Performance Based Evaluation of Existing RC Building in Chiplun, Maharashtra.

Mr. Sujit Joshi[1] and Dr. Chetan S. Patil[2]

[1]PG Student, Department of Civil Engineering, Sanjay Ghodawat Group of Institutions, Kolhapur, Maharashtra, India.
[2]Assistant Professor, Department of Civil Engineering, Sanjay Ghodawat Group of Institutions, Kolhapur, Maharashtra, India.

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Abstract - *Civil engineers deal with earthquakes in seismically active areas. Earthquakes cause building collapses and deaths in cities. Older buildings designed with outdated laws and architectural norms may not meet seismic design standards. Outdated rules and codes. This study analysed an older structure's seismic load to evaluate retrofitting needs. The building met Eurocode 8's seismic norms after retrofitting. 1970 concrete structure in Chiplun, Maharashtra, India. India's Maharashtra. ETAB software evaluates seismicity. Building seismic reactivity is determined by two analyses. Before and after retrofitting, modal analysis is undertaken. This analysis measures torsional strength. Pushover analysis compares construction deformation to target displacement. The building's target displacement. This displacement must not be exceeded for structural integrity. If the projected displacement is greater, the structure's weaknesses must be recognised and retrofitted. If goal displacement is lower, the comparison is useless. Analyzing pushover before and after retrofitting.*

Eigenvalue and pushover analyses indicated the building's torsional sensitivity and shear failures. Both were found after inspection. The structure is weak. The desired displacement did not exceed the structure's displacement when the building's initial member reached a limit condition. True. The building didn't collapse. Many beams sheared when X-shaped steel bracing were installed. This increased stiffness and torsional resistance. Some steel-braced columns collapsed. Wrapping the structure's problematic members in fiber-reinforced plastic prevented shear and compression failures. Possible shear failures. Reduced seismic risk. After retrofitting, the building met India's current seismic design regulations. This project thesis could lead to greater earthquake damage prevention and seismic retrofitting research.

Key Words: Pushover analyses, Retrofitting, Torsional strength, Structural integrity, Stiffness etc.

1. INTRODUCTION

Earthquakes are the most destructive natural hazard. Instead than trying to prevent damage and minimise economic losses, seismic design should emphasise life protection. Because reducing damage could threaten a building's structural stability. In contrast to force-based techniques, displacement-based seismic design gives a logical procedure for estimating a building's earthquake resistance. Nonlinear static approaches are popular. Based on the design response spectrum, these methods provide direct information on the size and distribution of plastic strains in a structure. This is done without the challenges of non-linear time-history analysis and the need to identify appropriate ground motion time histories. Static pushover study reveals the structure's strength, ductility, and progressive manner of collapse. Therefore, the strategy emphasises performance over strength.

Already-built structures are compared to newly-built structures' performance requirements. This part establishes the minimum evaluation criteria for expected life-safety performance of existing buildings with necessary adjustments to IS: 1893seismic force, which applies to the seismic design of new buildings. Existing buildings must meet these seismic standards. Because this code has a significant association with IS:1893's design standards for new buildings, it must always be referred to. All existent structural elements must be able to carry full non-seismic loads under current loading and material strength regulations.

"Nonlinear Static Analysis to Assess Seismic Performance of Code-Conforming RC Buildings" (2012). This study analyses 4- and 6-story RC constructions in India. IS: 456-2000 and IS: 1893-2002 are applicable standards. Designing ordinary and outstanding moment-resisting frames (SMRF). Pushover study captures immediate yielding, steady progressive plastic behaviour, and total building reaction to seismic excitations. Pushover analysis simulates a plastic hinge by deforming structural parts. Analytical methods analyse beams' yield, plastic, and final rotation capabilities and plastic hinge lengths. This study model's user-defined plastic hinge properties of beams and columns utilising Eurocode 8 analytical expressions and SAP2000 pushover analysis. These idioms reference Eurocode 8. Basic load patterns are analysed nonlinearly. Based on member materials and dimensions, the analysis evaluates the structural system's seismic capacity.

Pavan Kumar et al. (2012) studied seismic retrofitting in zone v. They found materials and processes.

They summarised using SAP 2000. According to study, five-story buildings could expect increased seismic damage. A building's seismic resistance determines whether to strengthen it. A building's earthquake resistance determines whether to fortify it. Buildings lack sufficient seismic design and details, thus retrofitting options are examined. India's seismic zones need upgrading. This study offers many retrofitting methods, such as plate binding and steel jacketing, and building element materials, such as ferrocement, glass fibre, HPFRCC, FRP strips.

In Rama Raju et al. (2012), a typical reinforced concrete (RC) structure frame is designed for four design cases according to three modifications of IS: 1893 and IS: 456, and user-defined nonlinear hinge characteristics or default-hinge (DF) properties are analysed in SAP 2000 based on FEMA-356 and ATC-40 requirements. IS-1893 and IS-456 were revised three times. 6-story concrete frame. Inelastic hinge effect for columns as P-M-M curves and beams as M3 curves. Analytical approach for analysing RC construction yield, plastic, and rotation capacity. A three-parameter model is employed for RC elements beyond the post-yield area of restricted concrete. Nonlinear static analysis evaluates building component performance. The effect of default and user-defined nonlinear component properties on pushover analysis results is studied.

Poluraju and Nageswara presented pushover analysis using SAP 2000. (2012). Non-linear static pushover analysis was used to assess framed buildings' seismic resilience. G+3 was inspected for this.

Kadid and Bourmrkik studied concrete frame pushover (2008). The seismic resistance of framed buildings was evaluated using nonlinear static pushover. This aim required 5-, 8-, and 12-story framed buildings. Older concrete structures need seismic restoration in earthquake-prone areas. Identifying vulnerable infrastructure and defining safety is crucial. Recent performance-based guidelines for designing or modifying structures in earthquake-prone areas show that "pushover analysis" can predict a building's damage risk. Performance-based codes show this. These construction codes are utilised for earthquake-prone buildings.

Kumbhar researched earthquake-proofing techniques (2007). G+3 employs SAP 2000 for seismic evaluation. Alternative load combinations are evaluated using three-dimensional models and linear static analysis. Existing buildings in earthquake-prone zones undergo screening (Tier 1), evaluation (Tier 2), and detailed evaluation (Tier 3). (Tier 3). This study uses a four-story hospital to demonstrate and explain seismic evaluation.

Durgesh (2005) offers a method for assessing a building's life safety. This strengthens a building. Unfavorable architectural elements that could ruin a component or the whole structure are identified.

According to Sucuoglu et al., recent earthquakes in Turkey damaged 130 reinforced concrete buildings (2004). Shear walls were created to restore these buildings to their previous glory. In the study, multiple seismic performance evaluation approaches are used to forecast damaged structures' performances. Then, renovation performance is analysed. Nonlinear static and dynamic techniques are equally accurate at predicting building performance. Nonlinear member performance ratios indicate linear spectral demand-to-capacity ratios.

Wenjun Guo et al. (2003) discovered structures fall slowly. We provide a simple design criterion for structural members. To show progressive collapse analysis, we create a single-degree-of-freedom model. Existing buildings are analysed nonlinearly. This approach compares a 6-story concrete structure to a nonlinear dynamic computation. The authors illustrate progressive collapse using a nonlinear spring and a concentrated mass. Section I explains. Second portion offers existing building nonlinear static analysis. Based on energy balancing, the structure must be able to absorb the potential energy produced by eliminating one column.

2. ANALYSIS OF EXITING STRUCTURE

This project involved studying and retrofitting an old building in Chiplun. The corporation chose this 1970 Indian-Regulation building for its operations. Given these factors, the structure is vulnerable to seismic events and must be retrofitted to be safe and conform with the Indian Code. 24 metres long, 18 metres wide. The building's tallest point is 16 m. It has four 6-m bays on the long side and three on the short side. Each store is 3.2 m tall. Not counting ground level. The building's floor plan and elevation are rectangular. The construction has a central elevator shaft.

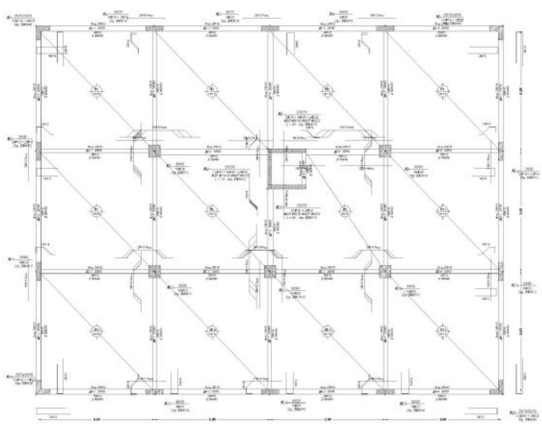

Figure 1. The drawing in the plan of the building.

Figure 2 shows the ETAB software's final 3D model. The long side has four bays with a 6.0 m spread along the X axis (shown in red), and the short side has three bays with a 6.0 m span along the Y axis. Red represents both sides (shown with green color). Long side is 24.0 m, short side is 18.0 m. The diagram shows that the building has four 3.2-m-high stories (this height does not include the ground level). The walls' weight is regarded a homogenous load on the beams, although they are not depicted. Model uses fixed supports. This is an assumption made to determine how the ground-floor columns are connected. Any fixed support is 0.00 m below ground.

Figure 3 shows a concrete building section. The elevator shaft is nearly equidistant from the building's ends. The elevator shaft walls are columns because three beams are linked to them. Using software constraints, the link was made. Tables 1 & 2 describe the beams and columns, including their size and steel reinforcing.

Table 1. Information's of the columns

Name	**Dimensions (mm)**	**Longitudinal reinf.**	**Transverse Reinf.**
C1, C2, C3, C4	3000 x 675	12#16 + 2#20	8mm # @ 300 mm C/C.
C5, C6, C7, C8, C9, C10, C11, C14, C15	450 x 900	8#20 + 2#16	8mm # @ 150 mm C/C.
C12, C13	375 x 900	8#20 + 2#16	8mm # @ 120 mm C/C.
C16, C17, C18, C19, C20	600 x 600	12#20	8mm # @ 110 mm C/C.

Table 2. Information's of the beams

Name	**Dimensions (mm)**	**Longitudinal Reinf.**	**Transverse Reinf.**
B1, B2, B3, 4, B5, B7, B8, B9, B10, B11, B12, B13, B14, B23, B24, B25	250 x 450	Top: 2#10, Bottom: 5#12	#8mm @ 300 mm C/C.
B15, B16, B17, B18, B19, B20, B21, B22	250 x 600	Top: 2#10, Bottom: 4#16	#8mm @ 225 mm C/C.
B26, B27, B28, B29, B30, B31	300 x 600	Top: 2#10, Bottom: 5#16	#8mm @175 mm C/C.

The computation of the building's dead loads considers the components' individual weights as well as the building itself. It has been taken into consideration that the self-weight of the walls will place an additional pressure on the beams. The additional permanent load of 8.0 kN/m that is imposed by the structure's outside walls, which are positioned along the perimeter of the structure, must be handled by the perimeter beams of the structure. Beams are capable of carrying an additional permanent load of 4.50 kN/m that is applied to the internal walls. The slabs have live loads of 2.00 kN/m^2.

3. ANALYSIS OF THE EXISTING BUILDING

3.1 Modal Analysis

The non-retrofitted building underwent a modal study. This section analyses torsional sensitivity by estimating the effective modal mass percentages. When the first two modes have almost 85% effective modal mass and are translational along the X and Y axes. The highest effective modal mass percentage for each mode is evaluated. The results show the actual modal mass percentages. The first mode is rotating along the Z axis and has 73.45% effective modal mass (the highest percentage for the first mode). Second and third modes are translational in the Y and X axes, and their effective modal mass percentages are 67.30% and 61.80%. The first mode spins along the Z axis and has a modal mass percentage of 73.45%. Due to its design and stiffness distribution, the pre-retrofitted building's effective modal mass percentages couldn't be higher. Due to the small gap between the results and allowable percentages, it was not possible to say with certainty that torsional sensitivity had been eradicated. The building's torsion behaviour had been considerably decreased, thus it was unlikely to cause difficulties.

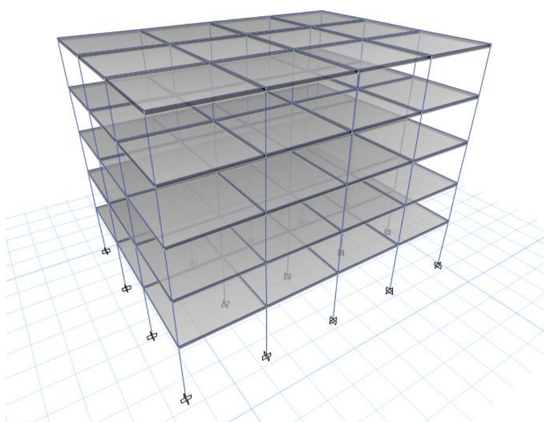

Figure 2. The three-dimensional model of the existing building.

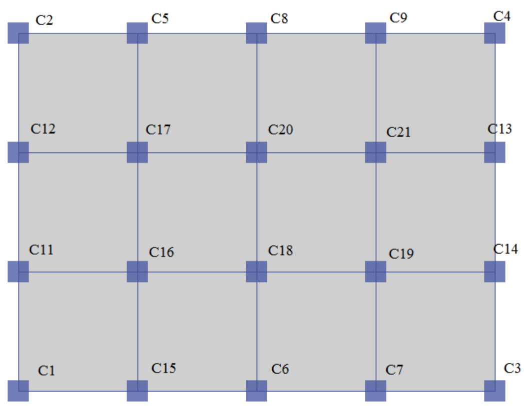

Figure 3. The plan of the existing building with the named column members.

3.2 Nonlinear Static Pushover Analysis

None of the building's members exceeded the limit states, ensuring even load distribution. Several members bent at larger displacements than expected (target displacements). No bending failures occur. Maximum base shear force along X and Y axes is 3850 kN for applied loads. First members exceeded shear capacity for X-axis stress uniformity. The building moved 0.006 m and sheared 570.00 kN. When the load was distributed equally along the Y axis, the first structure members exceeded their shear capacity at 0.003 m displacement and 285.00 kN base shear. Beams failed in shear for X and Y loadings. The building needed modifications before it could be judged safe. Figures 5 and 6 show the capacity curves for X and Y loadings. These graphics show the intended displacements and the displacements when the first member reached each limit state along the capacity curves.

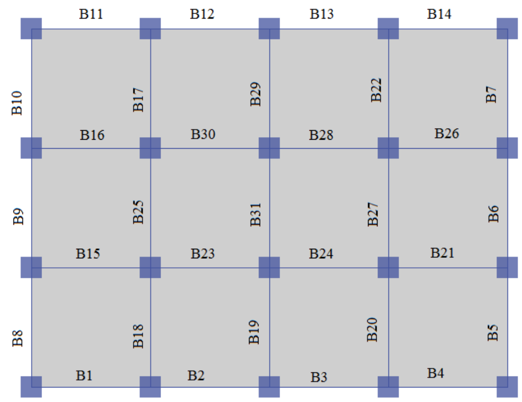

Figure 4. The plan of the existing building with the named beam members.

Table 3. Displacement along the 'X' axis when the initial member of an existing structure reached each limit state.

Limit state	Target Displacement (m)	Displacement First member reached the limit state (m)	Status
Life Safety (LS)	0.034	0.071	Accepted
Immediate Occupancy (IO)	0.044	0.108	Accepted
Collapse Prevention (CP)	0.077	0.142	Accepted

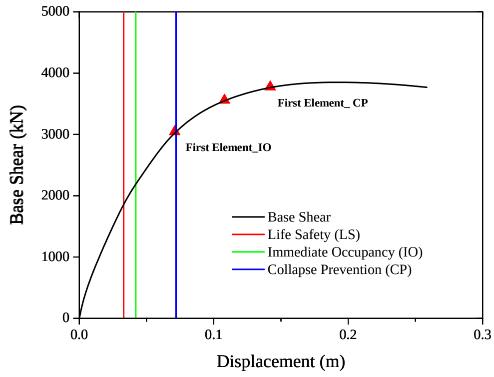

Figure 5. Capacity curve with target displacements along the 'X' 'axis for Exiting Structure.

Table 4. Displacement along the 'Y' axis when the initial member of an existing structure reached each limit state.

Limit state	Target Displacement (m)	Displacement First member reached the limit state (m)	Status
Life Safety (LS)	0.041	0.062	Accepted
Immediate Occupancy (IO)	0.053	0.121	Accepted
Collapse Prevention (CP)	0.084	0.163	Accepted

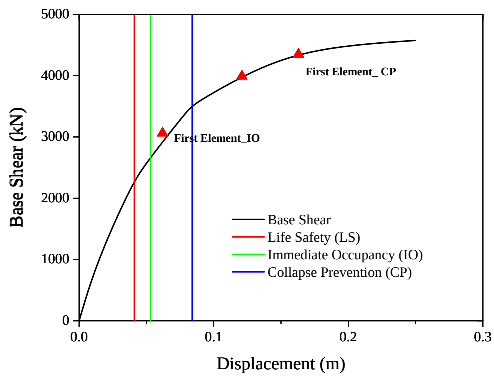

Figure 6. Capacity curve with target displacements along the 'Y' 'axis for Exiting Structure.

4. RETROFITTED BUILDING WITH STEEL BRACES

Global retrofitting is chosen to improve the existing building. Due to the original building's poor earthquake response, concentric X-shaped steel supports were added. Steel bracing provide additional structural rigidity and transfer seismic lateral loads to the ground. Steel bracing is used to support excess weight caused by earthquakes and relieve pressure on older areas of the structure. Steel braces are overwhelmed by the modified frame's ability to absorb seismic energy. This deserves discussion. The members fail when the concrete's compressive capacity is exceeded. Steel bracing also changes how the building transfers its loads to the ground. Due to the newly produced load "paths," certain previously invulnerable members may now fail. Then, a fresh seismic evaluation and retrofitting should be done.

Steel bracing can offer a building greater rigidity. Global retrofitting reduces or eliminates the structure's torsional sensitivity. In this study, steel bracing are constructed around the building's perimeter to evenly distribute the structure's stiffness along the X and Y axes. This maintains structural symmetry. Figure 7 shows the steel braces on red frames. IS2062 grade WFB sections are used for this construction's steel components. Table 5 lists floor cross-sections. As floor levels rise, greater steel member cross sections are no longer needed. Figure 8 illustrates the braced structure in 3D.

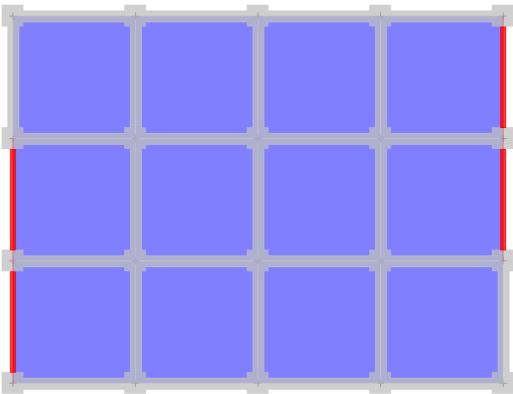

Figure 7. The position of the installed steel braces (with red color).

Table 5. The steel braces on each level floor.

Floor level	Steel brace cross section	Steel class
Ground-floor	WB450	IS2062
1st floor	WB400	IS2062
2nd floor	WB350	IS2062
3rd floor	WB350	IS2062
4rth floor	WB300	IS2062

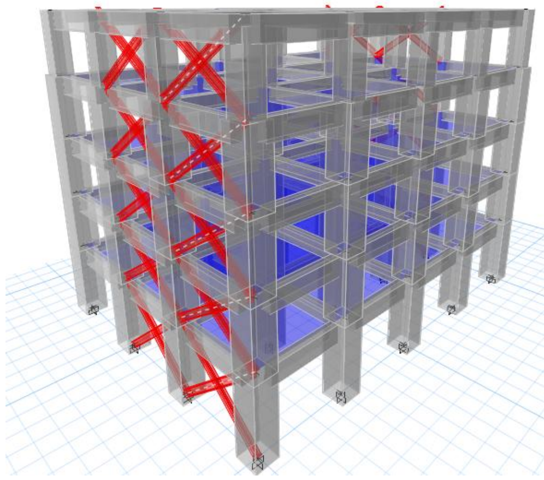

Figure 8. The 3D model of the retrofitted with steel braces building.

5. ANALYSIS OF THE RETROFITTED BUILDING

5.1 Modal Analysis

The retrofitting technique that involved installing steel braces in the structure changed how the building behaved. The building's rigidity was raised as a result of the retrofitting technique including steel bracing. It is readily clear that the periods are shorter and the frequencies are higher than they were in the building before to the retrofitting because of the increased stiffness. The effective modal mass percentages changed as a result of placing the steel bracing strategically in frames located on the building's edge. As a result, the effective modal mass percentages of the first two modes, which are translational in the X and Y axes, are 78.60 and 74.07 %, respectively. The third mode has an effective modal mass percentage of 69.52 % and rotates around the Z axis.

5.2 Nonlinear Static Pushover Analysis

None of the building's modified steel braces exceeded load-distribution limits. Bending failures aren't an issue. The goal displacements are higher than the current buildings. The building received a maximum X-axis shear force of 4,500 kN. Due to the steel bracing, the building was subjected to a maximum Y-axis shear force of 11000 kN. The steel braces worked effectively and withstood Y-axis loading, thus this is apparent. Some beams' shear capabilities are reached early, likely due to insufficient transverse reinforcing. When the building moved 0.006 m and the base shear reached 628.012, the initial members surpassed their shear limit for uniform load distribution along X. These initial shear-failed components were all long-side beams, as shown in Figure 9. Initial building members sheared at 0.006 m displacement and 2641.50 kN base shear. When Y was loaded equally, this happened. Figure 10 shows beams on the long or short side of the building. When loaded along the Y-axis, capacity dropped quickly (Figure 9). This happened when a steel-braced column couldn't handle axial stresses and failed under compression (Figure 10 below shows the column that failed). Shear and compression issues made the structure unsafe to occupy. To prevent problems, the structure was renovated a second time with steel braces and a local retrofitting strategy.

Table 5. Displacement along the 'X' axis when the initial member of an existing structure reached each limit state for retrofitted building.

Limit state	Target Displacement (m)	Displacement First member reached the limit state (m)	Status
Life Safety (LS)	0.067	0.078	Accepted
Immediate Occupancy (IO)	0.087	0.112	Accepted
Collapse Prevention (CP)	0.141	0.186	Accepted

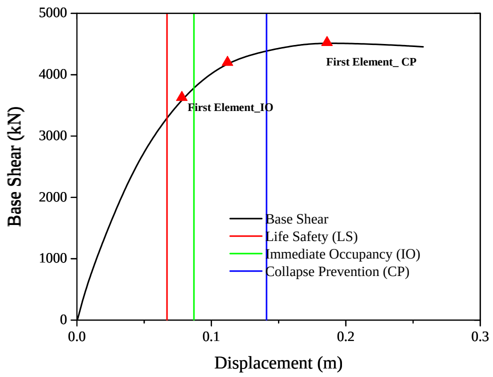

Figure 9. Capacity curve with target displacements along the 'X' 'axis for retrofitted building.

Table 6. Displacement along the 'Y' axis when the initial member of an existing structure reached each limit state for retrofitted building.

Limit state	Target Displacement (m)	Displacement First member reached the limit state (m)	Status
Life Safety (LS)	0.021	0.032	Accepted
Immediate Occupancy (IO)	0.034	0.104	Accepted
Collapse Prevention (CP)	0.044	0.128	Accepted

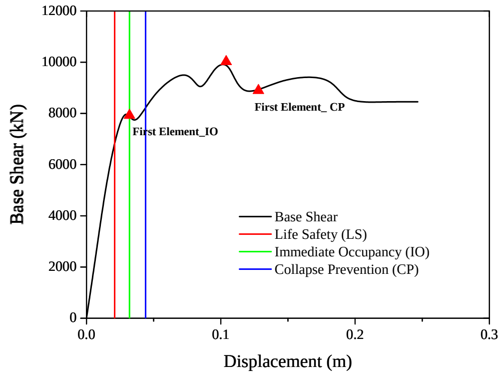

Figure 10. Capacity curve with target displacements along the 'Y' 'axis for retrofitted building.

6. CONCLUSIONS

An analysis of the findings shows that after seismic retrofitting, the building's earthquake behaviour improved dramatically. The building's structural integrity must be enhanced to withstand earthquakes, according to seismic assessments. Various seismic assessments helped attain this goal. The improvements prevented bending, shear, and compression failures. The existing building had a high torsional sensitivity and the bulk of its beams had a poor shear capacity due to insufficient transverse reinforcing. Insufficient transverse reinforcement prevented confinement in the structure's concrete elements. No building members failed in bending, hence the longitudinal reinforcement was probably sufficient.

Steel braces improved the building's torsional sensitivity. The building's overall rigidity increased, and it could withstand greater Y-axis seismic loads. Massive seismic stresses passed through steel bracing caused column breakdowns in the same frames. The steel bracing did not reduce the seismic loads on the beams, therefore shear failures occurred again. This study offers new insights on how to monitor seismic behaviour and fortify existing structures. [Seismic activity and building resistance] To fortify an existing structure and meet construction laws and standards, you must understand retrofitting techniques and their applications.

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