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Study of Progressive Collapse Analysis of RCC Framed Building

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ABSTRACT: Progressive collapse is a chain reaction of failures that propagates either throughout or a portion of the structure disproportionate to the original local failure. The research material available for progressive collapse failure of structures suggests that buildings designed to resist seismic actions have good robustness against progressive collapse. However, no detailed investigations have been conducted so far to assess this robustness. Hence this study is made to examine the potential ability of seismically designed building against progressive collapse. In the present study, a case study of 8 story reinforced concrete framed structure is considered. A linear static analysis is carried out using ETABS 2018 Software Version. The analysis is carried out by removing columns at different locations one at a time and then failure for beam and column as well effect on structure as a whole are evaluated.

KEYWORDS: Progressive collapse, framed structure, Response spectrum analysis, ETABS

I. INTRODUCTION

Progressive type collapse is a condition where locally failed member of a main structure like columns triggers the collapse of whole structure. Progressive type collapse happens when a building structure has its own loading arrangement changed such that structural members are fails due to loading beyond their capacity. As mentioned in USA's GSA guidelines progressive type collapse of a building occurs when critical column get fails. When a column is failed, the weight of upper structure transfers to neighbouring members in the structure. If these parts are not appropriately designed to redistribute the additional impact load that part of the structure fails. The load carrying members like column of the structure fails unless the further loading is dissolved. As a result, adjacent part of the structure also collapses, causing more damage to the structure than the previous disaster. The analysis procedure of progressive failure is depends on the alternate load path method which is suggested in the design and analysis guidelines of the General Services of Administration (GSA) and the Department of Defence. In which demand capacity ratio is the key factor because the analysis procedure of progressive type collapse is based on the demand capacity ratio. In this thesis the ratio of bending moment of beam and unfactored moment carrying capacity of beam is taken into consideration to decide it is progressive type collapse or not.

There are many research papers published for the progressive type collapse of the structure. The purpose of research of progressive type collapse is to find out the remedies for it. Without analyzing structure the contractors go for renovation of structure this is the current problem of great political and social relevance. Most of the Indian buildings are in high population areas; therefore it is very important to study progressive type collapse. During the past forty years many structures failed due to lack of information of analysis and design of structure or faults in planning by the architects. The resent incidence happen in Ghatkopar the name of the building was Sai Darshan many peoples lost their lives in this incident but this is not the only incident happens there are many such cases in which we can see the same reason of failure. To avoid all these, the study of the subject is very important. From past few years because of the demand of the customers building with soft storey are constructed, it is convenient for parking purpose but it increases the vulnerability of the structure. Structural engineer do not recommend these type of structure. While parking any vehicle there are chances that any vehicle may collide with the column and column may fail, it is very dangerous because when a beam element get fail structure fail locally but when a column element get fail structure fail globally. Failure of one column triggers overloading of adjacent other structural member due to change of pattern of loading which ultimately leads to failure of the building structure. As a result, total or partial breakdown of structure occurs.

Also whole world has threat about the terrorist attacks. If terrorist attack on the critical column in the structure then as a result the partial failure or entire failure can be occurred. Here failure of column triggers a chain reaction which then results in failure of entire structure. The term progressive type collapse is termed as the collapse of all or a large



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part of a structure due to loss or failure of a relatively small part of it. It is sometimes also called an uneven collapse, which is defined as a structural collapse uneven to the source of the collapse. As the small structural component fails, it starts an alternate reaction that results other structural elements to fail in a result, making a bigger and harsh collapse of the building structure. A good example of progressive type collapse is a house of cards; if one card is removed or collapse, it causes whole structure to collapse due to the impact of the first card. There are usually many factors that transpire to initiate a progressive type collapse. The structural engineers apply their understanding to design and construct buildings and infrastructure to fulfil the requirements of our society. Structures are designed and check to resist usual loads such as those due to self-weight, residence, wind, earthquake and other loading situations in building codes. Any failure must be considered by the structural designer. However failures occur in the process of construction also. The meaning of failure is difficult to exactly express because of the many different kinds and harshness of harm that can occur in structural systems.



Fig -1: Progressive Collapse of RCC building

II. RELATED WORK

H.R. Tavakoli, A. Rashidi Alashti & G.R. Abdollahzadeh (2012) presented the three and two dimensional modelling and push-over analysis of seismically designed special dual system steel frame buildings with concentrically braced frames with complete lose of critical elements. The study was conducted on multi story buildings by applying alternate load path method. The results showed that parameters like number of bays, height and location of removed elements have significant effect on progressive collapse chances of buildings under seismic loading. They concluded that the buildings designed according to seismic specification, when a column and adjacent braces in the first story for any reason did not do their load carrying role properly, were strengthen enough to resist progressive collapse and no plastic rotation exceeded given acceptance criterion. As the rotation of plastic hinges were relatively small compared to standards limitations, despite of having limited simulation, it is predicted that the system will not collapse progressively for these scenarios. [1]

F. Nateghi Alahi, N. Parsaeifard (2012) in this paper progressive collapse potential of a special moment resisting steel building was investigated under earthquake action. A three-dimensional model of the structure with an initially damaged corner-column was analyzed by increasing lateral loads, through nonlinear static procedure. Based on the observations, in the starting steps of the analysis, the damaged frame supports major deformation, so part of lateral loads sustained by damaged frame was propagated toward nearer one because of stiffness reduction caused by wearying the corner-column. In the next step, the damaged frame and nearby frames support more deformation compared to other frames. This may be due to a twist in the structure as a result of moving the center of stiffness to another point far away from the damaged column. Another one-story building with five frames in both directions was modeled to better recognize the behavior of the one-story building. Linear elements were used to model columns and beams, and plastic hinges to define the non-linear behavior of the elements. As shown, the energy absorption of the damaged frame is of great value compared to the primary model. Moving away from the damaged frame reduces the total rotation of the frame's plastic hinges. [2]

Rakshith K G, Radhakrishna (2013) evaluated demand capacity ratio (DCR) of reinforced concrete twelve storey framed structure as per U.S. General Services Administration (GSA) guidelines. The Linear static analysis was carried



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out using software, ETABS V9.7. Using the pre-processing function of the structural analysis program, we investigated the structural behavior of the building against progressive collapse and the finite element model. Further loads were assigned to the model according to the IS code. An analysis was conducted on the details of the power and reinforcements of the members. They concluded that the DCR value for the column was less than 2. We have shown that the column is safe according to the GSA guidelines for progressive decay analysis. Therefore, the columns of seismically designed buildings had the inherent ability to withstand progressive collapse. Beams with DCR values above the permissible reference values of the Progressive Collapse Guidelines proposed by GSA were unsafe. [3]

Panagiotis Kyriakopoulos et. al. (2013) studied the dynamic response of a 30-storey steel-concrete composite building with Delta beams after a sudden column loss was investigated through the implementation of nonlinear dynamic analysis (alternate path method). It was found that the catenary actions were highly depended from the type of connections and govern the design. They were also considerably higher than the required tying resistance provided by EN 1991-1-7. Finally, unexpected failure modes which may endanger the stability of high-risk buildings were discussed and suggestions on the improvement of EN 1991-1-7 were proposed. [4]

Shefna L Sunamy, Binu P, Dr. Girija K (2014) described linear static analysis of a multi-storeyed building using SAP 2000 by static removal of a major column. They concluded that seismically Designed building has inherent ability to resist progressive collapse. Nonlinear static analysis reveals that hinge formation starts from the location having maximum demand capacity ratio. Appropriate reinforcement is needed to limit the DCR to acceptable standards to avoid progressive beam and column breakage caused by breakage of a particular column. To mitigate progressive collapse, you need to provide an alternative load path. Alternative load paths can be favourably adopted, such as providing braces at the floor level and increasing the size of the columns on the outer surface. [5]

Peiqi Ren et. al. (2015) investigated the progressive collapse resistance of high-rise reinforced concrete (RC) frame shear wall structures, two typical 15-story building models are designed with equivalent overall lateral resistance to seismic actions. The structural layout for resisting lateral forces is quite different between the two buildings. Building A is a frame structure that is strong against weak walls, and Building B is a frame system that is weak against strong walls. A 3D finite element model of two structures is established using a fibre beam and a multi-layer shell element. Progressive collapse resistance of both structural frames and shear walls is evaluated in various column (shear wall) removal scenarios. The results show that different structural layouts have different progressive anti-collapse performance. Progressive collapse resistance tends to be inadequate for weak frame systems with strong walls. We will then redesign such a system using the linear static AP method proposed in GSA2003 to verify the reliability and efficiency of this method. The outcome of this study has provided a reference for progressive collapse prevention designs of typical and representative high-rise RC frame shear wall structures. [6]

Ram Shankar Singh et.al. (2015) examined the potential ability of seismically designed building against progressive collapse. Symmetrical and asymmetric five-story reinforced concrete frame structures are considered in the study to assess demand capacity ratio (D.C.R.), member force ratio, and member strength according to the guidelines of the U.S. General Service Agency (GSA). I did. Linear static analysis was performed using software ETABS V9.7 according to Indian standard code. We ran the analysis and design to get the final output of the design details. To study the collapse, we removed typical pillars one at a time and continued analysis and design. Many of these columns were removed in various trials to see the effectiveness of progressive analysis. Details of member power and reinforcements have been calculated. From the analysis, the DCR value of the beam is calculated. They concluded that appropriate reinforcement was needed to limit DCR within acceptable criteria to avoid progressive breakage of beams and columns caused by breakage of certain columns. Applying GSA standards to prevent progressive collapse of concrete buildings can be achieved with software readily available to structural engineers at little additional construction cost. [7]

R. Jeyanthi, S. Mohan Kumar (2016) focused on progressive collapse analysis of reinforced concrete framed structure under column removal consideration using commercially available computer program ETABS. The G + 8 RCC Educational Building was reviewed and designed according to the Indian Building Standards Act and a pushover analysis was performed. Next, we identified and removed key pillars and began a progressive collapse. We also checked parameters such as demand capacity ratio and robustness index for the acceptance criteria specified in GSA 2003. We also compared the results of these parameters before and after the collapse of the building. They concluded that ground-level column loss activates damage above column removal and does not propagate to adjacent spans. Also, earthquake-resistant buildings resist progressive collapse because the robustness indicator is almost equal to 1 in all cases. [8]

Suraj .B.Gaikwad, Mukund .M. Pawar (2017) studied the progressive collapse of regular and irregular steel structure. For this G+15 regular as well as irregular building with missing column at different locations has been taken. For this linear static analysis, linear dynamic analysis, nonlinear static and nonlinear dynamic analysis of structure was carried out. To compare the progressive collapse responses 2D and 3D models were prepared and Percentage change in the values of base shear, demand capacity ratio and roof displacement. They concluded that for regular structure base



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shear is maximum when transverse direction middle column is removed. So regular steel structure is most vulnerable to progressive collapse when transverse direction middle column is get removed. For irregular structure base shear values is maximum when transverse direction middle column is removed. So irregular steel structure is most vulnerable to progressive collapse when transverse direction middle column of building is get removed. [9]

A. Manjari et al (2018) focused on investigating the response of the structures after the sudden column loss design scenarios. Important columns were identified based on the Capacity Ratio (DCR). The reinforced concrete G + 12 frame structure was analysed for linear dynamic analysis according to General Services Administration (2016) guidelines and key columns were redesigned. Various design parameters such as bending moment, axial force, DCR, etc. are determined based on the structural response after the sudden column loss design scenario. The analytical results showed that following the imposed initial damage, the bending moments in columns increased 78 times whereas the axial force increased by 5 times in linear dynamic analysis. The entire G+12 RC framed structure was made resistant to progressive collapse by increasing the size of columns and the percentage increment of area for critical columns in linear dynamic analysis varies in between 56.25% to 86.5% of before change of section respectively. [10].

Objectives of investigation:

- To check the stability of structure with seismic load for progressive collapse.
- To understand the effect of sudden removal of columns on structure as a whole.
- To find the effect of sudden removal of column on beams, slab and other part of the structure.
- To compare the results for composite column and RCC column for progressive collapse.

III. METHODOLOGY

For present work seismic analysis is carried out for reinforced concrete moment resisting building frame having (B+S+24) storey situated in zone IV. The analysis is carried out using finite element software ETABS.

- Following cases are studied and ETABS models have been modelled accordingly.
- 1. Removal of central RCC column
- 2. Removal of peripheral corner RCC column
- 3. Removal of peripheral center RCC column
- 4. Removal of central Equivalent composite column
- 5. Removal of peripheral corner Equivalent composite column
- 6. Removal of peripheral center Equivalent composite column



Fig. 2 Plan of the Building in AutoCAD

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Fig. 3 Plan and 3d view of the Building in ETABS



Fig. 4 Removal of columns form different locations in Plan



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IV. RESULTS AND DISCUSSIONS

The response spectrum analysis method is carried out as mentioned earlier and results are shown via figures.



Fig. 5: Variation of maximum Story drift in X & Y direction for RCC Columns and with Composite Columns

From Figure [5] it is found out that, the value of story drift in X direction increases to around 4-6% after the removal of columns from various locations as compared to building with all columns and maximum drift is observed when central column is being removed. Also drift is around 3-4% less in building with composite columns as compared to building with R.C.C. Columns. Also it is found out that, the value of story drift in Y direction increases to around 2 - 3% after the removal of columns from various locations as compared to building with all columns and maximum drift is observed when peripheral corner column is being removed. Also drift is around 3-4% less in building with all columns and maximum drift columns as compared to building with R.C.C. Columns.



Fig. 6: Variation of maximum lateral displacement drift in X & Y direction for RCC Columns and with Composite Columns

From Figure [6] it is found out that, the value of maximum lateral displacement in X direction is increased by around 4-7% after the removal of columns from various locations as compared to building with all columns and maximum lateral displacement is observed when central column is being removed. Also maximum lateral displacement is around 4-5% less in building with composite columns as compared to building with R.C.C. Columns. Also it is found out that, the value of maximum lateral displacement in Y direction is increased by only around 1-3%% after the removal of columns from various locations as compared to building with all columns and maximum lateral displacement is observed when peripheral corner column is being removed. Also maximum lateral displacement is around 2-3% less in building with composite columns as compared to building with R.C.C. Columns.



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Fig. 7: Variation of Time Period RCC Columns and with Composite Columns

From Figure [7] it is found out that, the value of time period of the building does not changes significantly after the removal of column from various locations. There is slight increase in time period in case of buildings with composite columns due to a little increase in ductility of the building.



Fig. 8: Variation of over-turning moment in X & Y direction for RCC Columns and with Composite Columns

V. CONCLUSION

From results, it is found out that the value of story drift after the removal of column at different locations increases but this increase is within the smaller range which will not cause the failure of the building as a whole. We found out that the value of maximum lateral displacement after the removal of column at different locations increases but this increase is also within the 10% thus it will not cause the failure of the building as a whole. Also value of maximum time period after the removal of column at different locations down not change much. The value of overturning moment in the case of column removal at peripheral corner increases significantly so strengthening of structure at base needs to be provided to reduce the overturning in the building.

REFERENCES

- [1] Tavakoli, H.R., Rashidi Alashti, A. and Abdollahzadeh, G.R., 2012, September. 3-D nonlinear static progressive collapse analysis of multi-story steel braced buildings. In 15th World Conference in Earthquake Engineering.
- [2] Parsaeifard, N. and Nateghi Alahi, F., 2012. Analytical study of seismic progressive collapse in a steel moment frame building. In Advanced Materials Research (Vol. 446, pp. 102-108). Trans Tech Publications Ltd.



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| DOI:10.15680/IJIRSET.2022.1106038 |

- [3] Rakshith, K.G., 2013. Radhakrishna,⁴. Progressive Collapse analysis of reinforced concrete framed structure'IJRET: International Journal of Research in Engineering and Technology.
- [4] Peltonen, S., Iliopoulos, A. and Kiriakopoulos, P., 2013, June. Progressive Collapse Analysis of Composite Framed Buildings with Encased in Concrete Steel Beams. In IABSE Workshop Tuusula, 144-151, Finland 2013.
- [5] Sunamy, S.L., Binu, P. and Girija, K., 2014. Progressive Collapse Analysis of a Reinforced Concrete Frame Building. Journal Impact Factor, 5(12), pp.93-98.
- [6] Ren, P., Li, Y., Guan, H. and Lu, X., 2015. Progressive collapse resistance of two typical high-rise RC frame shear wall structures. Journal of Performance of Constructed Facilities, 29(3), p.04014087.
- [7] Shankar, S.K., 2015. Indias of the Mind: Responses to Cultural Nationalism in Indian Popular Culture Post-Hindutva (Doctoral dissertation, University of Southern California).
- [8] Jeyanthi, R. and Kumar, S.M., 2016. Progressive collapse analysis of a multistorey RCC building using pushover analysis. International Journal of Engineering Research & Technology (IJERT), 5(03).
- [9] Gaikwad, S.B., Pawar, M.M. and SVERI's, C.O.E., 2017. Assessment of Progressive Collapse of Steel Structure. International Journal of Engineering Science, 13697.
- [10] A.Manjari, 2018. Progressive collapse of RC framed structure Due to column loss scenario, International Journal for Research in Engineering Application & Management (IJREAM) ISSN : 2454-9150 Vol-04, Issue-02, May 2018.



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