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EFFECT OF BRACED SPECIAL SHAPED COLUMN CROSS SECTION ON RESPONSE MODIFICATION FACTOR OF REINFORCED CONCRETE BUILDING

Baviskar Vinita[1], Dr. S. K. Hirde[2]

[1]PG Student, Department of applied mechanics, Government college of engineering, Amravati, Maharashtra, India
[2]Professor& Head of Applied Mechanics Department, Government College of Engineering, Amravati, Maharashtra, India

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Abstract - *Earthquake is the most dangerous and destructive natural hazard in the world. When earthquake resistant structure are designed, designed forces are lesser than that of actual forces developed. The actual base shear force needs to be reduced by the factor known as response reduction factor(R) to get design lateral force. Response reduction factor is very important in seismic design of structures. Components of response reduction factor (R) are ductility factor, redundancy factor, overstrength factor and damping factor. Response reduction factor is taken from seismic design codes of developed countries such as United States and India. Column plays important role in RC buildings as overall load is transferred through the column. Special shaped column not only gives good aesthetical view but also performs better in seismic conditions better than rectangular columns. So, this study aims at calculating response reduction factor(R) for combination of column cross section with special shapes (L, T, +) and 'X'& 'V' type bracing. Total 28 models of different number of storeys i.e. 5,10 are analyzed using Pushover analysis for different seismic zones for different seismic codes.*

Key Words: **Response modification factor, Special shaped column, Braced column, Ductility factor, Pushover analysis.**

1. INTRODUCTION

Response modification factor plays important role in seismic design of any structure.. R determines the nonlinear performance of building structures during earthquakes. Ductility, Redundancy, Damping and Overstrength are the component parts of response modification factor. These factors are taken into consideration because of the impact they produce on various aspects of the structural energy absorption and dissipation, internal forces redistribution in the elastic range and structural damping.

Response modification factor=Rs*Rμ *Rξ *Rr (1)

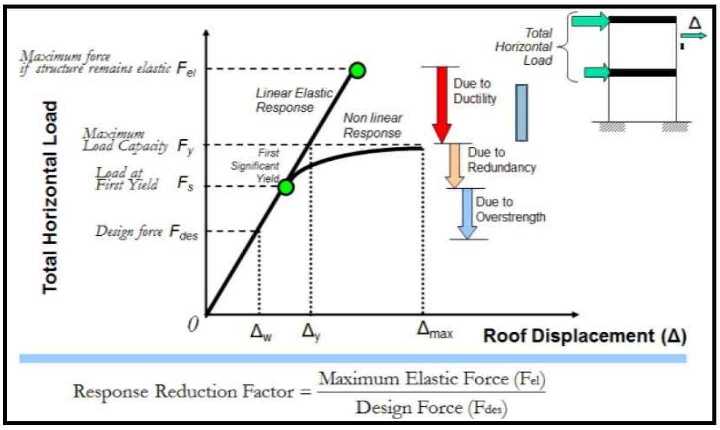


Figure 1: Components of Response Modification (reduction) Factor (19)

a)Ductility factor

The capacity of the structure to dissipate energy depends on the ductility of the structure. According to ATC-19 ductility is represented as:

$\mu = (\Delta m) / (\Delta y)$ (2)

Where:

Δm- Maximum drift capacity

Δy-Yield displacement

Short period T < 0.2 seconds $R\mu = 1$

Intermediate period 0.2 < T < 0.5 seconds $R\mu = \sqrt{2\mu - 1}$

Long period T > 0.5 seconds $R\mu = \mu$

2)Overstrength factor

The overstrength factor measures additional strength of any structur beyond its design strength.It prevents collapse of the buildings. It can be defined as the ratio of actual lateral strength to the design lateral strength.

$R = Vy/Vd$ or $Rs = Vmax/Vd$ (3)

Where:

Vd -Code prescribed unfactored design base shear coefficient

Vy (Vmax) - Base shear coefficient corresponding to the actual yielding of the structure

3) Redundancy factor

Redundancy factor Rr can be calculated as the ratio of ultimate load to the first significant yield load; estimation of this factor requires detailed non-linear analysis.

$R = Vu/ Vy$ (4)

4)Damping factor

Damping factor is used for the structures in which additional energy dissipating (Viscous damping) devices are provided. The damping factor is taken as 1 for the buildings in which no such devices are used.

II. LITERATURE REVIEW

An detailed literature review was carried out prior to the project. This literature survey includes SMRF and OMRF, Response reduction factor, ductility, pushover analysis, braced columns, shape of columns.

According to IS 1893: 2002 (Part1) [2] and IS 1893:2016 (Part1) [3] Criteria for earthquake resistant design of structures Part 1 General provisions and buildings, Bureau of Indian Standards RC frame buildings are classified in two classes,OMRF and SMRF having response reduction factors 3 and 5 respectively, whereas for braced frames response reduction factor is 4.5. According to ASCE 7 [5] RC frames are classified into three ductility classes: and the Response reduction for OMRF is 3,IMRF is 5 and SMRF is 8, whereas for braced SMRF is 6 & OMRF is 5.5 .Sadjadi et.al. [8] studied seismic performance of RC frames of 5-story frame designed as ductile, nominally ductile and GLD and concluded that the nominally ductile frames behaved better under earthquake conditions.

V. Gioncu [10] observed that factors regarding seismic actions ie. Velocity and cyclic loading reduce available ductility.

Whittaker et.al. [11] identified formulation for response modification factor. Asgarian and Shokrgozar [13] checked ductile, over- strength and response modification factor of BRBF and it was perceived that the R factor drops as the height of building increases. Mondal et. al. [14] studied the nonlinear response of a structure through a response reduction factor (R) and stated that value recommended by Indian standards is higher than the actual value. Swajit Singh Goud et. al. [15] studied the seismic resistant design philosophy and stated that value of R is directly related to the ductility level provided in the structure.

Jianguo et al. [18] investigated the seismic behaviour of concrete-filled rectangular steel tube structures and concluded that in push-over analysis different types of plastic hinges should be applied for the beam elements and the column elements separately.

B. Shah and P. Patel [19] assessed a ground + six storey RC frame models and stated that square shape column performs better in seismic conditions and improves the seismic response of a structure as compared to the rectangular shape of an same area A. Rahaman et.al. [20] compared the lateral load resistance capacity of buildings with rectangular columns and buildings with special shaped columns and concluded that the buildings with specially shaped columns perform better under lateral load conditions than the buildings with conventional rectangular columns under the same loadings.

Abdel-Rahman Sobhy et al. [21] studied 2D braced and un-braced RC moment resisting frames for the effect of position of bracing and type of bracing used and concluded that provision of bracing leads to change the value of R factor and leads to improve the behavior of the structure in seismic conditions.

III. BUILDING DETAILS

The structural models considered in this study are 5 & 10 storeyed buildings symmetrical about both axis with 3 bays. Width of bay is 4m. Typical height floor is 3m. Modelling is done using the software ETABS.

Table 1: Details and dimensions of building models

	Parameters	**Values**
1	Type of structure	Special moment resisting RC frame
2	Grade of concrete	M50
3	Grade of steel	Fe 415
4	Floor height	3 m
5	Beam size	350 mm X 400 mm
6	Column size	400 mm X 400 mm
7	Slab thickness	150 mm
8	Live and dead load on floor	2 kN/m^2
9	Live load on roof	1.5 kN/m^2

Table 2: Seismic Properties (IS 1893:2016)

Sr. No.	**Parameters**	**Values**
1	Seismic zone	V (Z=0.36)
2	Importance Factor	1.2
3	Damping	5%
4	Site Class	Type II (Medium soil)
5	RMF (Braced frames)	4.5
6	RMF (Unbraced frames)	5

Table 3: Seismic Properties (ASCE 7-16)

Sr. No.	Parameters	Values
1	Seismic zone	IV (Z=0.4)
2	Importance Factor	1
3	Damping	5%
4	Site Class	D (Stiff soil)
5	RMF (Braced frames)	6
6	RMF (Unbraced frames)	8

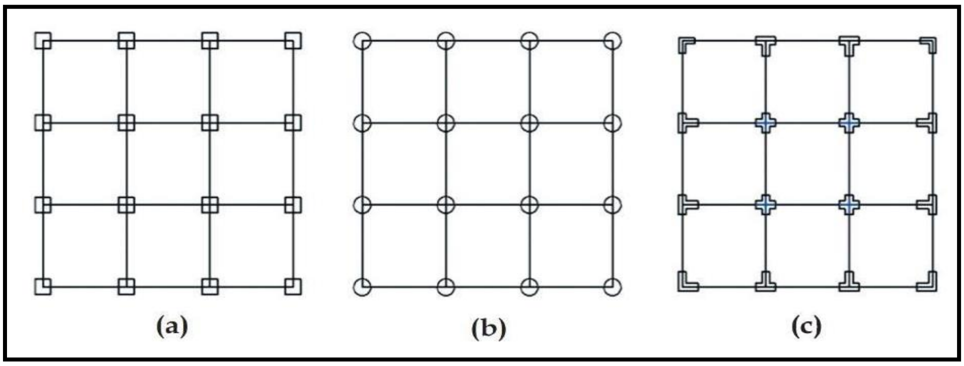


Figure 2: Plans having column cross sections (a) Plan with square columns,

(b) Plan with circular columns, (c) Plan with plus, L and T-shaped columns

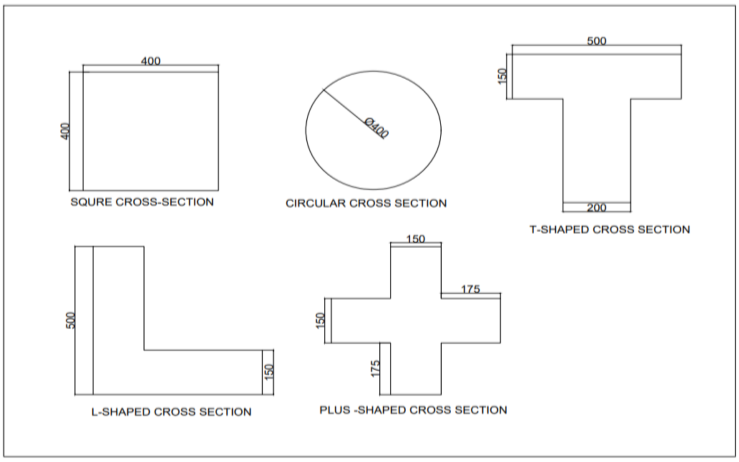


Figure 3: Cross sections of different shapes of column

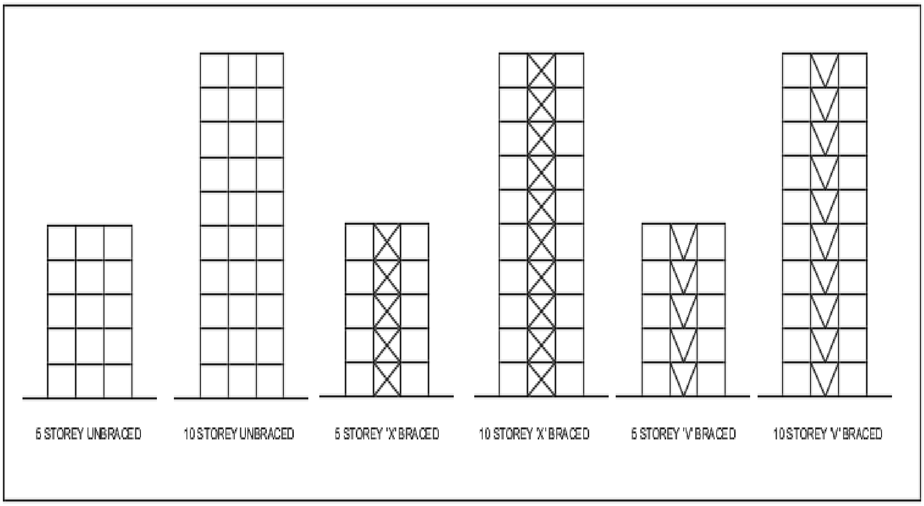


Figure 4: Cases for multistoried structures

IV. ANALYSIS

Analysis of the frames has been done using ETABS17.0.1, which is structural analysis software used for static and dynamic analysis. Pushover analysis is performed using ETABS nonlinear version 17.0.1 Capacity curve is obtained from the graph of base shear versus displacement. Displacement control strategy is used for nonlinear static analysis.

NOTATIONS:

I-IS 1893:2016

A-ASCE 7-16

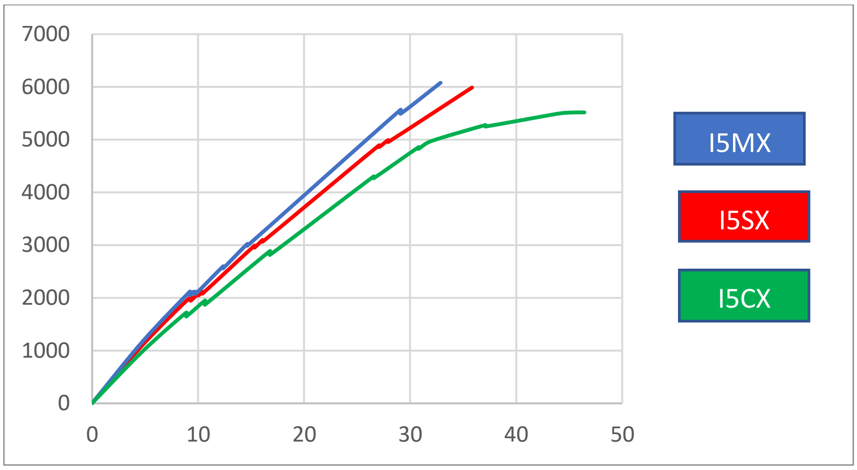
S- Square column

C-Circular column

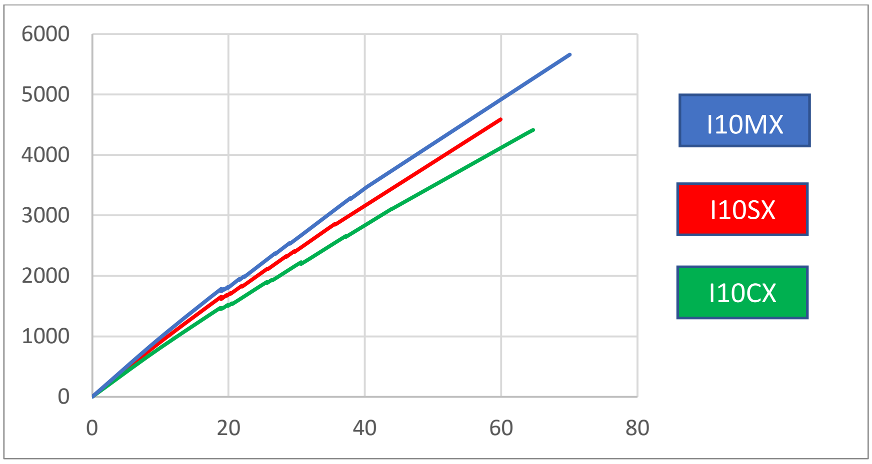
M- Mix column

X- X Type bracing

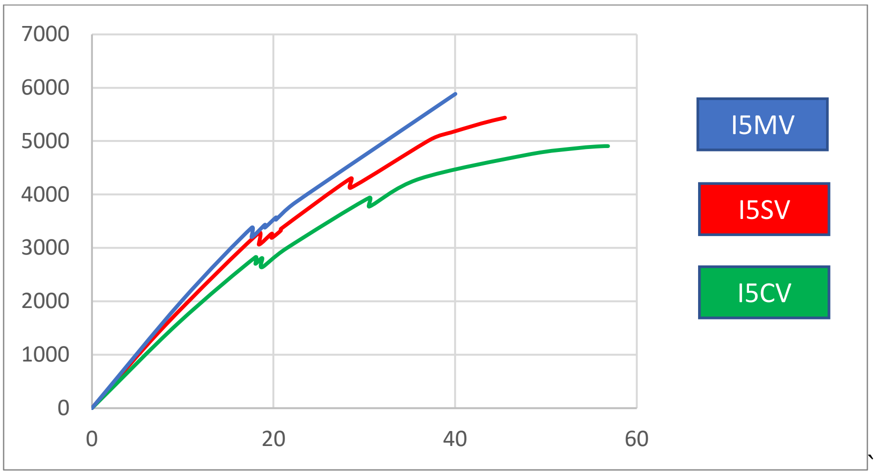
V-V type bracing



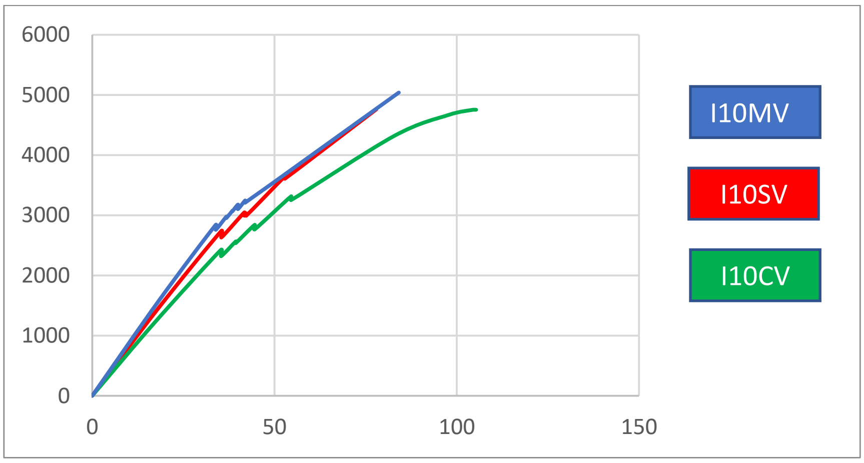
Static pushover curves for 5 storey 'X' braced column cross section



Static pushover curves for 10 storey 'X' braced column cross section

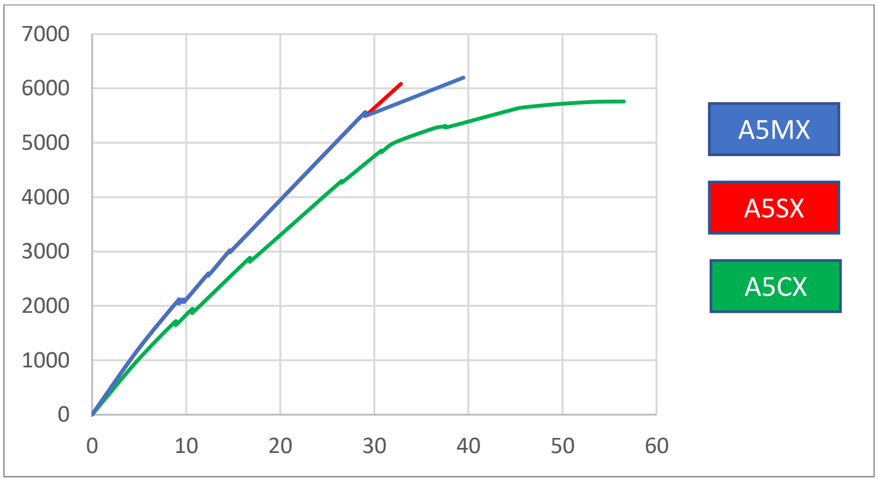


Static pushover curves for 5 storey 'V' braced column cross section

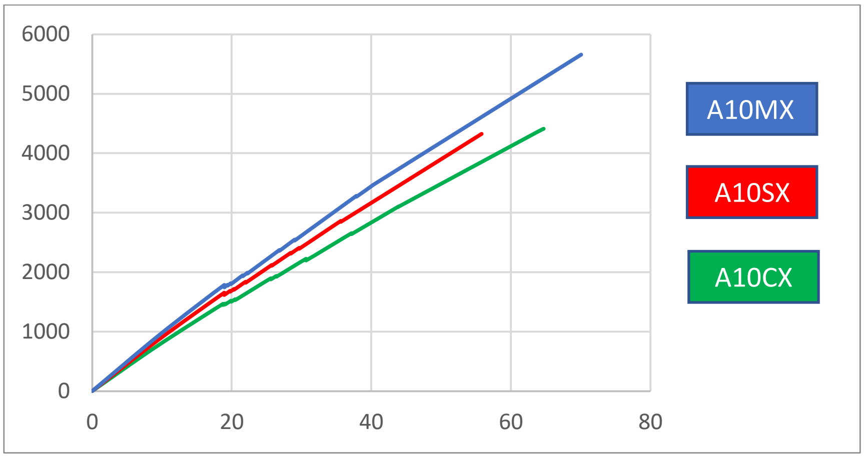


Static pushover curves for 10 storey 'V' braced column cross section

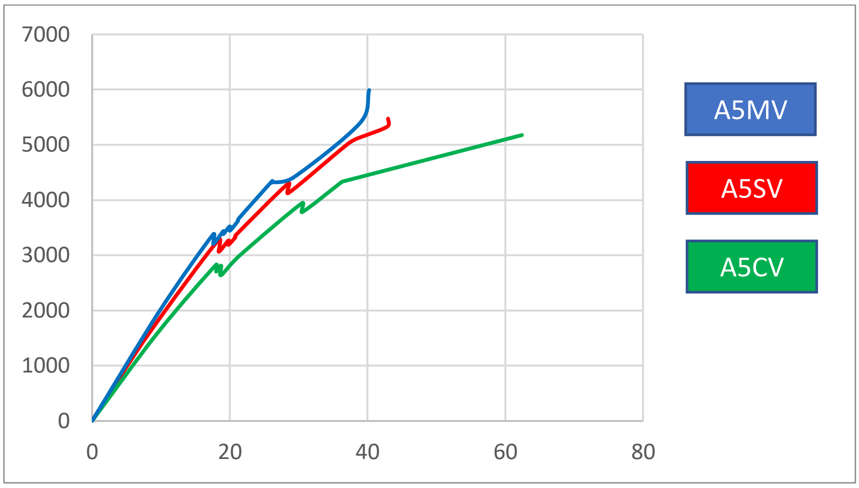
Fig 5: Comparative effect of different column cross section on static pushover curve IS 1893:2016



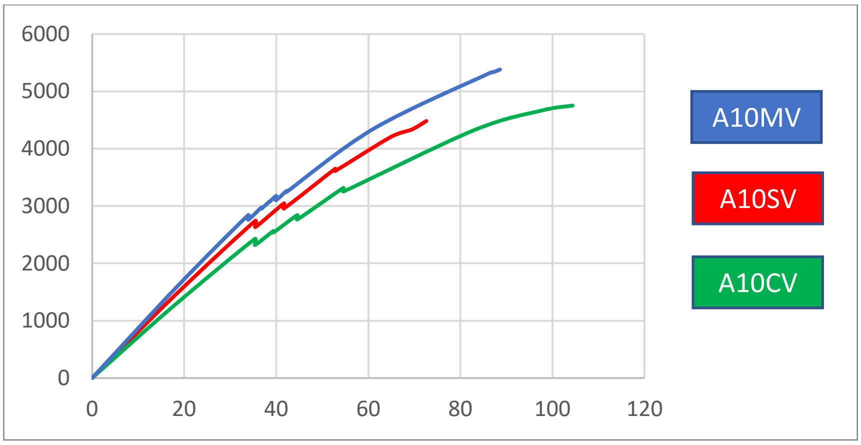
Static pushover curves for 5 storey 'X' braced column cross section



Static pushover curves for 10 storey 'X' braced column cross section



Static pushover curves for 5 storey 'V' braced column cross section



Static pushover curves for 10 storey 'V' braced column cross section

Fig 6: Comparative effect of different column cross section on static pushover curve ASCE 7-16

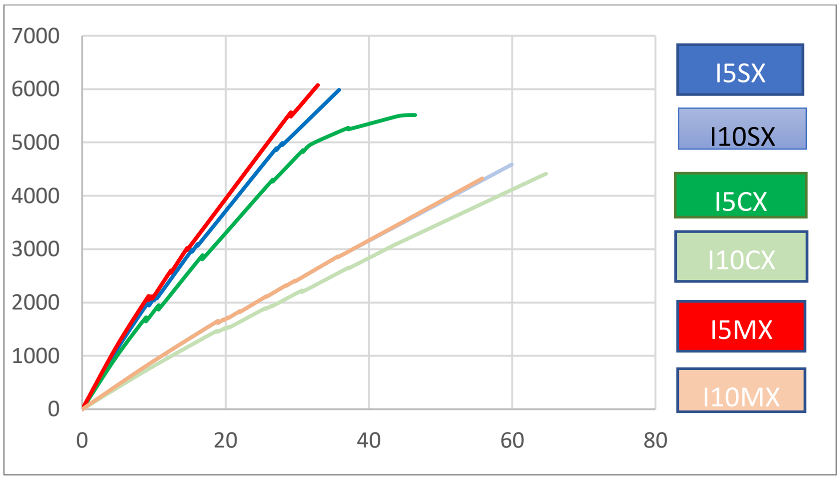


Figure 7: Comparative effect of different heights on static pushover curve for different column cross sections for 'X' braced structure: IS 1893:2016

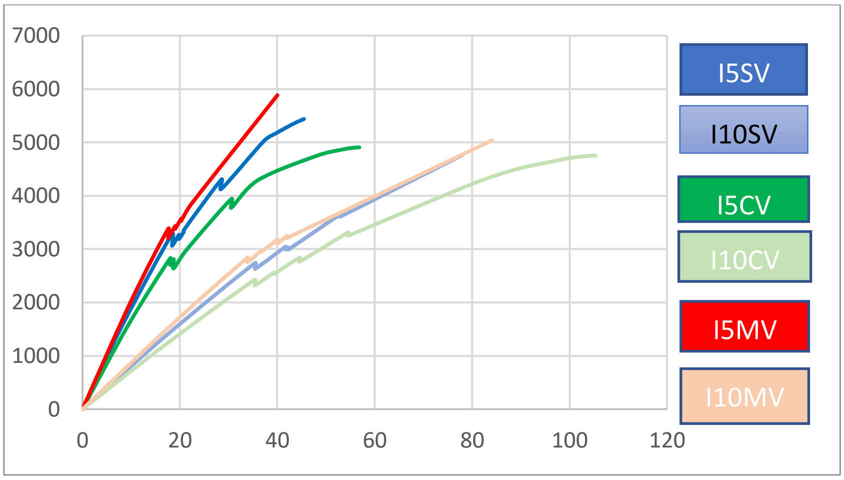


Figure 8: Comparative effect of different heights on static pushover curve for different column cross sections for 'v' braced structure: IS 1893:2016

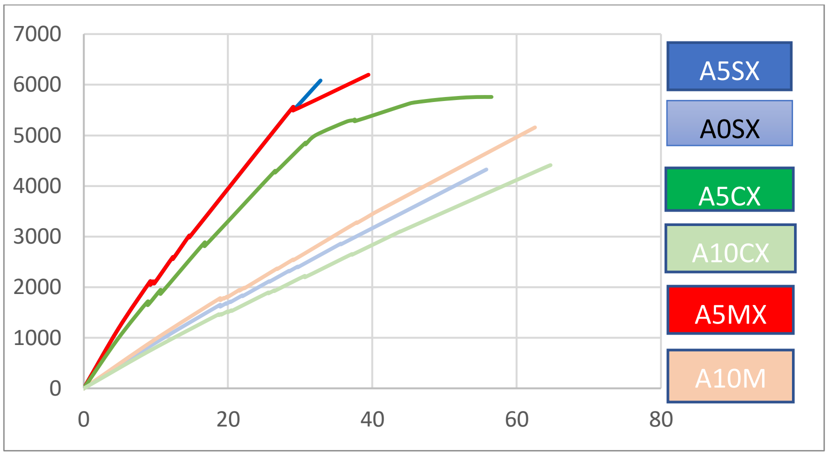


Figure 9: Comparative effect of different heights on static pushover curve for different column cross sections for 'X' braced structure: ASCE 7-16

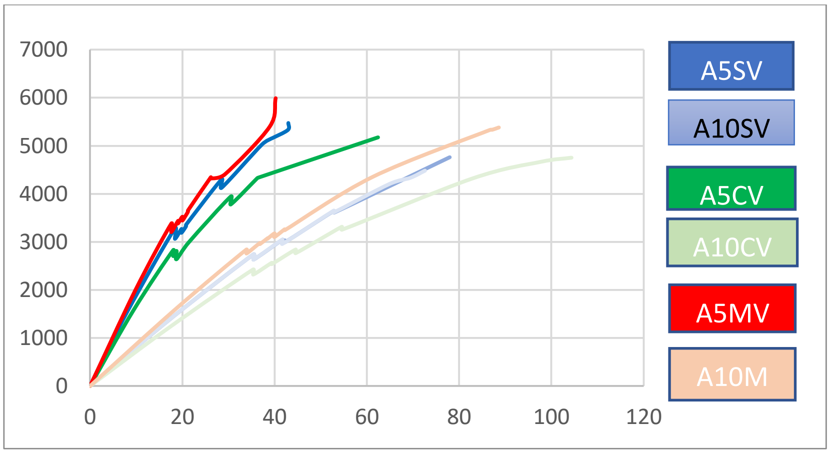


Figure 10: Comparative effect of different heights on static pushover curve for different column cross sections for 'V' braced structure: ASCE 7-16

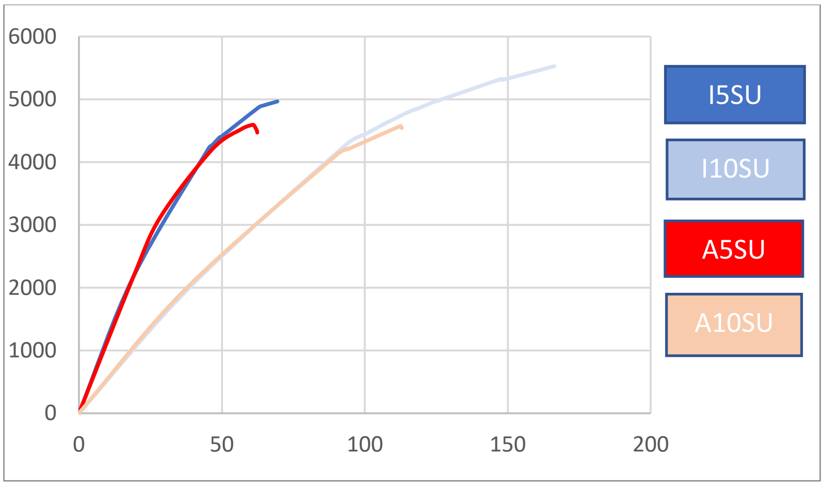


Figure 11: Comparative effect of different heights on static pushover curve for different unbraced structure

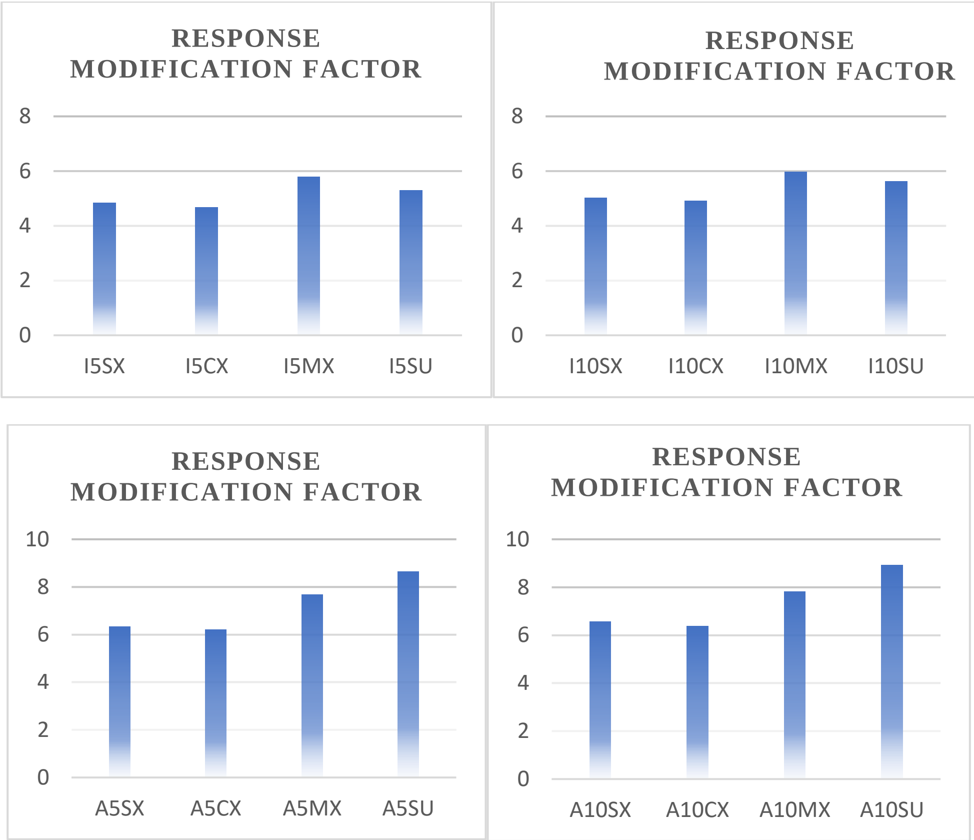
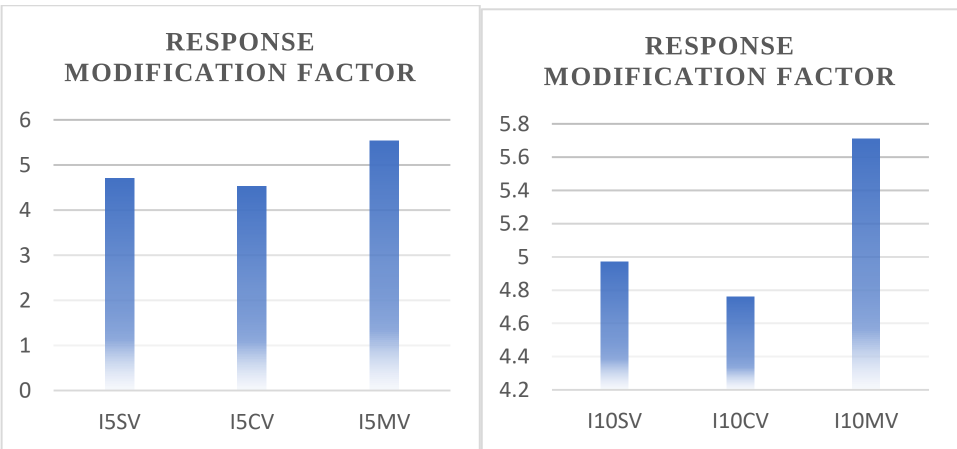


Figure 12: Variation in response modification factor with different cross sectionof column and different codes for 'X' bracing



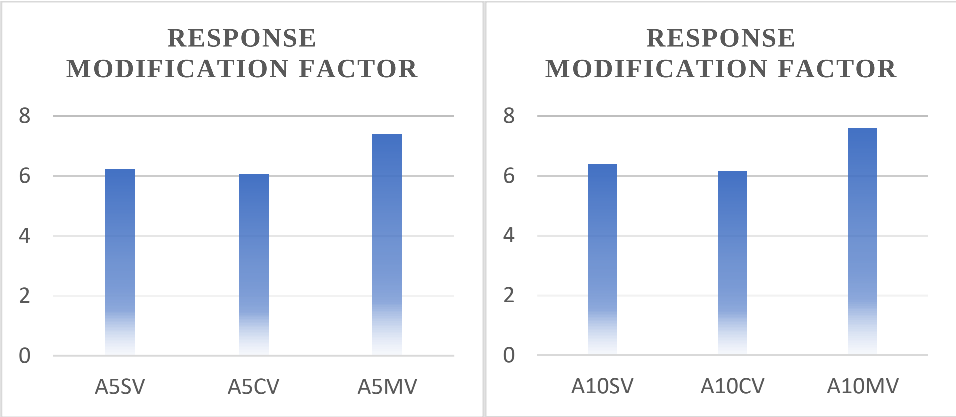


Figure 13: Variation in response modification factor with different cross section of column and different codes for 'V' bracing

VI. CONCLUSIONS

The seismic assessment of braced reinforced concrete frames having different number of stories viz.5 storey &10 storey and special shaped viz. circular, square, T shaped, plus shaped &L shaped column cross section is presented in this paper. These models are developed and pushover analysis is carried out in ETABS. From the static pushover curve values of response modification factors are calculated.

Concluding remarks drawn from the analysis are as follows:

1. From the analysis it is observed that values of response reduction factor for the structures designed as per ASCE 7-16 is on higher side than that of structures designed with IS1893:2016.
2. The values of response reduction factor computed from static pushover analysis is strongly affected by changing number of stories, geometric properties and by providing bracing as it can be seen in figure 12 & figure 13.
3. As height of the structure increases ductility factor and overstrength factor alsoshows increase in trend.
4. The value of response reduction factor given in design codes often do not match the true values. As the value of response modification factor given is ASCE 7-16 for SMRF is 8 and for SBF is 6 whereas for IS 1893:2016 SMRF is 5 and SBF is 4.5 whereas obtained values are different from these values.
5. From the analysis results it is observed that response reduction factor for structures using special shaped column cross section is higher than that of structures of regular shaped column cross sections.

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