IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

ANALYSIS OF PROGRESSIVE COLLAPSE IN RC FRAME STRUCTURE FOR DIFFERENT SEISMIC ZONES

Syed Asaad Mohiuddin Bukhari*, Shivaraju G D, Ashfaque Ahmed Khan

* PG Student, Department Of Civil Engg, MVJ College Of Engineering,Bengaluru, India.
Assistant Professor, Department Of Civil Engg, MVJ College Of Engineering,Bengaluru, India
Assistant Professor, Department of Civil Engg, HKBK College Of Engineering,Bengaluru, India

ABSTRACT

When a building gets exposed to any natural hazards say Tsunami or Earthquake or due to manmade hazards such as fire, explosion of gases, impact of vehicles ,etc., it effects the behavior of structure and causes collapse of a portion of structure or entire building.Progressive collapse implies a phenomenon of sequential failure of part of the structure or the complete structure initiated by sudden loss of vertical load carrying member (mostly column). In this present study, the behavior of RC framed buildings with 5 stories and 8 stories to progressive collapse located in different seismic zones (zone ii and zone v) is investigated.A linear static analysis is worked out using ETABS Software Ver. 15.0 respectively. The demand capacity ratio is assessed in the critical region of the RC portion associated with the column removed, as per the provisions of GSA guidelines. The paper concluded that with the additional reinforcement in beams there is less susceptibility of progressive collapse, and also a building designed to resist earthquake loading has intrinsic capacity against progressive collapse.

KEYWORDS: Progressive Collapse,DCR ratio,GSA,ETABS,Removal of Column.

INTRODUCTION

Progressive collapse implies disproportional global structural system failure originated by local structural damage. It is a rare event, as it necessitates an initiation of local element removal criteria either due to the inevitable forces of nature or due to manmade hazards. The gravity load of the building is now transferred to neighboring columns,these columns should resist the additional abnormal gravity loads & redistribute loads to avoid failure of the major part of the structure. Present day building design practices & lesser integral ductility and continuity, gets more prone to progressive collapse. However, there should be certain provisions needed for additional consideration to ascertain the safety of structure after any local failure.

The concept of progressive collapse comes to image after the collapse of the 22 story Ronan Point Apartment Tower in1968[1].The gas explosion occurred on the 18th floor that vigorously rapped out the exterior load bearing panels of the kitchen near the corner of the building. This results in loss of support at that story (i.e., 18th floor) & triggered above floors to collapse. The potential of this collapsing floors causes, impact load on lower stories & set up a progressive collapse. The entire exterior corner of the building collapsed from top to bottom. Recently, an interest in this topic has been increased after the destruction of Murrah Federal Office building in Oklahoma City due to terrorist attacks,and also the collapse of the unforgettable Twin tower of the World Trade Center in New York (Sept 2001). These events define the progressive collapse very well. The provision of the range & type of progressive collapse in different situation provides much important information with particular regard to progressive collapse resistance, by complementing additional measures in the design. In order to secure structural safety against progressive collapse additional considerations such as abnormal loadings must be taken. The abnormal loads arise from vast sources such as explosion of gas, vapor inferno or confined dust, malfunctioning of machines, bomb explosion, the sudden impact of vehicles, etc.. Nevertheless till date, there are no adequate tools that can analyze the progressive collapse with satisfactory reliability.

In this present study, the behavior of RC framed buildings to progressive collapse located in different seismic zones is investigated. Two different buildings with 5 stories and 8 stories are analyzed for different seismic zones. The

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

demand capacity ratio is assessed in the critical region of the RC portion associated with the column removed, as per the provisions of GSA guidelines[2].

A linear static analysis is carried out using Etabs Software Ver. 15.0[3] respectively.

GSA GUIDELINES

The aim of GSA guidelines is to help in evaluating the risk of progressive collapse in new and existing Federal Office Buildings. This document offers compact & direct guidelines. For the determination of analysis we have taken 4x6 bays model with difference in number of storeys as 5storey and 8 storey, and analysed for different seismic zones (ii and v). The following analysis cases should be considered.

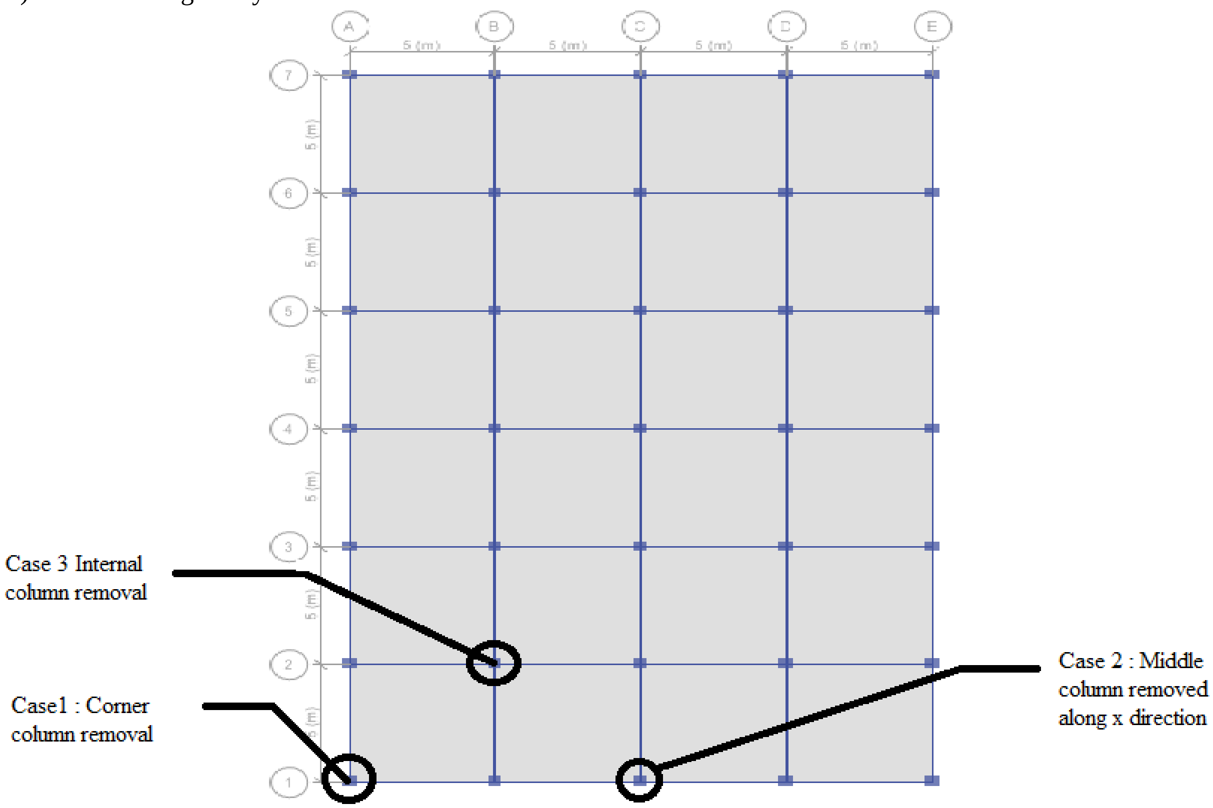

Fig 1 Typical 4X6 bay showing case1 case2 case3 for all storeys building model

Case1. Analyze for the sudden loss of a column for one floor above ground level (grade) situated at the corner of the building.

Case2. Analyze for the sudden loss of a column for one floor above ground level (grade) situated at or near the middle of the shorter directions side (X-direction in this case) of the building.

Case3. Interior column removal analysis at any suitable location should be carried out for buildings that have underground parking and/or uncontrolled public gatherings at ground floor areas.

Analysis Procedure And Permissible Criterion For Progressive Collapse.

Possibility of Progressive Collapse can be evaluated from various different analysis techniques ranging from the simplest Linear static analysis process to complex Non-linear 'Time history analysis' & 'Pushover analysis'.The failure of the major bearing structural elements commencing damage is modeled as a sudden dynamic removal depending on analysis method used. As per Indian Standard Codes, the linear elastic static analysis is carried out using ETABS V 15.0 Software.

Linear static analysis

This analysis is the most fundamental and the easiest type for progressive collapse analysis. It involves statically removal of major structural elements. Since this method is most basic & almost accurate, most conventional load conditions are applied with highly moderate assessment conditions.

Step1. First,the building is analyzed with gravity load (Dead Load+Live Load)…Eq 1, and obtain the output results for moment and shear without removing any column.

Step2. Now remove a vertical support (column) from the position under consideration and carry out a linear static analysis to the altered structure and Load this model with 2{ Dead Load + 0.25(Live Load)}…Eq 2.

Step3. The Static load combinations were entered into the ETABS 2015 V15.0 program and a model of the structure was generated. An ETABS 2015 computer simulation was executed for each case of different Column removal location on the model and the results are reviewed.

Step4. Further ,from the analysis results obtained ,if the DCR for any member end connection or along the span itself is exceeded the allowable limit based upon moment and shear force, the member is expected as a failed member.

Step5. If DCR value surpass its criteria then it will leads to progressive collapse.

Permissible Criterion For Progressive Collapse

The GSA guidelines Adviced the use of the Demand–Capacity Ratio (DCR) which is defined as the ratio of the structural member force after the sudden removal of a column to the member strength (capacity) ,as a benchmark to determine the failure of major structural members by the linear static analysis procedure (GSA 2003).

$$DCR = Qud / Que \qquad \text{…Eq 3}$$

Where,

Qud = Acting force (demand) observed in member or connection

(shear, axial force, bending moment, and possible combined forces)

Que = Expected ultimate, unfactored capacity of the member or connection (axial force ,moment, shear and possible combined forces)

The permissible DCR values for primary and secondary structural elements are:

• Demand capacity ratio (DCR) < 2.0 for typical structural configurations.

• Demand capacity ratio (DCR) < 1.50 for atypical structural configurations.

METHODOLOGY

The structures which are used in this study are a 5storeys and 8storeys with 4x6 bays reinforced concrete frame structure. The Proposed plan of the buildings is typical (symmetrical) . The typical structural bays are uniform in terms of dimension as shown in Figure.

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

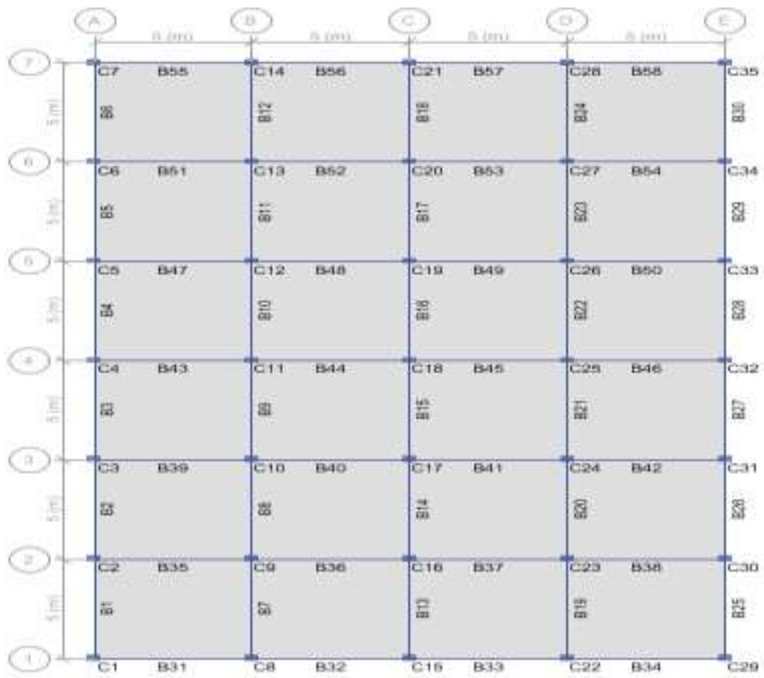

Fig 2 Plan Of Framed Building

Detailed Data Of The Buildings

The bottom story height is 3.4m and rest all storey height kept constant as 3.1m for all building models. In five storeys beam size for zone 2- is taken as B-300X400 for top 2 storeys,300x600 for remaining storeys and column size 300x400 and 300x600 respectively.For zone 5- B-300X400 for top 2 storeys,300x450 for remaining storeys and column size 300x400 and 450x500 respectively.

In Eight storeys beam size for zone 2- is taken as B-300X400 for top 3 storeys,300x800 for remaining storeys and Column size 300x400 and 300x800 respectively.For zone 5- B-400x500 for top 3 storeys,500x600 for remaining storeys and column size 400x500 and 500x600 respectively.

Intensities of Load considered are as follows

Roof and floor finish: 1.5kN/m2 ,Live Load at Floor: 3kN/m^2

Material Properties considered are as follows

Grade of Concrete: M20 ,Grade of Steel: Fe 415 ,Modulus of Elasticity, E: 22360.68 N/mm^2

Poisson's ratio of Concrete: 0.20

The structural properties such as Thickness of Slab= 150mm is taken.

Seismic loading is taken into consideration as per IS: 1893 (part1):2002 [5]

Zone II,zone V

Soil type II, Response Reduction Factor(R) = 5

Importance factor (I) =1.5

***Fundamental Period (Ta)**:* Ta=0.075h^(0.75)……(for RC frame building)

Progressive Collapse Analysis

In this analysis method ,structural bearing element(column) removed are C1 (corner),C15 (middle along X direction),C9 (interior nearer to first bay) & linear static analysis is executed with gravity loads given by Equation 2 forced upon the structure. Now, from the analysis results demand at critical section is worked out , also capacity of section is evaluated from the originally seismically designed section.

If Demand Capacity Ratio (DCR) of a section (member) go past the acceptable limit in flexure and shear, then the member is treated as failed. The DCR computed from this procedure (linear static) assists to figure out the potential for Progressive Collapse of Structure.

Calculation of Demand Capacity Ratio

Capacity of the member at any section is evaluated as per IS 456:2000[4] from the obtained flexure and shear after analysis and design. The member shear and moment after removal of column loaded with the load combination as per GSA code of practice,Demand of the member is found out . Demand Capacity ratio for each section is found using above data.Member shear and flexure are obtained by analysis results carried out in ETABS 15.0

RESULTS AND DISCUSSION

General

Employing the linear elastic static analysis using ETABS 2015 bending moment diagram is obtained, the DCR values for member under consideration loaded with GSA code of practice is worked out to know the behavior of columns and beams in the structure.

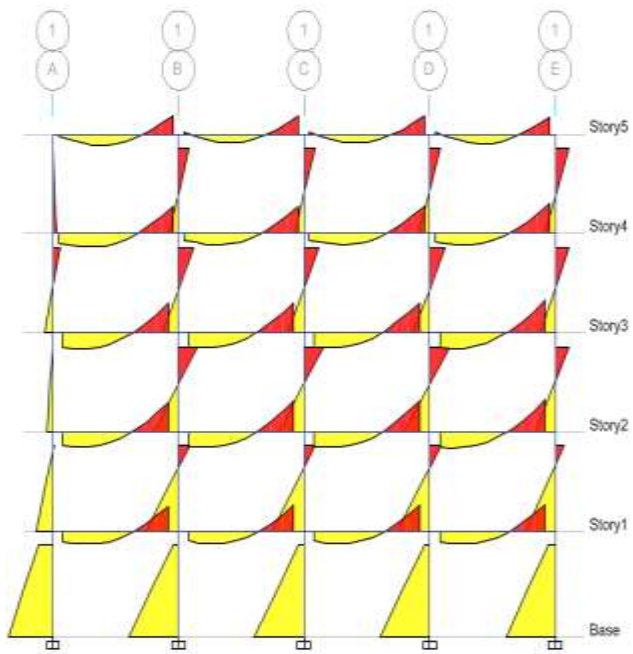

Fig 3 Bending moment diagram for Capacity Building

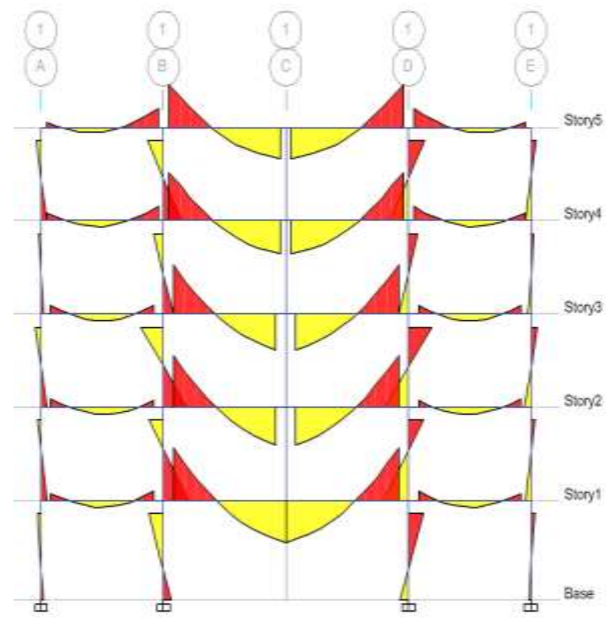

Fig 4 Bending moment for Demand Building when C15 is removed (case 2)

The removal of middle column C15 caused moment reversal in the beams B32,B33 and B13 intersecting at the column removed location shown in Fig 2. Fig 3 shows the moments distribution in elevation before the removal of the column. Fig 4 shows the moments distribution in different elevation after the column is removed. The figures show that removal of column at the middle of the shorter direction of structure (case 2) developed a positive moment just above the column lost,because the span was doubled from 5m to 10m .This new span beam must be able to resisit additional load and provide alternate load path within adjacent columns.

Graphical Representation of DCR

After getting all the DCR values for building models ,for all cases of column removal and for zones ii and v ,a graph of DCR Vs Storeys is plotted

Case 1:

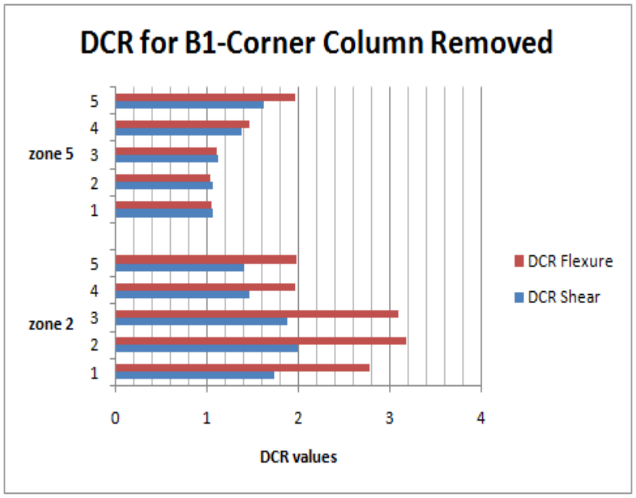

Fig 5

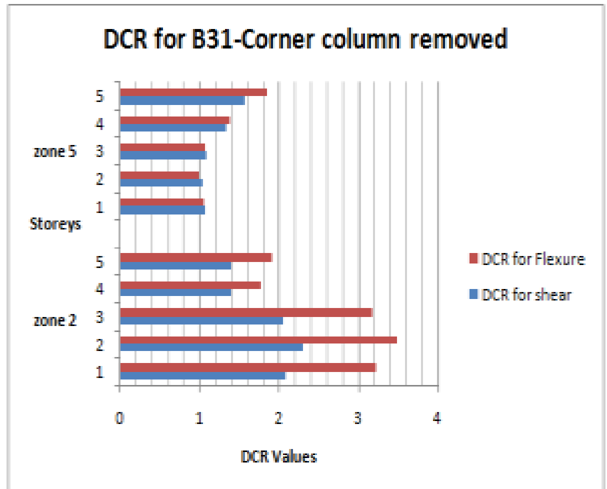

Fig 6

For zone2 ,Initially for all the 3 cases there was progressive collapse i.e., all floors were failing,before modifying beam properties. But after increasing the beam depth upto size of column,progressive collapse was resisted .

The above figures ,Fig 5 and Fig 6 shows that in case1 the 3rd, 2nd and 1st storey beams in x direction and in y direction are crossing the DCR limits for flexure (DCR>2) for zone 2,so these 3 storeys are collapsing,but doesn't leads to progressive collapse.Where as for zone 5, no beam is crossing DCR limits which resembles that none of the storey is collapsing.In zone 5,DCR values for top 2 storey is more than bottom storeys (but lesser than 2),because amount and size of reinforcement is more in bottom stories than top 2 storeys.

Case 2:

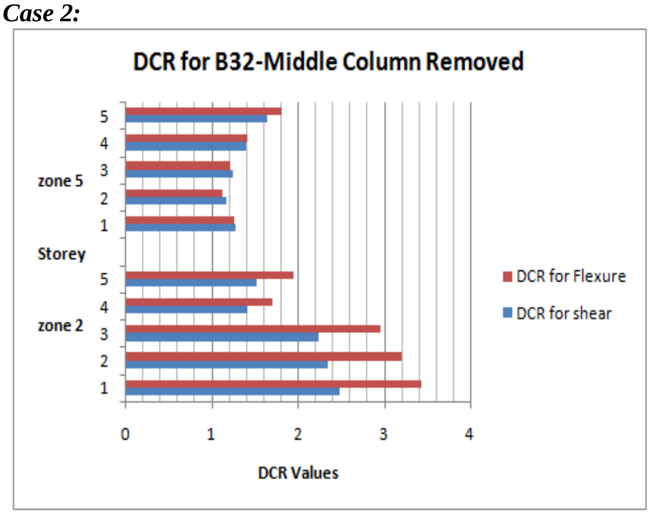

Fig 7

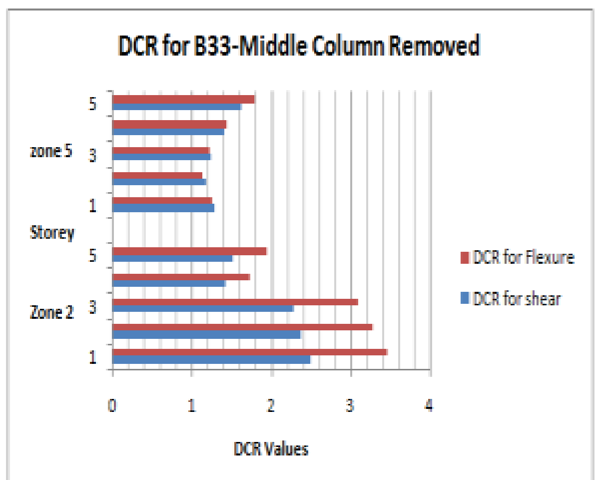

Fig 8

 ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

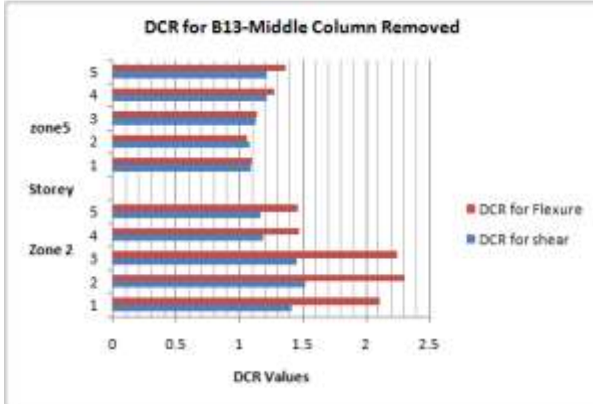

Fig 9

In case2,for zone 2 , the beams in X direction of first 3 storeys have exceeded the DCR limits upto 20%, rest top 2 storeys are within limits.For zone 5, normally seismic designed building will be resisting progressive collapse, and there is not even a single storey which is collapsing.

Case 3:

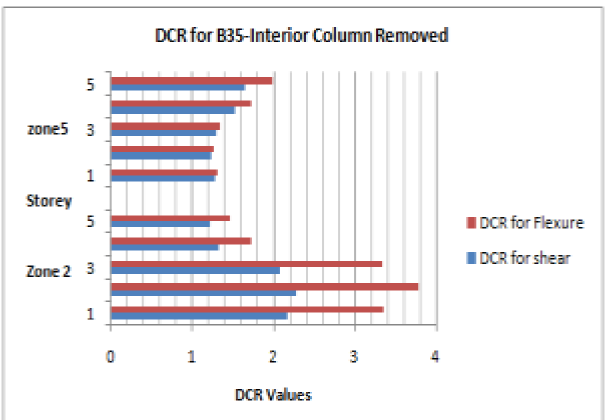

Fig 10

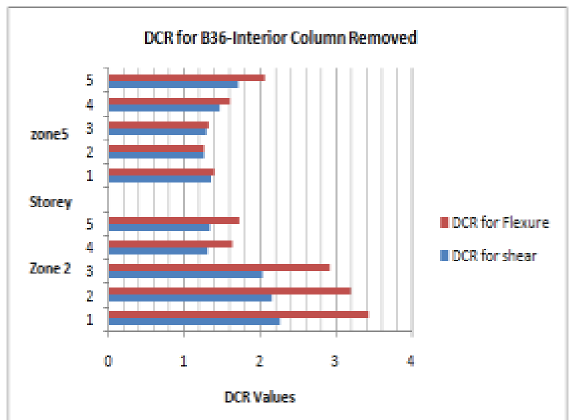

Fig 11

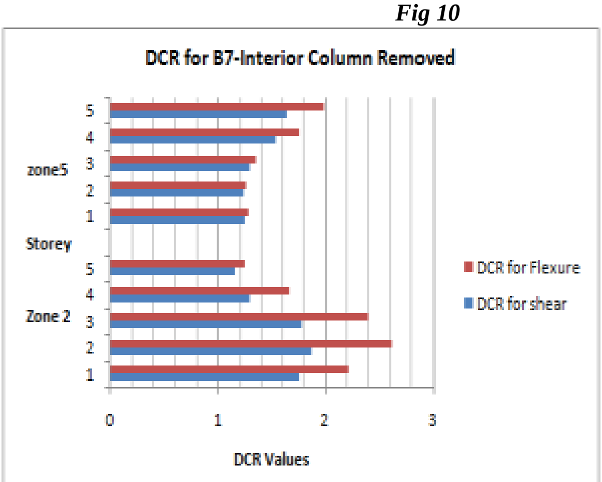

Fig 12

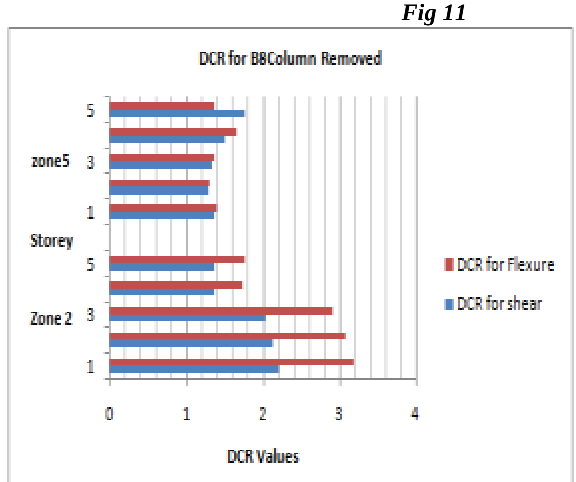

Fig 13

In case 3,for zone 2 -the beams in X and Y directions for top 2 storey's are found to be within the DCR limits (DCR<2).For zone 5, all the beams in X and Y directions are found to be within the DCR limits (DCR<2).

Similarly,the above same procedure was carried out for an eight storey building,for seimic zones ii and v.
The results that are obtained are as follows-

Case 1:- For zone 2 , Initially for all the 3 cases there was progressive collapse i.e., all floors were failing,before modifying beam properties. But after increasing the beam depth upto size of column, in case1 the bottom 5 storey's beams in x direction and in y direction are crossing the DCR limits for flexure (DCR>2).For zone 5, without modifying any properties of beams, normally seismic designed building will be resisting progressive collapse.

Case 2 :- For zone 2, the beams in X direction of bottom 5 storey's are going beyond the DCR limits upto 73%, remaining 3 storey's are within limits. For zone 5, normally seismic designed building will be resisting progressive collapse, and there is not even a single storey which is collapsing.

Case 3:- For zone 2,the beams in X and Y directions for top 3 storey's are found to be within the DCR limits (DCR<2),where as shear for bottom 5 stories exceeds by 33% along with flexure which surpass 142% than DCR limits.For zone 5 ,the beams of all the stories were within the DCR limits.

CONCLUSION

The conclusions that are be drawn from above obtained results is as follows.

1) A building designed to resist earthquake loading has inherent capacity to resist progressive collapse.
2) For C1 column removal, DCR of beams B1 an B31for all stories is less than 2 in seismic zone 5, and for zone 2 bottom 3 stories are collapsed.
3) Buildings which are normally designed in zone 2 is having high progressive collapse,but can be overcome by redesigning.
4) Higher storey buildings are more sensitive to progressive collapse than low rise buildings.
5) Among 3 cases of column removal, most damaging collapse occurs when interior column is lost, next is corner column failure, finally middle column failure.
6) Increasing beam size will be more effective in avoiding or delaying collapse rather than increasing column size.

In general, Modifying the beam dimension results in increase of cost of structure, but negligible when compared to loss of life and property .So, it may be adapted to important structures.

REFERENCES

[1] R. Shankar Nair, Ph.D., P. E., S. E. (2004)."Progressive Collapse Basics" *NASCC Proceedings.*
[2] General Services Administration (GSA). (2003). *Progressive collapse analysis and* design guidelines for new federal office buildings and major modernization projects, GSA.
[3] ETABS 2015. Version 15, *Extended 3-D Analysis of Building Systems*, Computers and Structures, Inc., Berkeley
[4] IS 456:2000, "Code of practice for plain and reinforced concrete"(Fourth Revision)
[5] IS 1893(Part-1):2002,"Criteria for Earthquake Resistant Design of Structures"(Fifth Edition).
[6] Rakshith K G, Radhakrishna (2013)." *Progressive Collapse Analysis Of Reinforced Concrete Framed Structure"*IJRET eISSN: 2319-1163 | pISSN: 2321-7308 pp.36-40.
[7] Meng-Hao Tsai, Tsuei-Chiang Huang (2011)." Progressive Collapse Analysis of an RC Building with Exterior Non-Structural Walls" . Procedia Engineering 14 (2011) 377
[8] B.A.Izzuddin, A.G.Vlassis, A.Y.Elghazouli, D.A.Nethercot, 'Progressive collapse of multi-storey buildings due to sudden column loss – Part II: Application', 'Engineering Structures' (2008), Elsevier science publishers, Page 1424-1438.
[9] Bhavik R. Patel (Sept 2014)." Progressive Collapse Analysis ofRC Buildings Using Non-Linear Static andNon-Linear Dynamic Method". International Journal of Emerging Technology and Advanced Engineering.Volume 4, Issue 9, September 2014 pp.503-507.
[10] S.M. Al Hafian and I.M. May [8](2012)." Seismic Progressive Collapse of Reinforced Concrete Framed Structures "
[11] Ayush Singhania, Vikas Khatuja, Vikram Singh Thakur, Dr. C.B.K. Rao [9](May2013)

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

[12] Abhay A. Kulkarni, Rajendra R. Joshi (2011)." Progressive Collapse Assessment of Structure". International Journal of Earth Sciences and Engineering ISSN 0974- 5904, Volume 04, No 06 SPL, October 2011, pp. 652-655

[13] B. Gururaja, R. Sridhar [14](2014) Progressive Collapse Potential of Irregular Concrete Building " *IOSR Journal of Mechanical and Civil Engineering (IOSRJMCE) e-ISSN: 2278-1684, p-ISSN: 2320-334X PP 67-70*

[14] Azlam Bin Adnan,Liew Yong Seong (Mar 2014). "Investigation of Progressive Collapse Resistance for a Seismically Designed RC Building".Research Journal of Applied Sciences, Engineering and Technology 7(10): 2154-2161, 2014.pp.2154-2161

[15] Miss. Preeti K. Morey, Prof S.R.Satone[13] (june 2012)." Progressive Collapse Analysis Of Building".(IJERA) Vol. 2, Issue 4, June-July 2012, pp.742-745