Progressive Collapse of Composites Structures

Mr. Yograj Ashok Nimbhorkar[1], Dr. D.P.Joshi[2]
[1] Dept of Civil Engineering
[2]Head of Department, Dept of civil Engineering
[1, 2] Late G.N.Sapkal college of Engineering , Nashik

Abstract- *The objective of this study is to investigate the progressive collapse of composite structures. For this G+20 building has been taken. For this linear static analysis and linear dynamic analysis, of structure has been carried out. The behavioral changes have been investigated to the sudden collapse of structures. The composite structure is design based on Indian Standard code of practice is considered. The investigation is carried out using ETABS software. Progressive collapse is to be considered for analysis as given by the US General services administration (GSA).Percentage change in the values of demand capacity ratio, base shear and roof displacement considering progressive collapse effect of structures were carried out. This simple analysis is used to analysis the structures for different failure conditions and then optimize it for various threat scenarios.*

Keywords- Progressive Collapse Analysis, composite structures, U.S. General Service Administration (GSA) Guidelines, Removal of Columns, Demand Capacity Ratio (DCR), Linear Static Analysis, ETABS.

I. INTRODUCTION

Progressive collapse is occurs when any one or more major structural load carrying element is removed suddenly from structure due unfavorable condition and if remaining element are not capable to carrying load of structures. If these columns are not much strong to capable to carrying loads and not properly, design to resist additional load so that part of structure also failed. Then the vertical carrying load elements continued failed until additional load is stabilized, as results on Heavy losses of human life and property. Progressive collapse implies a phenomenon of sequential failure of part of structure by sudden loss of vertical load carrying member such as columns. As a failure will transfer from one member to another which leads to collapse of whole structure. Such type of failure of structureis known as progressive collapse. Progressive collapse is generated for localized failures of one or more major structural elements due to vehicle impact, explosions and blast or terrorist attacks. Designing for example a reinforced concrete building against progressive collapse due to blast loading is a big challenge. Analyzing such a building and checking if a progressive collapse could happen or not depends on many assumptions. For example the major unknown's problems are: how far from the building the explosive is detonated, and whether the blast affects building the ones situated in the middle and sides the corner load-bearing elements of the of the building's etc.

II. LITERATURE REVIEW

Suraj B. Gaikwad (2017)(1) work onAssessment of Progressive Collapse of Steel Structure. In this study G+15 regular as well as irregular building with missing column at different locations has taken. For this study linear static analysis, linear dynamic analysis, nonlinear static and nonlinear dynamic analysis of structure has been carried out. It was observed that regular structure base shear is maximum when transverse direction middle column is removed and irregular structure base shear values is maximum when transverse direction middle column is removed. Percentage change in the values of demand capacity ratio, base shear and roof displacement considering progressive collapse effect of structures has been carried out.

Mohamadreza Rohani (2017)(2) studied Progressive Collapse Analysis of Reinforced Concrete Structures: A Simplified Procedure.In this study analysis procedure to calculate the columns removed point displacement at progressive collapse analysis of reinforced concrete structure. In this paper linear static analysis, nonlinear static analysis, linear dynamic analysis and nonlinear dynamic analysis was performed.The accuracy of the proposed method was demonstrated by comparing the results to three experimental and analytical results. This investigation was done for concrete structure but procedure would be valid for both steel and concrete structures. Finally, the effect of the material properties, sections dimensions, spans length and the beams reinforcements of column removed spans on substructure behavior was studied.

Kripalsinh Kheradiya (2017) (3) work on Progressive Collapse on Rcc Multistorey Building. In this paper a symmetrical and unsymmetrical 5m x 5m bay frames with four-storey building was studied for progressive collapse analysis with SMRF design without Infill masonry wall using alternate load path method. All the building frames are designed with dead load, imposed load and earthquake load with different zone and importance factor I = 1. The progressive collapse potential for seismic loading was carried out using linear static analysis and it was performed in ETABS software. In this study, it was observed that to avoid the progressive failure of beams and columns, after failure of particular column due to extreme loading, adequate reinforcement is required to limit the DCR within the acceptance criteria.

Yogesh T. Birajdar (2017)(4) studiedProgressive Collapse Analysis of Multi-Storied RCC Building. The objectives of this paper to study various types of progressive collapse and its mechanisms and analyze (G+15) RC earthquake resisting building for seismic zone III as per IS 1983:2002 by using ETABS 2016 software for linear dynamic analysis procedure. The Complete the mathematical modeling of multistory building and different types of loading combination and to find out axial forces variation time period, DCR for column, bending moment variation, and beam in different cases, and knowing the response of the structure for progressive collapse by using ETABs software. The results obtained increasing beam size will be more effective in avoiding or delaying collapse rather than increasing column sizes.

A. Choubey (2016)(5)work onProgressive Collapse Analysis of Rcc Structures.In this paper aims to investigate the progressive collapse behavior of RCC building under extreme loading events such as gas explosion in kitchen, terroristic attack, vehicular collisions and accidental overloads. Different studies was carried out to investigate the behavior of progressive collapse under the umbrella of changes in such as shear forces, bending moment, beam forces, reactions at nodes, node displacement and induced beam stresses subjected to sudden loss of a vertical support member.The behavioral change has been investigated and a node displacement was computed. Here RCC building was design and base on Indian standard code of practice. The investigation was carried out using commercially available software. The paper results obtained that the node displacement values was found under the column removal conditions and collapse resistance of building frame is studied due to increased loading for different scenarios.

C. R. Chidambaram (2016)(6) work onA Study on Progressive Collapse Behavior of Steel Structures Subjected to Fire Loads. In this study G+ 7 moment resisting steel frame residential building was analyzed using ETABS software to predict the sensitivity of the structure to progressive collapse due to fire loads. The Columns at different levels were given a temperature of 550̊C with reduced material properties and yield strength as per code IS 800 and Progressive collapse load combination was adopted as per GSA guidelines. The Corner, edge, intermediate and re-entrant columns was removed separately at alternate storeys. It was observe that the lower storey was found to be more susceptible than the upper storeys. This paper shows that intermediate column was 27.8 % and 16.36% more critical when compared to re-entrant column and corner column respectively.

JianWeng (2016)(7) work onDamage assessment for reinforced concrete frames subject to progressive collapse.In this paper presents a set of damage assessment criteria that can be easily implemented for progressive collapse analysis of reinforced concrete (RC) frames. Shear, Flexural and axial damage criteria for RC members are separately proposed incorporating axial-shear-flexural interactions in the analysis.Three scaled moment resisting RC frame structure tests were conducted to validate the proposed axial damage criteria and flexural. The results show that proposed flexural damage criteria predict well the critical damage characteristics (cracking and crushing of concrete, yielding of rebar etc.) of RC frames at the stage of flexural action.

FlorianaPetrone (2016) (8) studied theModeling of RC Frame Buildings for Progressive Collapse Analysis.In this paper, the progressive collapse analysis of reinforced concrete (RC) moment-frame buildings under extreme loads was discussed from the perspective of modeling issues.Using a prototype RC frame building, issues and considerations in constitutive modeling of materials, options in modeling the structural elements and specification of gravity loads was discussed. One of the objectives of the study was to consider simplified approaches for progressive collapse analysis using advanced finite element software was used in the simulations presented in this study. Finally, a new collapse index was proposed that can be used to assess both the damage state and the reserve capacity of the system and also serve as a means to identify critical load-bearing element in the structure. Finally, an energy-based approach for identifying the proximity to collapse of regular multi-story buildings was proposed.

Mrs. Mir Sana Fatema (2016)(9) studied the Progressive Collapse of Reinforced Concrete Building. In this study to carry out progressive collapse analysis of 13 storey RC frame building by removing different column one at a time as per the GSA guidelines. The building consists of 5 X 5 bay 5 m in both direction and designed by Indian code as a special moment resistant frame. Structural model created on ETABS software and load was applied as per GSA guidelines. As per GSA guidelines three column removal case one at a time has studied, namely Corner column removal at ground floor, interior column at ground floor and Exterior column at ground floor. For all three cases linear and non-linear analysis has done. The result obtained that shear in beam is not critical in any case, Columns are also not critical in Progressive collapse. But by Linear static analysis and nonlinear static it is obtained that beams was going to fail in flexure.

S Jeyarajan (2015)(10) work onAnalysis of Steel-Concrete Composite Buildings for Blast Induced Progressive Collapse.In this paper to investigate the progressive collapse behavior of steel concrete composite buildings subject to ground blast explosion using nonlinear dynamic analysis and conventional alternate path approach. In this present study, composite slab model based on equivalent area approach and composite joint model based on Euro code's component method was proposed for nonlinear analysis of building framework. The results show that a heavy blast load may wipe out a series of columns/beams at once instead of a single one. High blast pressure may induce large lateral drift and lead to significant damage to structural elements spreading over several storeys of the building.

III. METHODS OF ANALYSIS

Seismic analysis is an important tool in earthquake engineering, which is must use to investigate the response of buildings in a simpler manner due to seismic forces. It is a part of structural analysis and a part of structural design where earthquake is prevalent. The earthquake analysis methods used in the study are-

I. Equivalent Static Analysis
II. Response Spectrum Analysis

I. Equivalent Static Analysis - This approach defines a series of forces acting on a building to represent the effect of earthquake ground motion, typically defined by a seismic design response spectrum. It assumes that the building responds in its fundamental mode. The response is read from a design response spectrum, given the natural frequency of the building.

II. Response Spectrum Analysis- This method permits the multiple modes of response of a building to taken into account. Computer analysis can be used to determine these modes for a structure. For each mode, a response is obtained from the design spectrum, corresponding to the modal frequency and the modal mass, and then they are combined to estimate the total response of the structure. In this, the magnitude of forces in all directions is calculated and then effects on the building are observed. It is the linear dynamic analysis.

IV. METHODOLOGY

GSA guideline has provided following stepwise procedure to carry out Progressive collapse analysis.

Step1: First, the building is analyzed with gravity load (Dead Load + Live Load) and earthquake load and results formoment and shear are taken without removing any column.

Step2: Now by removing a vertical support (column) from the position under consideration and carry out a linear staticanalysis to the different structure model and Load this model with 2{Dead Load + 0.25(Live Load)} load combination inETABS.

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

Table 1 Element sizes

Storey	Beam(mm)	Column(mm)	Composite Column (mm)
1-4	230x400	625x625	550x550
5-8	230x400	600x600	525x525
9-12	230x400	575x575	500x500
13-15	230x400	550x550	475x475
16-20	230x400	525x525	450x450

Step4: Further from the analysis results obtained, DCR for different member is found out. If the DCR for any memberend connection or along the span itself is exceeded, the allowable limit based upon moment and shear force, the memberis expected as a failed member.

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

The basic outline for analysing a structural model with the Etabs structural analysis program:

General data:

- Type of structure: Composite Framed Structure
- Number of stories : G+20
- Floor to floor Height of each storey: 3.0 m

- Height of the buildin : 60m(above GL)
- Software used: Etabs
- Fck:30 N/mm2
- Fy :500 N/mm2

Loading considered on the building for the study are as follows:

Dead load as per IS 875 (Part I):

- Self- weight of the structural element
- Floor finishes = 1.5kN/m2
- Wall load on beams = 7kN/m(115mm)
- Wall load on beams = 14kN/m (230mm)

Live Load as per IS 875 (Part II):

- On roof 1.5kN/m2 , and
- on floors 3kN/m2

Seismic loading as per IS: 1893

- Soil type - II ,
- Importance factor – 1
- Type of soil- Medium
- Response reduction factor –5

Building is analyzed for above loading and designed in the ETABS. Load combinations for seismic design are considered as per IS 1893: 2002 as:

- 1.2 (DL + LL ± EQX) And 1.2 (DL + LL ± EQY)

Column Removal Cases:

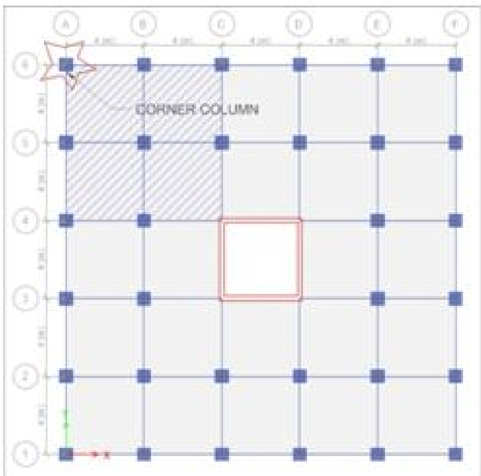

Fig. 3.2 Corner Column Remove

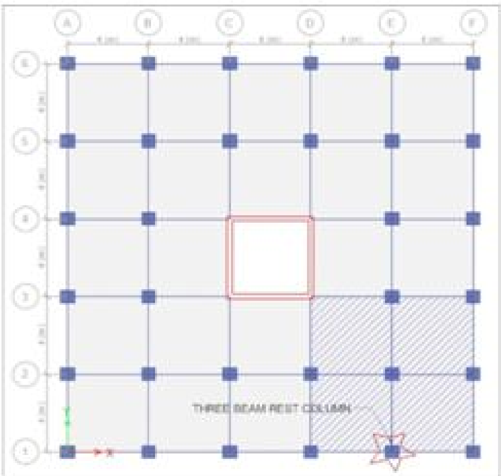

Fig. 3.3 Three Beam Rest Column Remove

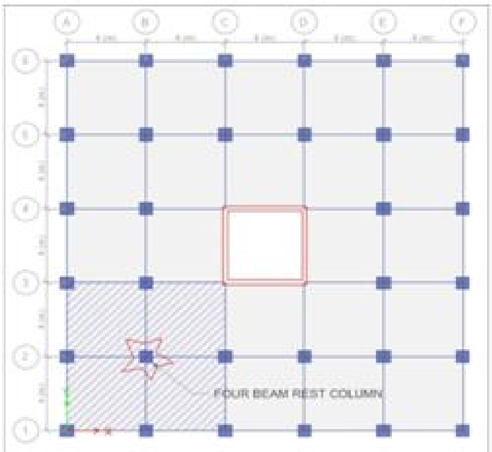

Fig. 3.4 Four Beam Rest Column Remove

V. RESULTS AND DISCUSSION

Base Shear: Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure. As height of the building increases the value of base shear also increases due to the increase of seismic weight of the building.

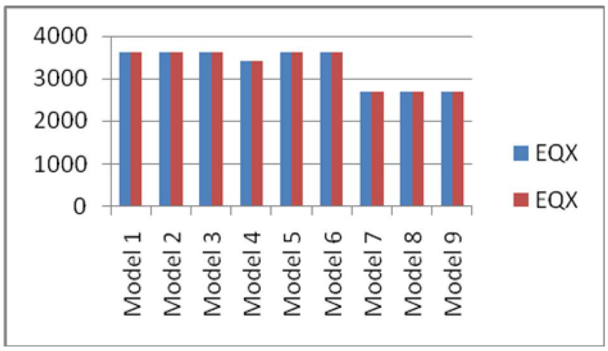

Chart 1: Graphical Representation of Base shear with respect to Earthquake forces

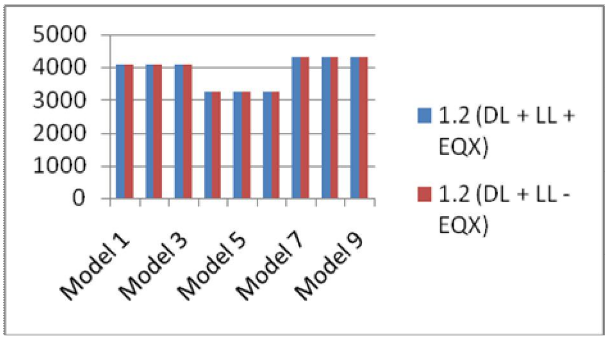

Chart 2: Graphical Representation of Base shear with respect to Critical Load Combinations.

From above results tables show that Composite frame structure base shear is more than R.C. structure. The base shear of Composite unsymmetrical structure is about 5.88 % higher as compared to conventional RCC Frame building and 21.05% higher compared Composite Symmetrical Structures.

Storey Displacement: Story drift is the difference of displacements between two consecutive stories divided by the height of that story. Story displacement is the absolute value of displacement of the storey under action of the lateral forces. From following results tables show that RCC frame structure Storey deflection is more than Composite structure in x directions and storey deflection y direction Composite symmetrical frames structures is maximum. The deflection of RCC structure isabout 16.86 % at storey 21 in x direction is higher as compared to Composite frame structure.

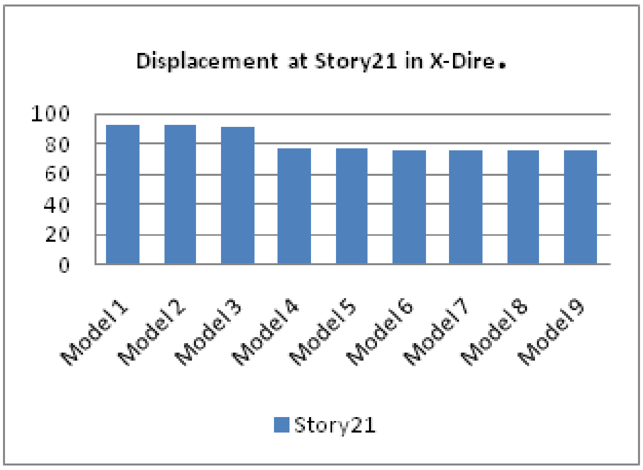

Chart 3: Graphical Representation of Storey displacement in X directions at Storey 21

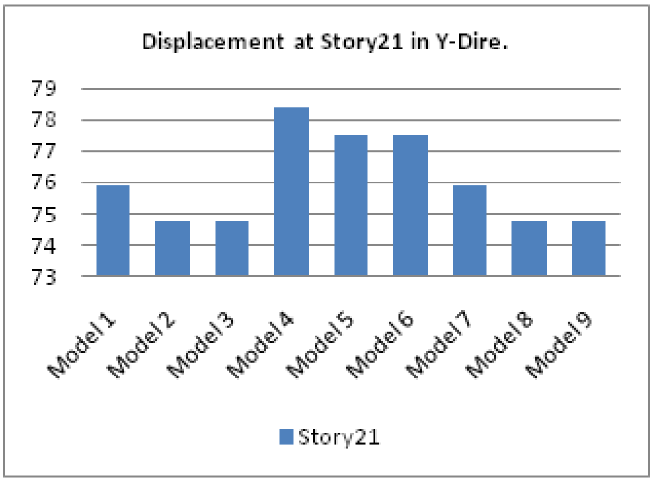

Chart 4:Graphical Representation of Storey displacement in Y directions at Storey 21

Time Period:A time period (denoted by 'T') is the time needed for one complete cycle of vibration to pass in a given point.

As the frequency of a wave increases, the time period of the wave decreases. From above results time period of RCC frame structure and composite Symmetrical structure are similar but composite Unsymmetrical frame structure is less. RCC frame structure and composite Symmetrical structure is 9.88% increase as compare to unsymmetrical frame structures.

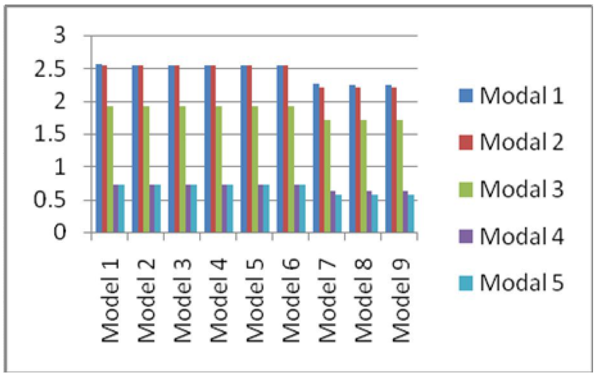

Chart 5: Graphical Representation of Time period for first three modes

StoreyDrift: Drift is defined as the lateral displacement. Storey drift is the drift of one level of a multistorey building relative to the level below. Inter story drift is the difference between the roof and floor displacements of any given story as the building sways during the earthquake, normalized by the story height.

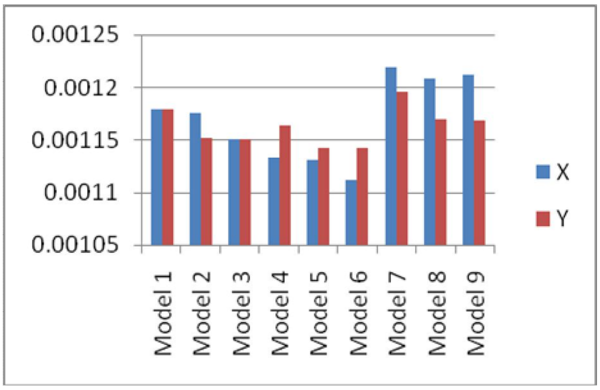

Chart 6:Graphical Representation of Storey drift at Storey 16

From the above Results it was observed that storey drift of RCC frame structure and Composite Unsymmetrical structure is more than Composite Symmetrical structures. As height of the building increases the value of storey drift also increases. The storey drift of RCC frame structure 3.44 % higher and Composite Symmetrical structures 7.43% as compared to Composite Symmetrical structures.

VI. CONCLUSION

1. The three column removal, most of the damage occurs at exterior and interior beam.
2. DCR ratio of beam is more as compare to DCR ratio value of column.
3. There are maximum beam damages, while composites columns are minimum.
4. For the corner column remove, there is less damage of structures and four beam rest column when remove there is maximum beam damage occurs.
5. From this observation to avoid the failure of beams and columns, after failure of particular column due to extreme loading, to increase size of section to limit the DCR within the acceptance criteria.

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