DESIGN OF RCC STRUCTURE AGAINST PROGRESSIVE COLLAPSE

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Abstract - *Structural engineers are facing new challenges in designing safe structures due to the increase in terrorist actions carried out on landmark buildings which has the potential to cause great destruction, damage, and danger to people. As designers, Engineers are tasked with understanding all the possible loads that a building may encounter in its life and ensuring that the structural system will remain standing and ensure the safety of those inside. An abnormal loading in the past were never considered during design, but an alarming string of events, mostly terrorist, have awakened the need for special considerations for potential targeted buildings. It is virtually impossible to predict what exact extreme load may be induced on a building, therefore when designing for structural integrity the most important consideration is progressive collapse.*

A building undergoes progressive collapse when a primary structural element fails, resulting in the failure of adjoining structural elements, which in turn causes further structural failure. Several examples will be given of progressive collapses that occurred in structures due to abnormal loading. Such a failure is catastrophic as collapse occurs in an instance, not allowing time for inhabitants to escape. There are certain details regarding design and retrofit of structures to resist progressive collapse that should be followed, especially for materials such as concrete and steel. In this thesis we have done structural modelling, analysis and design a structure against the progressive collapse.

Keywords: RCC, Progressive collapse, Modeling, Analysis, Design and STAAD Pro

1.INTRODUCTION

Structural engineers are facing new challenges in designing safe structures due to the increase in terrorist actions carried out on landmark buildings which has the potential to cause great destruction, damage, and danger to people. As designers, Engineers are tasked with understanding all the possible loads that a building may encounter in its life and ensuring that the structural system will remain standing and ensure the safety of those inside.

Abnormal loadings in the past were never considered during design, but an alarming string of events, mostly terrorist, have awakened the need for special considerations for potential targeted buildings. It is virtually impossible to predict what exact extreme load may be induced on a building, therefore when designing for structural integrity the most important consideration is progressive collapse. Progressive collapse results when a localized failure spreads to a larger portion of the structure.

Several examples will be given of progressive collapses that occurred in structures due to abnormal loading. Such a failure is catastrophic as collapse occurs in an instance, not allowing time for inhabitants to escape. There are certain details regarding design and retrofit of structures to resist progressive collapse that should be followed, especially for materials such as concrete and steel.

As a result of increasing catastrophic events in recent years, the prevention of progressive collapse is becoming a requirement in building design and analysis. Many approaches have been proposed to minimize the risk of progressive collapse in new and existing buildings. Among a number of building codes, standards, and design guidelines for progressive collapse, General Services Administration (GSA, 2003) and Department of Defense (DoD, 2005) address progressive collapse mitigation explicitly. They provide quantifiable and enforceable procedures to resist progressive collapse.

2. Literature Review:

Wood, C., Lodhi, M., and Sezen, H. - Their paper of this research is to better understand progressive collapse mechanisms of buildings, and to evaluate the current modelling and analysis techniques and design methodologies. Field experiments and numerical simulations were performed to investigate the progressive collapse potential of several reinforced concrete and steel frame buildings. Up to four first-story columns were physically removed from the buildings to understand the subsequent load redistribution within each building. Experimental data from the field tests were used to compare and verify the computational models and analysis results. Due to the scarcity of data from full-scale tests, the experimental data of this research is a valuable addition to the state of knowledge on progressive collapse of buildings. The design guidelines typically recommend simplified analysis procedures involving instantaneous removal of specified critical columns in a building. This research investigates the effectiveness of such commonly used progressive collapse evaluation and design methodologies through numerical simulation and experimental data.

Haberland, M. and Starossek, U - Their paper presents Structural robustness is recognized as a desirable property of structural systems which mitigates their susceptibility to progressive collapse. However, there is some confusion in the literature regarding the usage of the terms structural robustness and collapse resistance as well as competing expressions such as prescriptive vs. performance-based, threat-specific vs. threat-independent or indirect vs. direct design. This article tries to distinguish between the different meanings of these four pairs of terms, which are important concepts in the field of progressive collapse. In this context, design strategies and associated methods to prevent progressive collapse are briefly explained.

Kirkpatrick, S., MacNeill, R., Smith, J., Herrle, K., and Erekson, M - Existing building codes contain some guidance on progressive collapse analysis and design. Unfortunately, in most of the U.S. building codes and standards that contain progressive collapse provisions, the available guidance is either vague, or does not define, the key issues that must be addressed. This lack of guidance has resulted in conflicting interpretations as to how one should approach progressive collapse analysis and design. The General Services Administration (GSA) and Department of Defence Unified Facilities Criteria (UFC) Progressive Collapse Guidelines [1–3] are currently the most complete sets of criteria in terms of providing usable guidance to the designer. However, only through experience can one identify the most appropriate modelling technique for a particular application.

Stylianidis, P., Nethercot, D., Izzuddin, B., and Elghazouli, A - Recent studies of progressive collapse have sought to move the design basis from one of the simple following of prescriptive requirements to approaches based on understanding, modelling and quantitative assessment. A key requirement for such approaches is the definition of a suitable failure criterion — expressed both in physical terms and in a way that accord with traditional views of structural analysis and design. The method developed at Imperial College London checks the ability of the damaged structure to attain a new equilibrium state expressed in terms of available connection rotation capacity. The effects of variations in connection type (and therefore properties) in improving resistance to progressive collapse may therefore be examined explicitly and quantitatively.

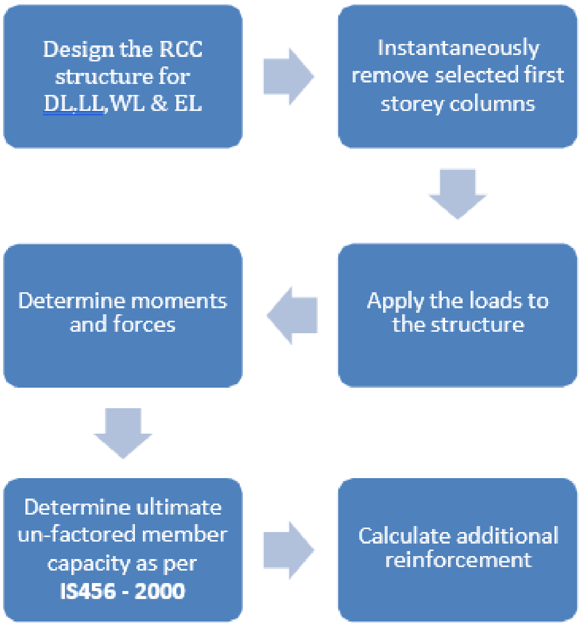


Fig -1 Methodology

3. Design approach (Alternative Path Method):

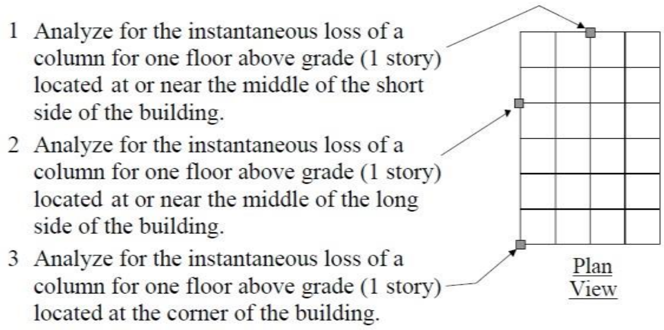
In alternate path (AP) method, the design allows local failure to occur, but seeks to prevent major collapse by providing alternate load paths. Failure in a structural member dramatically changes load path by transferring loads to the members adjacent to the failed member. If the adjacent members have sufficient capacity and ductility, the structural system develops alternate load paths. Using this method, a building is analyzed for the potential of progressive collapse by instantly removing one or several load bearing elements from the building, and by evaluating the capability of the remaining structure to prevent subsequent damage.

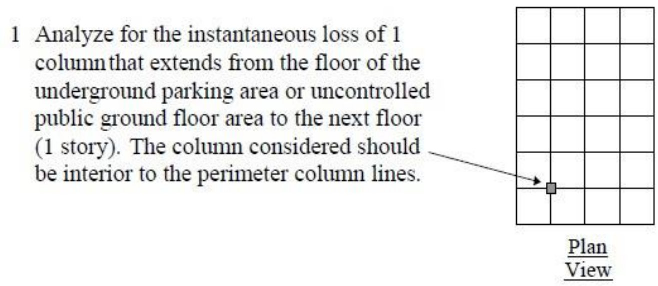
The advantage of this method is that it is independent of the initiating load, so that the solution may be valid for any type of the hazard causing member loss. The alternate load path method is primarily recommended in the current building design codes and standards in the U.S., including General Services Administration (GSA, 2003) and the Department of Defense (DoD, 2005) guidelines. Thus, this research also focuses primarily on the AP method and used it for progressive collapse analysis.

4. Column removal procedure:

For progressive collapse analysis, GSA mandates several column loss scenarios as shown in figure. The GSA guidelines require removal of first-storey columns. To determine the potential of progressive collapse for a typical structure, designers can perform structural analyses in which the instantaneous loss of one of the following first floor columns at a time is assumed:

- An exterior column near the middle of the long side of the building.
- An exterior column near the middle of the short side of the building.
- A column located at the corner of the building.
- A column interior to the perimeter column lines for facilities that have underground parking or public ground floor areas.





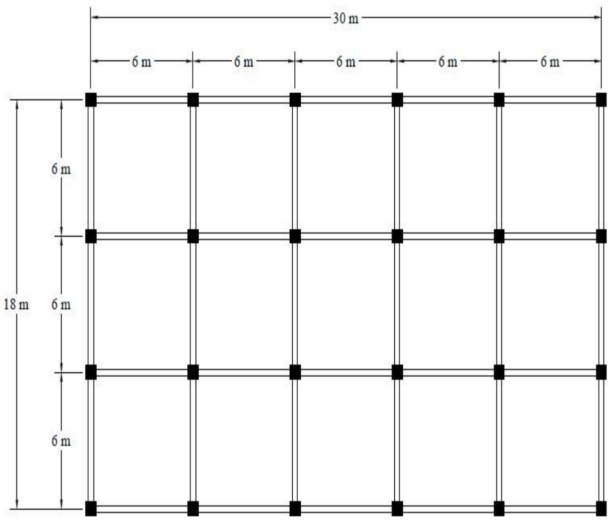


Fig -2 Plan of the Structure

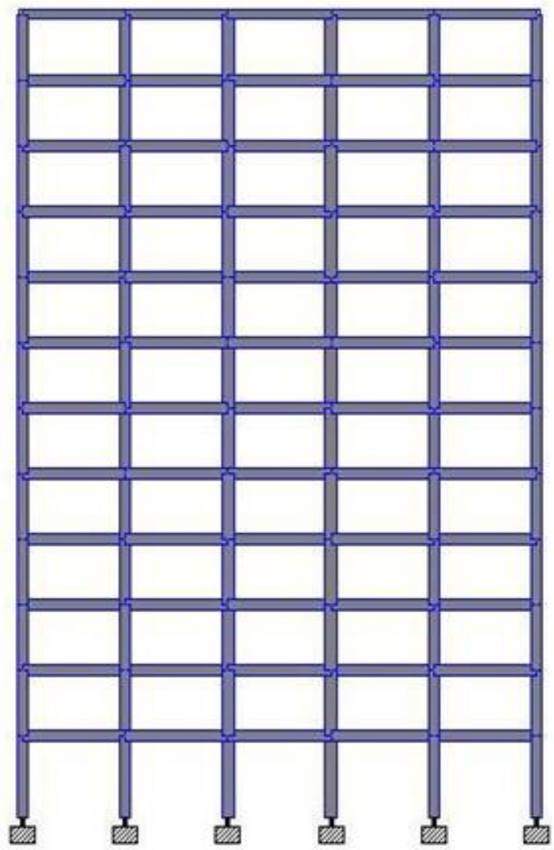


Fig -3 Elevation of the Structure

5. Load calculation:

Load calculation: Dead Load
Super Imposed Dead Loads (SDL):

Floor Finishes = 1.00 kN/m2

Partitions load = 0.50 kN/m2

Total loads = 1.50 kN/m2

Wall Load in Beams

= 0.23 x 3.00 x 20 = 13.80 kN/m

Wall Load in Terrace

= 0.23 x 1 x 20 = 4.60 kN/m

Live Load

Live load at floor levels = 4.0 kN/m2

Live load at Terrace level = 5.0 kN/m2

Seismic load

The following Seismic parameters were taken in accordance with IS: 1893 – 2002. For design consideration the building is situated Zone III and medium soil location

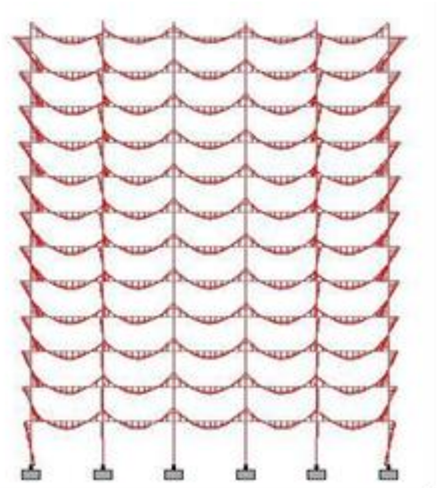


Fig. 4 Conventional Analysis & Design results from STAAD Pro

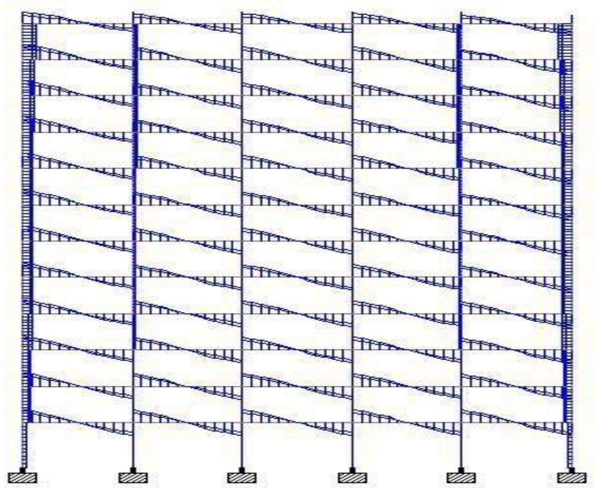


Fig. 5: Beam design from STAAD Pro

6. Beam design from STAAD Pro:

Width of Beam = 400 mm
Depth of Beam = 600 mm
Length of the Beam = 6000 mm
Concrete grade = M25
Steel grade = Fe415

Main reinforcement:
Provide 3nos of bars #25 at the both face of span section.

Shear reinforcement:
Provide 8mm bars @ 2 legged vertical stirrups at 200 mm c/c

7. Column design from STAAD Pro

Width of Column = 700 mm
Depth of Column = 700 mm
Concrete grade = M25
Steel grade = Fe415

Main reinforcement:
Provide 32nos. of 25mm bars
Lateral reinforcement:

Provide 8mm # 300mm c/c as lateral ties

8. Progressive Collapse Analysis & results:

Following the design of the building for Gravity and Seismic loads, first storey columns were removed at each of the four locations of the buildings as specified by the GSA criteria. The specified GSA load combination was applied and the demand forces were calculated for each member again using the STAAD program.

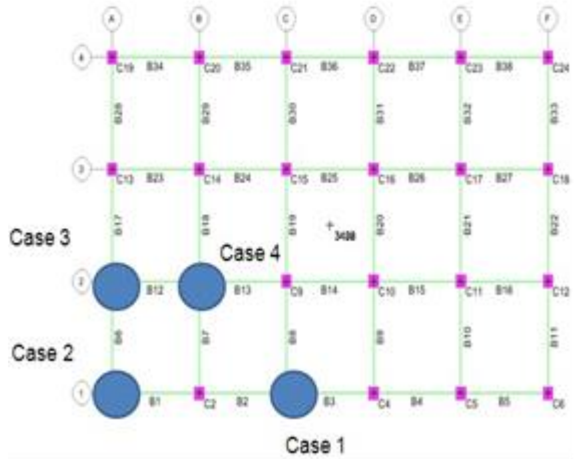
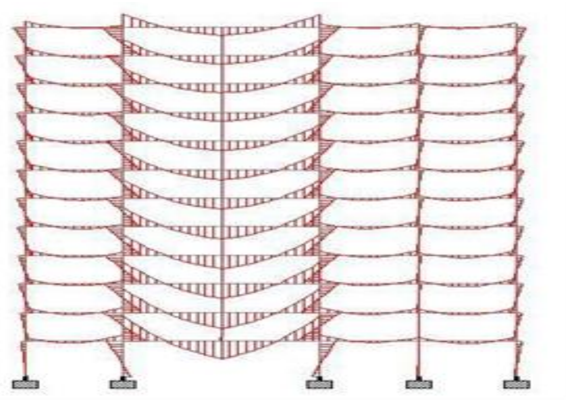


Fig. 6: Progressive Analysis & Design results from STAAD Pro (Case 1):



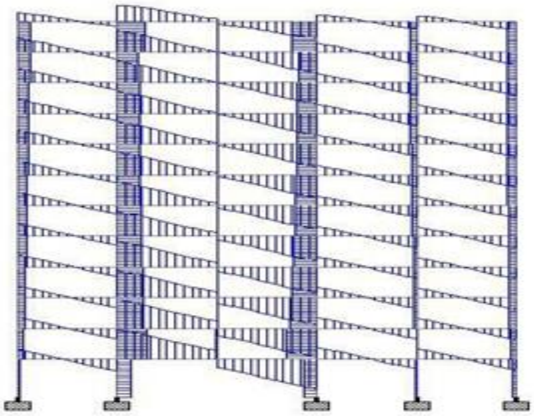


Fig 7: Beam design from STAAD Pro

Width of Beam = 400 mm
Depth of Beam = 700 mm
Length of the Beam =12000 mm
Concrete grade = M30
Steel grade = Fe415

Main reinforcement:
Provide 3nos of bars #32 at the both face of span section.
Shear reinforcement:
Provide 8mm bars @ 2 legged vertical stirrups at 220 mm c/c

9. Column design from STAAD Pro:

Width of Column = 700 mm
Depth of Column = 700 mm
Concrete grade
Concrete grade = M30
Steel grade = Fe415

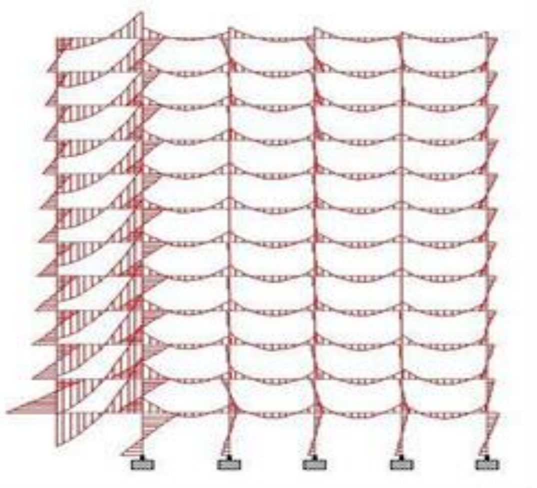
Main reinforcement:

Provide 36nos. of 25mm bars

Lateral reinforcement:

Provide 8mm # 300mm c/c as lateral ties

10. Progressive Analysis & Design results from STAAD Pro (Case 2)



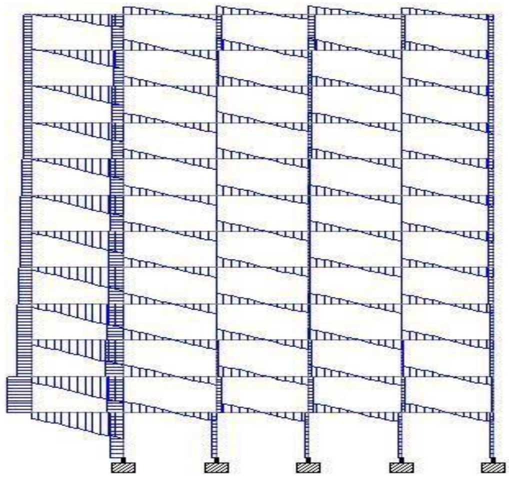


Fig 8 : Beam design from STAAD Pro

Width of Beam = 400 mm

Depth of Beam = 700 mm

Length of the Beam = 6000 mm

Concrete grade = M30
Steel grade = Fe415

Main reinforcement:

Provide 6nos of bars #32 at the both face of span section.

Shear reinforcement:

Provide 8mm bars @ 2 legged vertical stirrups at 120 mm c/c

11. Column design from STAAD Pro:

Width of Column = 700 mm
Depth of Column = 700 mm
Concrete grade
Concrete grade = M30
Steel grade = Fe415

Main reinforcement:
Provide 28nos. of 25mm bars
Lateral reinforcement:
Provide 8mm # 300mm c/c as lateral ties

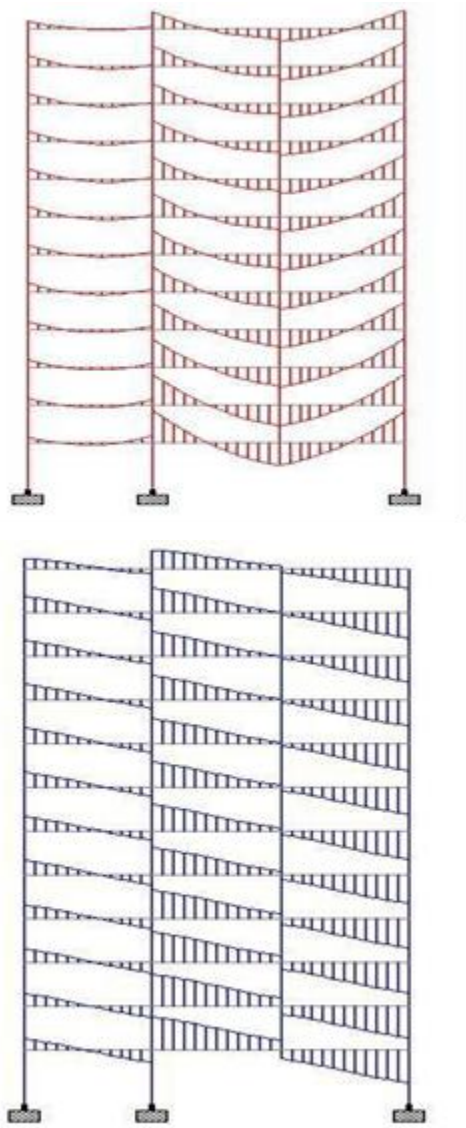


Fig 9 : Progressive Analysis & Design results from STAAD Pro (Case 3):

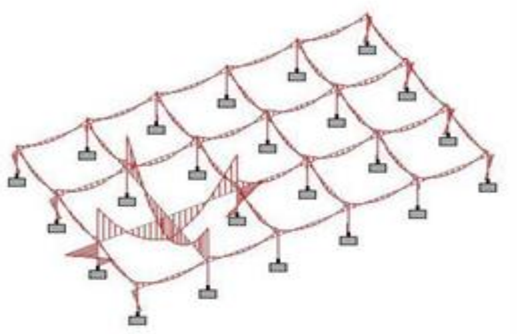
12. Beam design from STAAD Pro:

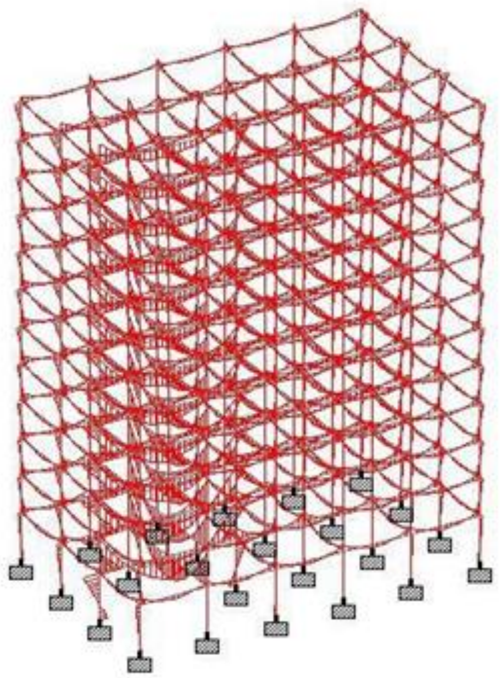
Width of Beam = 400 mm
Depth of Beam = 700 mm
Length of the Beam = 6000 mm
Concrete grade = M30
Steel grade = Fe415
Main reinforcement:
Provide 5nos of bars #32 at the both face of span section.
Shear reinforcement:
Provide 8mm bars @ 2 legged vertical stirrups at 200 mm c/c

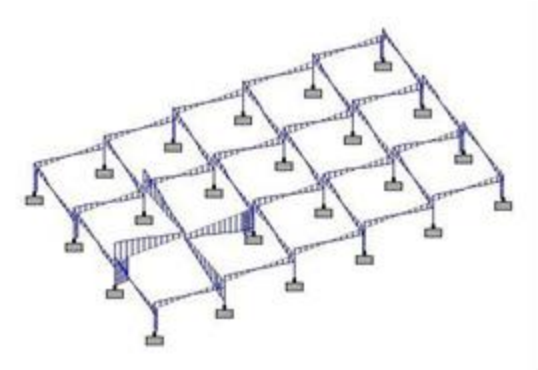
13. Column design from STAAD Pro:

Width of Column = 700 mm
Depth of Column = 700 mm
Concrete grade
Concrete grade = M30
Steel grade = Fe415

Main reinforcement:
Provide 16nos. of 32mm bars
Lateral reinforcement:
Provide 8mm # 300mm c/c as lateral ties







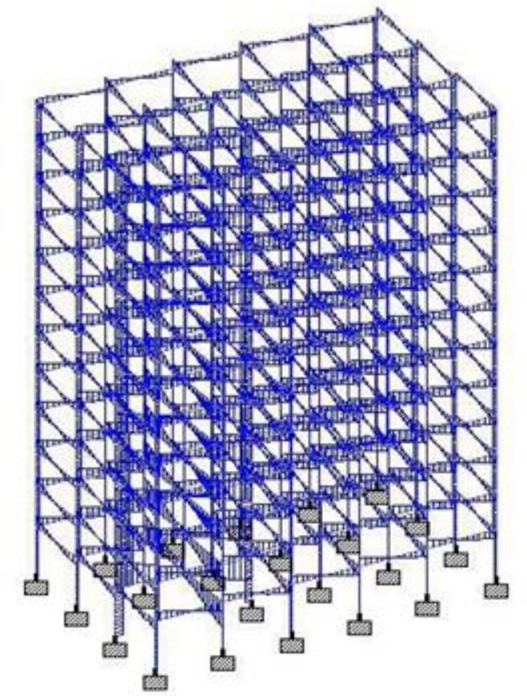


Fig 10 : Progressive Analysis & Design results from STAAD Pro (Case 4):

14. Beam design from STAAD Pro:

Width of Beam = 400 mm
Depth of Beam = 700 mm
Length of the Beam = 12000 mm
Concrete grade = M30
Steel grade = Fe415

Main reinforcement:

Provide 9nos of bars #32 at the both face of span section.

Shear reinforcement:

Provide 8mm bars @ 2 legged vertical stirrups at 100 mm c/c

15. Column design from STAAD Pro

Width of Column = 800 mm
Depth of Column = 800 mm
Concrete grade
Concrete grade = M30
Steel grade = Fe415

Main reinforcement:

Provide 20nos. of 32mm bars

Lateral reinforcement:

Provide 8mm # 300mm c/c as lateral ties

16. CONCLUSION

This study illustrates the inherent ability of seismically designed RC beam- column frames to resist progressive collapse. The main objective of Progressive collapse design of buildings is to avoid total catastrophic damage and to restrict the structural damages caused, to the performance limit of the building.

reinforced concrete buildings. The main parameters studied were the axial load, flexure, and shear reinforcement required for the moment resisting concrete framed buildings designed for Dead load, Live load and Seismic loads. The column removal has been done as per the GSA criteria.

From this study, it is observed that to avoid the Progressive failure of beams and columns, after failure of particular column due to extreme loading from blast, adequate reinforcement and in some cases increasing the cross sectional dimensions will avoid the Progressive failure of the structure. We found that Case 4 beams and columns are getting critical among all other cases, if we provide Case 4 resultant section and additional reinforcements for all the columns and beams in base floor we could avoid the structure from progressive collapse. For concrete buildings designed for Dead, Live, and Seismic loads, progressive collapse prevention as per the GSA criteria can be achieved with small increase in reinforcement & concrete cost.

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