International Journal of Civil Engineering and Technology (IJCIET)
Volume 8, Issue 11, November 2017, pp. 474-483, Article ID: IJCIET_08_11_050
Available online at http://www.iaeme.com/ijciet/issues.asp?JType=IJCIET&VType=8&IType=11
ISSN Print: 0976-6308 and ISSN Online: 0976-6316

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EFFECTIVENESS OF USE OF SPECIAL SHAPED BEAMS & COLUMS IN ELONGATING THE FUNDAMENTAL TIME PERIOD TO IMPROVE THE RESPONSE OF R.C. STRUCTURES

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ABSTRACT

In Structural dynamics, every structure has a fundamental time period and a frequency, longer the time period, lesser the frequency making the structure flexible. As the structures with long periods are very flexible they do not excite during earthquakes as much as the structures with shorter periods excites. In this study it was objected to elongate the fundamental time period of reinforced concrete structures so as to make it flexible/ductile and improve the response of the structure. Special shape of cross sections of columns and beams has been analyzed. The Special shape being T-shaped and + shaped columns whereas the beams with trapezoidal ends and rectangular mid span. Time History Analysis of various models have been done for ground motions of Imperial Valley Earthquake. The elongation of fundamental time period and decreased base shear was seen for the special shaped beams and columns.

Keywords: Base Shear (V_B), Fundamental Frequency (F_n), Fundamental Time Period (T), Response of Structure, Stiffness (K).

Cite this Article: Shaikh Sohail Ahmed and L.G. Kalurkar, Effectiveness of Use of Special Shaped Beams & Colums In Elongating The Fundamental Time Period To Improve The Response of R.C. Structures, International Journal of Civil Engineering and Technology, 8(11), 2017, pp. 474-483.
http://www.iaeme.com/ijciet/issues.asp?JType=IJCIET&VType=8&IType=11

1. INTRODUCTION

1.1. General

The fundamental time period of any structure depends upon various factors, height of the structure and the base dimension of the structure [13]. Apart from these two parameters there are various factors which also affect the fundamental time period like number of floors [1], presence or absence of the bracings system [5], percentage of shear walls, position of shear walls, percentage of infill walls and number of bays [4]. In this study use of various non-conventional cross sections has been used such as cross shaped (+), L-shaped and T-shaped columns. The effect of these shape of cross sections basically over the fundamental time period has been studied. Secondly over the conventional rectangular cross section of beams the effect of trapezoidal ends with rectangular mid span beams has been analyzed. By the use of these type of cross sections of columns and beams, it was expected that the fundamental time period would increase, resulting into the improved response as the structures with longer periods are flexible. Also the combination of special shaped columns with non-prismatic beams has also been analyzed.

The response of any structure depends upon the horizontal acceleration (A_h) to which it is subjected during earthquake which in turn depends upon the fundamental time period of the structure. If the fundamental time period is less the building will have high frequency i.e. the no. of oscillations will be more leading to more damage to the structure. Similarly if the fundamental time period is more the frequency or the no of cycles per unit time will be less, resulting into less destruction of the structure.

1.2. Related studies

Related studies available dependent upon experimental research over special cross sectional shapes of columns and beams have been limited as the material required, the vibrating simulators and the other experimental apparatus which such researches requires becomes very costly. Secondly the theoretical investigations which are available in this stream are also limited. Various studies which has been described below.

Pu Yang et. al. 2008 [5] The research showed the comparison of various modelled structures in large finite element modelling software ABAQUS showed that the columns with cross sections like cross shaped (+), T- Shaped, L- Shaped, the torsional distortion of the structure was less as compared to the columns with rectangular shapes. Also the story drift was lesser in case of special columns. The design of such columns must be based upon the Chinese existing codes and clauses. Wen Hu Tsao et. al. 1992 [6] carried a research over bi-axially loaded square and shaped column so as to check the deformations of the column. The test being not only experimental but also analytic, the tests for ductility and plastic hinge were performed. Linda Ann Mathew et. al. 2015 [7] made a research of behavior of reinforced concrete structures with H-Shaped plan and T shaped columns compared with Square shaped plan of RC structures and conventional square columns. It was seen that the drift and distortion of the structure with rectangular plan is more as compared to H shaped and the T-shaped columns resist more lateral forces than conventional shape columns. All the analytical results were carried on the finite element based software, Staad Pro. Jing Jiang et. al. 2012 [8] This research simulated the impact of T-shaped columns over the Lateral Resistance properties of the structure using the software ABAQUS. Various time displacement curves were gained and it was known that the structure with T shaped column proved to be more ductile. Also the structure showed good stability and deformation capacities. Kelly Young, Hojjat Adelli et. al 2016 [9]. In this paper 12 EBF's were analyzed for the fundamental periods with varying geometric irregularities. It was shown that the periods from Rayleigh equation and ETABS modal analysis were identical. Secondly the general structures without irregularities tends to have larger periods than that of structures with regular shapes. Horizontally irregular structures have slightly lesser periods than that of horizontally regular structures. Structures with vertical and combination irregularities exhibit very similar periods. A new equation was proposed for steel EBF's.

1.3. Objective

According to IS-1893, it is known that the spectral acceleration (sa/g) depends upon the fundamental period of the structure. As the fundamental period will increase it will decrease the spectral acceleration (sa/g), which ultimately would reduce the horizontal seismic coefficient (A_h). As the horizontal seismic coefficient decreases it will decrease the Base shear (V_B) of the structure and would improve the response. The prime objective of this study is to investigate if the fundamental time period could be increased by using T-shaped, Cross shaped (+), L-Shaped columns as well as Beams with varying cross sections. Also the effect of combination of these special shaped columns and non-prismatic beams (NPVCS) has been studied.

2. SYSTEM DEVELOPMENT

In this paper six G+25 models were developed and analyzed using finite element modelling based software, ETABS. The different models consisted of a bare frame, a frame with a combination of cross shaped, L-shaped & T- shaped columns with conventional beams, two frames having beams with non-prismatic cross sections with trapezoidal ends and rectangular conventional cross section at the mid span and additional two frames with combination of special shaped columns with NPVCS beams with 1:3 and 1:5 end slopes for the end trapezoidal section. Also the frames with non-prismatic cross sections of beams (NPVCS) had two variants with end slopes of 1:3 and 1:5. These models were analyzed for Non-linear Time History Analysis (FNA). The ground motions of Imperial Valley earthquake has been considered for the analysis. Firstly the bare frame was analyzed and the other structures were compared for the fundamental frequency, fundamental time period, stiffness & the base shear of the structures. All the models had a same structural specifications apart from the variants. It has a base dimension of 25m X 25m and the total height of the structure was kept 75m. Each floor had a height of 3.0 m. The base was considered to be fixed and soil structure interaction is neglected. There were five bays in X as well as Y directions each of which was 5m wide. The views of the beam and cross sections of columns have been shown below:

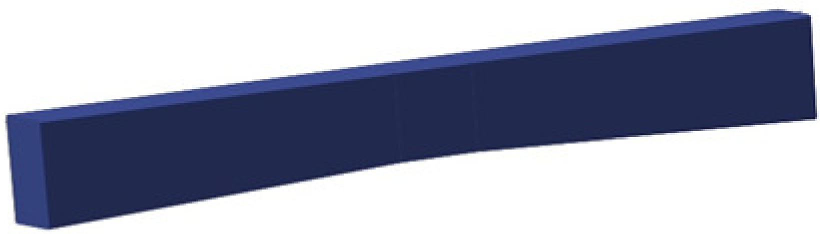

Figure 1 NPVCS beam with end slopes 1:3

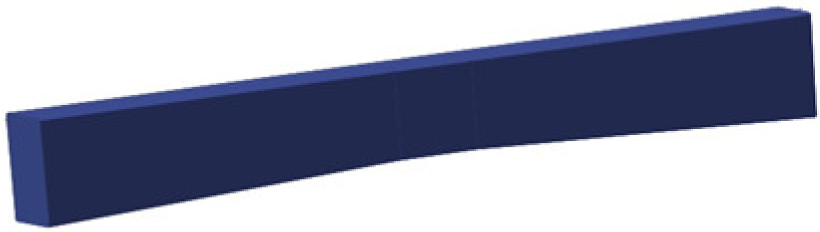

Figure 2 NPVCS beam with end slopes 1:5

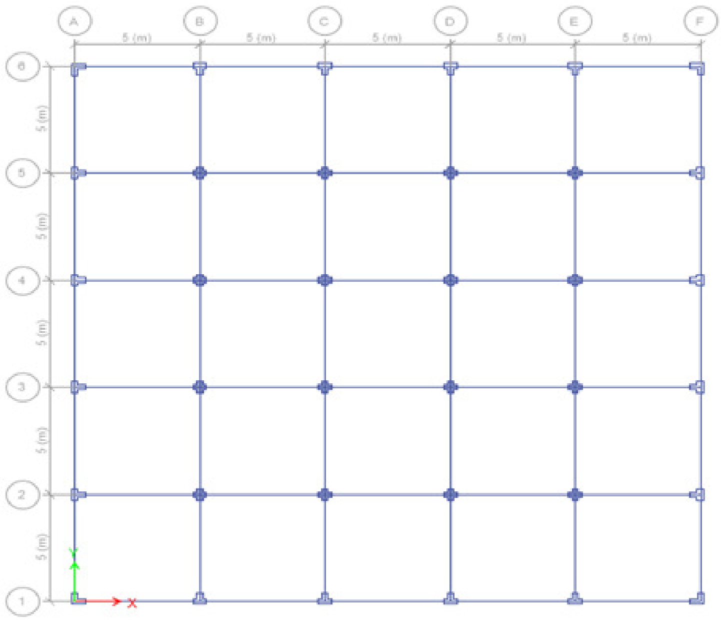

Figure 3 Plan with L, Cross & T- shaped columns

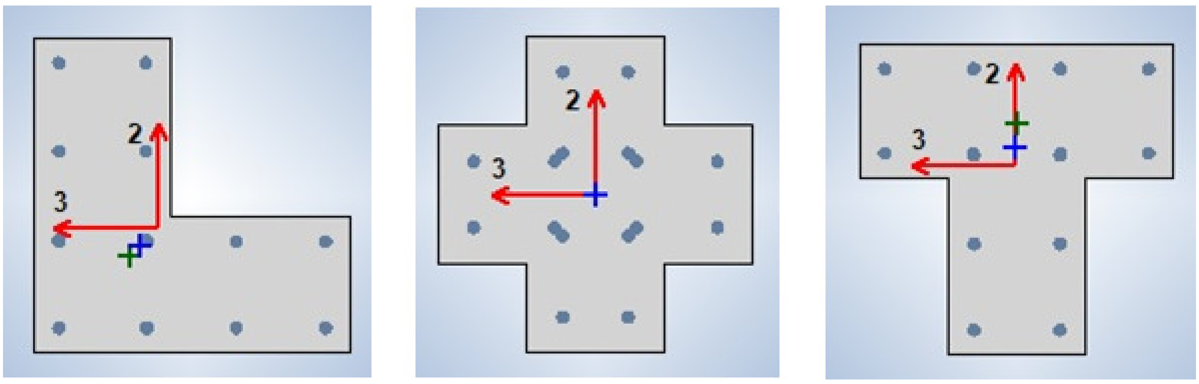

Figure 1 L, Cross & T shaped column's cross sections

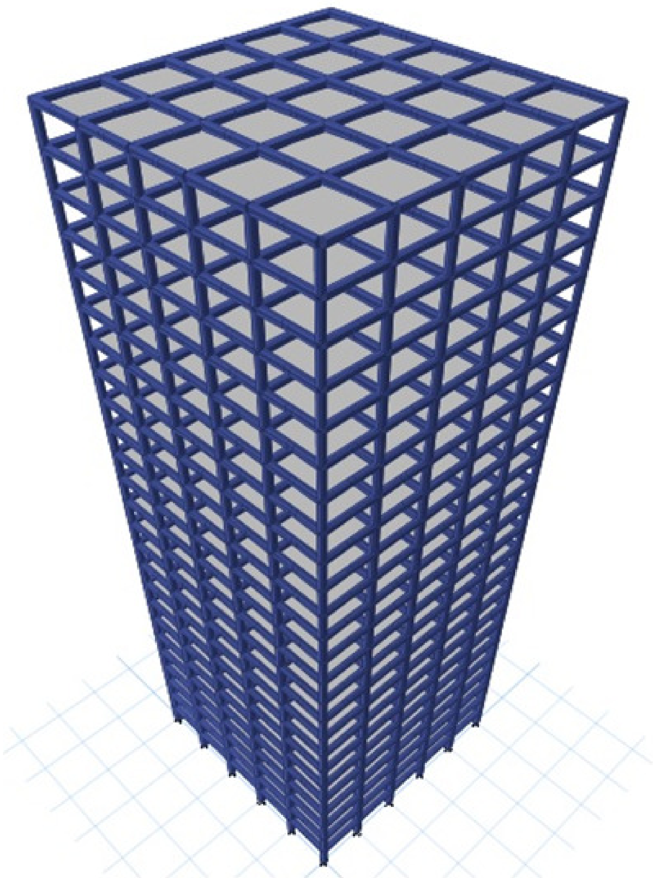

Figure 4 extruded view of models with special shaped beams and columns

Table 1 Material Properties

1.	Grade of concrete	M25
2.	Grade of reinforcing steel	Fe 500
3.	Grade of steel	Fe 345
4.	Density of concrete	25 KN/m3
5.	Density of brick masonry	19 KN/m3
6.	Damping ratio	5%

Table 2 Gen. Specifications of Building

1.	Plan Dimensions	25m X 25m
2.	Height of the structure	75 m
3.	Height of each storey	3.0 m
4.	Thickness of Slabs	150 mm
5.	Internal / External Wall thickness	150 mm
6.	Depth of footings	3 m

Table 3 Structural Specifications

1.	Type of sections			R.C.C.
Sizes of Column sections				
2.	Columns (R)	300 X 600		
3.	Columns (T)	Depth		530
		Width		530
		Web/Flange thicknesses		230
4.	Columns (L)	Depth		530
		Width		530
		Leg Thickness		230
5.	Cross Shaped Column (+)	Depth		530 mm
		Width		530 mm
		Thickness of flange/ web		230 mm
Sizes of beam sections				
6.	NPVS Beams (B1) 1:3	End S/c	230 X 450	
		Mid S/c	230 X 380	
7.	NPVS Beams (B2) 1:5	End S/c	230 X 450	
		Mid S/c	230 X 380	

Table 4 Load Specifications

1.	Floor load	1.0 KN/m^2
2.	Live load	3.5 KN/m^2
3.	Internal / External wall load	15 KN/m
4.	Code for RCC	IS 456 (2000)
5.	Code for Earthquake analysis	IS 1893 (2002)
6.	Zone	V (v. severe)
7.	Zone factor (Z)	0.36
8.	Importance factor	1.0
9.	Moment resisting frame type	OMRF
10.	Response reduction factor	3.0
11.	Site soil type	Medium (II)

Table 5 Load Combinations as per IS-1893 (2002)

1.	0.9DL+1.5EQX	7.	1.5(DL+EQX)
2.	0.9DL-1.5EQX	8.	1.5(DL+EQY)
3.	0.9DL+1.5EQY	9.	1.5(DL+LL)
4.	0.9DL-1.5EQY	10.	1.5(DL-EQX)
5.	1.2(DL+LL+EQX)	11.	1.5(DL-EQY)
6.	1.2(DL+LL+EQY)	12.	1.2(DL+LL-EQY)
7.	1.2(DL+LL-EQY		

3. RESULTS & DISCUSSIONS

The modelling and analysis of all the structures has been done in the finite element based software ETABS. Nonlinear Time history analysis (THA) was done and seismic ground motions of Imperial Valley earthquake were considered. In all, six models were modelled, consisting of a Bare frame (BF), a frame with a combination of cross shaped, L-shaped & T-shaped columns, two frames having beams with non-prismatic cross sections with trapezoidal ends and rectangular conventional cross section at the mid span and two frames with the combination of Special shaped columns and NPVCS beams with two slope variants of 1:3 and 1:5.

The special shaped columns which was modelled had the same cross sectional area, the cross sectional dimensions were adjusted according to the cross sectional area.

3.1. Frequency (fn)

The frequencies of all the structures were evaluated & compared. First four modes were considered for comparison. It was seen that the frequencies of special shaped column with conventional beams (SSC) and special shaped column with non-prismatic beams with end slope 1:3 (SSC 1:3) was approximately same. These two frequencies were minimum of all.

3.2. Time Period (T)

As shown above the frequencies of SSC & SSC 1:3 was minimum in the same way, the fundamental time period of these two frames increased to a considerable extent making the structure flexible and ductile. Also the frame, SSC 1:5 has also shown increase in the time period which is considerable. As the fundamental time period increases the structures proves to be more ductile than all other type of frames and will not excite as much as bare frame excites during earthquakes.

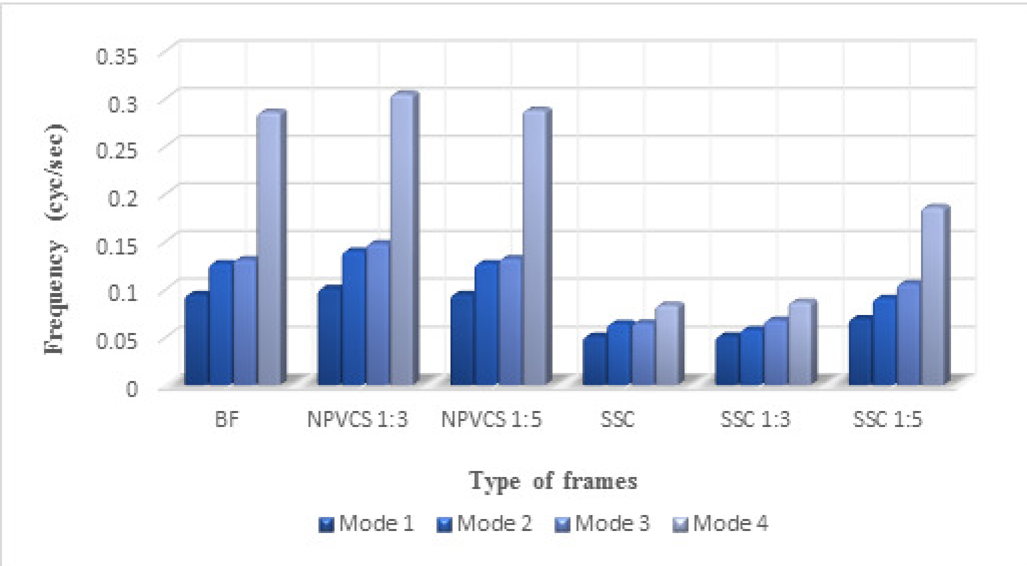

Figure 2 Frequencies for various frames

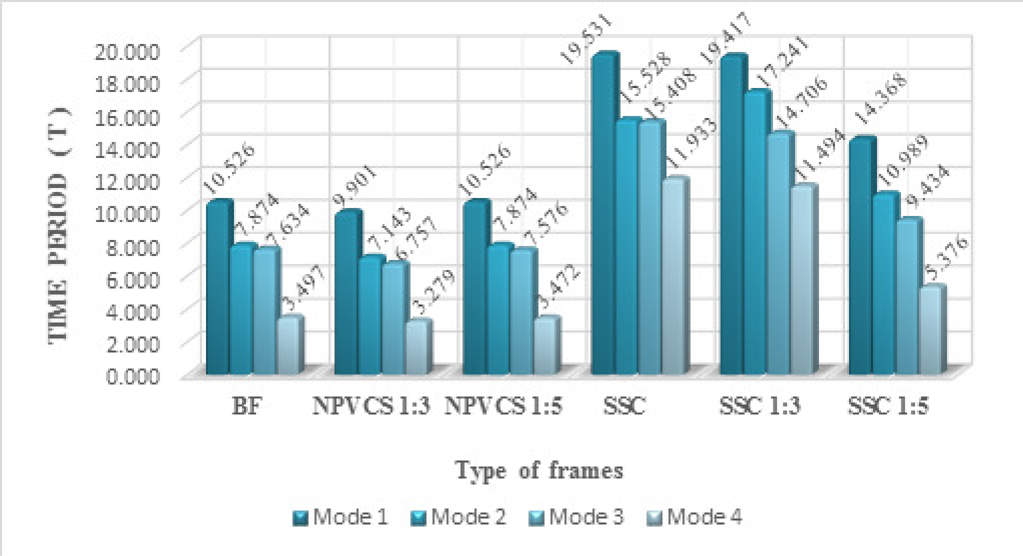

Figure 3 Time periods for frames with special shaped beams and columns

3.3. Stiffness

The basic objective of this study is to check the effect of special shapes of beams and columns in increasing the fundamental time period and decreasing the fundamental frequencies of the structure. The fundamental frequency have two dominating parameters, the mass of the structure (m) and the stiffness (K). Here in this study the stiffness of the various frames has been compared. It is seen that for the frames which have lesser frequencies and maximum fundamental time periods the stiffness has to be less. Lesser the stiffness lesser the frequency and more will be the time period which makes the structure more flexible and such structures proves to have better response than that of stiffer structures. It was seen that the SSC and SSC 1:3 has lesser stiffness.

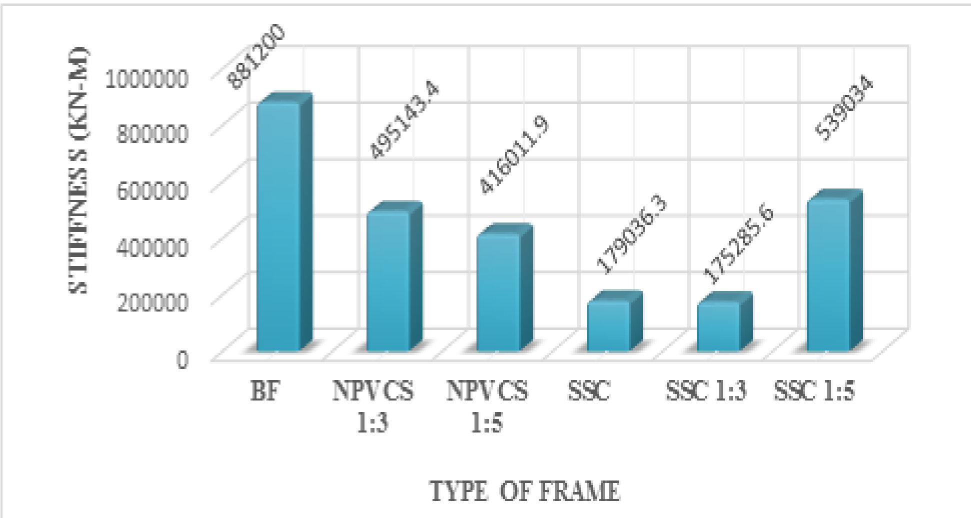

Figure 4 Stiffness for various frames

3.4. Base Shear

The Shaking of earth during a quake is random and time variant. Most of the codes including IS 1893 represent the earthquake-induced inertia forces as the net effect of such random shaking in the form of design equivalent static lateral force, called as the Seismic Design Base Shear. In this study the effect of special shaped cross sections of columns and beams on the fundamental time period has been evaluated. The increased fundamental time period for the SSC, SSC-1:3. SSC-1:5, type of frames shows us that the structures becomes flexible /ductile and would experience lesser shear at the base, it is shown in the figure below.

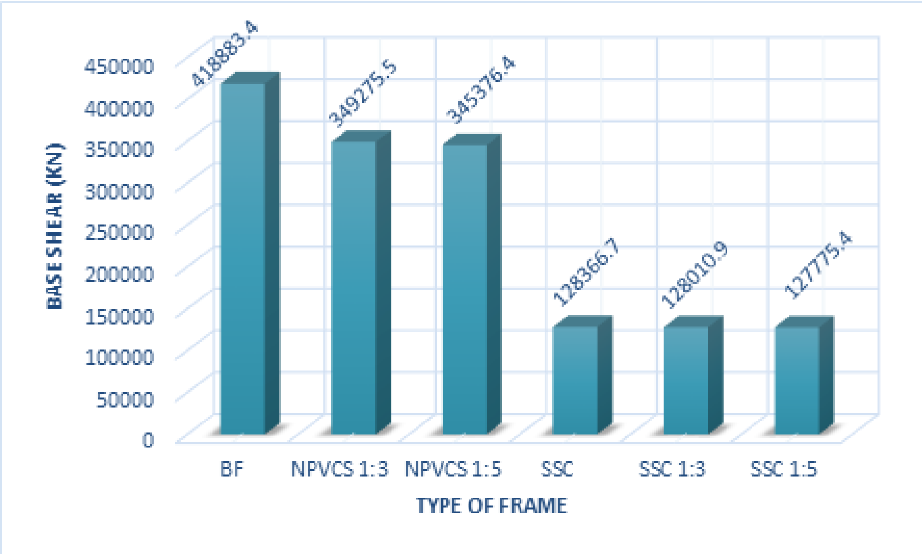

Figure 5 Base Shear of various frames.

4. CONCLUSIONS

This comparative study represents the comparison of various parameters gained after Time History Analysis of different braced frames. After studying all the results the following conclusions has been drawn:

- It was seen that the special shapes of columns and beams has considerable effect over the fundamental frequencies and fundamental time periods.
- It is suggested that the effect of these special shapes of columns and beams over fundamental frequency and time period must be considered in the equation of estimation of these parameters.
- It is suggested that in high rise structures the special shaped columns or NPVCS beams or combination of both may be used so as to resist the earthquake forces safely.
- The fundamental time period of bare frame and NPVCS with 1:3 slope is approximately same whereas the increase in time period in SSC and SSC 1:3 is also approximately same.
- The fundamental time period of the frames with special shaped columns with conventional beams (SSC) & special shaped columns with NPVCS beams (SSC 1:3) was maximum.
- The base shear of NPVCS 1:3 and NPVCS 1:5 was maximum after the bare frame, which is not desirable as we are objected to have a flexible and ductile structure.
- As objected the base shear which is experienced in three of the frames with special shaped columns, i.e. SSC, SSC 1:3 & SSC 1:5 is very less which will improve the response during earthquake and minimizing the destructions
- Both the variants of the frames with conventional columns and NPVCS beams has shown a greater base shear hence cannot be used for frames expected to be flexible during earthquake with conventional shape of columns.

- To make a structure flexible and to ensure that it experiences minimum shear at its base, combination of special shapes of columns with NPVCS 1:3 are suggested to be used.

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