Effect of Moment Capacity Ratio on Ductility of Different shape RC Framed Building in Various Seismic Zones

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ABSTRACT: *Beam column joints are most fragile in RC Frame in term of seismic resistance. The material for limited strengths the joints have limited load carrying capacity when load is more during the earthquakes the joints damaged severely. Fixing of damaged joints is difficult so must be avoided .In multistory RC Framed building, it consist of horizontal and vertical members namely Beam and Column.. During this it affects largely Column Beam joint which are brittle during the earthquake. So failure of column leads the global failure of structure. So to avoid the damages one of the important factor is Moment capacity Ratio(MCR) given by IS (13920, 2016) But IS code provided same value for every shape of buildings, for different seismic zones. From the study it knows that it changes due to different shape different sizes of building also according to different seismic zones. Structure need to withstand with forces the MCR value gives lateral strength stiffness and Ductility of the structure. So this study carried out for one Regular RC framed shape and another Irregular shape RC framed building. For this study SAP2000 software is used.*

Keywords - ***Non-linear static analysis, moment capacity ratio, ductility, lateral strength, SAP 2000 etc.***

1. INTRODUCTION

Due to occurrence of earthquake large forces leads to shaking of ground and its behavior has impact on the response of structure. With cause vibrate structure and induce inertia forces in them. During earthquake beam column joint considered brittle when structure is subjected to seismic loading.

we cannot develop the structure earthquake proofs there is one of solution that is make it ductile So which can allow yield before collapse otherwise it remain brittle and will collapse without warning. Design the RC structure to behave elastically during the earthquake without damage make project uneconomical. It's necessary RC Structure withstand any kind of earthquake

Mathematically it can be expressed as, Mc>Mb. Where Mc and Mb are the moment capacities at the end of column and beam meeting at a joint respectively

1.1 MOMENT CAPACITY RATIO

Column beam flexural strength ratio is important variable for overall structure performance. Many international codes provided different MCR values.

Moment capacity ratio (MCR) defined as the ratio of the summation of column moment capacities to the summation of beam moment capacities at a given beam-column joint in the considered direction of loading.

$$\text{Moment capacity ratio (MCR)} = \frac{\sum Mnc}{\sum Mnb}$$

Where Mnc= Flexural strength of columns framing into joint and Mnb = Moment capacities of beam framing it.

Table1. Minimum MCR recommended by design codes and literature

Documents	MCR
ACI 318M-14 [5]	1.2
EN 1998-1:2004 [6]	1.3
NZS3101:1995 [7]	1.4xΩ
IS 13920:2016 [8]	1.4

These are the values are provided by different codes in world.

2. PUSHOVER ANALYSIS

The pushover analysis is done after designing reinforcement for the building in order to check structure whether
Pushover is a static-nonlinear analysis method where a structure is subjected to gravity loading

And a monotonic displacement controlled lateral load pattern .Lateral load may represent the range of base shear induced by earthquake loading. Output generates a static-pushover curve which plots a strength based parameter

Against deflection in this study force deformation criteria for hinges developed by ATC 40 and FEMA have been used in pushover analysis.

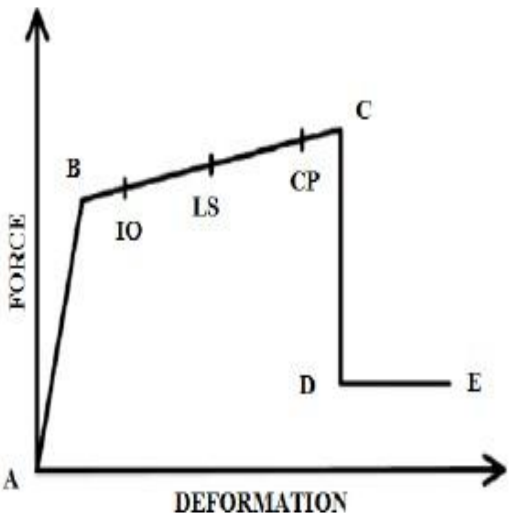


Fig.1. Typical force-deformation curve showing performance levels

1. Point A is original state of the structure.
2. Point B showing yielding. No deformation occurs in the hinge up to point B.
3. Point C represents ultimate capacity of the pushover analysis.
4. Point D represents residual strength of the structure. After this limit structure initializing to collapse.
5. Point E is total failure of structure. After this point hinge breaks down

3. METHODOLOGY

1. A different shape of RC framed building is designed using ETABS software with different seismic zones.

2. Ultimate flexural capacity of beam (Mrb) is determined from the obtained data.

3. Reinforcement in the column of buildings is progressively increased to accomplish different moment capacity ratio at Beam Column joint.

4. Later same building designed in SAP2000.Assign of hinges is carried out.

5. Nonlinear static analysis is run on SAP2000 Software.

6. Check the effect of various MCR on ductility and strength of RC framed structure.

3.1 Details OF building design

The input data required for the design of these buildings are presented in Table 2 to 4.

Type of structure	**Regular RC frame**
Zone	V, VI, III, II
Soil type	Medium
Damping	5%
Bay width	4m and 3m
Storey height	3m
Design philosophy	Limit State method as per IS 456:2000

Table2. General building and location details

Beam for G+5 building	230mm x 400mm
Column for G+5 building	300mm x 450mm
Concrete	fck = 25MPa Poisons ratio=0.2 Density=25kN/mm^2 Modulus of elasticity= $5000\sqrt{fck}$ =25000MPa
Steel	fy = 415MPa Modulus of elasticity= 2x10^{5}MPa

Table3 Details of materials and section property

Wall load	13.8 kN/m
Live load	2 kN/m
Floor finish	1 kN/m
Equivalent lateral loads	As per IS1893(part 1):2016

Table4. Loading details for the design

All design of the building done as per the IS 456-2002 and all the loads are taken as per the IS 1893 Part 1

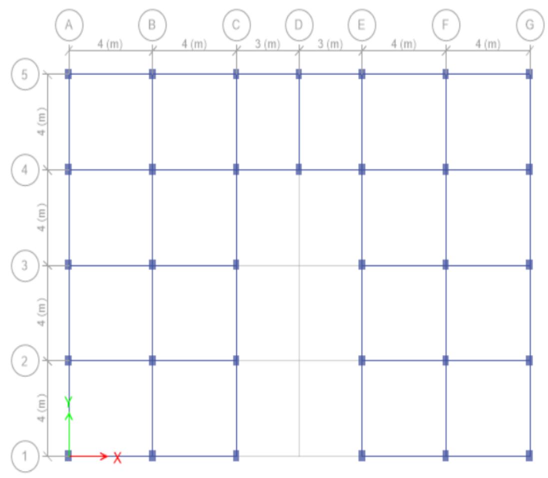


Fig.2. Plan of different shape RC framed building consider for study.

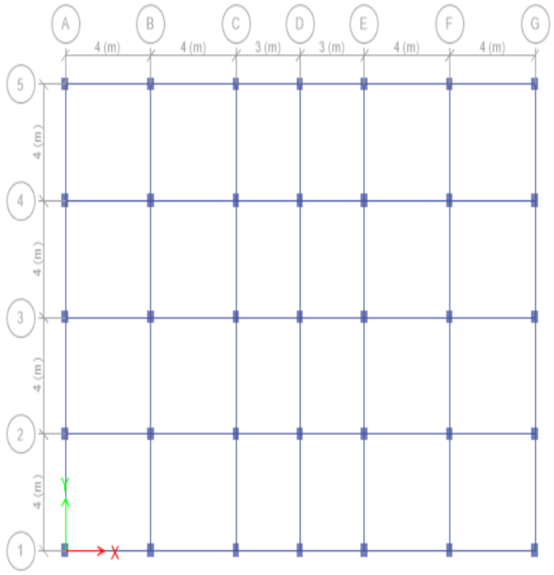


Fig.3 Plan of different shape RC framed building consider for study

4. Design approach in SAP2000

1. Create the basic computer model (without the pushover data)

2. Define properties and acceptance criteria for the pushover hinges

3. The program includes several built-in default hinge properties that are based on average values from ATC-40 for concrete members and average values from FEMA for steel members

4. Locate the pushover hinges on the model by selecting one or more frame members

5. Define the pushover load cases o Gravity load Case and lateral load case.

6. In Pushover analysis the magnitude of the lateral load is increased monotonically maintaining a predefined distribution pattern along the height of the building.

7. Building is displaced till the 'control node' reaches 'target displacement 'or building collapses

8. The sequence of cracking, plastic hinging and failure of the structural components throughout the procedure is observed.

9. The relation between base shear and control node displacement is plotted for all the pushover analysis

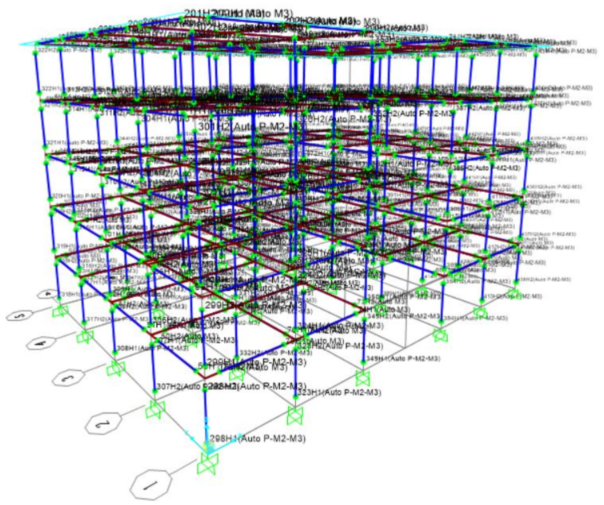


Fig.4 Assigning of hinges for Regular plan building

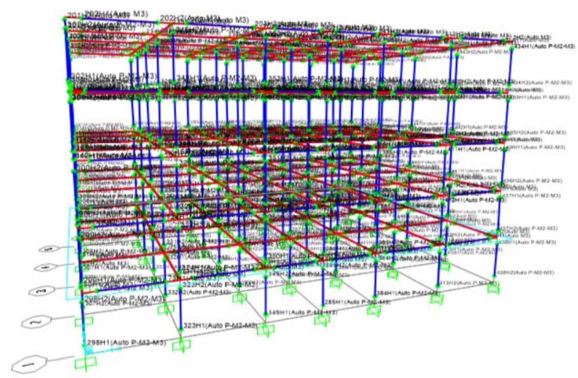


Fig.5 assigning of hinges Irregular plan building

5. RESULTS AND DISCUSSION

The main output of pushover analysis is pushover curve i.e. base shear versus roof displacement curve. This capacity curve is generally constructed to represent first mode response of the structure assuming that fundamental mode of vibration is predominant. The pushover curve for five storey building

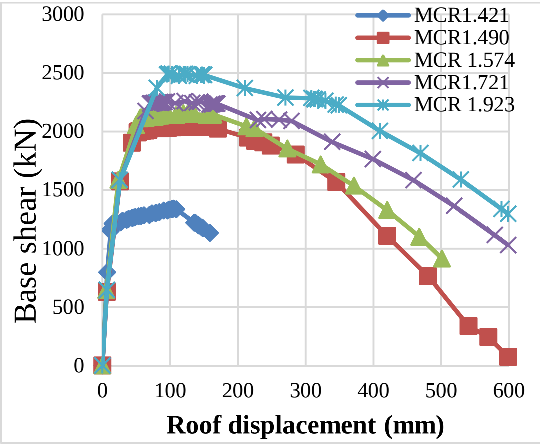


Fig.6. Pushover curve for 5 storey Regular building frame (zone V)

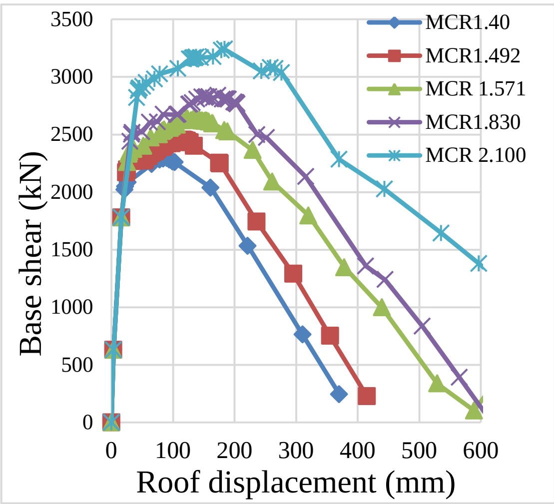


Fig.6. Pushover curve for 5 storey Irregular building frame (zone V)

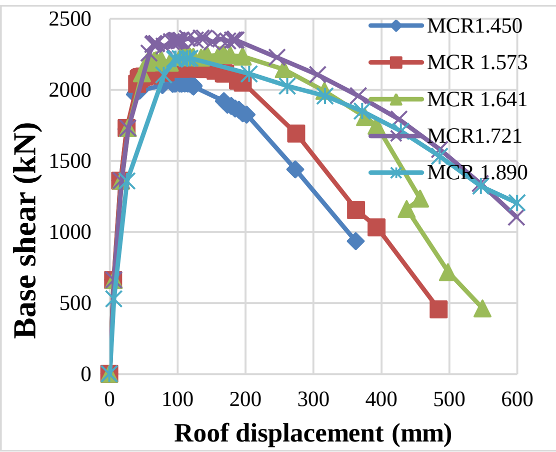


Fig.7. Pushover curve for 5 storey Regular building frame (zone IV

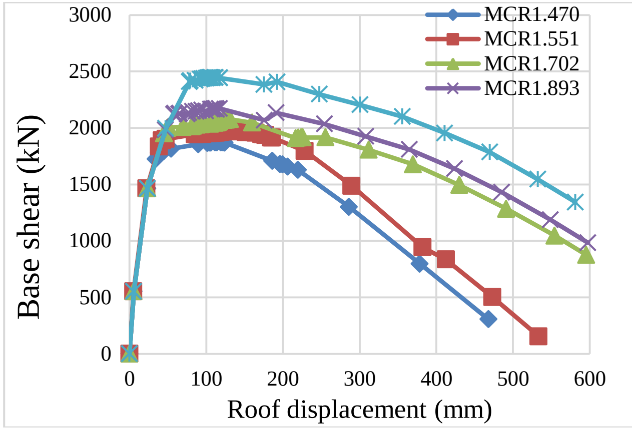


Fig.9. Pushover curve for 5 storey Regular building frame (zone III)

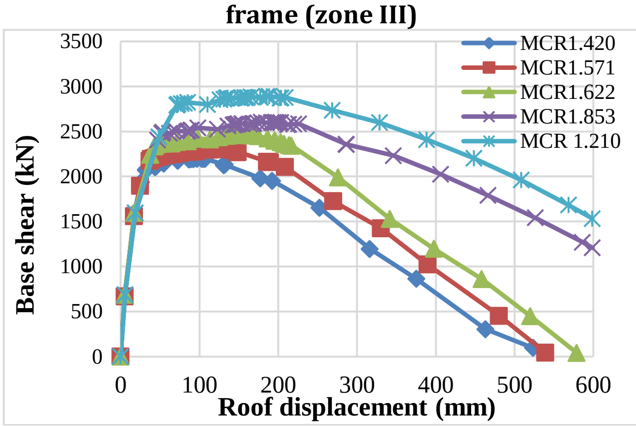


Fig.9. Pushover curve for 5 storey Regular building frame (zone III)

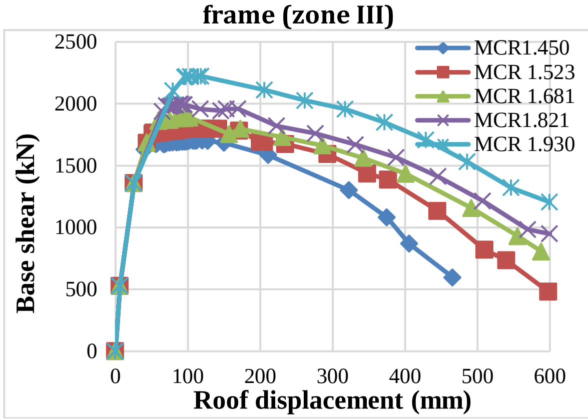


Fig.10. Pushover curve for 5 storey Irregular building frame (zone III)

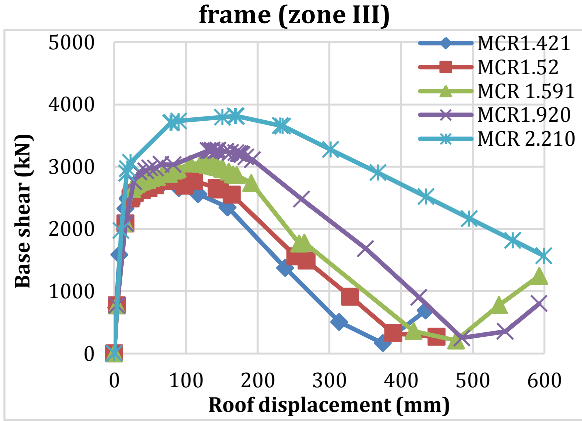


Fig.11. Pushover curve for 5 storey Regular building frame (zone II)

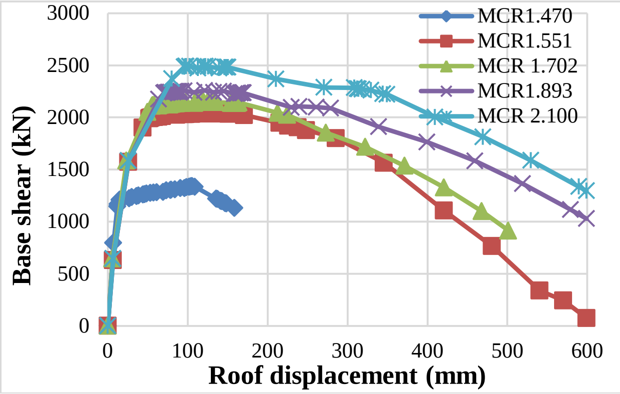


Fig.12. Pushover curve for 5 storey Irregular building frame (zone II)

1.For 5 storey Different plan and Regular plan building in varying seismic zone ductility increases up to MCR value increases but after one point increase of MCR value but ductility remains constant but strength increases with increasing MCR.

2. Ductility of regular shape of building is more as compare to the different shape building because earthquake shaking occurs in all directions because of adequate load path there are damages reduced but in different shape building damages are more. So for improve the ductility we can use MCR changes for different shape of buildings.

3.As per IS 13920:2016 MCR value given 1.4 which is not adequate for high rise buildings , different shape so study is done and following values of MCR given in various seismic zone.

4.In seismic zone V, the value of MCR for regular shape building gives ductility at 1.9 further ductility remains same but if we use that value then structure become uneconomical , so we can use between 1.60 to 1.65 for better results and for Irregular shape of building we can use between MCR 1.70 and 1.75.

5. In seismic zone IV, maximum ductility for regular shape building at more than MCR 1.750 and Irregular shape building more than 1.890. Therefore, the value of MCR 1.6 to 1.7 shows better Performance as per the results of building in zone IV.

6. In seismic zone III, for regular shape building maximum ductility shows at MCR value at 1.50 and for irregular shape building shows MCR value at more than 1.650.so from results we can say for regular shape building we can use MCR 1.5 to 1.55 and for Irregular shape we can use MCR value more than 1.6 to 1.7

In seismic zone II, for regular shape building MCR value at 1.470 and for Irregular shape it Gives MCR at 1.60 so in seismic zone II we can use value For regular shape building MCR value up to 1.5 is sufficient but for irregular shape building we need to use MCR at 1.6 to 1.65 which gives better results and ductility.

Detail results of all seismic zones after the calculations are given in the following tables.

5.1RESULTS

Table 6.3 Results for 5 story Regular plan building frame in seismic zone V

Area of Steel (%)	MCR	Yield disp. in mm	Ultimate disp. in mm	Max strength in kN	Ductility
0.91	1.470	29.56	434.89	2414.10	14.71
1.11	1.551	30.01	449.63	2580.73	14.98
1.34	1.702	35	593.18	2918.16	16.94
1.62	1.893	35	600	3276.41	17.14
2.27	2.100	35	600	3863.75	17.14

Table 6.3 Results for 5 story Irregular plan building frame in seismic zone V

Area of Steel (%)	MCR	Yield disp. in mm	Ultimate disp. in mm	Max strength in kN	Ductility
0.91	1.470	40.01	370.27	1976.95	9.25
1.34	1.552	42.33	417.13	2291.01	9.85
1.44	1.702	45.21	607.30	2591.46	13.43
2.27	1.893	46	613.55	2851.64	13.33
3.30	2.100	46	621.59	3285.45	13.51

Table 6.3 Results for 5 story Regular plan building frame in seismic zone IV

Area of Steel (%)	MCR	Yield disp. in mm	Ultimate disp. in mm	Max strength in kN	Ductility
0.91	1.470	35.25	523.29	1974.053	14.84
1.11	1.551	39.70	539.17	2178.075	14.94
1.34	1.702	40	578.86	2431.88	14.47
1.62	1.893	40	600	2620.36	15
2.27	2.100	40	600	2906.20	15

Table 6.3 Results for 5 story Irregular plan building frame in seismic zone IV

Area of Steel (%)	MCR	Yield disp. in mm	Ultimate disp. in mm	Max strength in kN	Ductility
0.91	1.470	38.32	468.22	1715.69	12.22
1.11	1.551	40.2	533.13	1910.43	13.26
1.34	1.702	42.5	600	1962.05	13.64
1.62	1.893	42.0	600	2140.925	14.28
2.27	2.100	42.0	600	2394.49	14.28

Table 6.3 Results for 5 story Regular plan building frame in seismic zone III

Area of Steel (%)	MCR	Yield disp. in mm	Ultimate disp. in mm	Max strength in kN	Ductility
0.91	1.470	26.47	363.50	1809.97	13.69
1.11	1.551	30.01	484.51	2055.46	16.14
1.34	1.702	33.21	544.52	2221.83	16.39
1.62	1.893	35	600	2707.25	17.4
2.27	2.100	35	600	2587.11	17.4

Table 6.3 Results for 5 story Regular plan building frame in seismic zone V

Area of Steel (%)	MCR	Yield disp. in mm	Ultimate disp. in mm	Max strength in kN	Ductility
0.91	1.470	16.66	301	1081.19	17.46
1.11	1.551	30.41	544.52	1974.54	17.90
1.34	1.702	30.18	549.34	2142.21	18.20
1.62	1.893	32	600	2103.64	18.75
2.27	2.100	32	600	2372.63	18.75

Table 6.3 Results for 5 story Regular plan building frame in seismic zone V

Area of Steel (%)	MCR	Yield disp. in mm	Ultimate disp. in mm	Max strengt in kN	Ductility
0.91	1.470	20.02	170.00	1602.29	8.50
1.11	1.551	35.03	598.33	1620.69	16.61
1.34	1.702	38.92	600	1632.38	15.41
1.62	1.893	37.00	600	1882.19	16.21
2.27	2.100	37.00	600	1945.21	16.21

Table 6.3 Results for 5 story Regular plan building frame in seismic zone V

Area of Steel (%)	MCR	Yield disp. in mm	Ultimate disp. in mm	Max strengt in kN	Ductility
0.91	1.470	40.02	465.32	1599.22	11.62
1.11	1.551	42.33	598.33	1698.66	14.13
1.34	1.702	44.29	588.56	1758.55	13.28
1.62	1.893	45.00	600	1836.80	13.33
2.27	2.100	45.00	600	2092.90	13.33

5.3Ductility as a function of MCR

From the idealized pushover curve yield point and maximum deformation point can be found out and displacement ductility of the structure is calculated. Displacement ductility is equal to ratio of maximum deformation to yield deformation

Fig.16. zone III for Regular shape Building and Irregular shape of building

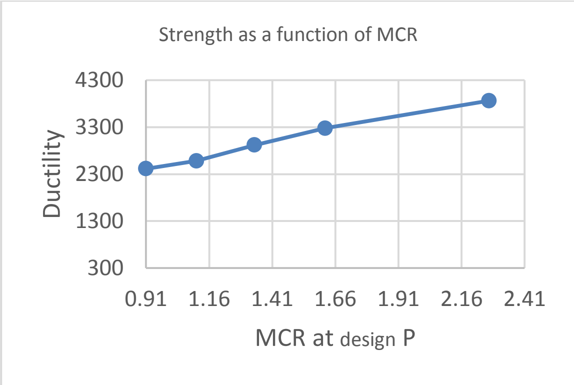


Fig.16. For zone V for Regular shape Building

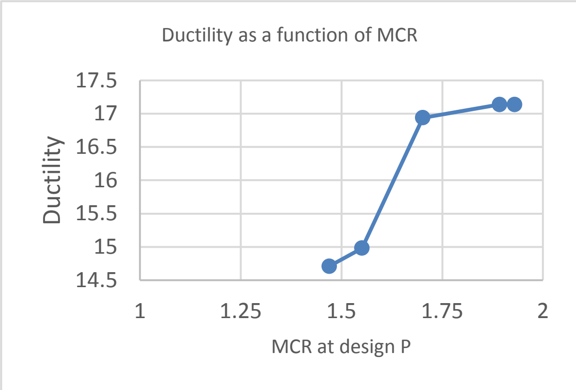


Fig.16. zone V for Irregular shape Building

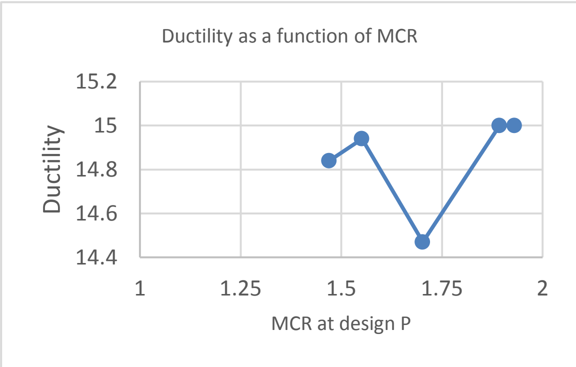
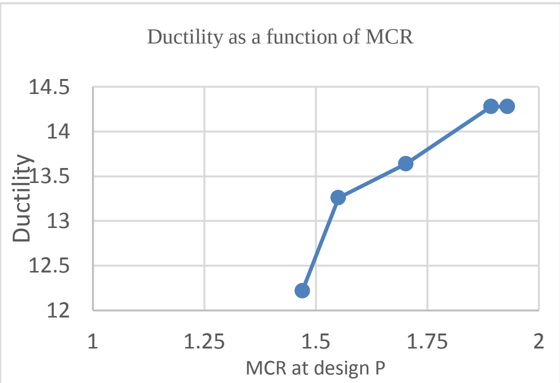


Fig.16. zone IV for Regular shape Building



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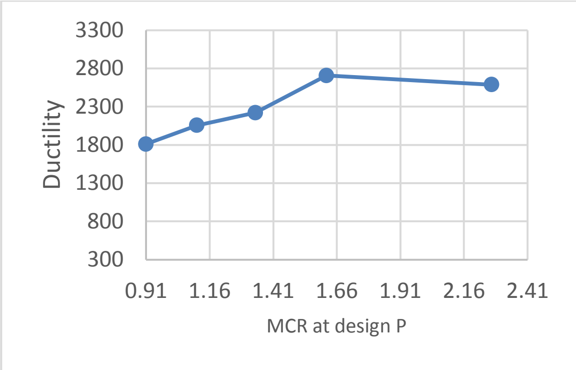

Fig.16. zone III for Regular shape Building

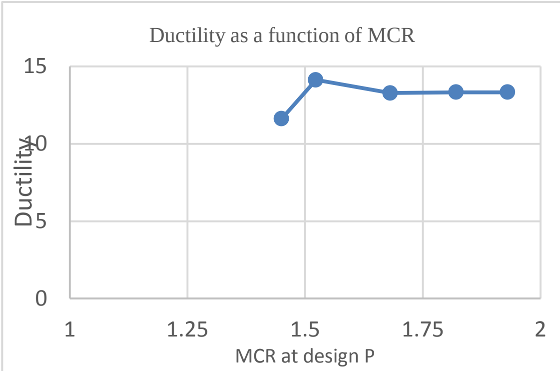

Fig.16. zone III for Irregular shape Building

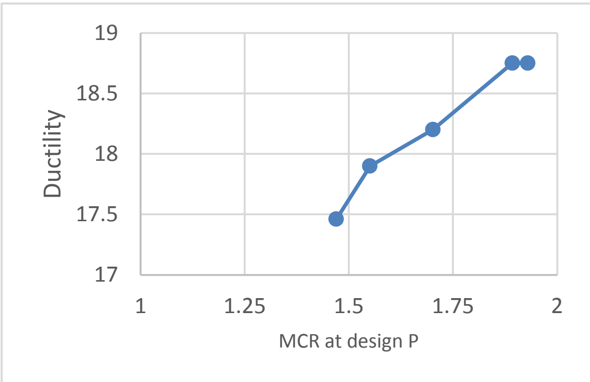

Fig.16. zone II for Regular shape Building

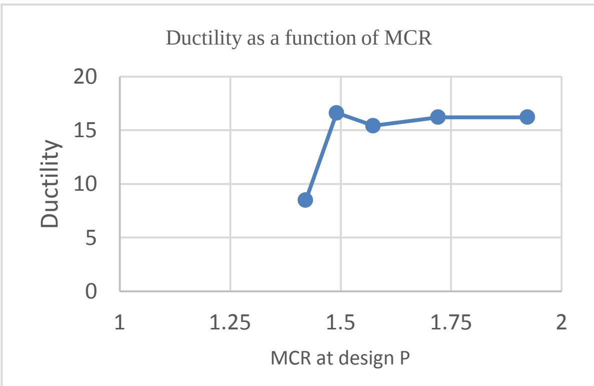

Fig.16. zone III for Irregular shape of building

6. CONCLUSIONS

1. For 5 storey Different plan and Regular plan building in varying seismic zone ductility increases up to MCR value increases but after one point increase of MCR value but ductility remains constant but strength increases with increasing MCR.
2. Ductility of regular shape of building is more as compare to the different shape building because earthquake shaking occurs in all directions because of adequate load path there are damages reduced but in different shape building damages are more. So for improve the ductility we can use MCR changes for different shape of buildings.
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7. In seismic zone II, for regular shape building MCR value at 1.470 and for Irregular shape it Gives MCR at 1.60 so in seismic zone II we can use value For regular shape building MCR value up to 1.5 is sufficient but for irregular shape building we need to use MCR at 1.6 to 1.65 which gives better results and ductility.
8. When the increasing value of moment capacity ratio (MCR), ductility of structure and economy of structure also increases. Therefore, the value of MCR, ductility of RC structure and economy of the structure are collinear with each other.
9. So from the study we can note that the value of MCR, ductility of RC structure and economy of the structure are collinear with each other.

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