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Investigating Progressive Collapse in Multi-Story Structures: Seismic Load Effects and Belt Wall Remediation

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ABSTRACT
Progressive collapse occurs when localized structural damage triggers a domino effect of failures in structural elements, leading to partial or complete building collapse. The initial damage that sets off this chain reaction is termed initiating damage. Typically unfolding in mere seconds, progressive collapse involves the rapid loss of load-bearing capacity in a small part of the building due to a seemingly ordinary load, which then cascades into widespread failures affecting a significant portion of the structure. This event is forceful, involving the intense vibrations of structural components and the generation of powerful internal forces like inertia forces, which the building structure cannot absorb. It is a naturally nonlinear phenomenon where structural elements are pushed beyond their elastic limits, resulting in failure. In this research study prepare G+ 14 structures with 6 different cases in ETABS. In one case consider bare frame with response spectrum analysis. In remaining cases remove columns from different locations. And in last case apply belt wall in model that shows maximum displacement.
Key words: Progressive collapse, Response spectrum, Belt wall, Displacement and Story drift etc.

I. INTRODUCTION
The destruction of specific building components or a whole failure could result from damage to building components brought on by abnormal stresses (explosion, splintering, rapid external impact, etc.). Even though there had been frequent collapses in the past, recent terrorist attacks, like the World Trade Center bombing and the severe destruction they affected to the Sector of Defense, had made buildings more resilient to extreme catastrophes. Progressive collapse is the result of excessive harm to the trigger mechanism. Structures that could withstand progressive collapse were not necessary components of structural engineering designs. However, some laws include specific standards and rules to lower the risk of sluggish falls. Because of the nature of the progressive collapse, it is challenging to forecast how buildings that endure gradual deconstruction would fare. They are not a necessary component of structural engineering designs. However, some laws include specific standards and rules to lower the risk of sluggish falls. Because the nature of the initial load or event and the behavior of organizational components during progressive collapse are not well understood, it was impossible to forecast how progressive collapse would proceed.

Figure 1 Collapse of Buildings in past decades

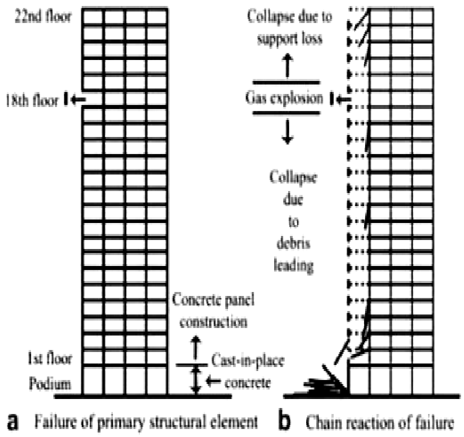


Figure 2Process of Progressive Collapse

High Rise Building
The nation's financial stability and distinctive qualities are both reflected in the investment projects (tower development) for skyscrapers. By promoting the creation of thorough plans to construct high-rise investment projects, several nations are enhancing their prestige and economic power. The financing of these initiatives is crucial to their success in nations like Malaysia, Hong

Kong, the United States, the United Kingdom, and Japan. Many significant investments are undertaken to guarantee that the projects yield targeted profits for investors both domestically and internationally after carefully compiling feasibility assessments. A detailed study of the building, design, marketing, and financial challenges was done for this project. Urban planning and economic growth have contributed to the advancement of the nation. The use of contemporary methods and materials should be encouraged to promote technical advancement for this reason above all others.

Figure 3High-rise buildings worldwide

Progressive collapse

A gradual drop only recently was the concept of "gradual decline" introduced. When the Ronan Point mansion was dismantled in 1968, engineers made their initial discovery of this occurrence. The load-bearing walls are made of precast concrete and have a height of 22 stories. In the example (which I will explain in detail) discussed elsewhere in this part, a gas blast happened on the corner of the eighteenth floor, abolishing the exterior walls and causing cracks in the corners of the structure that extended to the rooftop structure and floor. As a result, this incident sparked additional investigations into collapses of a similar nature that happened in Europe, the US, and Russia. Since then, the phrase "progressive collapse" has been used to indicate how a local calamity spreads, setting off a series of events that eventually cause a structure to completely or partially collapse. The end-collapse condition of a progressive collapse is typically far worse than the initial collapse, which is its defining feature. The following are examples of abnormal stresses that may result in progressive falls:

1. Pressure Loads
2. Impact Loads

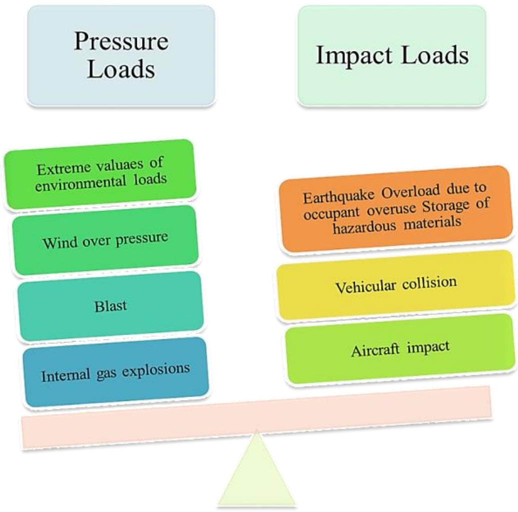


Figure 4 Pressure load v/s Impact load

Response Spectrum Analysis

In 1932, Maurice Anthony Biot's PhD research at the California Institute of Technology defined the response spectrum method (RSM). This approach evaluates the response of a structure to an earthquake using waveforms and vibration patterns. In the middle of the 20th century, the reaction spectrum idea was used to apply design criteria to national building codes. The capacity to forecast the displacements and forces of elements in a structural system is the response spectrum method's computational advantage for seismic analysis. The maximum element displacements and forces for each mode are determined using this method, which makes use of a smooth design spectrum (an average of several base vibrations).

Belt wall

Belt walls remove many of the challenges that come up when using the outriggers approach. Their function is to enhance the columns' torsional and axial rigidity. Belt walls are very helpful in preventing column settling as well as differential elongation and shortening. Further outer columns are built to provide stability and prevent the outriggers from toppling over. In order to achieve this effect, the outside columns are secured to a wall that surrounds the building like a belt—thus being known as a "belt wall." Although quite stiff in their own plane, the floor diaphragm is flexible in the out-of-plane vertical axis and is therefore unaffected by the different settlement of columns.

II. OBJECTIVES

- To assess for progressive collapse in a G+14 RCC building using linear static analysis
- To identify which columns are required for a multi-story building's progressive collapse analysis.
- To reduce the building's collapse in the model that has a belt wall.

- To establish a structure's moment and drift ratios following the removal of a column at crucial locations.
- To study the effect of belt wall used in bare frame with maximum generated failure column case.

III. METHODOLOGY

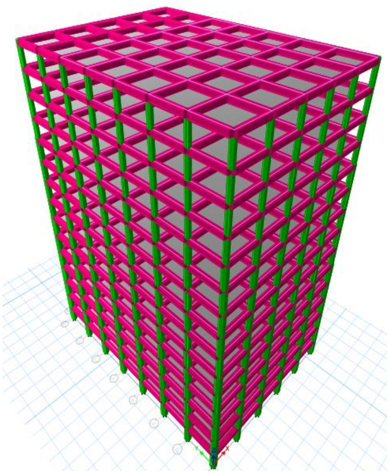
In this section of study decide title of work and prepare methodology of research. To complete the modeling work use ETABS with response spectrum method of analysis. This chapter embodies the main work done in the project including the procedures involved, plan and the section of the building investigated and the major data obtained from the analysis.

Cases

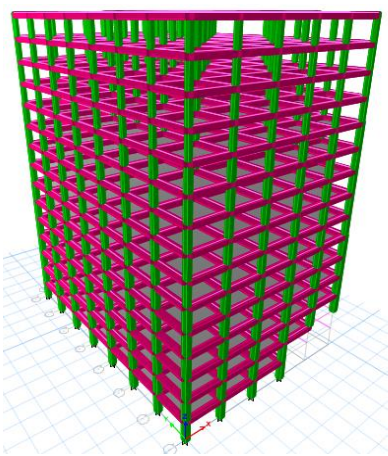
- Bare frame
- Bare frame with corner column removed from one side
- Bare frame with column removed from long side edge
- Bare frame with column removed from short side edge
- Bare frame consider belt wall along with critical case of removed column
- Bare frame consider belt wall connected along with center in critical case

Table 1 Basic Specification of Model

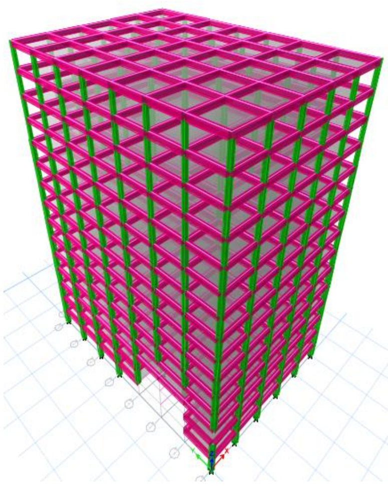
Data	Value
Grade of steel	Fe375
Grade of concrete	M35
Belt Wall	200mm
No. of stories	G+14
No. of bay along X-direction	5
No. of bay along Y-direction	7
Span along X-direction	5m
Span along Y-direction	5m
Floor height	3m
Column size	500X500,600X600, 400X400mm
Beam size	600X500, 600X400mm
Depth of Slab	150mm
Dead load	---------------
Live load	2.5kN/m^2
Software	CSI ETABS with Response Spectrum



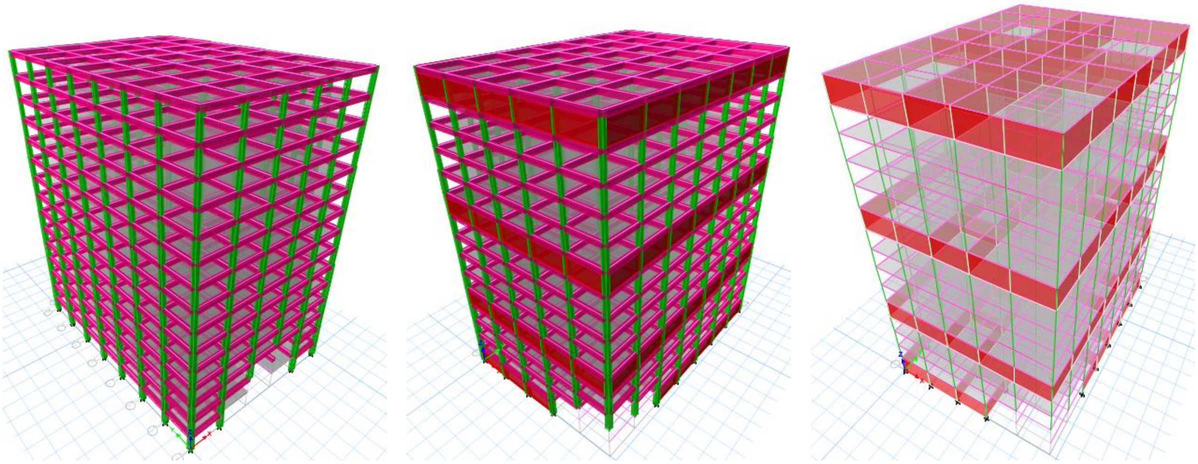
a) Model with bare frame



b) Bare frame with corner column removed from one side



c) Bare frame with column removed from long side edge



d) Bare frame with column removed from short side edge | **e) belt wall with critical case of removed column** | **f) belt wall connected with center in critical case**

Figure 5 G+14 floor model in different cases

IV. RESULT AND DISCUSSION

This section focuses on specific parameters such as storey displacement, base reaction, bending moment, shear force, and demand capacity ratio. To conduct a detailed analysis, gather data from the analysis conducted using ETABS 2016 and create graphs. Then, compare the results and draw conclusions based on the comparison.

Storey Displacement

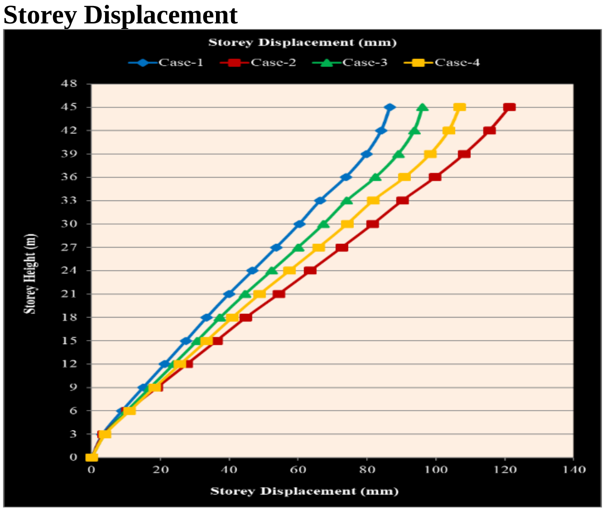


Figure 6Storey Displacement Comparisons between Bare Frame and Scenarios with Column Removal at Various Locations

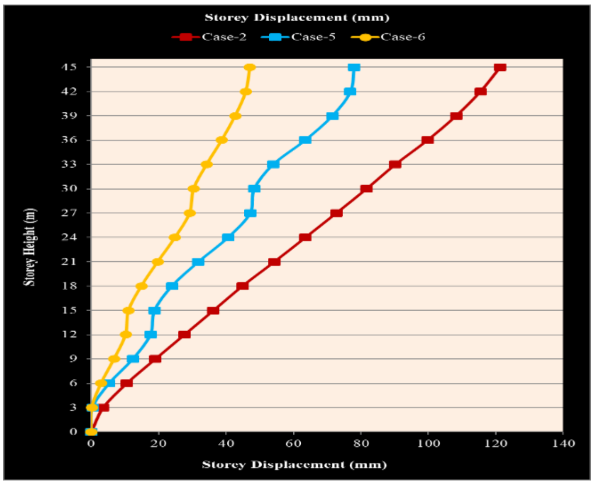


Figure 7 Comparative Analysis of Storey Displacement Controlled by Belt Walls at Various Locations

Storey Drift

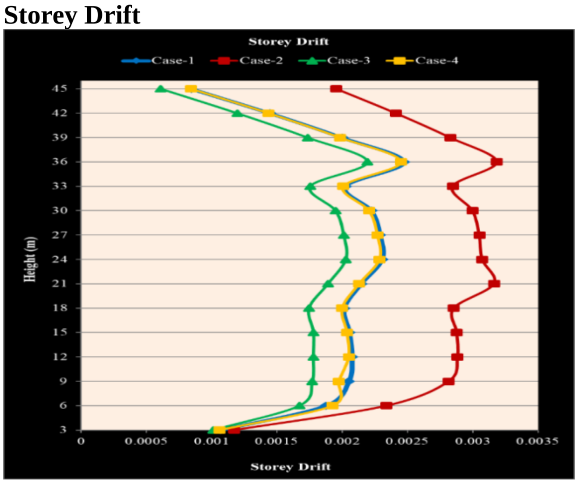


Figure 8Comparison of Storey Drift between Bare Frame and Scenarios with Column Removal at Various Locations

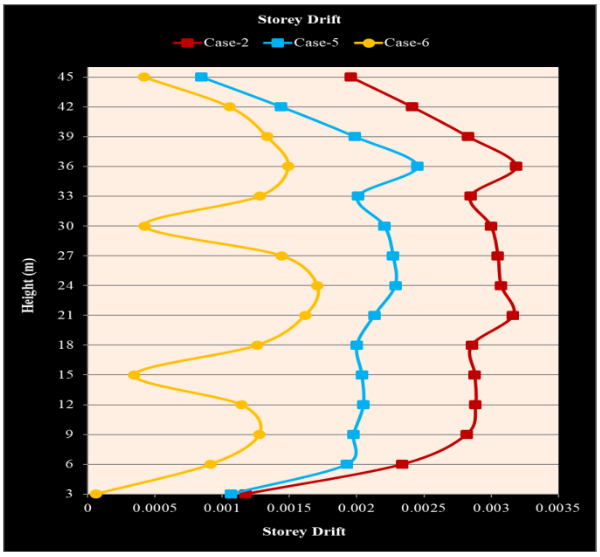


Figure 9Comparison of Storey Drift Controlled by Belt Walls at Various Locations

Storey Stiffness

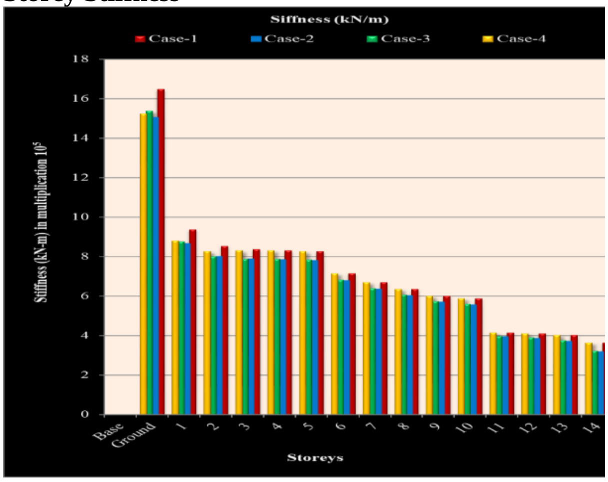


Figure 10 Storey Stiffness Analysis: Bare Frame and Cases of Column Removal at Various Locations

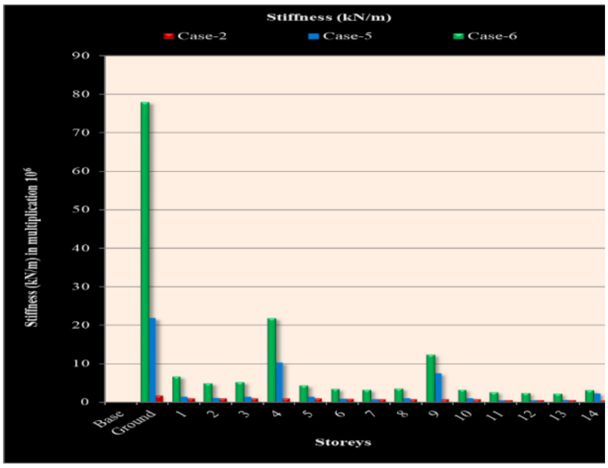


Figure 11 Comparative Analysis of Storey Stiffness Controlled by Belt Walls at Various Positions

Bending Moment

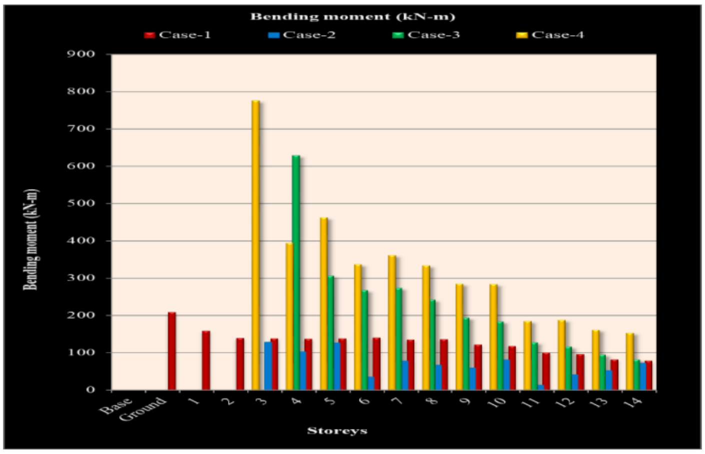


Figure 12 Bending Moment Comparison between Bare Frame and Various Scenarios of Column Removal at Different Locations

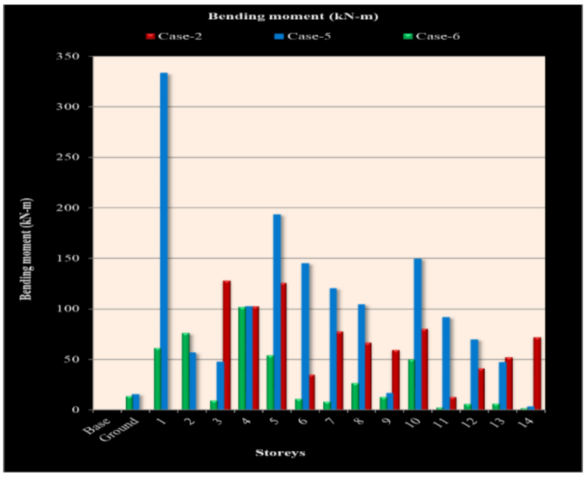


Figure 13 Comparative Bending Moment Control by Belt Wall at Various Locations

Shear Force

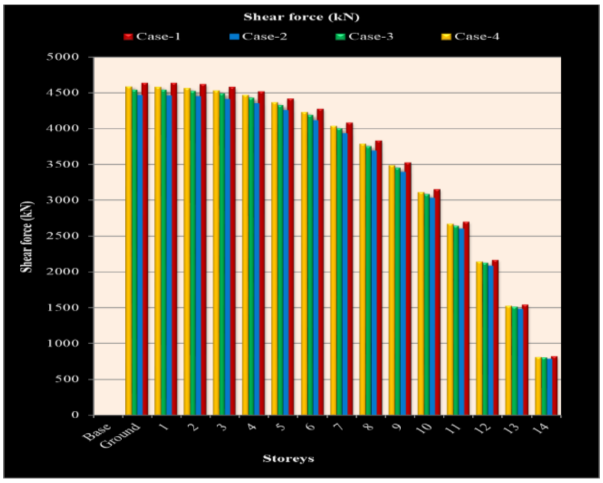


Figure 14 Variation in Shear Force: Bare Frame vs. Column Removal Scenarios at Various Locations

Figure 15 Comparative Shear Force Controlled by Belt Wall at Various Positions

V. CONCLUSION

- Storey Displacement occurred is 86.668mm in case-1 but this storey displacement were increased 40.04% when removal of column from corner of building consider.
- Model with column removed from long side storey displacement as compared to storey displacement of bare frame were increased 10.86%.
- Model with column removed from short side storey displacement as compared to storey displacement of bare frame were increased 23.37%.
- After compare all 4 cases choose case-2 as critical cases this case have maximum increment of storey displacement. To control this displacement use belt wall at outer periphery in case-5 and in case-6 belt wall connected with core of building for critical case.
- It is noticeable that 35.79% displacement reduced in case-5 and 61.22% displacement reduced in case-6.
- Storey Drift occurred is 0.00247 in case-1 but this storey drift were increased 28.84% when removal of column from corner of building consider.
- Model with column removed from long side storey drift as compared to storey drift of bare frame were decreased 11.25%.
- Model with column removed from short side storey drift as compared to storey drift of bare frame were decreased 0.81%.
- After compare all 4 cases choose case-2 as critical cases this case have maximum decrement of storey drift. To control this storey drift use belt wall at outer periphery in case-5 and in case-6 belt wall connected with core of building for critical case.
- It is noticeable that 23.01% drift reduced in case-5 and 46.37% drift reduced in case-6.
- Stiffness occurred is 1643232.8kN/m in case-1 but this stiffness were decreased 8.53% when removal of column from corner of building consider.
- Model with column removed from long side stiffness as compared to stiffness of bare frame were decreased 6.67%.
- Model with column removed from short side stiffness as compared to stiffness of bare frame were decreased 7.55%.
- After compare all 4 cases choose case-2 as critical cases this case have maximum decrement of stiffness. To control this stiffness use belt wall at outer periphery in case-5 and in case-6 belt wall connected with core of building for critical case.
- It is noticeable that 13.437 times stiffness reduced in case-5 and 50.805 stiffness reduced in case-6.
- Bending moment occurred is 206.98kN-m in case-1 but this bending moment were decreased 38.29% when removal of column from corner of building consider.
- Model with column removed from long side stiffness as compared to bending moment of bare frame were increased 2.031 times.
- Model with column removed from short side stiffness as compared to bending moment of bare frame were increased 2.739 times.
- After compare all 4 cases choose case-2 as critical cases this case have maximum decrement of bending moment. To control this bending moment use belt wall at outer periphery in case-5 and in case-6 belt wall connected with core of building for critical case.
- It is noticeable that 1.6086 times bending moment increased in case-5 and 0.2059 bending moment reduced in case-6.
- Shear force occurred is 4630.30 kN in case-1 but this shear force were decreased 3.71% when removal of column from corner of building consider.
- Model with column removed from long side shear force as compared to shear force of bare frame were decreased 2.06%.
- Model with column removed from short side shear force as compared to shear force of bare frame were decreased 1.16%.
- After compare all 4 cases choose case-2 as critical cases this case have maximum decrement of shear force. To control this b shear force ending moment use belt wall at outer periphery in case-5 and in case-6

belt wall connected with core of building for critical case.

- It is noticeable that 0.327 times shear force increased in case-5 and 1.875 times shear force reduced in case-6.

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