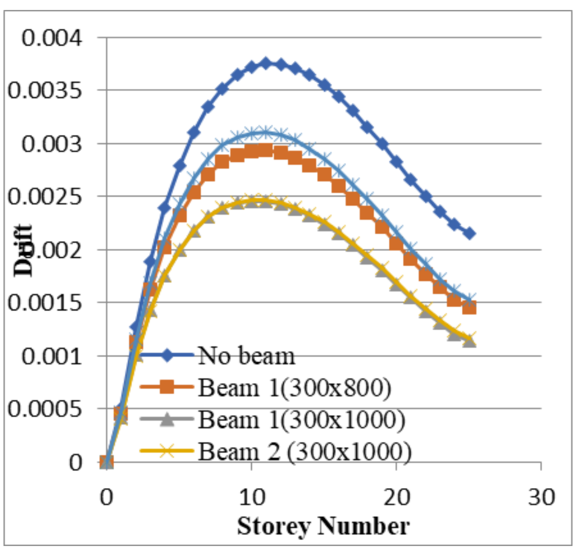

Figure (4) Drift for the tower using different ring beams and bracing

The base shear for different type systems used is given in Figure (5), which was considered all with the range of 2900 kN-3250 kN and the slight difference was from the main dimensions of each system and location.

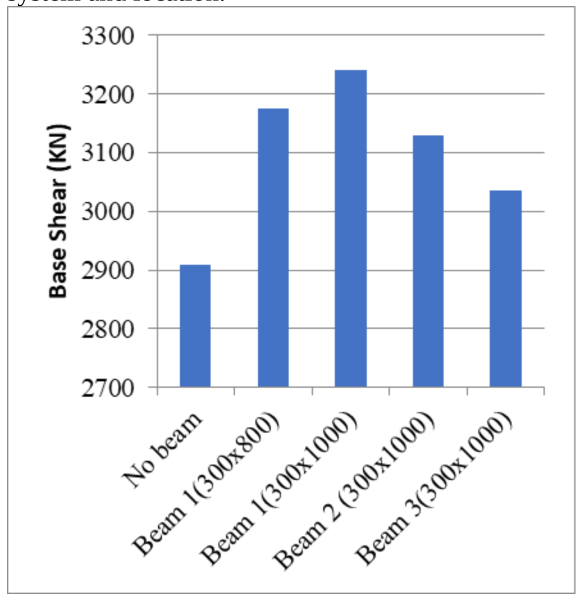

Figure (5) Base shear using different ring beams and bracing

The ring beams played an important role in enhancement of the stiffness of the building structures. Figure (6) showed the stiffness of the high rise in the bottom storeys and the maximum displacement was reported in the case of beam1 of radius 15.0 meters, although the case without beam monitored the least stiffness in all floor levels.

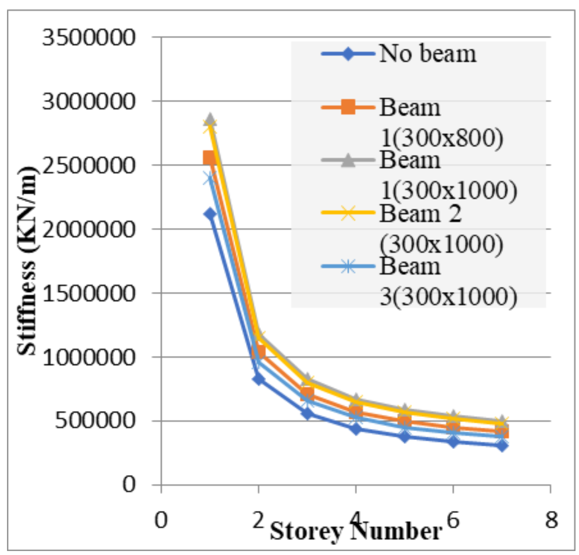

Figure (6) Stiffness in the tower using different ring beams and bracing

<u>Zip code 98112 (Seattle)</u>

The second major earthquake zone is Seattle city in the United States where the maximum displacements and drift were given in Figures (7-8) respectively. It was well known that using ring beams 1 and 2 of radius 15 and 10 meters, respectively increased the stiffness of the building structure, thus decreasing the displacements and drift for both ring beams, although using bracing systems in both directions enhances much the decreased of the displacements and drift to it's least limit.

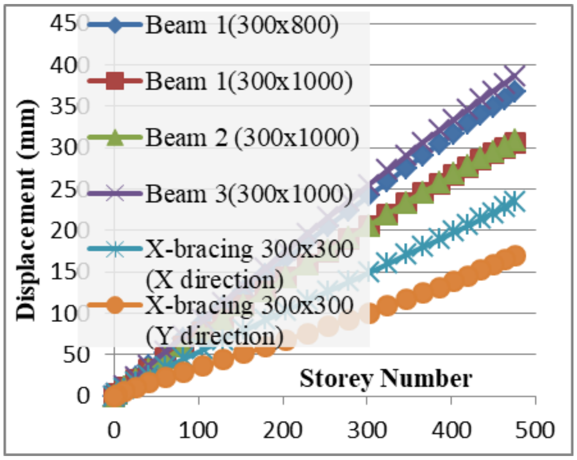

Figure (7) Displacement for the tower using different ring beams and bracing

The maximum drift calculated is not permitted in the cases of without beam and in the case of beam 1 (300x800), where the depth of the beam was increased to an upper value to be sure as to be in the safe limit. For the case of beam 3 of radius =5 meters, it's drift is also not permitted by the code.

The two other systems of the ring beam 10 and 15 meters radius were both with in the permitted range but using the bracing system decreased much the drift as given in the figure (8).

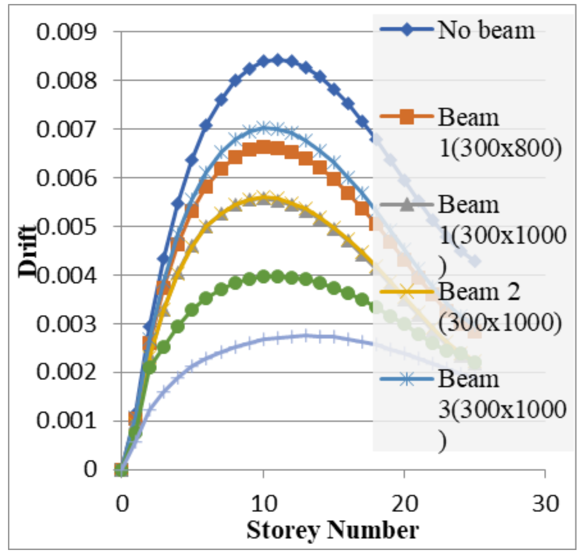

Figure (8) Drift for the tower using different ring beams and bracing

The base shear rages from 7400 kN from the case of the building without ring beams till nearly 8300 kN for the case of ring beam 1 of radius 15.0 meters as given in Figure (9). In comparison the base shear with the pervious case of Las Vegas city, it is well known that the base shear is nearly 2.5 times that of Las Vegas city.

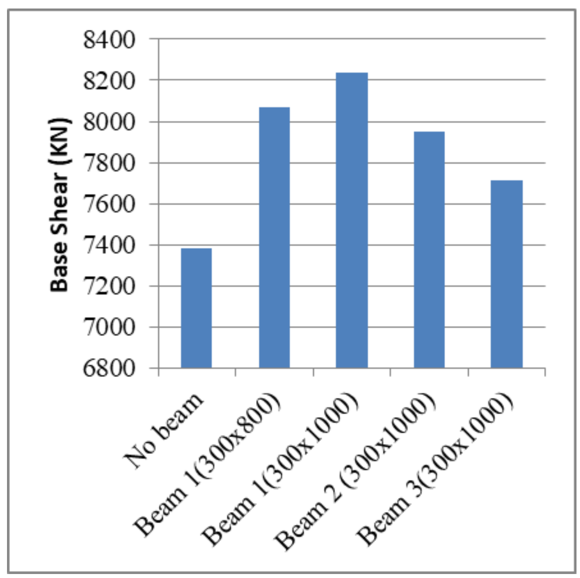

Figure (9) Base shear for the tower using different ring beams and bracing

The bracing system and the ring beams played an important role in enhancement of the stiffness of the building structures. Figure (10) showed the stiffness of the high rise in the bottom storeys and the maximum displacement was reported in the case of bracing systems, although the case without beam monitored the least stiffness in all floor levels. Table (3) in next figure presented the drift and diplacement and shear base values for the seismic zone of Seatle city.

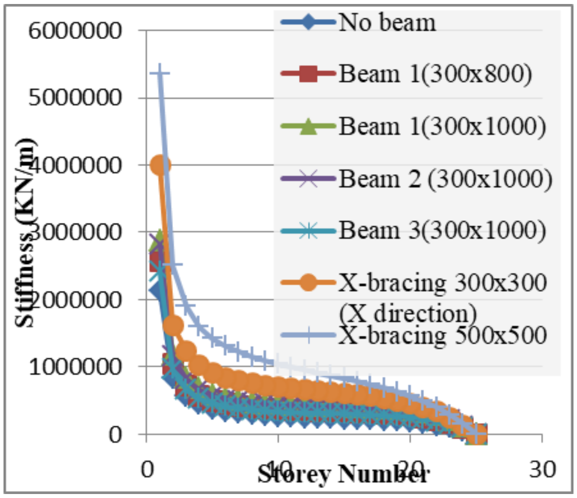

Figure (10) Stiffnesst for the tower using different ring beams and bracing

Table (3)Maximum displacements and drift and base shear and time period for Zip code (98122)

25 storey	Slenderness=75/30=2.5		Zip (98122)	**Seatle**	1
parameter	No beam	beam 1 *300x800)	beam 1(300x1000)	beam 2(300x1000)	beam 3(300x1000)
Ex=	475	367	306	308	386
Ey=	471	364	305	308	385
Drift x	0.0084	0.0066	0.00557	0.0055	0.007
Drift y	0.0084	0.0066	0.00557	0.0056	0.007
T calculated x=	1.68	1.687	1.687	1.687	1.68
T calculated y=	1.68	1.687	1.687	1.687	1.68
Base shear x=	7384	8066	8336	7952	7710
Base shear y =	7384	8066	8236	7952	7710

Zip code 90009, Los Angeles

Increasing the seismic effect by choosing more vulnerable city to earthquake as Los Angeles in the United States ,the maximum displacements and drift increased much from the other two cases of Seattle and Las Vegas as shown in figures (11-12).

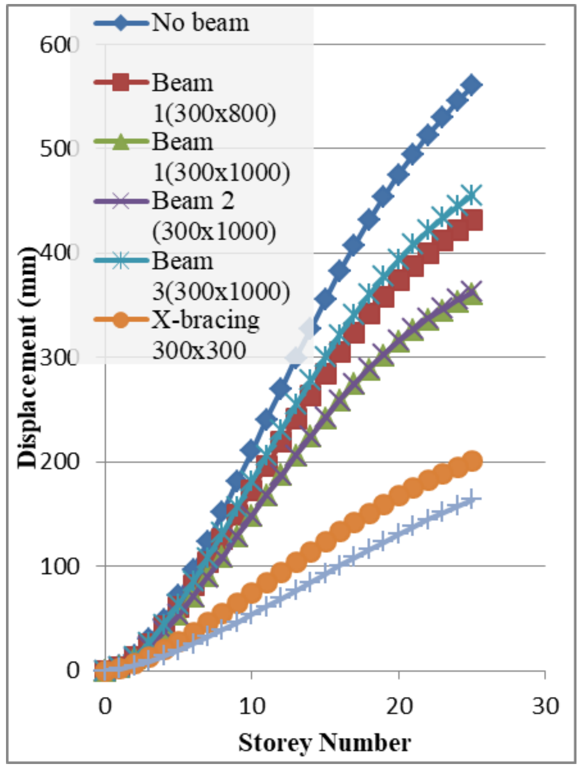

Figure (11) Displacement for the tower using different ring beams and bracing

The Maximum drift given in figure (11) was not permitted in all ring beams cases thus the usage of bracing system in this seismic zone was a must. Two bracing dimensions were taken (300x300) and (500x500) both are with the safe and permitted range by the ASCE code.

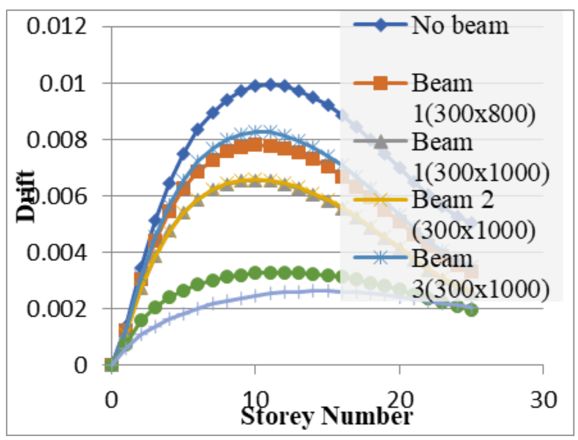

Figure (12) Drift for the tower using different ring beams and bracing

The base shear in Figure (13) showed that the range of 8700 kN till 9700 kN for both systems, either ring beam which were not permitted by the code for the drift was above the limited range and the bracing system which was permitted by the code and had values of 8900 and 9350 kN .

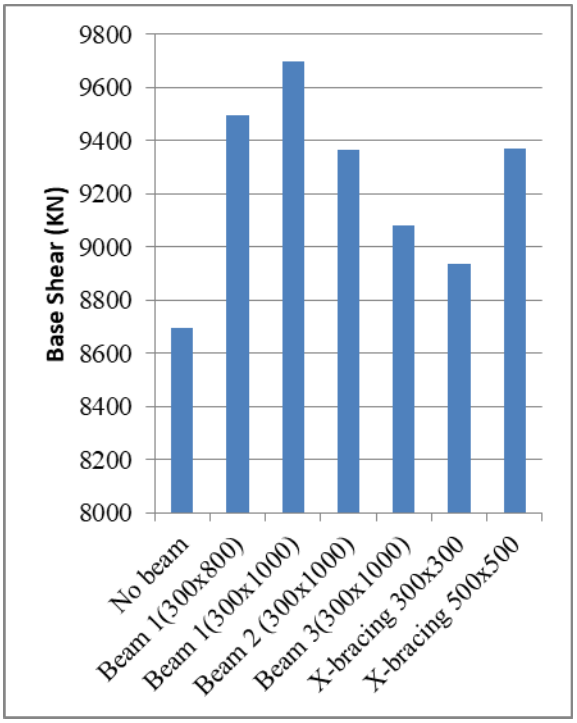

Figure (13) Base shear for the tower using different ring beams and bracing

The bracing system and the ring beams played an important role in enhancement of the stiffness of the building structures. Figure (14) showed the stiffness of the high rise in the bottom storeys and the maximum displacement was reported in the case of bracing systems, although the case of bracing systems monitored the high range stiffness in all floor levels. Table (4) in next figure presented the drift and diplacement and shear base values for the seismic zone for Los Angeles city.

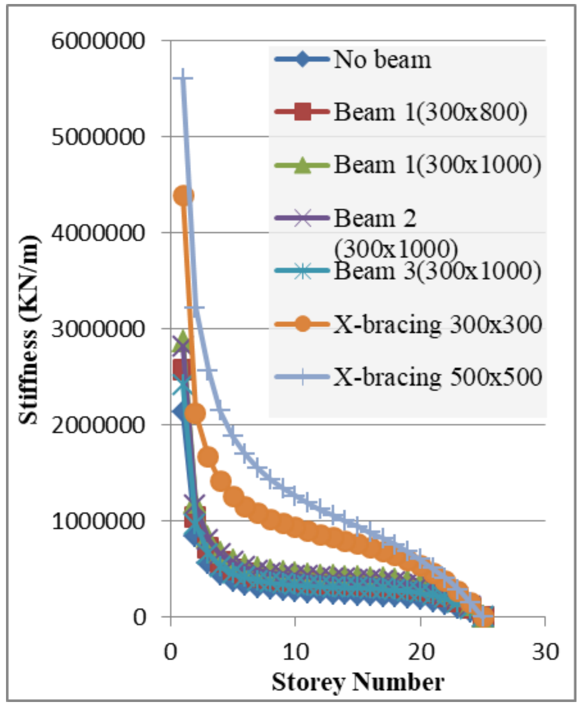

Figure (14) Stiffness for the tower using different ring beams and bracing

Table (4)Maximum displacements and drift and base shear and time period for Zip code (90009).

	Slenderness=75/30=2.5		Zip (90009)	LosAngeles	2		
25 storey	No beam	beam 1 *300x80(	beam 1(300x1000)	beam 2(300x1000)	beam 3(300x1000)	bracing(50(	bracing (300x300)
parameter	560	432	360	362	455	562	547
Ex=	560		359	363		163	200
Spy=	0.0093	0.0078	0.0065	0.00659	0.0082	0.0093	0.0095
Drift x	0.0093	0.0078	0.0065	0.0066	0.0082	0.00263	0.00329
T mode 1=	1.68	1.68	1.68	1.68	1.68	1.68	1.68
T calculat	1.68	1.68	1.68	1.68	1.68	1.68	1.68
T calculat	8694	9497	9698	9363	9078	9370	8938
Base shear	x=		9698			9370	8938

<u>Zip code 94704 (Western California –Berkley)</u>

The Zone area in Western California in Berkley city in the United states is one of the most high seismic zones in the States, thus the study will focus directly on the bracing system without introducing the ring beam system as it failed in the previous model for less seismic power of Los Angeles. Figure (15) monitored the maximum displacements for the case without a beam or bracing and for the two case of bracing in X and Y direction using (V-Bracing and X-Bracing) respectively as given previously in figure (2).

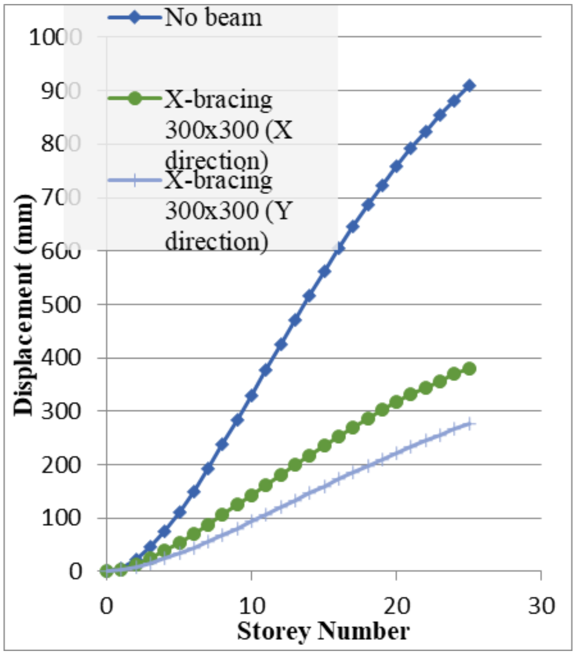

Figure (15) Displacement for the tower using different ring beams and bracing

The Calculated drift for the twenty five building structure tower assured that the type of bracing was a major parameter in the analysis and design of concrete high rise buildings as the case of V-bracing system in the X-Direction of the circular building was not permitted by the ASCE code(0.025 times the story height), although the case of X –bracing system was with in the permitted range.

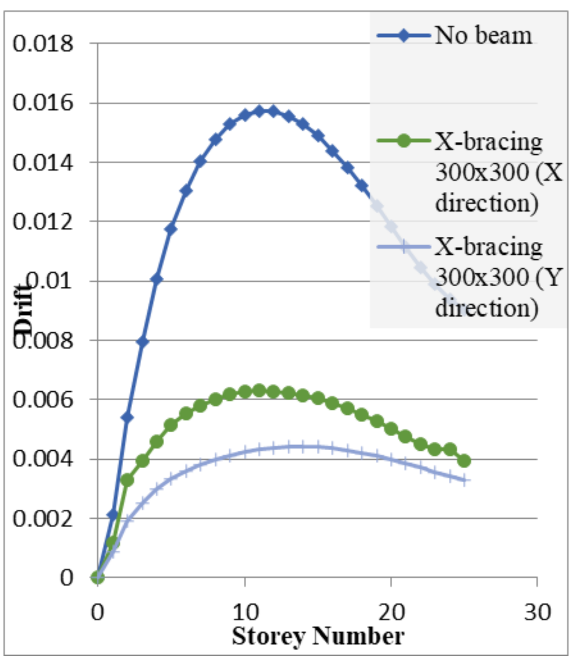

Figure (16) Drift for the tower using different ring beams and bracing

Figure (17) showed that the bracing systems increased much the stiffness of the building structures hence improved the drift and decreased the maximum displacement.

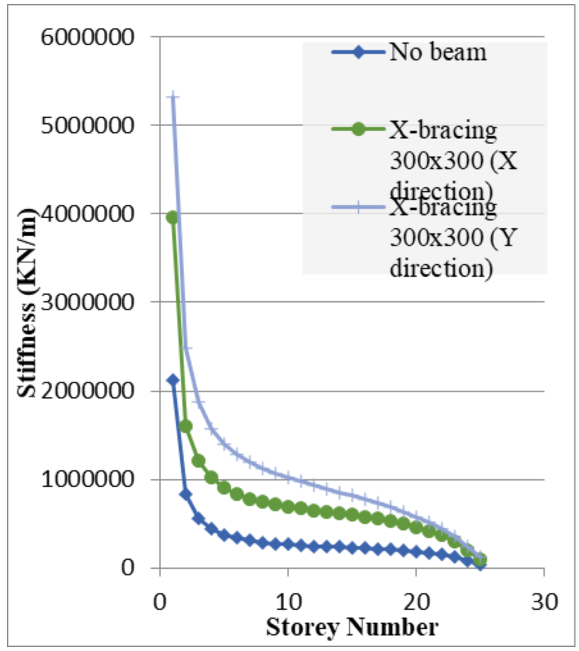

Figure (17) Stiffness for the tower using different ring beams and bracing

Figure (18) was a full comparison for all the systems and the seismic zones (Cities) presented in this study. The strategy of choosing the right system was quite clear in this comparison chart as it describes that Las Vegas which have the least seismic effect all systems are proved to be within the permitted range of the ASCE code, although for Seattle the system of ring beams is quite safe and permitted and it is not required to use the bracing system.

In Los Angeles of higher seismic effect the ring beam system is all not permitted by the code, thus the bracing system was the choice to make the system within the permitted range,

Western California especially Berkley is considered one of the most high seismic zones around the United States thus the ring beam system will not be considered in this zone area for its high seismic effect and the bracing system was used as an alterative. Two types of bracing systems were considered the V-Type in the x- Direction and X-Type in the y-direction. The figure (16) showed that the v type in x direction was not permitted by the ASCE code either, but the X-type in Y direction is permitted and safe for building structure in this zone area.Table (5) showed the displacements and drift and shear base for this seismic zone.

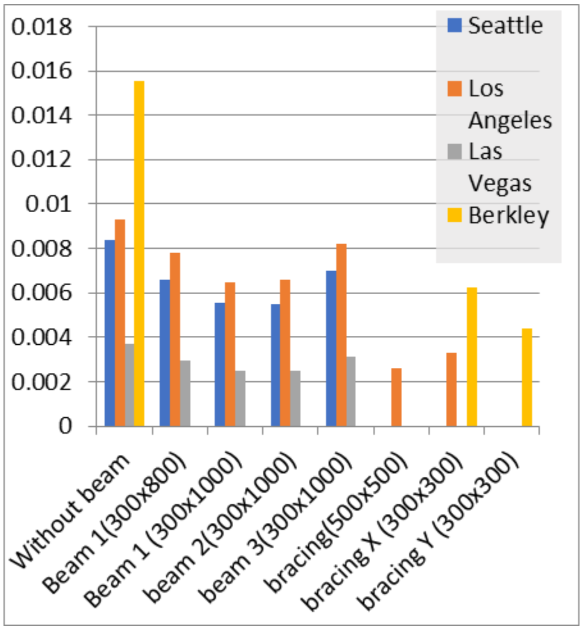

Figure (18) Maximum Drift for various Cities and systems

The over turning moment for all cases was calculated in the next figure (19) and a comparison was made to account for the effect of using different seismic zones in the case of without ring beams for all Zip code areas and it was found that The over turning moment at the base in the most high seismic zone area (94704) is nearly 4.1 times that of the Zip code (89110) and about 1.88 times that of the Zip code (98112) and of magnitude 1.6 times that of the Zip code (90009). The same figure (19) showed that the bracing systems of X and Y direction used decreased the over turning moment by 5%.

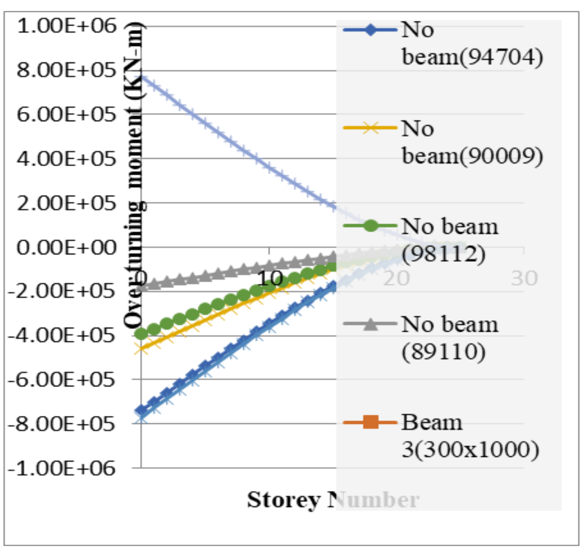

Figure (19) The over turning moment in different systems and seismic zones area

Table (5)Maximum displacements and drift and base shear and for Zip code (94704).

			Berkely
25 storey	Berkely	Zip (94704)	3
parameter	No beam	bracing X dir(300x300)	bracing Y dir (300x300)
Ex=	908.729	380.716	275.979
Ey=	908.729	380.716	275.979
Drift x	0.015567	0.006243	0.004419
Drift y	0.015567	0.006243	0.004419
Base shear	1156.239	1187.437	1187.437
Base shear	1156.239	1187.437	1187.437

5.1 Pushover analysis technique

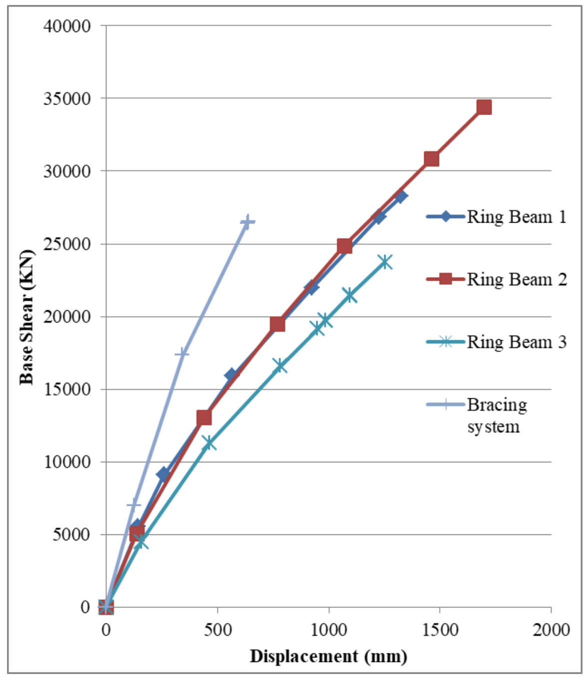

Figure (20) Pushover analysis for different ring beams and bracing in the structural buildings

The performance monitoring of the three different ring beam diameters shown in Figure (20) revealed that ring beams 1 and 2 experienced the maximum displacement. This occurred despite the high stiffness of the bracing system, which significantly decreased the displacement while maintaining nearly the same base shear value. Conversely, the system with the small ring beam 3 demonstrated the least efficient base shear values and less displacement compared to the other ring beams.

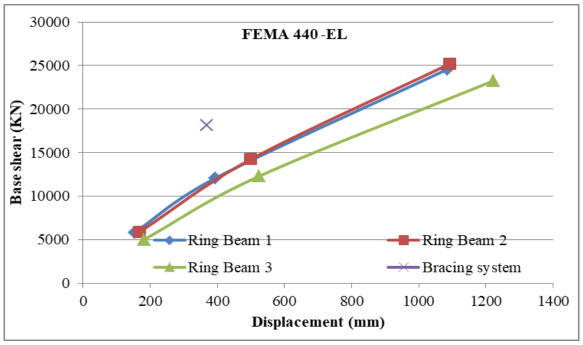

Figure (21) The relationship between the base shear and displacement for different ring beams and bracing in the structural buildings (FEMA-440 EL)

The performance point calculated by the FEMA-440 EL for diferent building ring beams and bracing as shown in Figures (21),(22).The ring beams 1&2 were nearly the same although ring beam 3 had less base shear and more displacements but the bracing system was found to be unsafe for seismic zone Zip code 98122 but for less seismic it was safe due to its high stiffness and rigidity.

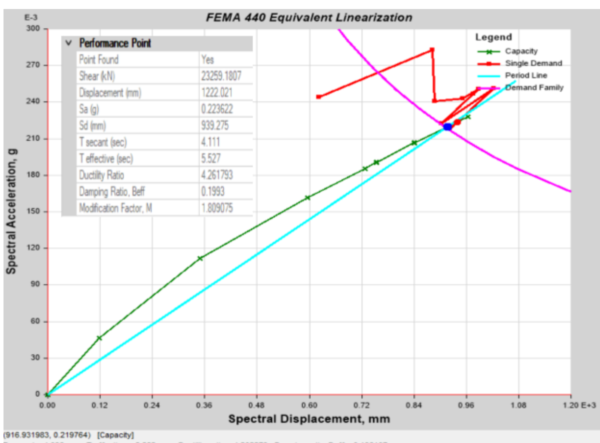

Figure (22) performance point by FEMA 440 EL for beam 3 ZipCode 98122..

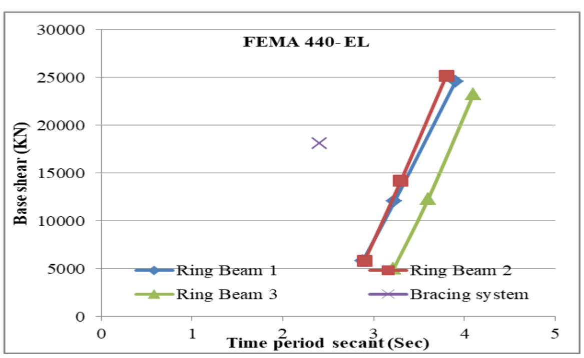

Figure (23) The relationship between the base shear and time period for different ring beams and bracing in the structural buildings(FEMA-440 EL)

The time period for different buildings ring beams and bracing systems in various seismic zones was given in Figure (23), the time period are nearly equal for ring beams 1&2 but is more in ring beam 3 but the bracing systems had a less time period for its more stiffness values.

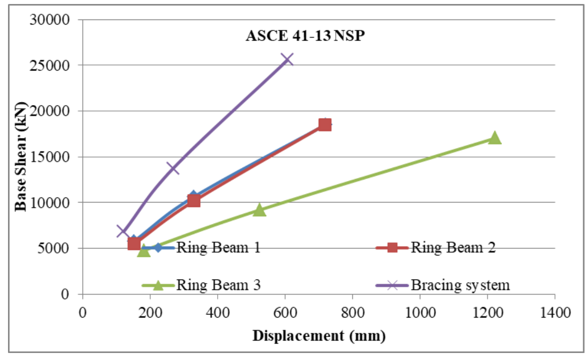

Figure (24) The relationship between the base shear and displacement for different ring beams and bracing in the structural buildings (ASCE 41-13 NSP)

ASCE 41-13 NSP in Figure (24) pointed that the maximum base shear achieved in the bracing systems and the ring beams of least diameter had the least base shear but of the maximum target displacement.

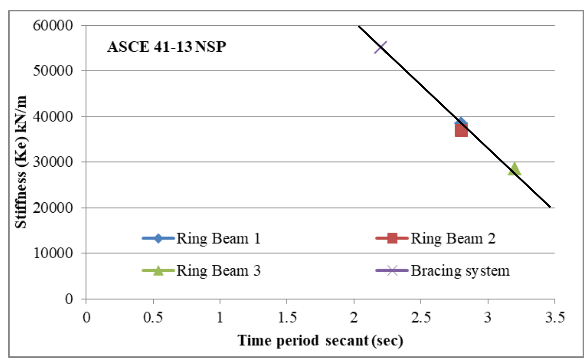

Figure (25) The relationship between the building stiffness and time period for different ring beams and bracing in the structural buildings (ASCE 41-13 NSP)

The stiffness (Ke) of the bracing systems was the most high value as shown in Figure (25) with the least secant time period, and a relationship between the stiffness of the different systems and the time period is plotted by a dotted line.

Tables (6) and (7) presented the values of the performance point due to push over analysis due to FEMA 440-EL and ASCE 41-13 NSP, respectively.

Table (6) The performance point in FEMA 440 –EL for different system used

	FEMA 440-EL		(performance point)	
System ued	**Zip code**	**Displacemet**	**Base shear**	**Tsecant**
Building Ring beam 1	**98122**	**1085**	**24582**	**3.9**
	89110	**393.8**	**12063**	**3.23**
	2131	**153.5**	**5829**	**2.88**
Building Ring beam 2	**98122**	**1092**	**25207**	**3.8**
	89110	**499.7**	**14233**	**3.3**
	2131	**167.4**	**5866**	**2.9**
Building Ring beam 3	**98122**	**1222**	**23259**	**4.1**
	89110	**525**	**12305.442**	**3.6**
	2131	**181.4**	**5019**	**3.22**
Building bracing	**98122**	**unsafe**	**unsafe**	**unsafe**
	89110	**369.2**	**18099**	**2.4**
	2131	**more safe**	**more safe**	**2.24**

Table (7) The performance point in ASCE 41-13 NSP for different system used

			ASCE 41-13 NSP		
System ued	**Zip code**	**Displacemet**	**Base shear**	**Tsecant**	**Ke**
Building Ring beam 1	**98122**	**719.708**	**18498.683**	**2.8**	**38408.547**
	89110	**328.905**	**10620.31**	**2.8**	**38408.547**
	2131	**151.751**	**5774.7754**	**2.8**	**38408.547**
Building Ring beam 2	**98122**	**718**	**18496**	**2.8**	**36921.747**
	89110	**329**	**10154**	**2.8**	**36921.747**
	2131	**152**	**5460**	**2.8**	**36921.747**
Building Ring beam 3	**98122**	**811**	**17021**	**3.2**	**28452.518**
	89110	**369**	**9194**	**3.2**	**28452.518**
	2131	**170**	**4773**	**3.2**	**28452.518**
Building bracing	**98122**	**607**	**25569.599**	**2.2**	**55108.445**
	89110	**268**	**13738.355**	**2.2**	**56141.476**
	2131	**121**	**6813**	**2.2**	**56141.476**

6. **Design Recommendations**:

Based on the comprehensive analysis, the paper will propose practical design recommendations for circular high-rise concrete buildings subjected to seismic lateral loading. These recommendations will address key aspects such as core wall effectiveness, stiffness requirements, and limitation of drifts within allowable code limits. The aim is to provide valuable guidance for engineers and practitioners seeking to utilize this innovative building type while ensuring structural safety and performance.

7. **Conclusions**

Ring beams are crucial for the safety, stability, and performance of high-rise concrete buildings by enhancing stiffness, strength, and mitigating lateral loads from wind and earthquakes. Their design is vital for structural optimization and occupant well-being. While improving seismic performance and material use, their cylindrical shape poses stability challenges under lateral loads, necessitating a thorough understanding of their response.

This research investigated the impact of ring beams and bracing systems on high-rise concrete buildings under seismic loads, focusing on stiffness, strength, stability, and overall performance. The study suggests shear walls were sufficient for residential buildings in moderate seismic zones. However, for moderate to high zones with circular buildings, ring beam systems were optimal for analysis and design. In high seismic zones, bracing systems were preferred, with X-type, two-span bracing acting as a restrained two-bay frame to significantly reduced drift and displacement within permitted limits. In conclusion, ring beams were essential for the structural integrity and performance of high-rise concrete structures, influencing lateral stability, load distribution, stress mitigation, and architectural aesthetics. Understanding their diverse contributions allows engineers and architects to advance high-rise construction.

1- The ring beam system and shear walls were capable of resisting seismic loading zones for seismic zones moderate and high.
2- The ring beam was more efficient in the outer edge of the circular building more that the inner radius. As the ring beam radius increased the beam improved more stiffness, strength and confinement, thus resisting drift and maximum displacements.
3- In high seismic areas as Los Angeles and Western California the system of shear walls with the help of ring beams in the concrete circular structure will be incapable of resisting the seismic loads.
4- In high seismic areas as Los Angeles the system of bracing system was used either the X- bracing of V –bracing in the addition of the shear wall.
5- In extremely high seismic zones as Western California it was advised to use X- bracing in two bay span, so as to resist the high seismic force using restrained frame in the addition of the shear wall.
6- The over turning moment at the base in the most high seismic zone area (94704) is nearly 4.1 times that of the Zip code (89110) and about 1.88 times that of the Zip code (98112) and of magnitude 1.6 times that of the Zip code (90009).
7- The bracing systems of X and Y direction used decreased the over turning moment by 5%. in the highest seismic zone area of (94704) Western California.
8- The pushover showed that the factor of safety of ring beam 2 had the most high value of 4.3 although the ring beam 3 monitored a factor of safety of 3.

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