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Pushover Analysis Between Different Shapes of BRB for Seismic Analysis in RCC Structure with IS 18993:2016

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Abstract:
When designing new structures as well as modifying and renovating existing ones, energy dissipation methods like buckling restraining braces (BRB) are routinely utilized. Because India is an earthquake-prone nation, these techniques are becoming increasingly widely understood and used regularly to lessen the effects of seismic events. This study's main goal was to assess how various buckling restraint brace designs might affect a G+14-storey RCC building structure. The comparison is carried out using ETABS after a pushover analysis has been completed. In order to extract information from the pushover curve, the response spectrum source for zone IV, soil type II, was defined in IS 1893:2016. Utilizing total seismic weight, lateral stiffness, yield force, goal displacement, base shear, and capacity or pushover curve, the performance of various shape buckling restrained braces were studied. It was discovered that the diagonal BRB performs better than the other bracing systems in an RCC construction compared to cross shape, v shape, and inverted v shapes.

Keywords: Buckling restrained braces (BRB), Pushover analysis, RCC structure.

1. Introduction

Through the application of additional damping devices, buildings may now disperse seismic energy thanks to advancements in energy dissipation technology over the previous few decades. By dispersing seismic energy through friction or inelastic hysteresis from bending, shear, and torsional deformations, energy-dissipating structural components like braces, shear walls, beam links, and friction connectors can also be employed to safeguard structures from damage or collapse. Due to their effectiveness in preventing serious structural damage from big earthquakes, damping devices have become more and more common. The two main types of energy dissipation devices are velocity dependent and displacement dependent, respectively [1]. Buckling restrained braces (BRB) is one of the types of displacement-dependent devices. Steel braced frames function well seismically during powerful earthquakes. However, under intense dynamic stresses brought on by earthquake and wind, steel bracing is vulnerable to buckling. If restraining devices are added outside or inside of the braces, converting them into buckling-restrained braces (BRB), this instability problem can be reduced or even eliminated. BRB may dissipate seismic energy in addition to strengthening and stiffening a structure [2]. Also, BRBs have changed in appearance throughout time and are now frequently seen as architectural components[3]. In 2020 Shankar et al. [4] shows concentric and eccentric BRB performance on RCC structure using response spectrum analysis and analysis was limited to an inverted v-shape configuration. Ghowsi and sahoo [5] also evaluate the performance of BRB in medium-rise steel structures under near-field earthquakes using inverted v (chevron) and double-x configuration. Abou-Elfath et al. [6] show BRB is very effective to increase the seismic capacity of RCC structures using diagonal configuration. But, the kind of beam-to-column connections has a clear influence on the seismic response of BRB frames, and these connections can be arranged in a variety of braced configurations[5]. So, this study focused on the comparative study of different concentric configuration systems of BRB in an RCC structure following pushover analysis. There are many RCC structures in India that were either not properly designed or did not have lateral load-resisting systems[7]. According to research on the Earthquake Disaster Risk Index, 59 percent of India is at risk from moderate to catastrophic earthquakes[8]. BRB can be a viable solution for increasing the seismic performance of those structures also.

1.1. Buckling Restrained Braces (BRB)

Wakabayashi, a Japanese engineer, is credited with the invention of buckling restrained braces (BRB). It was created as a lateral load resting system around the start of the 1980s. In Japan, this method was first applied in February 1990. Before being put into use, the BRB system underwent numerous tests in the middle of the 1980s. The United States received the technology in 1988. Following extensive testing, the technology was deployed for the first time in North America at UC Davis in January 2000 [3]. BRBs have been created gradually, using a similar methodology. The main objective of the ductile steel core is to yield tension and compression. To prevent global buckling during compression, a steel core is initially placed in the hollow structural section before being filled with mortar or concrete. [4]. The BRB system is much more stable in tension and compression during the yield cycle than conventional bracing [5].

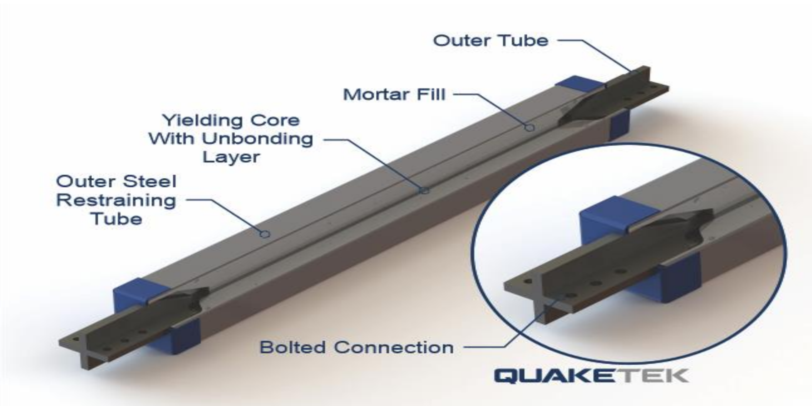

Fig 1. The design and behaviour of BRB[5].

According to the Chinese seismic design code, it was shown that standard braces lose their ability to support loads due to severe buckling during powerful earthquakes; nevertheless, BRB exhibits noticeably higher performance and satisfies the code requirement under comparable circumstances. [6]. Even if BRB improve the seismic performance of RC buildings, there is currently no BRB design provision for RC building retrofits. It is mostly used in steel projects that follow American and Japanese regulations because European standards have not yet offered design instructions. [7].

1.2. Pushover Analysis

Pushover analysis, generally known to as nonlinear static analysis, is an effective technique for evaluating how well structures respond during earthquakes. Due to its simplicity in computation and execution, it is the main method for performance evaluation as stipulated by major seismic rehabilitation recommendations and regulations. Pushover analysis makes it straightforward to calculate the system's overall capacity as well as the yielding and failure of structures[14]. The performance point or target displacement is the intersection of the capacity curve and the demand spectrum, and it represents the structure's maximum inelastic capacity to withstand base shear.

It is critical to investigate how well BRB and FVD perform in RCC buildings that were built in accordance with IS 456:2000 and have seismic standards that follow IS 1893:2016 because RCC structures make up the majority of building constructions in India. the results could benefit the construction industry. The performance of BRB and FVD on the G+14 storey RCC structure after pushover analysis was evaluated in this study using ETABS V20. Following IS 1893: 2016 demand spectrum function for seismic zone IV, ASCE 41-13 NSP total seismic weight, lateral stiffness, yield force, target displacement, and capacity curve were computed and compared.

2. Methodology

This study focused on a study of BRB applied in a different shape in an RCC structure following pushover analysis to produce a pushover curve and evaluate structural performance. The research process followed to achieve the mentioned objectives are given below-

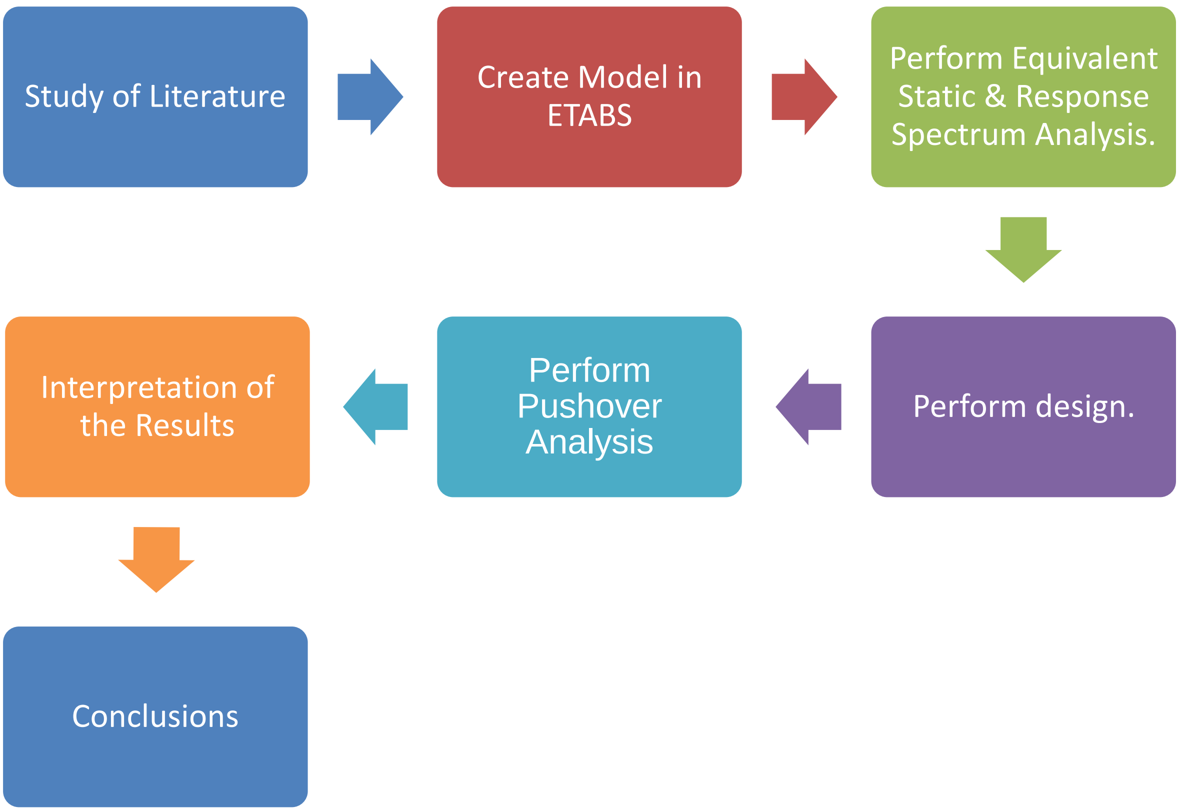

Fig 1. Flow chart for methodology.

2.1. Model Specification

Modeling a sample G+14 story RCC building structure in Etabs V20, where Table 1 represents the basic specifications such as length, width, story height, slab thickness, beam, and column size, Table 2 about material properties, Table 3 is representing the seismic parameters used in models under IS 1893:2016, and following IS 875 dead loads, live loads, as well as wind load are applied as indicated in Table 4. BRB specifications from Table 5 are used in this study for analysis and comparison.

Table 1. Specifications of the building

Name	Size	Unit
Length of Building	36	m
Width of Building	24	m
Bottom Storey Height	3	m
Storey Height	3	m
Slab Thickness	150	mm
Beam Size	650 X 400	mm
Column Size	950 X 850	mm

Table 2. Materials Properties

Name	Grade	Hysteresis Type
Concrete	M40	Takeda
Rebar	HYSD 500	Kinematic

Table 3. Seismic load details[15]

Name	Factor
R	5
I	1.2
Z	0.24

Table 4. Load details of the building[16][17][18]

Name		Load	Unit
Live Load	Roof	1.5	kN/m^2
	Floors	3	kN/m^2
Imposed dead load on the slab		1.47	kN/m
Imposed dead load on the outer beam		7.5	kN/m
Imposed dead load on the inner beam		7.13	kN/m
Imposed dead load on roof beam (Outer)		2.82	kN/m
Wind Speed		47	m/s

Table 5. BRB Specification

Material of Yielding Core	Total Weight (kN)	Yielding Core Area (cm^2)	Fy in Tension (kN)	Fy in Compression (kN)
Fe250	7.9267	22.6	502.4	496.77

Table 6. Braced configuration

Number	Configuration type	Nos.
1	Diagonal Shape	224
2	Cross Shape	224
3	V Shape	224
4	Inverted V shape	224

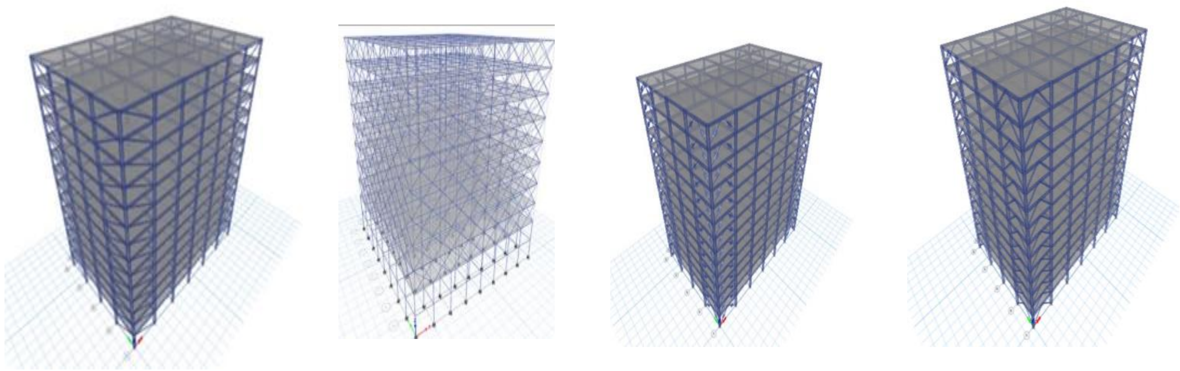

Fig 2. Different shape BRB 3D view in Etabs.

2.2. Plastic Hinge

In this work, nonlinear models were defined using plastic hinges. According to ASCE 41-17 of Tables 10-7, plastic hinges are allocated in beams with M3 degrees of freedom utilizing Takeda hysteresis. Concrete columns with plastic hinges are given P-M2-M3 degrees of freedom according to tables 10-8 and 10-9[13]. The relative distance between each hinge in the beam and column was set at 5% from the beam-column intersection. Using BRB hardening hysteresis, P axial plastic hinges were allocated in BRB at a 50% relative distance.

3. Results and discussion

The outcomes of applying a BRB with a different shape in an RCC structure were assessed using ETABS V20's displacement-controlled nonlinear static technique and IS1893: 2016 response spectrum source as the source for the NSP graph used in ASCE 41-13. The total seismic weight of the structure with BRB is 174640.3313 kN and weight of bare frame is 172864.7434 kN. The yield displacement of the system is calculated as 60 mm.

3.1. Lateral Stiffness

The structure's lateral stiffness is depicted in Fig. for the Push X load case, which represents the X-direction, and the Push Y load example, which represents the Y-direction. The bare frame has a lateral stiffness of 97593.942 kN/m in the X direction. After using BRB on a bare frame, it was observed that lateral stiffness increased in the X-direction for the diagonal shape by 66.50 percent, the IV shape by 52.52 percent, the cross shape by 51.31 percent, and the V shape by 49.21 percent. The bare frame's lateral stiffness, on the other hand, is 88034.344 kN/m in the Y direction, and it increases in the BRB with the diagonal shape, IV shape, cross shape, and V shape, respectively, by 76.87 percent, 58 percent, 56.67 percent, and 54.35 percent.

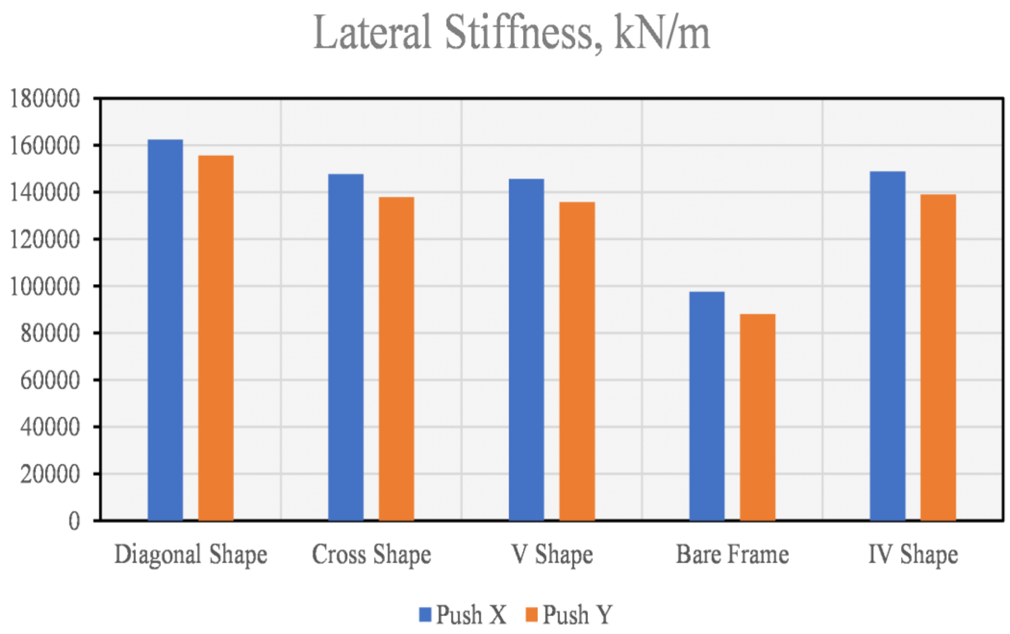

Fig 2. Lateral Stiffness for different shape BRB

3.2. Yield force

Figure showing the yield force needed to obtain the system's predicted yield displacement of 60 mm. After using BRB, the structure's yield force significantly increased in both directions. The yield force for a bare frame in the X direction is computed to be 5855.6365 kN, while the yield forces for the diagonal, cross, V, and IV shapes after applying BRB are 9749.8518 kN, 8860.0541 kN, 8737.0773 kN, and 8930.8841 kN, respectively. The computed yield force in the Y-direction for a bare frame is 5282.0607 kN, and it is 9342.6756 kN, 8275.5022 kN, 8153.1578 kN, and 8345.8843 kN after applying BRB as a diagonal shape, cross shape, V shape, and IV shape, respectively.

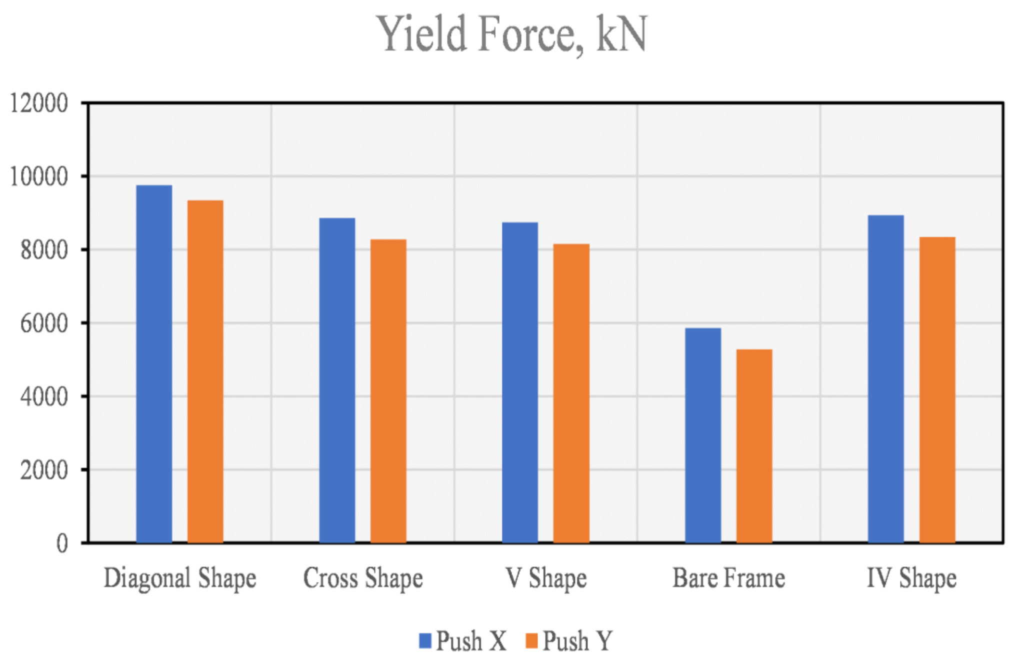

Fig 3. Yield force of the structure for different shape BRB

3.3. Base shear and target displacement

Table _ contains the calculated target displacement and base shear resist capacity of the structure in terms of bare frame and BRB with diagonal shape, cross shape, V shape, and IV shape.

Frame type	Push X		Push Y	
	Base Shear, KN	Displacement, mm	Base Shear, KN	Displacement, mm
Bare frame	2229.182	22.841	2145.3468	24.369
Cross Shape	2696.055	18.258	2616.5281	18.971
V Shape	2677.8247	18.389	2596.2501	19.106
IV shape	2707.4832	18.19	2628.9435	18.9
Diagonal shape	2838.5889	17.469	2801.4194	17.991

3.4. Capacity curve

Capacity curve is depicted in fig as base shear versus displacement. It is evident from the capacity curve that BRB may significantly improve the performance of RCC structures. The BRB positioning method also plays a significant role in achieving peak performance. The graph clearly shows that BRB with a diagonal shape worked exceptionally well and is highly steady in both directions.

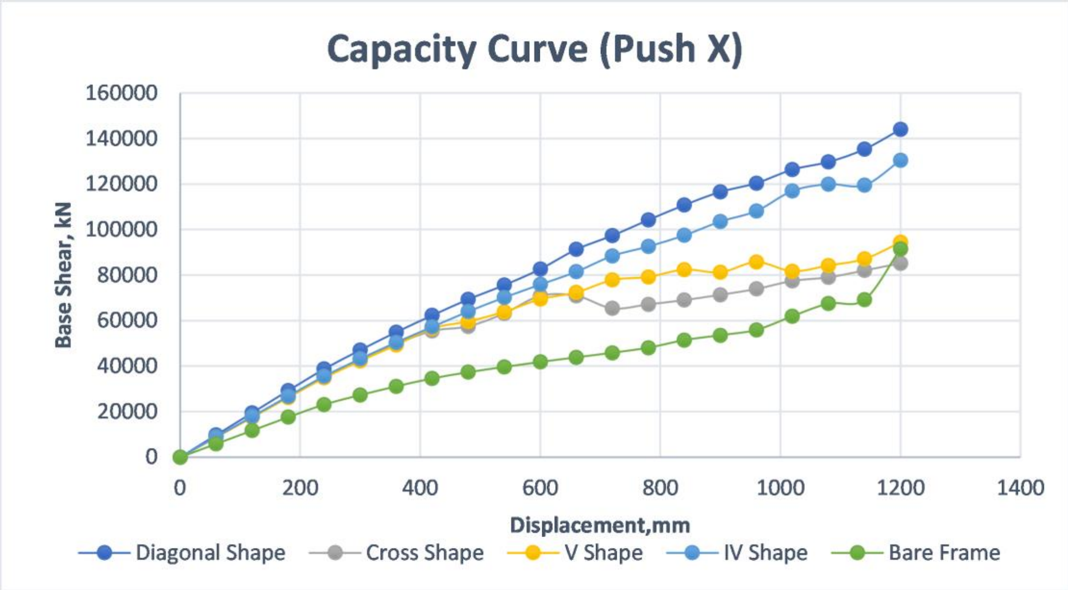

Fig 4. Capacity curve for Push X load case

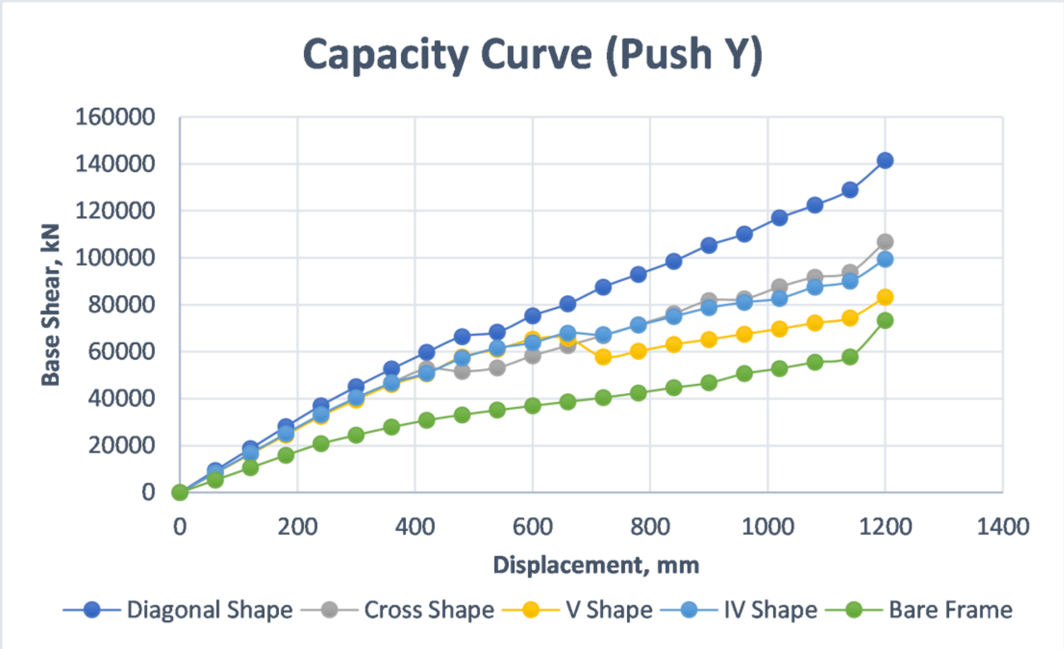

Fig 5. Capacity curve for Push Y load case

4. Conclusions

The results of nonlinear static analysis also known as pushover analysis were compared to bare frame and different concentric BRB placement system in terms of diagonal shape, cross shape, v shape, and inverted v shape in a RCC structure. Lateral stiffness, yield force, target displacement, base shear at the target displacement point, and capacity curve were compared between the study's findings. Particularly, BRBs in a diagonal configuration are considerably superior at increasing lateral stiffness and yield force than other placement systems. In terms of lowering target displacement and boosting base shear resist capability, diagonal BRB performs better than others. Additionally, it has been shown that diagonal BRB increases the structure's total capacity and is more stable.

5. Recommendations

- Cost analysis could be utilized in future studies.

6. Practical Applications

- This study might be helps to understand the behaviour of BRB. So that engineers can make decision while performing design or rehabilitation RCC structure using BRB in order to meet the actual requirements of the construction.

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