STATIC AND DYNAMIC ANALYSIS FOR THE G+14 PROGRESSIVE COLLAPSE RESISTING RCC STRUCTURE

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ABSTRACT

This study focuses on analyzing the progressive collapse of RCC buildings under dynamic loads. Progressive collapse occurs when local failures propagate through a structure, leading to significant breakdowns. The General Services Administration (GSA) has developed standards to address this issue, particularly for Federal buildings. These standards aim to mitigate and evaluate progressive collapse risks. The GSA's Design Criteria for Resistance (DCR) assesses member efficiency relative to overall strength, with values of 2 for unusual buildings and 1.5 for ordinary ones. The dissertation's objective is to analyze the structural response of a 14-story building using a three-dimensional ETABS model after removing a vertical load-bearing member in various scenarios. The analysis employs two methods based on the Alternate Load Path technique recommended by UFC and GSA. This research seeks to enhance understanding of how structures react to member removal and contribute to strategies for mitigating progressive collapse risks.

Keywords: Progressive Collapse, Demand capacity ratio, column removal, seismic loading, ETABS.

1. INTRODUCTION

The gradual collapse of structures can result from changes in loading patterns or boundary conditions, exceeding the capacity of its sections until failure. Modern architectural styles and construction methods permit lighter, optimized designs, reducing overdesign. While it's impractical to fortify buildings against every possible threat, including terrorist attacks, advancements in engineering enhance their resilience to earthquakes and explosions. Although preventing such attacks entirely may not be feasible, mitigating collateral damage, casualties, and public fear remains crucial.

The United States General Services Administration (GSA) provides guidelines detailing steps to withstand gradual collapse. These involve strategically removing vertical structural components like columns or load-bearing walls from the load path, simulating localized damage. Subsequently, engineers analyze the remaining structure for alternative load paths capable of bearing the load. This method allows for the identification of vulnerabilities and the implementation of measures to strengthen the structure against potential failures. Overall, integrating these guidelines into design and maintenance practices enhances structural resilience while addressing safety concerns in the face of evolving threats.

1.1 Definition of progressive collapse

Progressive collapse occurs when the failure of one structural element triggers the collapse of adjacent components, often due to unforeseen events like explosions, vehicle impacts, or human error. This phenomenon, posing a significant risk to safety, is addressed by enhancing structures' continuity, ductility, and redundancy through seismic design standards tailored to specific seismic zones and ductility classes. However, conventional design lacks universal provisions to mitigate progressive collapse, contributing to a global rise in catastrophic incidents.

Recognizing the urgency, governmental bodies like the US Department of Defense (DOD), the General Services Administration (GSA), and Euro codes have issued directives and standards to address this issue. Collaboration between governmental and non-governmental entities has led to the establishment of design standards aimed at preventing progressive collapse.

Guidelines from entities like the United Facilities Criteria (UFC) provide a systematic approach, endorsed by the GSA and DOD, to withstand progressive collapse. This involves simulating localized damage by removing a critical vertical element and analyzing the structure's dynamic response to assess alternative load paths. By monitoring pressure fluctuations over time, the effectiveness of these measures can be evaluated.

2. THEORETICAL CONTENT

In adverse conditions, structural integrity is paramount to prevent catastrophic failure. Shear failure, resulting from the exceeding of shear capacity before flexural capacity, poses a significant risk to structural stability. Thus, under stress, main and secondary structural elements must maintain both strength and ductility to ensure resilience and prevent collapse.

These guidelines are essential for the renovation or construction of any facility overseen by the General Services Administration (GSA). They are mandatory for engineers working within government agencies, as well as for architectural and engineering firms contracted by the GSA. Primarily aimed at structural engineers and architects, the guidelines ensure adherence to standards that prioritize safety and durability.

Furthermore, while these guidelines are obligatory for GSA projects, they are openly available for adoption by both public and private entities. This inclusivity encourages widespread implementation of best practices in structural design and construction, fostering safer built environments beyond government-owned facilities. Hence, establishing criteria for acceptable structural components is foundational to safeguarding infrastructure and mitigating risks of structural failure.

$DCR = Q_{UD}/Q_{CE}$

Where,

QUD = In components or connections, determined forces include moment, axial force, shear, and possible combinations of these acting forces.

QCE = Maximum capacity of a part or joint, unaltered by factors, including moment, axial force, shear, and possible combined forces.

Exceeding specified DCR values for structural elements and connections indicates significant damage or collapse, per linear elastic method criteria.

The allowable DCR values for primary and secondary structural elements are:

- DCR < 2.0 for typical structural configurations (Section 4.1.2.3.1 as per GSA)
- DCR < 1.5 for atypical structural configurations (Section 4.1.2.3.2 as per GSA)

When laying out, it's typical to prioritize the positive aspects over the negative ones due to their greater impact.

3. PROBLEM STATEMENT

Analyzed using ETABS software, a G+14 RC building with 2.9m floor height undergoes Non-Linear Dynamic Analysis for Zone III seismic conditions. Static and dynamic forces are assessed. The project, born from this analysis, will be constructed on soft soil.

Table 1: Model Description

Model 1 (M1)	Before Removal of Column	RC Service Model With Dual System
Model 2 (M2)	After Removal of Column	RC Service Model With Dual System
Model 3 (M3)	Before Removal of Column	RC Service Model With Shear Wall
Model 4 (M4)	After Removal of Column	RC Service Model With Shear Wall

Fig 1 RC Service Model with Dual System

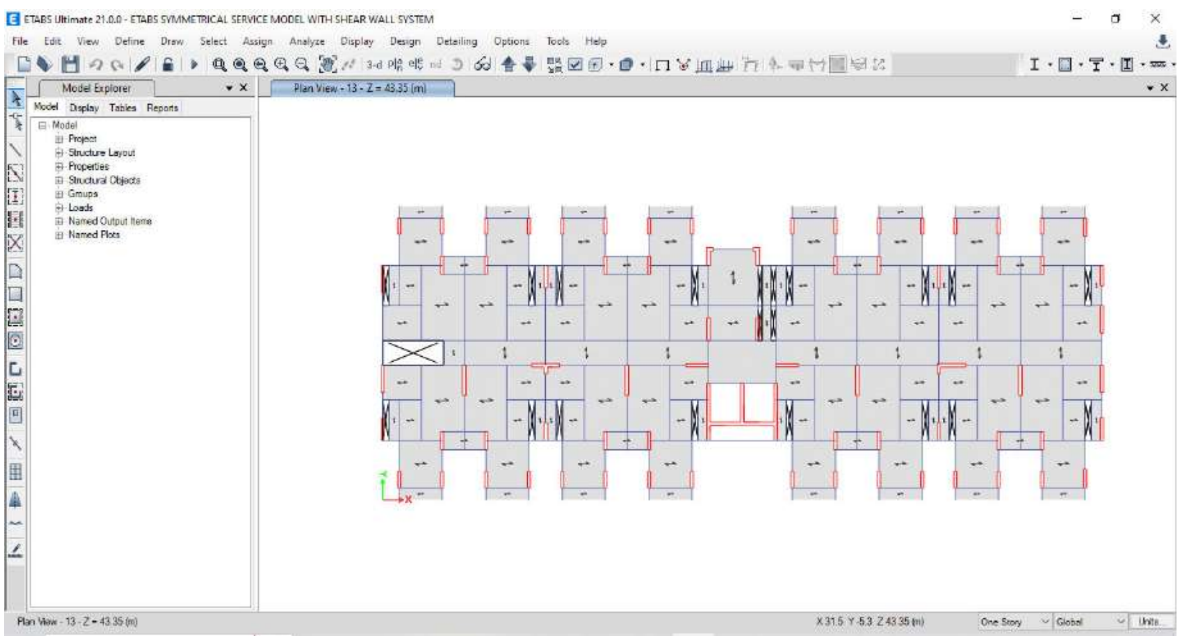


Fig 2 RC Service Model with Shear Wall

An assessment was conducted on the 8th and 7th levels of the structure, focusing on Beams B389 and B391 to analyze their bending moments both pre and post the removal of a column. Columns C104, C106, and C108 underwent scrutiny. In the study of progressive collapse, the targeted removal included Column C106 and SW19.

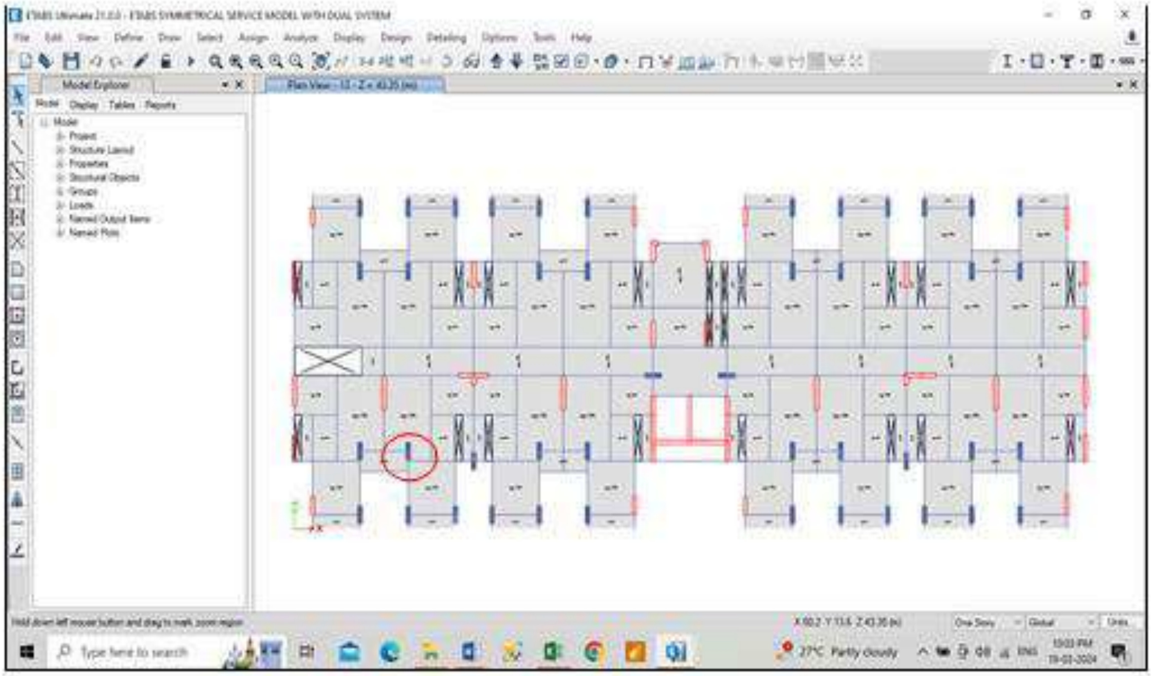


Fig 3: RC Service Model with Dual System Removal of C106

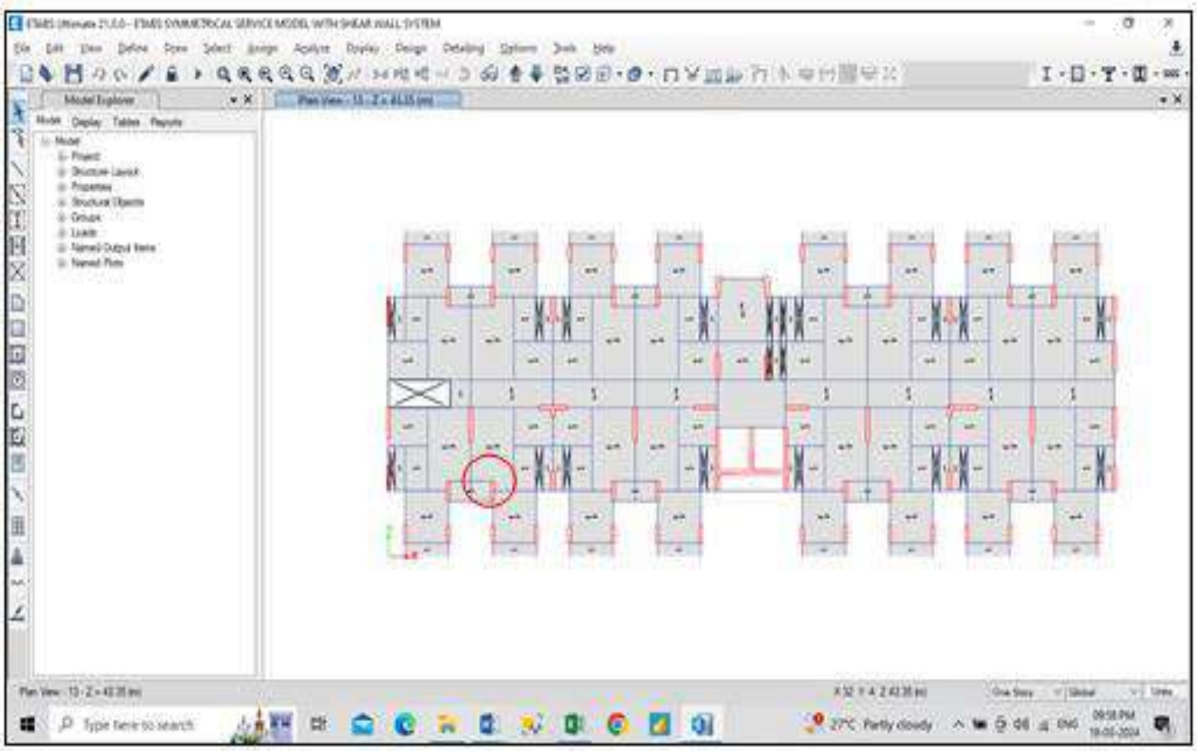


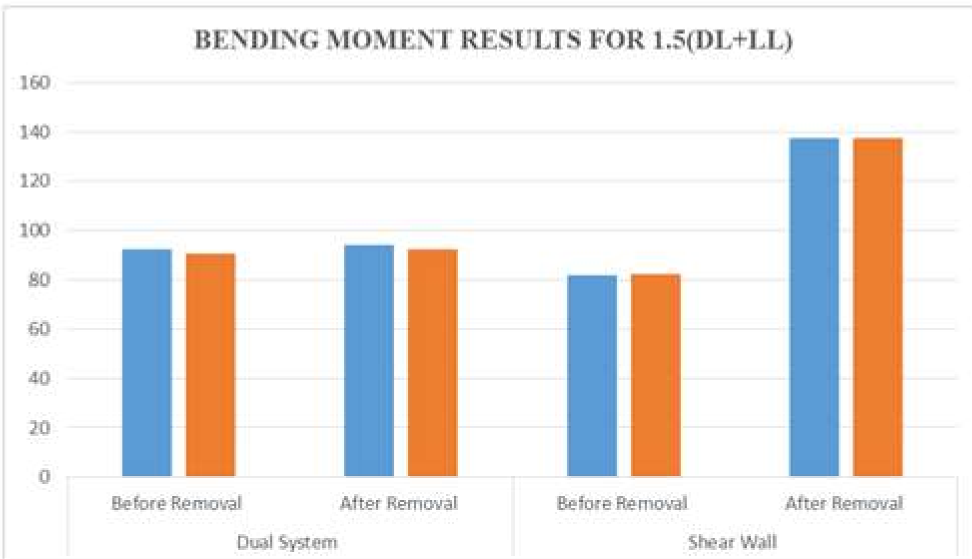
Fig 4: RC Service Model with Shear Wall Removal of SW19

4. RESULTS AND DISCUSSION

4.1 Bending Moment Results For 1.5(DL+LL)

Table 2: Bending Moment Results For 1.5(DL+LL)

	Dual System		Shear Wall	
Model	Before Removal	After Removal	Before Removal	After Removal
BM (B389)	92.17	94.08	81.63	137.37
BM (B391)	90.36	92.32	82.3	137.23



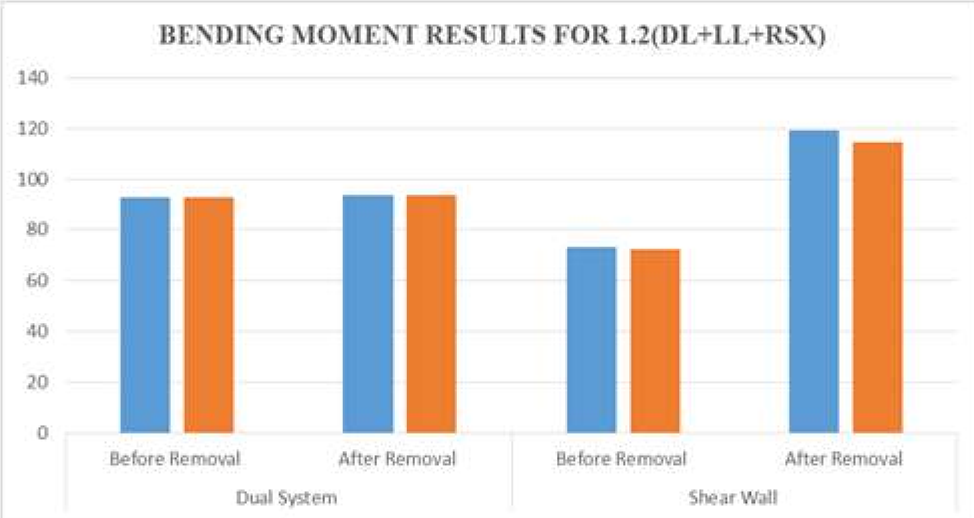
Graph 1: Bending Moment Results For 1.5(DL+LL)

The data presented illustrates findings from static analysis on beam bending moments under a load combination of 1.5 times the sum of Dead Load (DL) and Live Load (LL). Post removal of the column and shear wall (SW), it's evident that the Dual System exhibits superior bending moment performance compared to the Shear Wall solution.

4.2 Bending Moment Results For 1.2(DL+LL+RSX)

Table 3: Bending Moment Results For 1.2(DL+LL+RSX)

	Dual System		Shear Wall	
Model	Before Removal	After Removal	Before Removal	After Removal
BM (B389)	92.58	93.59	73	119.09
BM (B391)	92.81	93.59	72.33	114.42



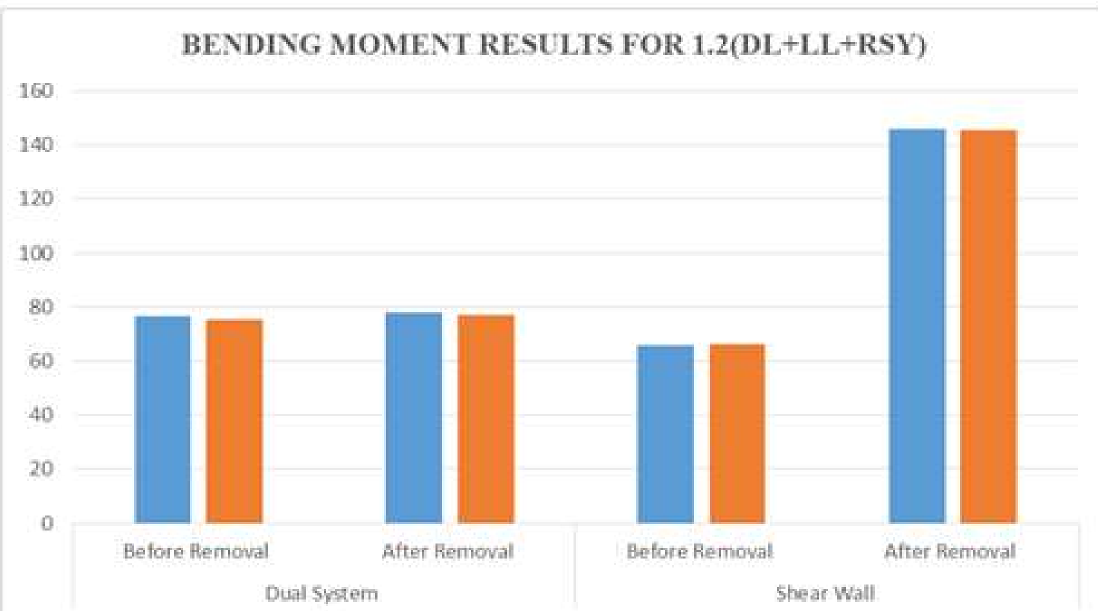
Graph 2: Bending Moment Results For 1.2(DL+LL+RSX)

Upfront Charts Presents the findings of the dynamic analysis for the bending moment of beams subjected to a load combination (1.2(DL+LL+RSX)). The results indicate that, after the removal of the column and SW, the Dual System bending moment outperforms the Shear Wall system.

4.3 Bending Moment Results For 1.2(DL+LL+RSY)

Table 4: Bending Moment Results For 1.2(DL+LL+RSY)

	Dual System		**Shear Wall**	
Model	Before Removal	After Removal	Before Removal	After Removal
BM (B389)	76.49	77.9	65.83	145.69
BM (B391)	75.5	76.89	66.36	145.55



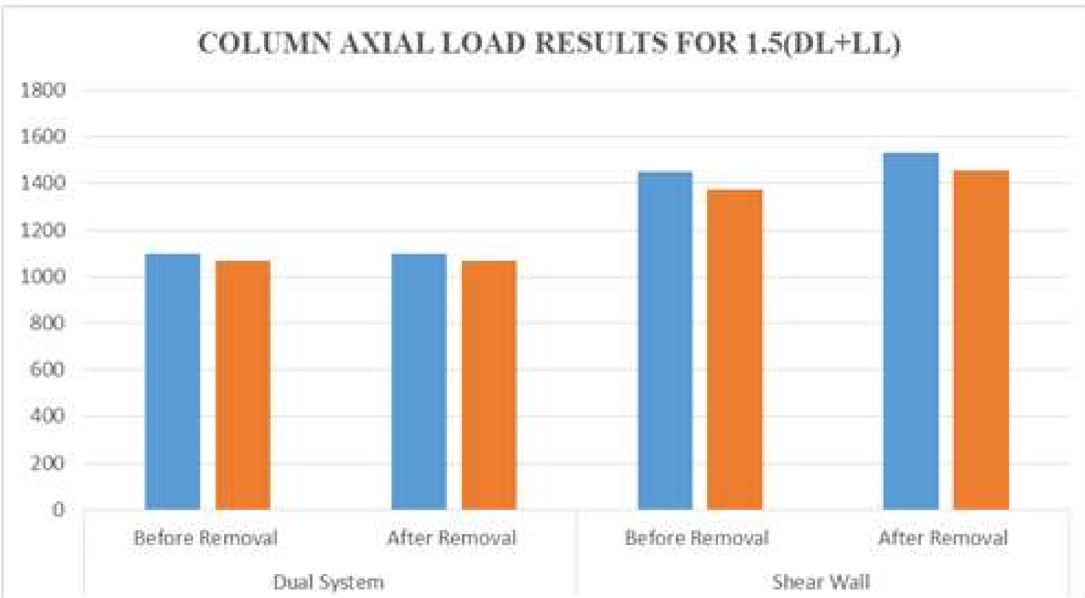
Graph 3: Bending Moment Results For 1.2(DL+LL+RSY)

Data shown in the chart above Displays the findings of the bending moment analysis for beams subjected to a load combination (1.2(DL+LL+RSY)). The results indicate that, after the removal of the column and SW, the Dual System bending moment system outperforms the Shear Wall system.

4.4 Column Axial Load Results For 1.5(DL+LL)

Table 4: Column Axial Load Results For 1.5(DL+LL)

	Dual System		Shear Wall	
Model	Before Removal	After Removal	Before Removal	After Removal
C104 , SW13	1097.96	1100	1448.39	1531.6
C108, SW24	1066.01	1068	1372.55	1456.8



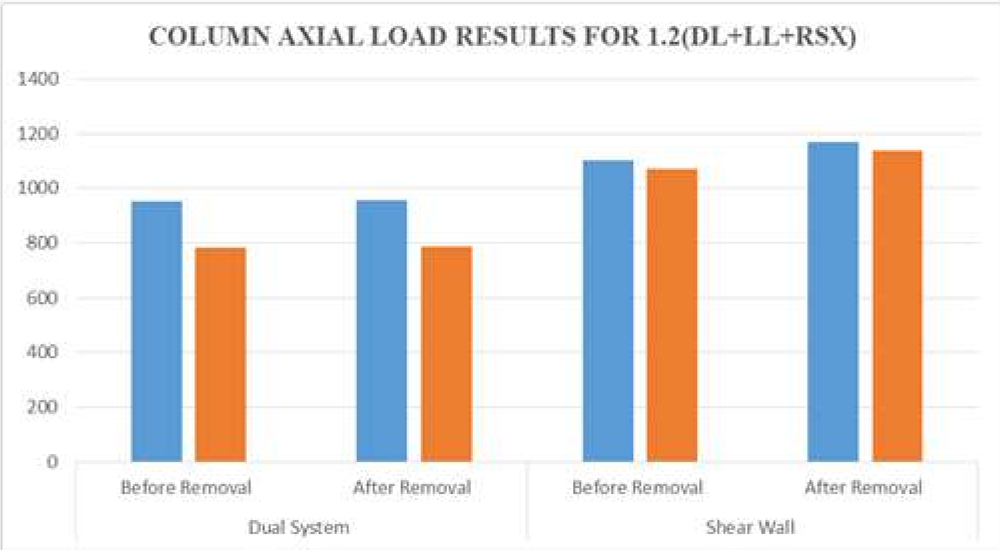
Graph 5.4 Column Axial Load Results For 1.5(DL+LL)

Comparison of column forces pre- and post-removal via static analysis for load combination (1.5(DL+LL)) indicates superior performance of Dual System over Shear Wall systems post-removal.

4.5 Column Axial Load Results For 1.2(DL+LL+RSX)

Table 5: Column Axial Load Results For 1.2(DL+LL+RSX)

	Dual System		Shear Wall	
Model	Before Removal	After Removal	Before Removal	After Removal
C104 , SW13	953.3	956.13	1103.21	1169
C108, SW24	783.99	785.59	1069.19	1135.4



Graph 5: Column Axial Load Results For 1.2(DL+LL+RSX)

The chart illustrates the column forces before and after removal via Dynamic analysis under load combination (1.2(DL+LL+RSX)). Post-column removal, the analysis reveals that Dual System configurations outperform Shear Wall systems.

Table 6: Check for DCR

	Dual System After Removal			**Shear Wall After Removal**		
LOAD	**Demand Force**	**Expected Ultimate**	**DCR**	**Demand Force**	**Expected Ultimate**	**DCR**
C104 , SW13	1100	956.13	1.15	1531.6	1169	1.31
C108, SW24	1068	785.59	1.36	1456.8	1135.4	1.28

The results indicate that the DCR ratio consistently remains below 1.5, obviating the necessity for adjustments to accommodate seismic stress. Notably, the dual system exhibits a superior DCR compared to the SW system, indicating its favorable suitability in model selection.

7. CONCLUSION

- Progressive Collapse has an important characteristic that the final damage is disproportionate to the initial local damage. However, the traditional designs do not take into account the extreme loading conditions that may provoke progressive collapse.The plan selected is Actual Live Project. The structure has been analysed for both static and dynamic forces.
- For The analysis two types of buildings are considered, one are Dual System And another are with Shear Wall. For dual system of the building Column no C104, C106, C108 and beam B389 and B391 are analysed at 7th and 8th floor of the building before and after removal of column C106. Similarly For Shear Wall of the building SW no SW13, SW19, SW24 and beam B389 and B391 are analysed at 7th and 8th floor of the building before and after removal of column SW19.
- The results for the bending moment for beams with static analysis for Load Combination (*1.5(DL+LL)*), (*1.2(DL+LL+RSY)*) and (*1.2(DL+LL+RSY)*). According to the analysis bending moment for Dual System gives a better results than Shear Wall systems after removal of column and SW

- Form the Static and dynamic analysis it is conclude that, for the progressive collapse analysis dual system gives better results in Bending moment and axial forces on the columns. DCR ratio in all cases is less than by 1.5 hence sections need not to be redesigned considering seismic load.
- According to model preference, the Maximum DCR for the dual system is 1.36 and maximum DCR for the shear wall system is 1.31 that means according to DCR dual system gives better results than SW system.

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