Study Of Beam-Column Joint And Effect On Moment Capacity Ratio On RC Frame Structure At Seismic Zone III

Mr. Onkar Anuse[1]*, Dr.V.S Kshirsagar[2], Manik.G. Deshmukh[3], Avinash.B.Kokare[4] , Shyam S .Kolekar[5]

[1] * PG.Student, SVERI's College Of Engineering, Pandharpur
[2] Associate Prof.,SVERI's College Of Engineering, Pandharpur
[3]Associate Prof.,SVERI's College Of Engineering, Pandharpur
[4]Assistant Prof. , SVERI's College Of Engineering, Pandharpur
[5]Assistant Prof., Fabtech College of Engineering, Sangola

***Corresponding Author:** Mr. Onkar Anuse
* PG.Student, SVERI's College Of Engineering, Pandharpur

Abstract:
The design of the beam-column joint is important in RC-framed buildings. A beam- column joint's behaviour is determined by its moment capacity ratio, which is typically larger greater than 1.The value of this varies greatly among different codes. It is stated quite clearly in IS: 13920 that the moment capacity ratio at the joint must be taken to be 1.4. In order to ensure a strong column–weak beam, pushover analysis is carried out on a frame whose moment capacity ratio (MCR) increases with an increase in column dimensions as well as reinforcements. Studying its impact on lateral displacement, base shear, storey drift, ductility, and hinge formation, the ideal moment capacity ratio is computed. The conclusion is that the MCR shouldn't be less than 1.4 in order to achieve greater ductility and plastic hinges at the ends of beams rather than in columns. In order to do this increase in reinforcement of column works better than expanding its size.

Keywords: Beam column joint , MCR ,plastic hinges

Introducton:

1.General In an RC-framed building, the beam-column joint is an extremely important area. where the frame's components join together. The frame's joint effectively transfers forces and moments between components such as beams and columns, guaranteeing the continuity of the develop at the joint and exhibit critical behaviour, the beam-column joint is susceptible to failure. The factors for the critical behaviour of joints have been identified through research on joint behaviour. These factors include loading, cross-sectional details, type of concrete, and reinforcement provided. When designing a structure to withstand earthquake forces, the most crucial factor is the structure's ductility. A structure's ability to deform even in the plastic range without collapsing is enhanced by its increased ductility, which lowers the effective earthquake forces.

1.2 Strong Column–Weak Beam Design (SCWB)

The strong column-weak beam theory, which Murthy has emphasized, states that the plastic hinge should form close to the beam's end. This can be accomplished by using ductile detailing on the structure to guarantee total dissipation of energy. Prior to the structure collapsing, it is anticipated that the greatest number of plastic hinges will form. In the first story, the hierarchy of plastic hinge formation is found first on beams and then at the base of columns. By keeping the right ratio between the moment carrying capacities of the beam and column meeting at the joint, this can be accomplished in design. In a capacity-based design procedure, the global strength hierarchy is established after the local member level. For this to happen, the strength of the columns (Mc) at the intersection must be adjusted to be greater than the strength of the beams (Mb). Consequently, Mc Mb.

The beam is intended to be the weakest by using the SCWB design. As a result, the beams flexure and fail, sparing the column and joint failure and averting the overall structure's global failure. Furthermore, since the beams' shear capacity will not be compromised, they can support the weight of gravity even in the event of a flexural failure. Soft storey formation could result from not using the SCWB design since the columns' strength will decrease relative to the beams.

2 Literature Review

The ratio of the total moment carrying capacities of all columns to the total moment carrying capacities of all beams meeting at a joint is known as the moment capacity ratio. It's expressed as

MCR = □□□ □□ □□□□□□ □□□□□□□□□ / □□□ □□ □□□□ □□□□□□□□□ ...(1)

where, as shown in Fig. 1, Mc and Mb represent the total moment carrying capacities of the column and beam, respectively, connected at the joint in a specific direction.Moment Capacity Ratio's Impact on RC Framed Structure

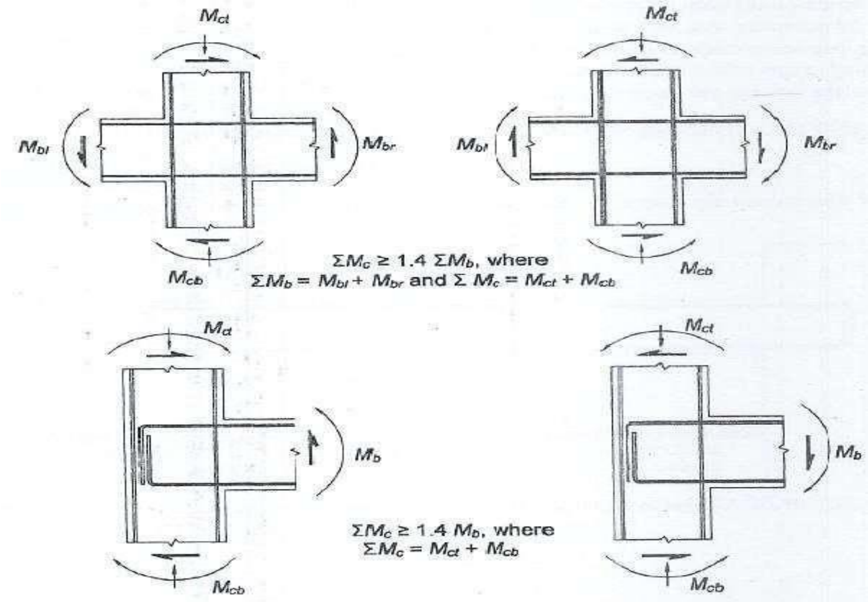


Fig. 1 Moment capacity ratio

Code	ACI318M-02	NZS3101:1995	EN1998-1:2003	IS13920:2014 (Draft)	IS13920:2016
Moment capacity ratio	$\Sigma M_c \geq 1.2\ \Sigma M_b$	$\Sigma M_c \geq 1.4\ \Sigma \Phi_0 \Sigma M_b$	$\Sigma M_c \geq 1.3\ \Sigma M_b$	$\Sigma M_c \geq 1.7\ \Sigma M_b$	$\Sigma M_c \geq 1.4\ \Sigma M_b$

The literature demonstrates that a lot of research has been done on how the moment capacity ratio affects RC-framed structures. Following a review of several codes, Table 1 lists the codal provisions pertaining to moment capacity ratio. Φ_0 is the overstrength factor for beams equal to 1.47

Uma and Jain [5]conducted research with reference to the above mentioned. codal provisions. The total moment capacity of columns in an RC moment-resisting frame that is subject to horizontal seismic loads at joints must be more than the total moment capacity of beams, or ∑Mc ≥ ∑1.1 Mb.

Ketut Sudarsana [6]et al. looked into how ductile reinforced concrete buildings behaved in relation to moment capacity ratio. Fourteen interior frame models of two building categories— one with five stories and the other with ten—were modeled and examined. There were several values for the moment capacity ratio, including 1.0, 1.2, 1.4, 1.6, 1.8, and 2.0.

The pushover analysis was used to examine each of the 14 frame models' performances. Each of the fourteen models displayed a life safety performance level. This led to the conclusion that strength and ductility are significantly increased when the moment capacity ratio is raised to 1.4. Further raising the MCR has no effect on ductility. Instead of adding more column reinforcement, Shivakumara Swamy et al. used pushover analysis for a range of stiffness ratios by altering the column's cross-section. The beam's cross-section remained constant across all instances. To achieve this, a two-dimensional RC concrete frame was modelled in ETABS, taking into account the effects of the soil type and seismic zones. This led to the conclusion that buildings with a lower MCR have a lower seismic capacity.[7]

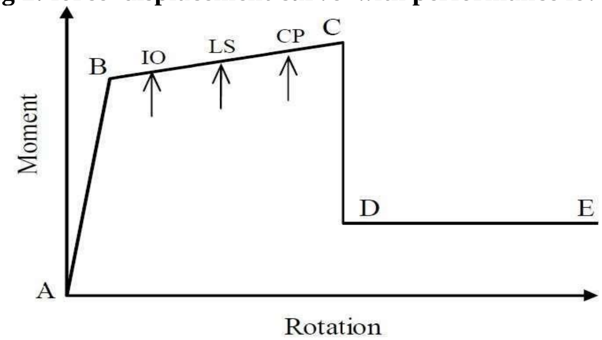
Praveen Kumar Parasa[9] performed a pushover analysis using higher MCR values. It was investigated how applying higher MCR values affected the structure's ductility. It was determined that the overall structure's ductility improves with an increase in MCR value. Buildings with lower MCR values were significantly more vulnerable to damage than those with higher MCR values.

Murthy C. V. R. et al.[10] discovered that the current code's requirements regarding the necessary column-to-beam strength ratio differ significantly from one another. Furthermore, it is made clear that the moment capacity ratio of 1.2–1.4, which is the minimum value used in codes, is insufficient. Using the findings of linear elastic static analysis, a straightforward process was put forth to apply the strong column–weak beam design philosophy, which causes moment frame buildings to behave in an inelastic manner that is desired during intense seismic activity. It is evident that a column's design moment capacity ought to be between 2.4 and 2.8 times that of a beam.

3.Performing structural Analysis

Pushover analysis using the displacement controlled method is used in this work to conduct the analysis. This method involves increasing the lateral forces on the structure until the designer's target displacement is reached. See Effect of Moment Capacity Ratio on RC Framed Structure. A total of 4% of the building's height is the target displacement that is utilized. Performance level points are denoted by the letters P, Q, R, S, and T in Fig. 2. These points indicate the hinge's moment rotation performance, and additional points IO,

Fig 2: force–displacement curve with performance levels



LS, and CP—which stand for immediate occupancy, life safety, and collapse prevention, respectively—define the hinge's acceptance standards.

3.Building Design and modelling

The following data are presented in Tables 2, 3, 4, and 5 for the RC multi- storeyed frame that is used in this work. Three models are identified, A, B, and C, as specified in Sect. 2; Table 5 provides further information on each model. A model A has an MCR value of less than 1.4. Model B indicates that the MCR increases as column dimensions increase, and Model C indicates that the MCR increases at beam-column joints as column longitudinal reinforcement increases.

Table No.2 General building details

Type of structure	Multi storey RC frame
Zone	III
Exposure conditions	Mild
Soil type	Medium
Damping	5 %
No of Storey	(G+6)
Storey height	3m
No of Bay	4
Bay width	4m
Design philosophy	Limit State method conforming to IS 456:2000

Table No.3 Details Of Material

Concrete	Grade (f_{ck})=25 MPa Poisons ratio =0.3 Density = 25 kN/mm^3 Modulus of elasticity = 5000 f_{ck} =25000 MPa
Steel	**f_y = 415 MPa** **Modulus of elas0city = 2x10^{5}MPa**

Table No.4 Loading Details

Dead Load	20KN
Live Load	10KN
EarthQuake Loads	1.Seismic Zone III 2.Importance factor I.F=1.5 3.Soil Category –Type II

Table No.5 Details of section

Model	A Moment capacity ratio < 1.4	B Moment capacity ratio > 1.4	C Moment capacity ratio > 1.4
Beam	325mm X 325mm	325mm X 325mm	325mm X 325mm
Column	330mm X 300mm - External 350mm X 350mm - Internal	410mm X 410mm -External 450mm X 450mm -Internal	330mm X 300mm - External 350mm X 350mm - Internal

When conducting a two-dimensional analysis, an intermediate plane frame of the building that is only subject to unidirectional lateral loading is taken into account. The following presumptions were made when developing the model:

a. The bottom of every column support has a fixed end condition. The impact of non-structural components is overlooked(Ignored).
b. For the column and beam, the designated locations of the plastic hinges are 0.05L and 0.95L, respectively. At the ends of the columns are PM2M3hinges, which combine axial force and biaxial moment hinge functionality. Only bending moment hinges (M3hinges) are offered for the beams.
c. The entire displacement target utilized is 4% of the building's total height.

4.Design Analysis

The capacity curve, also known as the pushover curve, shows the maximum lateral displacement of the structure in relation to the base shear force acting on the structure's base. These curves for models A, B, and C are displayed in Figure 3, and Table 6 displays the corresponding pushover curve values. Table 6 and Fig. 3 compare the pushover curves for Model A, Model B, and Model C that were found through pushover analysis. Figure 3 illustrates how the maximum lateral load carrying capacity increased as the moment capacity ratio increased. The displacement and base force for each model that correspond to the collapse condition are displayed in Table 6.

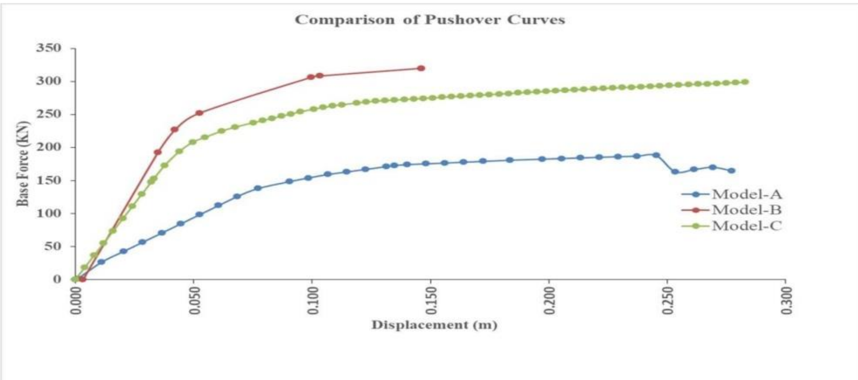


Fig 3 Comparison Of Pushover Curves

	Model A	Model B	Model C
Base Force (kN)	164.79	319.93	298.78
Displacement (m)	0.277	0.146	0.283

Table No.6 Comparison of Disp Vs Displacement Model A, Model B, Model C

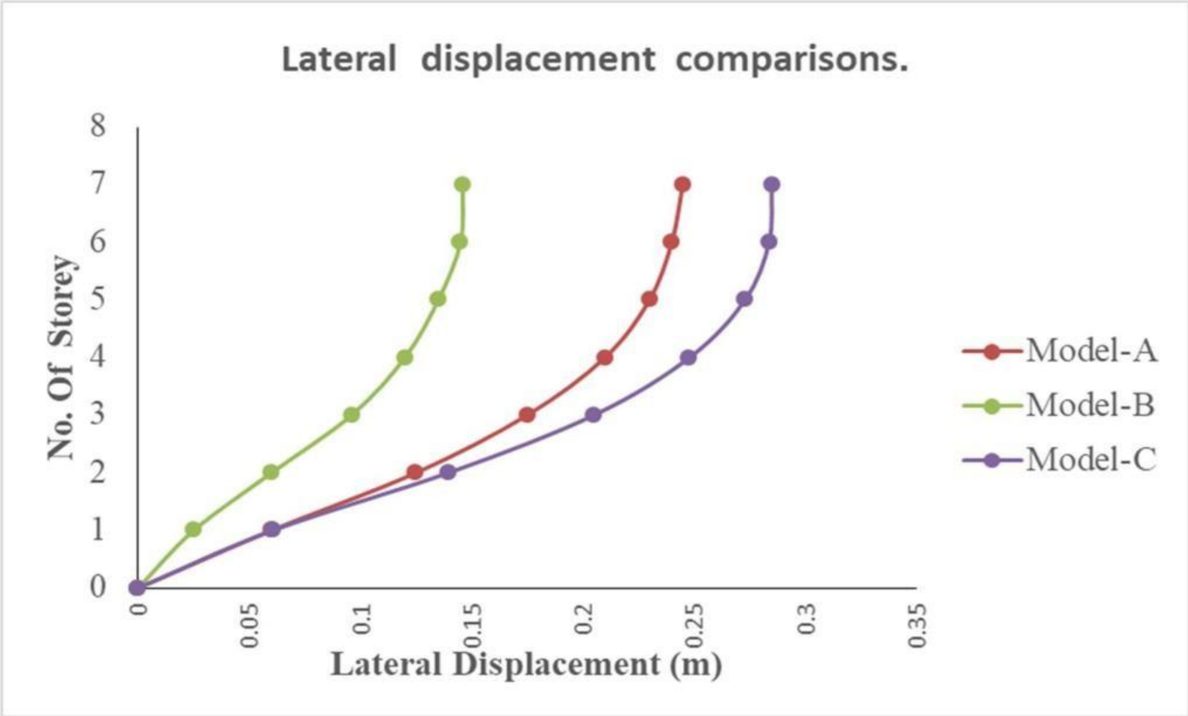


Fig. 4 Comparison of Lateral displacement

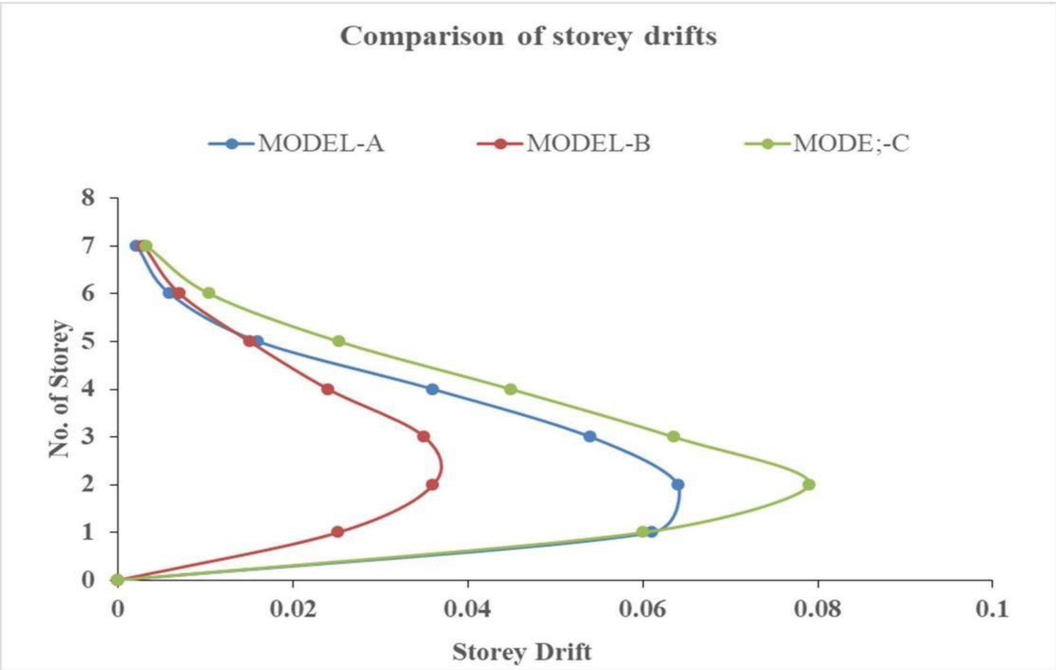
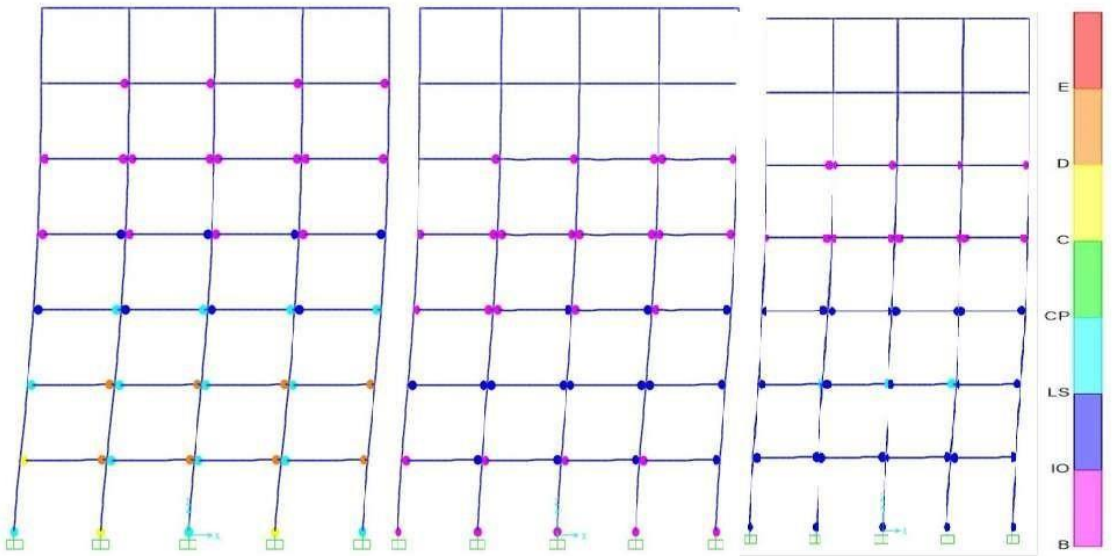


Fig 5 Storey drifts comparison

The lateral storey displacement and storey drift for each of the models A, B, and C are displayed in Figures 4 and 5. The interstorey drift obtained satisfies the IS1893:2016 codal requirement, falling within 0.4% of the total height.

Plastic Hinge Results:

Figure 6 shows the plastic hinge formation, details of which have been shown in Table 7. Model A has 11 hinges going beyond collapse prevention range, whereas model B and model C have no hinge beyond collapse prevention range. So model B and model C are safe for collapse prevention performance level.



Model A Model B Model C

Fig. 6 Formation of Plastic hinge

Table 7 Results Of Plastic Hinges

Model	A-B	B-IO	IO-LS	LS-CP	CP-C	C-D	D-E	>E	Total
A	77	16	8	14	0	3	8	0	126
B	84	27	15	0	0	0	0	0	126
C	84	13	26	3	0	0	0	0	126

Comparison of Various Parameters from Pushover Curve

The stiffness, strength, and ductility of models A, B, and C are contrasted in Table 8. The results indicate that while model C has the highest ductility, model B has greater strength and stiffness than models A and C.

Model	Stiffness(KN/m)	Strength(KN)	Yield Displacement (m)	Ultimate displacement (m)	Ductility
MODEL-A	1500.58	170.75	0.081	0.245	2.94
MODEL-B	5500.37	320.96	0.06	0.147	2.53
MODEL-C	3500.68	290.68	0.063	0.281	4.77

RESULTS AND CONCLUSIONS

Three models are designed for Zone V in the current study: model A, which has a moment capacity ratio less than 1.4, and models B and C, which have a moment capacity ratio greater than 1.4. Pushover analysis is used to evaluate each model's performance after it has been designed.

1. The lateral displacement of the frame for model A is determined to be 245mm. The displacement decreases to 147 mm when model B's column sizes are increased. The displacement is 281 mm in model C as a result of the increased reinforcement. In comparison to model A, which has a lateral load carrying capacity of 170.75 kN, models B and C have corresponding capacities of 320.96 and 290.68 kN.
2. When the size of the column increases, the ductility of the frame decreases to 2.53 from 2.94, but increases to 4.77 when the reinforcement is increased. 3.With moment capacity ratios greater than 1.4, Models B and C perform better than

Model A, which has a moment capacity ratio of less than 1.4.

4.Even though Model B's increased column sizes result in a noticeable increase in strength and stiffness, the structure's ductility significantly declines. Model C shows
to be more successful in ensuring ductility by increasing column reinforcement while maintaining strength and stiffness levels.

Consequently, it is advised that MCR> 1.4 be maintained; in order to do this, it is more effective to increase column reinforcement rather than column dimensions.

REFERENCES

Jain S.K1, Ingle Ingle R.K., Mondal (2006) 2, "Proposed codal provisions for design and detailing of beam-column joints in seismic regions", The Indian Concrete Journal

1. Jain S.K1., Murty C.V.R 2, "Proposed Draft Provisions and Commentary on Ductile Detailing of RC Structures Subjected to Seismic Forces" Department of Civil Engineering Indian Institute of Technology Kanpur
2. Subramanian N. and Prakash Rao D.S. (2003), "Design of Joints in RC structures with particular reference to seismic conditions", The Indian Concrete Journal.
3. Swamy B.S., Prasad S.K. and Sunil N. (2015), "Influence of Strong Column and Weak Beam Concept, Soil Type and Seismic Zone on Seismic Performance of RC Frames from Pushover Analysis", International Journal of Research in Engineering and Technology.
4. Uma, S.R., Jain, S.K.: Seismic design of beam-column joints in RC moment resisting frames—review of codes. Struct. Eng. Mech. 23(5) (2006)
5. Sudarsana, I.K., Budiwati, A.M., Aditya P.W.: Effect of column to beam strength ratio on performance of reinforced concrete frames. ICETIA (2014)
6. Shivakumara Swamy, B., Prasad, S.K., Sunil, N.: Influence of strong column and weak beam concept, soil type and seismic zone on seismic performance of RC frames from pushover analysis. Int. J. Res. Eng. Technol. (2015)
7. Paulay T. and Priestley M.J.N., "Seismic Design of Reinforced concrete and masonry buildings" A Wiley Inter science Publications.
8. Parasa P.K.: In a Rectangular RC framed building moment capacity ratio at beam columnjoints.Int. J. Adv. Res. Sci. Eng. (2015)
9. Vijayanarayanan, A.R., Goswami, R., Murty, C.V.R.: Simple linear elastic static analysis procedure to attain desired collapse mechanism for moment resisting frames. In: 16th World Conference on Earthquake, Santiago Chile (2017.