Progressive Collapse Analysis of Steel Frame Structure For Different Earthquake Zones

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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 effect the behavior of structure and causes collapse of a portion of structure. 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 Steel framed structure with 10 stories for progressive collapse located in different seismic zones is investigated. A linear static analysis is worked out using ETABS Software respectively. The demand capacity ratio is assessed in the critical region of the Steel portion associated with the column removed, as per the provisions of GSA guidelines. The topic concluded that with the designed to resist earthquake loading has intrinsic capacity against progressive collapse.

Keywords- Progressive collapse, GSA-2013, Linear analysis, Steel structure failure, ETABS-2015, Non-Linear Static analysis, D.C.R.

I. INTRODUCTION

Progressive collapse of structures is initiated by the loss of one or more load-carrying members. As a result, the structure will seek alternate load paths to transfer the load to structural elements, which may or may not have been designed to resist the additional loads. Failure of overloaded structural elements will cause further redistribution of loads, a process that may continue until stable equilibrium is reached. Equilibrium may be reached when a substantial part of the structure has already collapsed. The resulting overall damage may be disproportionate to the damage in the local region near the lost member. Loss of primary members and the ensuing progressive collapse are dynamic nonlinear processes.

A structure undergoes Progressive Collapse when a primary structural element fails, resulting in the failure of adjoining structural elements, which in turn causes further structural failure.

It is sometimes also called a disproportionate collapse, which is defined as a structural collapse disproportionate to the cause of the collapse. As the small structural element fails, it initiates a chain reaction that causes other structural elements to fail in a domino effect, creating a larger and more destructive collapse of the structure. A good example of progressive collapse is a house of cards; if one card falls near the top, it causes multiple cards to fall below it due to the impact of the first card, resulting in full collapse of the house of cards.

II. LITERATURE REVIEW

1] Analysis of progressive collapse in RC frame structure for Different seismic zones

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

The conclusion that from paper,

a) A building designed to resist earthquake loading has inherent capacity to resist progressive collapse.
b) Higher storey buildings are more sensitive to progressive collapse than low rise buildings.
c) 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.

2] Progressive Collapse of Steel Frames: - (1995)

Keywords: Finite Element Model; Multistorey Buildings; Nonlinear Analysis; Progressive Collapse; Steel Frames

Nonlinear finite element models investigating the progressive collapse of steel frames have been developed and reported in this paper. The finite element models have accounted for the nonlinear material of the steel frames and the nonlinear geometry was also considered. The investigated steel frames had different geometries and different damping ratios. Overall, the paper addresses how multi-storeyed frames would behave when subjected to local damage or loss of a main structural carrying element. The history behaviour of the steel frames deformations and failure modes were investigated and discussed in this paper. The nonlinear finite element models accented the nonlinear material and geometry behaviour of the steel frames. The study has shown that:

- By increasing damping ratios in dynamic analysis the maximum lateral deflection decreased for all frames.
- The progressive collapse potential decreased as the number of story increased since more structural members participate in resisting progressive collapse.
- The nonlinear dynamic analysis method provided a realistic representation of the progressive collapse behaviour.
- The increase only in the girder size for the purpose of preventing progressive collapse may result in weak story when the building is subject to seismic load.

The formation of weak story can be prevented by increasing the column size in such a way that the strong column-weak beam requirement is satisfied. The maximum lateral deflection obtained for internal column-removed case using the 3D-model was slightly higher (within 2%) than that obtained for internal column removed case using the 2D-model.

3] Progress Analysis Procedure for Progressive Collapse

Authors: - S. M. Marjanishvili.

In this paper, present four successively more sophisticated analysis procedures for evaluating the progressive collapse hazard: linear-elastic static; nonlinear static; linear-elastic dynamic and nonlinear dynamic. In this paper discuss the advantages and disadvantages of each method. The conclude that the most effective analysis procedure for progressive collapse evaluation incorporates the advantageous parts of all four procedures by systematically applying increasingly comprehensive analysis procedures to confirm that the possibility of progressive collapse is high.

Main objective of this paper is to formulate an easy-to-follow, comprehensive analysis procedure that will, in most cases, yield reliable and accurate results to estimate the likelihood of progressive collapse.

To attain this objective, we perform the following tasks:

1. Description of progressive collapse phenomena;
2. Review of current guidelines and state of the practice;
3. Evaluate and compare various analysis procedures; and
4. Formulate the preferred method of analysis.

Major topics covered in this paper include:

• Selection of the analysis procedure,
• Verification and validation of the results, and
• Evaluation of the results.

The three most effective analysis procedures discussed in this study are linear elastic static, linear elastic time history, and nonlinear time history. The simplest analysis methodology includes static linear elastic procedures, and the most exhaustive procedure is nonlinear time history analysis. Several design guidelines provide an excellent methodology regarding the selection of analysis procedures, enabling the use of simpler analysis methods for relatively simple structures and thereby saving engineering time and computer resources. However, simpler analysis procedures use more conservative response evaluation criteria than more elaborate analysis procedures. It is expected that more elaborate analysis methods will result in less severe structural response, due to the more accurate estimates of load distribution and less stringent evaluation criteria.

In This paper recommended that, in order to determine the likelihood of progressive collapse, a progressive analysis procedure be used. In progressive analysis, a structure's response is evaluated by starting with simpler static methodology and then by proceeding to increasingly complex analysis methods as necessary, until it is determined that the possibility of progressive collapse is low or until all available engineering methodologies are exhausted. The advantages of this methodology include relative simplicity in performing the calculations as well as ease in evaluating the results.

III. DESIGN METHODLOGY

General

This chapter describes various methods and approaches used for analysis and design of structure. The present study is carried out on analysis and design of low rise steel building using ETABS 2015 software. Modeling of G+10 storey structure is done in ETABS 2015.The models are analyzed and designed for design loading and load combinations.

Design methodology

The structures in the present work are designed for progressive collapse according to "GSA Alternate Path Analysis and Design Guidelines for Progressive Collapse Resistance." The GSA guidelines are applicable in following cases.

These Guidelines apply to GSA owned (new and existing) and new GSA lease construction. If stated as a tenant specific requirement within the Program of Requirements (POR), these Guidelines may also apply to new lease acquisitions or succeeding leases that are established through full and open competition. These Guidelines do not apply to lease renewals, extensions, expansions, or superseding and succeeding leases that are established other than through full and open competition.

IV. VALIDATION, ANALYSIS & DESIGN

General

This chapter describes problem statement, validation of software, loading on structure, modeling and analysis of structure in ETABS 2015. To study Progressive Collapse Analysis of Low Rise Steel Frame Structure with and without Bracing System, G+10 steel frame structures have been taken. The complete modeling and analysis of structure is carried out using ETABS 2015.

Problem Statement

A G+10 steel frame structure storied are taken for proposed study in which all typical floor height is kept 3m.

Validation of analysis results

For the validation of analytical results of ETABS 2015 software, a G+10 steel frame structures are analyzed by using ETABS 2015 and by considering GSA guidelines.

Preliminary data required for analysis (Validation)

Sr. No.	Particulars	Details
1	Type of Structure	Low Rise Steel Frame Structure
2	Type of building	Public building
2	Seismic Zone	(IS:1893-2002)
3	Number of Stories	G+10
4	Floor Height	3000 mm
5	Spacing of grid	5000 mm in both direction
6	Imposed load	2.5 KN/m^2
7	Floor Finish	1.25 KN/m^2
8	Wall Load	10 KN/m^2
9	Wall Load at Roof	3 KN/m^2
10	Materials	Concrete M25, Reinforcement Fe 415& Structural steel (Fy-345)
11	Depth of slab	150 mm thick

Structural modeling, analysis and design

Modeling of building structure is done by using ETABS 2015. The complete modeling, analysis and design of structure is done in three phase namely preprocessing, processing and post processing.

Preprocessing

In preprocessing phase, building is modeled by forming a grid, defining material properties, defining of section properties and defining support conditions. Loading and load combinations are defined as per IS: 1893-2002 (Part-I) & IS: 875-1987 and assigned to model. Response Spectrum function is defined as per IS: 1893-2002 for the purpose of seismic analysis. The developed model of building in ETABS 2015 is as follows.

Processing

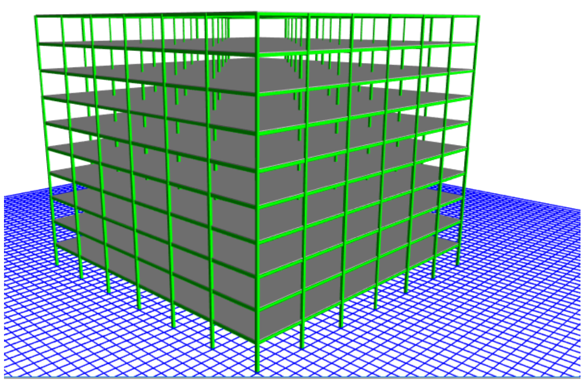
After carried out all the steps involved in pre-processing phase, structure are ready to analysis and design. There is option of Run analysis cases. As per requirement, specific analysis cases are chosen and analysis of structure is performed. After analysis, design is carried out to get, DCR, Joint Displacement, Axial Force Shear force and Bending Moment for different position of column removal and bracing system.

Post processing

In post- processing phase, obtained results of analysis and design are verified.

Model Description

In present study, ten story models were prepared on E-TABS 2015.spacing of grids is 5 meters on both the direction and floor to floor height is 3 meter. In both the cases before progressive collapse of structures we have taken the demand capacity of members as 0.5-0.9. Loading on structures are taken as Live Load-2.5KN/m and Floor Finish-1.25KN/m. for the 10 story we considered the wind load effect as per IS-875-2007. Seismic loads are applied on the structures as per the IS-1893-2007.this structure analysis for different earth quake zones



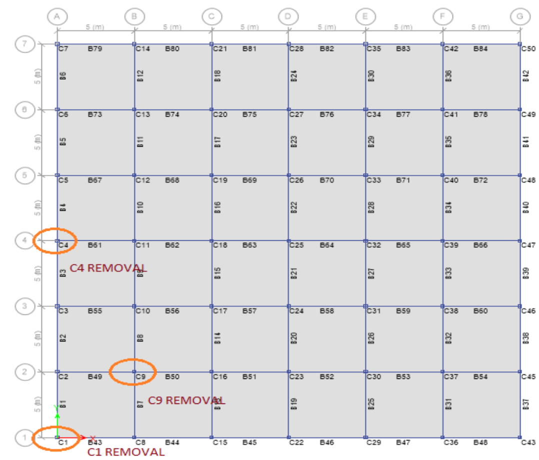
Ten Story Building (6X6 Bay Size)

V. RESULT AND ANALYSIS

The results of analysis and design of a G+10 steel frame structures using Linear Static method are presented and discussed in the following manner:

1) Verification of analysis results of G+10 steel frame structures by the results of ETABS 2015 software using Linear Static Analysis method.
2) Demand Capacity Ratio (D.C.R) verses Storey Level Graph carried for G+10 steel frame structures.
3) Joint displacement of Steel Structures provided for G+10 frame structures.
4) Axial Force(P), Shear Force(V2) and Bending Moment(M3) have been carried for before and after column removal and for bracing system for G+10 steel frame structures.

ANALYSIS PROCESS



Plan View of G+10 ETABS model with column removal position

For Seismic Zone II and Zone V

Case: 1 Analysis for the sudden loss of a column situated at the corner of building
Case: 2 Analyses for the sudden loss of a column situated at the middle of the one of building
Case: 3 Analyses for the sudden loss of a column situated at or near middle removal at any suitable location should be carried out for building .in these case columns next to middle position.

VI. CONCLUSION

The study focuses on the relieve measures to reduce the risk of Progressive Collapse of steel buildings. This steel structure analysis for different earthquake zone systems are used and find out cost effective & the most practically stable system to improve Progressive collapse bearing capacity.

A 3D Model is prepared in finite element based E-Tab Software tool and APM approach is used. These frame structural system are examine under various column removal conditions as stated in GSA [2].

It is observed that effect of progressive collapse was more when corner column was suddenly removed, as the number of story increases effect of progressive collapse decreases since the number of members for taking distributed load is more.

As the number of storey increases effect of progressive collapse decreases since number of members for taking distributed load are more and hence DCR values of beam go on decreasing for upper levels beams. Which shows the more failure occurs in nearby area of removed column

DCR values of beam go on decreasing towards upper levels but DCR values of column go on increasing towards.

It is observed that effect of progressive collapse was more when corner column was suddenly removed, as the number of members participating in progressive collapse event is more.

It is increase in bending moment of beam due to redistribution of loading on removed area location which leads to failure may be partial or fully but not shear force (strong column & weak beam)

From above results it is found that the structure design in seismic zone II is less susceptible to progressive collapse as compare to design in seismic zone V.

VI. FUTURE STUDY

In the present study we have used finite element based E-Tabs software for analysis. Similar analysis can be done in SAP2000 software tool and the results thus obtained are to be compared with literature available & with E-Tab results and graphs are to be plotted.

VII. ACKNOWLEDGMENT

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