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PROGRESSIVE COLLAPSE ASSESSMENT OF MULTI STOREY BUILDING USING IS 1893

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Abstract

Progressive collapse refers to the failure of a structure or a part of a structure that initiates a chain reaction, leading to partial or total collapse. In multi-story buildings, progressive collapse can result from unexpected events such as earthquakes, structural irregularities, or localized damage. This study focuses on assessing the progressive collapse potential of a G+6 multi-story building using the guidelines provided in IS 1893: Part 1 (2016) –Criteria for Earthquake Resistant Design of Structures. Using linear and nonlinear static analysis, key structural parameters including story displacement, story drift, base shear, andstory moments are evaluated to understand the building's response under seismic loading conditions. The results provide insight into the weak points of the structure, allowing engineers to implement design modifications to enhance resilience. The study highlights the importance of compliance with IS 1893 for ensuring structural stability and mitigating the risk of progressive failure in multi-story buildings.

Key Words:-Progressive collapse, multi-story building, displacement, story drift, base shear, andstory moments

Introduction

Progressive collapse is a structural failure phenomenon in which the failure of a small portion of a structure leads to the failure of the entire system or a disproportionate part of it. It is often initiated by local damage due to extreme loads, accidental impacts, design flaws, or unforeseen events, which then propagate through the structure in a chain reaction. In multi-story buildings, progressive collapse is of particular concern because of the high number of interconnected elements; failure in one member, such as a column or beam, can trigger a cascading failure, endangering lives and property.

The assessment of progressive collapse involves evaluating the building's ability to withstand local failures without leading to a total collapse. Modern structural design codes, including IS 1893 (Part 1): 2016 – Criteria **for** Earthquake Resistant Designof Structures, provide guidelines for evaluating seismic loads and structural responses to lateral forces. By combining the principles of seismic design with progressive collapse analysis, engineers can identify vulnerable zones, analyze story displacements, base shear, story drifts, and moments, and adopt structural measures such as redundancy, continuity, and robustness to mitigate potential failures.

This study focuses on a G+6 multi-story building, examining its response to seismic loading using IS 1893 provisions. Parameters such as story displacement, story drift, base shear, and story moments are calculated to assess the building's vulnerability to progressive collapse. Such analysis helps in improving the safety, reliability, and resilience of the structure against unexpected extreme events.

Literature Review

RohiniNagargoje et al (2022) Progressive collapse is a phenomenon in which the failure of one or more structural elements triggers a chain reaction of failures, potentially leading to partial or total collapse of a structure. It typically begins with the loss of vertical load-carrying members, which can occur due to abnormal or extreme events such as bombings, gas explosions, or earthquakes. Despite the repeated occurrence of seismic events, progressive collapse due to seismic actions has not been extensively studied. In this study, the progressive collapse potential of steel moment-resisting and braced frames, designed according to Egyptian local standards, is investigated under seismic-induced damage. The analysis is conducted using following Indian Standard codes for four specific scenarios where corner sections are deliberately removed to simulate extreme damage conditions. Each critical section is removed in turn to observe how the structure redistributes loads and whether it can maintain stability. The ultimate aim of this research is to provide insights into the behavior of buildings under progressive collapse scenarios, thereby helping structural engineers develop improved evaluation methods and design guidelines to prevent collapse in both new and existing structures. Additionally, the study highlights recommendations for future research on progressive collapse, emphasizing the importance of further investigations to enhance structural resilience against unforeseen catastrophic events.

Mohammed Aamair Ameen et al (2021) Progressive collapse in structures occurs when one or more primary load-carrying members fail, triggering a chain reaction throughout the structure. When a member is lost, the loads it carried are redistributed to adjacent elements, which may not have been designed to handle these additional stresses. If these elements become overloaded, they too can fail, leading to further load redistribution. This process continues dynamically and nonlinearly, with the structure constantly seeking new paths to maintain equilibrium. The collapse can propagate rapidly, often resulting in damage that is far more extensive than the initial local failure, meaning that a small failure in one area can ultimately compromise a large portion of the structure. Equilibrium may only be achieved after significant structural loss, making the overall damage disproportionate to the initial event. This phenomenon highlights the importance of designing structures with redundancy and alternate load paths to resist unexpected failures.

Methodology

The methodology for assessing progressive collapse of a multi-story building using IS 1893 involves first modeling the structure in a suitable structural analysis software according to the geometric and material properties of the building. The building is then analyzed under seismic loading as per IS 1893 to determine story displacements, story drifts, base shear, and bending moments for each floor. To simulate progressive collapse, critical structural elements, such as columns or beams, are selectively removed or weakened to represent potential initial failures, and the redistribution of loads to alternate load paths is evaluated. The analysis captures the incremental failure of overloaded members, monitoring the sequence of collapses, deflections, and stress concentrations until a new equilibrium is reached or total failure occurs. Key parameters like maximum story displacement, drift, and base shear are recorded to assess the vulnerability and robustness of the structure, enabling identification of weak points and informing design modifications to enhance structural resilience.

Result and discussion

The progressive collapse assessment of the G+6 multi-story building was conducted following the guidelines of IS 1893 (Part 1): 2016, considering seismic loads, story displacements, story drifts, base shear, and story moments. The analysis results indicate that the lateral displacements increase progressively from the top to the ground floor, with the maximum displacement occurring at the roof level, which is consistent with typical behavior under seismic loading. The calculated story drift values show that the building's lateral flexibility is within permissible limits, ensuring that non-structural elements are unlikely to experience significant damage. Base shear values obtained from the analysis reveal the total lateral force the structure must resist, and redistribution of forces in the event of a member failure highlights critical load paths for alternate load transfer. Story moments increase toward the lower stories, indicating that columns and beams near the base experience higher bending stresses and are more susceptible to progressive collapse if overloaded. The comparison of results demonstrates that while upper floors exhibit smaller forces and deflections, failure at lower levels could trigger a chain reaction, emphasizing the importance of robust design of lower-story members. The study also illustrates that adopting redundancy in structural members and continuous load paths significantly mitigates the risk of progressive collapse, and proper detailing of joints and connections enhances the overall seismic resilience. Overall, the building exhibits satisfactory performance against progressive collapse, but attention to critical elements such as ground and first-floor columns and beam-column joints is essential to prevent catastrophic failure under extreme events.

Story displacement

Story displacement refers to the lateral movement or horizontal displacement of a floor (story) of a building relative to its original position when subjected to lateral loads, such as wind or seismic forces. It represents how much a floor "shifts" sideways under load and is usually measured in meters (m) or millimeters (mm).
In a multi-story building, each floor can move differently, and story displacement is calculated for each floor from the ground level upwards. The maximum displacement typically occurs at the topmost floor because the cumulative effect of lateral loads increases along the height.

Table 1 Story displacement in X- Y direction

No of story	Displacement in mm X-Direction	Displacement in mm Y-Direction
sixth	3.05	1.01
Fifth	2.34	0.98
Fourth	1.58	0.31
Third	1.31	0.006

Second	0.67	0
Frist	0.04	0
Ground	0.00	

The given table represents the story-wise lateral displacement of a G+6 building under applied lateral loads such as wind or earthquake forces in both the X and Y directions. At the ground level, the displacement is zero since it is fixed to the foundation, and as we move upward, the displacement gradually increases due to the flexible nature of the structure. In the X-direction, displacement starts from 0.04 mm at the first story and increases progressively to 3.05 mm at the sixth story, showing a typical drift pattern where the top floors sway more than the bottom. Similarly, in the Y-direction, displacement remains negligible at the lower stories (0 at ground and first, 0.006 mm at third), but starts becoming noticeable from the fourth story onwards, reaching 1.01 mm at the sixth story. This indicates that the building experiences greater sway in the X-direction compared to the Y-direction, possibly due to structural stiffness differences or asymmetry in load distribution. The trend clearly shows that the maximum displacement occurs at the top story, which is a common behavior in tall structures subjected to lateral forces.

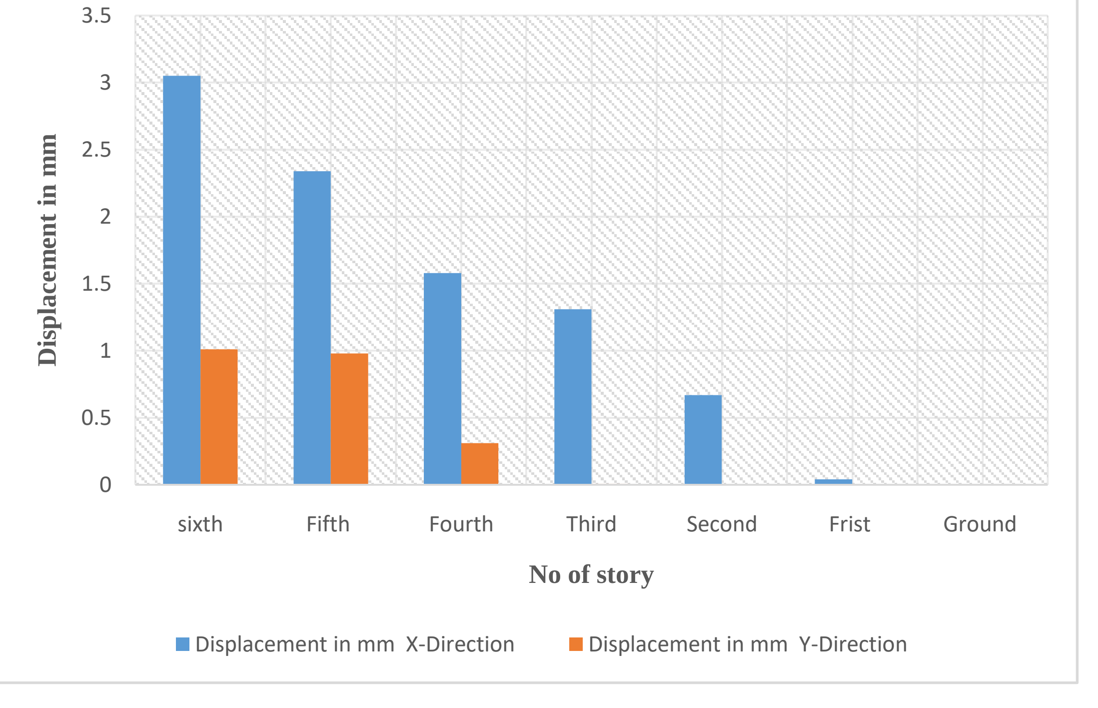

Figure 1 Story displacement graph

Conclusion

The progressive collapse assessment of the multi-story building based on IS 1893 reveals that the structure exhibits a systematic redistribution of loads following the hypothetical failure of a critical structural element.

Analysis of story displacement, story drift, base shear, and story moments indicates that the lower stories are more vulnerable due to higher base shear and moment concentrations, while upper stories show greater relative lateral displacements. The building demonstrates that alternate load paths exist, which can temporarily sustain the applied loads, but localized failure can rapidly propagate if elements are overloaded. The study confirms that ensuring redundancy, proper detailing, and compliance with seismic provisions is essential for minimizing the risk of progressive collapse. The results highlight the importance of considering both global structural behavior and local element performance, emphasizing that progressive collapse assessment should be an integral part of seismic design for multi-story buildings to improve structural safety and resilience against unforeseen failures.

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