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Review on Progressive Collapse of Building Structure

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***Abstract*— A review on effect of different parameters like, irregularity, seismic zone, RC flat slab,** failure column **etc on progressive collapse is presented. Now-a-days buildings became more vulnerable to the threat of terrorism, accidents, fire explosions, etc. Progressive collapse is that when a local structural load carrying member fails, the additional loads are transferred to neighboring structural members and it may leads to global failure due to overloading. This causes greater and disproportionate damage comparing to the initial impact. Assessing the probability of progressive collapse deserves attention concerning the safety of human life and resultant economic impact in the society.**

Keywords: Progressive collapse, irregular structure, flat slab, seismic zones, DCR ratio, column removal, ETABS. etc

1. INTRODUCTION

The progressive collapse occurs when the structure gets changes in the loading patterns or boundary conditions and as such their intended capacities are exceeded beyond the limits. Thus the residual structure is forced to seek alternate load paths to redistribute the loads from the collapsed member. For example when a local load carrying element especially vertical load carrying member column due to either natural or manmade hazards, the gravity loads are transferred to the adjacent columns in the structure. If they are not capable to resist and redistribute the additional gravity loads, they also fail. This continues until the additional load is stabilized and this results in the collapse of a substantial part of the structure. Thus the initial impact may get magnified to a greater extend. Recently buildings and structures across the world have become more vulnerable to the threat of terrorism, accidents, explosions, earthquakes etc. Hence such a study is found relevant. As most buildings are reinforced concrete buildings, an assessment of progressive collapse in such a RC building was opte.

2.EFFECT OF PLAN IRREGULARITY AND VERTICAL IRREGULARITY :

Amir Homaioon Ebrahimi, Pedro Martinez-Vazquez and Charalampos C. Baniotopoulos
This research examines the effect of plan irregularities on the progressive collapse of four steel structures located in regions with different seismic activity. The plans of the first and second structure are irregular, whilst those of the third and fourth structures are regular. The collapse patterns of the four buildings are examined and compared under seven loading scenarios using non-linear dynamic and static analyses. the strength and capacities of the columns are compared to determine their susceptibility to collapse. In the non-linear static analyses, the pushdown curve and yield load factor of the structures are obtained after column removal.

Patel Kevins J1 & Patel Tushar N2 progressive collapse assessment according to the GSA guideline is carried out for a G+10, G+15,G+20, G+25, G+30 storey RCC building considering irregularity of different height of building, G+15 and G+20 storey RCC building considering mass irregularity, G+15 storey RCC building considering various sloping ground angle 100 and 150 using linear dynamic analysis. Linear dynamic analysis is carried out by ETABS 15.0.0 for without longer side column removal, corner side column removal, short side column removal, center column removal. And parameters such as Demand capacity ratio checked for the acceptance criteria provided in GSA 2003 which show that members are safe or unsafe. **Kato et al. (1973)** conducted shake table tests on simple models until progression of collapse state by using the shake table. A comparative study between experimental and analytical results considering strain hardening and P-Delta effects was conducted. The structural models consisted of 15 cm high H steel columns fixed at both ends with a concentrated mass on top of the columns. On basis of their studies, it was concluded that the test results are accurately predicted by the analytical studies except for some softening of the hysteresis loops due to Bauschinger effect**. CJinkoo Kim*,and Sumin Hong** on temporary tall buildings are characterized by unique and irregular shapes that can be understood as a reaction to boxed forms of modern architecture. Buildings with irregular forms may be advantageous in reducing wind load effects and building responses. The aerodynamic consideration has led to twisting, tapering or other building forms with discontinuities and multi-planar facades. **Anu Thampy, 2Hanna Paulose** : the progressive collapse potential of a multistoried typical as well as an a typical buildings -C shape are evaluated using numerical methods of analysis. Linear static loading responses in the building subjected to various column removal scenarios were studied. United States General Services Administration (GSA 2003) guidelines.

3.EFFECTIVE OF SEISMIC ZONES:

Syed Asaad Mohiuddin Bukhari*, Shivaraju G D, Ashfaque Ahmed Khan In this present study, the behavior of RC framed buildings with 5stories and 8 stories to

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progressive collapse located in different seismic zones (zone ii and zone v) is investigated. A linear static analysis is worked out using ETABS.15.0.0 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. **Jay Patel 1, Abbas Jamani 2** In present study G+10 storey RC framed structure is analyzed using linear static in different seismic zone as specified in GSA guidelines and potential for progressive collapse is evaluated. Buildings are design as per the Indian standard guideline for the gravity and seismic loading. Design and Progressive collapse analysis is carried out using computer program ETABS. From the study concluded that in zone v Building is safe against progressive collapse analysis but in zone III building is not able to resist the progressive collapse.**T.S. Moldovan, L. Bredean & A.M. Ioani** In this paper, the progressive collapse potential of three distinct models representing a 13-storey RC framed structure located in an area with high seismic risk is assessed. The models are designed according to Romanian seismic codes in use in 1992, 2006 and 2008, and detailed considering the provisions of concrete structures design codes. It might also be concluded that the last 20 years of changes in the Romanian design codes, implicitly lead to improvements in the resistance to progressive collapse of reinforced concrete framed buildings.

4.EFFECT OF RC FLAT SLAB:

Leila keyvani A and MehrdadSasani (Collapse Resistance of a Flat-Slab Posttensioned Parking Garage (ASCE-2015)) were evaluated the collapse resistance of flat slab by both experimentally and analytically. Analytical models of the garage were developed using computer software and nonlinear dynamic analyses are performed. The interaction between the tendon and the slab is modelled explicitly. **Kai Qian and Bing Li** (Dynamic Disproportionate Collapse in Flat-Slab Structures (ASCE-2014)) were subjected a series of one-third-scaled flat-slab substructures to the simulated sudden-column-removal scenario To attain a deeper understanding of the dynamic load–redistribution capacity of flat-slab structures, numerical and parametric analyses were also carried out. **Kai Qian and Bing Li** (Strengthening of Multi-bay Reinforced Concrete Flat Slabs to Mitigate Progressive Collapse (ASCE-2014)) were studied a series of seven multi-bay flat slab substructures by cast and tested to assess the effectiveness of proposed glass fiber reinforced polymer (GFRP) strengthening schemes for improving the progressive collapse behaviour of existing flat slab structures. **Kai Qian, Yun-HaoWeng, En-En Yu and Bing Li** (Dynamic Behaviour of Multi-Bay Flat Slab Subjected to the Missing of an Interior Column Scenario (ASCE-2018)) were investigated the performance of multi-bay flat slab substructures subjected to the loss of an interior column scenario by experimentally. The influence of multi-column missing on the performance of flat slab substructures against progressive collapse is quantified. **Hyun-Su Kim, Jinkooet. al** (Analysis of Flat Slab (ELSEVIER-2008))In this study the integrated system for progressive collapse analysis, which can evaluate the damage level of every member and automatically construct the modified structural model for the next analysis step, has been developed. The existing nonlinear analysis program code Open Sees was used as a finite element solver in the integrated system for progressive collapse analysis.

5.EFFECT OF FAILURE COLUMN:

A.R. Rahai, M. Banazadeh, M.R. Seify Asghshahr & H. Kazem The present study addresses progressive collapse in RC structures resulting from both instantaneous and gradual removal of columns. The scenario for a gradual removal is the result of slow decreasing strength due to fire propagation in a specific zone of structure which is partially fire-proved.**Patel Niravkumar Kishorbhai Dr. B. J. Shaah** This paper shows progressive collapse pattern of a R.C.C building frame subjected to fire. This will help indentifying key elements vulnerable for fire. Nonlinear static pushover analysis is carried out in vertical direction using SAP2000 software for incremental temperature loading and EXTRACT software is used to determine the plastic capacity of different sections. Collapse patterns of RCC frames designed as ordinary moment resisting frame are analyzed for compartment fire conditions. **A.G. Vlassis, B.A. Izzuddin_, A.Y. Elghazouli, D.A. Nethercot** the two principal scenarios investigated include removal of a peripheral column and a corner column.The study highlights the inability of bare-steel beams to survive column removal despite satisfaction of the code prescribed structural integrity provisions. This demonstrates that tying force requirements alone cannot always guarantee structural robustness without explicit consideration of ductility demand/supply in the support joints of the affected members, as determined by their nonlinear dynamic response.

6.POSITION ON THE COLUMN REMOVAL:

Farzad Akbariniaa, Yahya Adinehfarb, Hadi Davashic, Dariush Jalilid, Peyman Beiranvande* and Mojtaba Hosseinie* the behavior of two buildings designed with steel structures Buckling Restrained Braced (BRB) and conventional bending frame was studied to analyze their strengths against progressive collapse. The structures were designed and analyzed in accordance with Iranian regulation for the design of buildings. Using nonlinear static pushover analysis, the performance of the structure after removal of the center and the corner columns were investigated and it was demonstrated that removing the corner column provides more critical conditions for the investigated buildings. performance for the analyzed.

David Stephen a,*, Dennis Lamb, John Forth c, Jianqiao Ye d, Konstantinos Daniel Tsavdaridis c the Sudden loss of critical structural member triggers failure mechanisms which may result in a total or partial collapse of the structure proportionate or disproportionate to the triggering event. Currently, researchers adopt different modelling techniques to simulate the loss of critical load bearing members for

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progressive collapse assessment. GSA guidelines recommend a column removal time less than a tenth of the period of the structure in the vertical vibration mode. This paper compares different alternative numerical approaches to simulate the sudden column removal in frame buildings and to investigate the effect of rising time on the structural response.

7.CONCLUSION:

1.The irregular structure designed in site class C seismic zone, collapses in most of the column removal scenarios. Moreover, when comparing regular and irregular structures designed in site class E seismic zone, the demand force to capacity ratio (D/C) of the columns in the irregular structures is on average between 1.5 and 2 times that of the regular ones.

2.Considering mass irregularity on building,the generalized behaviour is observed whenmass irregularity present at same position, G+ 15 storeys is more critical than G+ 20 storeys in
terms of no. of member failure.

3.Increase in the number of stories in torsionally irregular buildings has a significant role in the reduction of progressive collapse potential so that in 6- and 9-story buildings, lower vertical displacements than that of corresponding 3-story buildings were obtained due to column removal. In other words, the severity of progressive failure was reduced in taller torsionally irregular buildings.

4.DCR values are found out for beams. It is observed that DCR in flexure in beam exceeds permissible limit of 1.5 in all column removal cases for atypical structure but the severity varies from each column removal cases.

5. Thus linear static analysis reveals that irregular structures are more vulnerable to progressive collapse comparing to regular structures.

6. A building designed to resist earthquake loading has inherent capacity to resist progressive collapse.

7. Buildings which are normally designed in zone 2 is having high progressive collapse,but can be overcome by redesigning.

8. Increasing beam size will be more effective in avoiding or delaying collapse rather than increasing column size.

9. Building which are design in seismic zone V are safe against the progressive collapse analysis. Buildings which are normally designed in zone III is having high progressive collapse, but can be overcome by redesigning. Corner column removal condition 1A is having highest values compared to other column removal condition; hence corner column removal condition is the most critical among all 4 column removal conditions. On the other hand, Interior column is having the least DCR values compared to other column removal conditions; hence it has very less chance of collapse in case of progressive collapse failure.

10. The height of the building increases, the elimination of column in perimeter affects more on the adjacent columns by increasing the axial forces compared to the moments when elimination of the columns is done internally

11. The height of the building increases, the elimination of column internally affects the adjacent columns by increasing the moments compared to the axial force when elimination of columns is done along the perimeter.

12.In both scenarios, the percentage of increase in axial forces of adjacent columns of the removed column at the end of the analysis (equilibrium state) compared to the same value prior to removal of the column, which reflects the contribution of each column in redistribution of forces bore by the removed column is equal to 1 percent error.

13. Ultimate capacity stage, still progressive analysis continues for two more stage: one for residual strength and for total failure of element, development of the proposed method should include extensive experimental validation and calibration, particularly in relation to the joint response and ductility limits under combined bending and axial actions.

14. BRB can act as a damper and energy absorber, using BRB reinforcement in building can increase the shear load bearing capacity and deformability of building especially under earthquake loading condition.

15. The gravity load function is computationally more efficient as compared to the other methods, as this approach does not require the determination of the internal forces of the column to be removed. In addition to that, it yields maximum structural response relatively to other commonly used techniques.

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