SEISMIC VULNERABILITY ASSESSMENT OF INSTITUTIONAL RC BUILDING IN SURKHET VALLEY

Er. Nirajan Adhikari*; Prof. Gokarna Bahadur Motra**

*M.Sc. in Structural Engineering,
Mid-West University Surkhet,
NEPAL
Email id: adhikarin84@gmail.com

**Ph.D,
Tribhuvan University, Institute of Engineering,
Pulchowk Campus, Kathmandu, NEPAL
Email id: gmotra@ioe.edu.np

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ABSTRACT

This study presents a seismic vulnerability assessment of existing institutional reinforced concrete (RC) buildings in Surkhet Valley, Nepal. The assessment is conducted using non-destructive testing (NDT) to obtain the material properties of the existing buildings, followed by a 3D modeling of the buildings using the Etabs 2000 software. The vulnerability assessment is conducted using a nonlinear static approach, which involves applying incremental displacement to the structure until it reaches a predefined limit state.
Based on the study results, some of the RC buildings in Surkhet Valley are vulnerable to seismic events, and some have low to moderate seismic performance. The study also identified the key factors contributing to the vulnerability of the structures, including insufficient seismic design and construction practices, lack of maintenance, and inadequate building codes and regulations.
Studies have shown that strengthening measure of buildings to improve their seismic performance can significantly enhance their overall performance. In this study, the recommended strengthening measure is to add shear walls at suitable locations in the building.
The findings of the study can be used to develop effective strategies for reducing the vulnerability of school buildings in Surkhet Valley to seismic events. These strategies may include retrofitting or strengthening measures of existing structures, improving construction practices, and enforcing stricter building codes and regulations. Overall, this study provides valuable insights into the seismic vulnerability of school buildings in Surkhet Valley and highlights the need for effective measures to reduce their vulnerability to seismic events.

KEYWORDS: *Vulnerability, Seismic Performance, Retrofitting*.

INTRODUCTION

School buildings in Birendranagar Surkhet, like many other areas in Nepal, are at risk of earthquake damage due to the region's proximity to the Himalayan mountain range, which is highly seismically active. The risk of earthquake damage in school buildings in Birendranagar Surkhet can be attributed to several factors, many school buildings in Nepal, especially those in rural areas, were constructed with poor construction practices and inadequate building materials, making them vulnerable to earthquake damage. Until recently, Nepal did not have mandatory seismic design codes for buildings. This resulted in many school buildings being constructed without adequate seismic design features. The region around Birendranagar Surkhet is geologically unstable, with active fault lines running through the area. This makes the area highly susceptible to earthquakes. The area around Birendranagar Surkhet has a high population density, with many people living in densely packed urban areas. In the event of an earthquake, this can increase the risk of casualties and property damage.

Given these factors, school buildings in Birendranagar Surkhet are at risk of earthquake damage. However, by conducting a seismic vulnerability assessment and implementing recommended retrofitting and strengthening measures, the risk can be significantly reduced, and the safety of students and staff can be ensured. It is important for schools in the area to take steps to assess and improve the seismic safety of their buildings to protect the lives of students and staff and ensure continuity of education in the event of an earthquake.

Rationale for the Selection of Study Area

The study area should be located in an area that is prone to seismic activity, particularly in Surkhet Valley, which is located in a seismically active region. The seismic hazard can be assessed by looking at the historical seismic activity of the region and considering the geological and tectonic setting of the area. The study area should have a significant number of RC buildings in the school sector. The building stock should be diverse, representing various types of schools, including primary, secondary, and higher secondary schools. Study area should have a high population density. This is important because high population density areas are more prone to the adverse effects of a seismic event. Additionally, the high population density also means that there is a greater need for safe school buildings. Study area should be easily accessible. This will enable easy access to data and information, and facilitate on-site inspections of the buildings.

There should be adequate data available about the buildings in the study area. This includes information on the construction material, building age, number of stories, occupancy, and usage. This data can be obtained through surveys, interviews, and visual inspections. The selection of the study area should be guided by the need to identify the seismic vulnerability of school RC buildings in a region with a high seismic hazard and a significant number of school buildings. The ultimate goal is to inform policy and decision-making on how to improve the safety of these buildings and protect the lives of the students and staff who use them.

Recent earthquakes have shown that older buildings, which were not designed to withstand earthquakes, have suffered damage, while buildings designed according to modern seismic codes have performed better. In Surkhet valley, many school buildings were constructed without seismic provisions and were designed only to support gravity loads. Following the Gorkha Earthquake in 2015, the Nepal National Building Code has been effectively applied, but most institutional buildings were constructed prior to the application of the code. Therefore, it is necessary to evaluate the vulnerability of these buildings to mitigate the risk of serious damage. This thesis focuses on evaluating the seismic vulnerability of old school RC buildings, which will help to identify the buildings that are capable of resisting seismic forces and suggest seismic strengthening measures for existing RC buildings.

Collection of Data

For the data collection the following methods are adopted:

i. Visual inspection and measurement of the building's structural geometry.

ii. Schmidt Hammer Test to determine the concrete strength.

iii. Rebar Scanner (Rebar Detection Test) to determine the reinforcement's number and size.

Data Analysis Procedures

Non-destructive testing (NDT) is conducted to determine the material properties of the building's components, such as concrete and rebar. The data obtained from NDT is used to build a 3D model of the building using ETABS 2000 software.

The demand capacity curve is determined using non-linear static analysis (pushover analysis) to evaluate the building's displacement and drift. The curve is then compared to the allowable limits specified in the Nepal National building design codes to determine the building's limit state.

Geometrical Description of Building

The research focuses on RC institutional buildings situated in the Surkhet District, specifically in the Birendranagar municipality area of Surkhet valley. The buildings, along with their plans and geometrical features, are illustrated in the below.

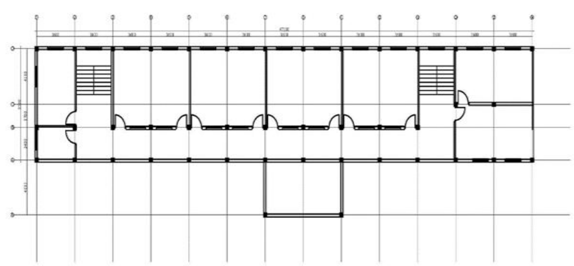

Figure 1: Building Type -

TABLE 1: DETAIL OF BUILDING TYPE -1

SN	Components	Dimension
1.	Length of Building	47.1 m
2.	Breadth of Building	8.5 m
3.	Height of Building	9 m
4.	Number of Storey	3
5.	Column Size	300*350 mm
6.	Beam Size	230*350 mm
7.	Slab thickness	125 mm
8.	No of column	43 nos.
9.	Brick Wall thickness	230 mm

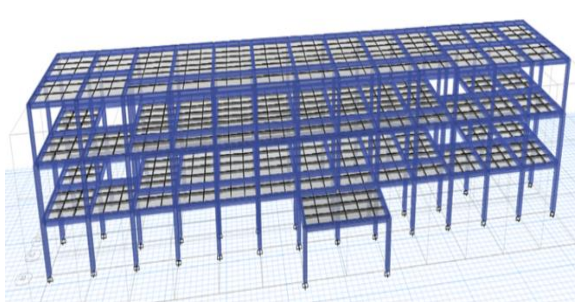

Figure 2: Model of Building Type -1

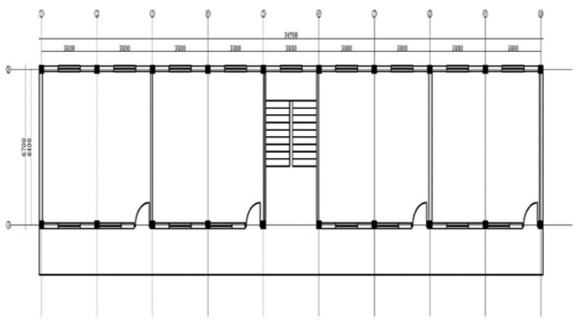

Figure 3: Building Type -2

TABLE 2: DETAIL OF BUILDING TYPE -2

SN	Components	Dimension
1.	Length of Building	34.5 m
2.	Breadth of Building	6.7 m
3.	Height of Building	9 m
4.	Number of Storey	3
5.	Column Size	300*300 mm
6.	Beam Size	230*350 mm
7.	Slab thickness	125 mm
8.	No of column	20 nos.
9.	Brick wall thickness	230 mm

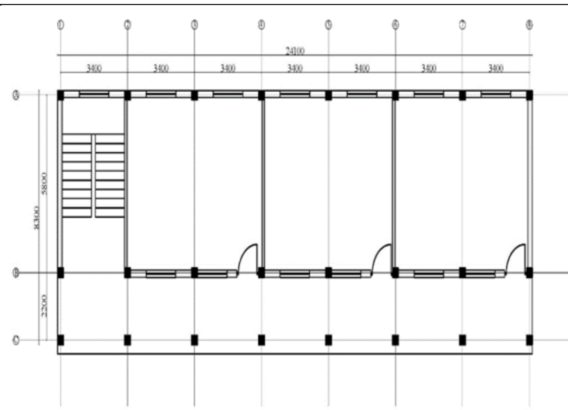

Figure 4: Building Type -3

TABLE 3: DETAIL OF BUILDING TYPE -3

SN	Components	Dimension
1.	Length of Building	24.1 m
2.	Breadth of Building	8.3 m
3.	Height of Building	9 m
4.	Number of Storey	3
5.	Column Size	300*350 mm
6.	Beam Size	230*350 mm
7.	Slab thickness	125 mm
8.	No of column	24 nos.
9.	Brick wall thickness	230 mm

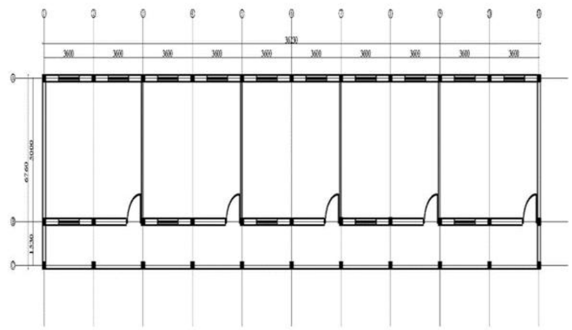

Figure 5: Building Type -4

TABLE 4: DETAIL OF BUILDING TYPE -4

SN	Components	Dimension
1.	Length of Building	36.23 m
2.	Breadth of Building	6.76 m
3.	Height of Building	6 m
4.	Number of Storey	2
5.	Column Size	230*230 mm
6.	Beam Size	230*300 mm
7.	Slab thickness	125 mm
8.	No of column	33 nos.
9.	Brick wall thickness	230 mm

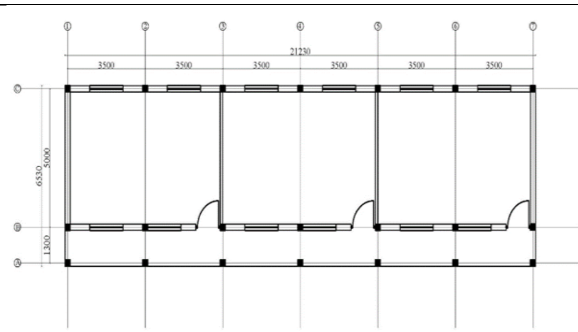

Figure 6: Building Type -5

TABLE 5: DETAIL OF BUILDING TYPE -5

SN	Components	Dimension
1.	Length of Building	21.23 m
2.	Breadth of Building	6.53 m
3.	Height of Building	6 m
4.	Number of Storey	2
5.	Column Size	230*230 mm
6.	Beam Size	230*300 mm
7.	Slab thickness	125 mm
8.	No of column	21 nos.
9.	Brick wall thickness	230 mm

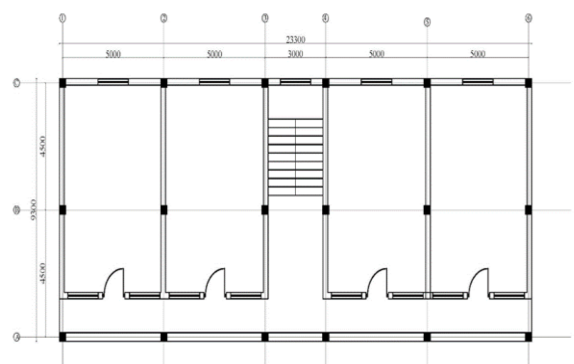

Figure 7: Building Type -6

TABLE 6: DETAIL OF BUILDING TYPE -6

SN	Components	Dimension
1.	Length of Building	23.3 m
2.	Breadth of Building	9.3 m
3.	Height of Building	6 m
4.	Number of Storey	2
5.	Column Size	300*300 mm
6.	Beam Size	230*355 mm
7.	Slab thickness	125 mm
8.	No of column	18 nos.
9.	Brick wall thickness	230 mm

Findings

A. Base Shear, Time Period, Drift, and Displacement

The seismic load, along with accidental eccentricity, was considered for the analysis of all types of RC institutional buildings. Seismic force was applied in both the X- and Y-directions, and some important results are presented below.

Base shear

TABLE 7: BASE SHEAR OF BUILDING.

Types of Building	Base Shear (KN)
Type -1	1860.456
Type -2	1178.7789
Type -3	881.0647
Type -4	639.1502
Type -5	443.4635
Type -6	702.1432

Time period

TABLE 8: TIME PERIOD OF BUILDINGS

Types of Building	Time Period (Sec)
Type -1	0.785
Type -2	0.855
Type -3	0.761
Type -4	0.696
Type -5	0.689
Type -6	0.599

Storey Drift

The storey drift values due to EQx and EQy in the x and y directions have been analyzed and tabulated below for all types of buildings.

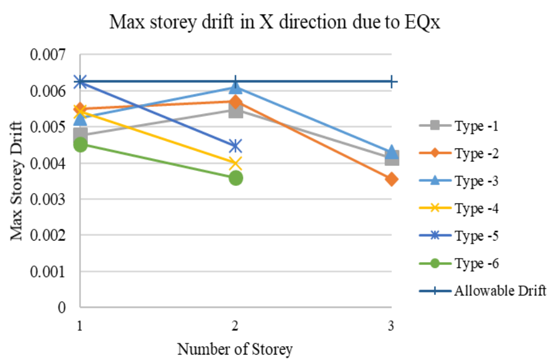

Figure 8: Max storey drift in X direction due to EQx

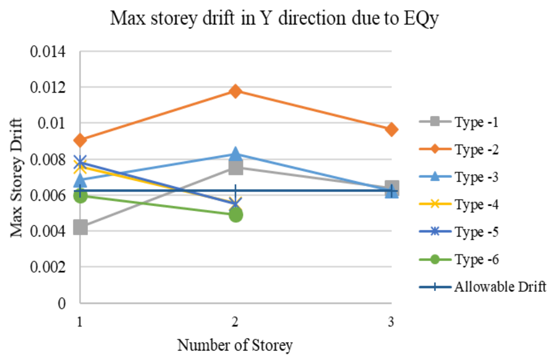

Figure 9: Max storey drift in Y direction due to EQy

The figure above displays the maximum drift values in Institutional RC buildings, as well as the allowable drift as specified by NBC, Ref (Cl 5.6.3). In this case, except building types -6, other all buildings fail the drift check as the ratio of inter-story deflection to the corresponding story height exceeds the allowable drift limit.

Storey Stiffness

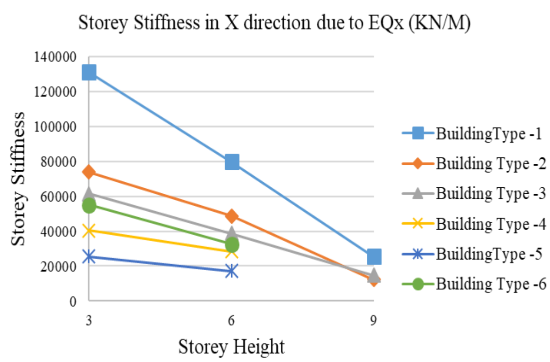

Figure 10: Storey Stiffness in X direction due to EQx.

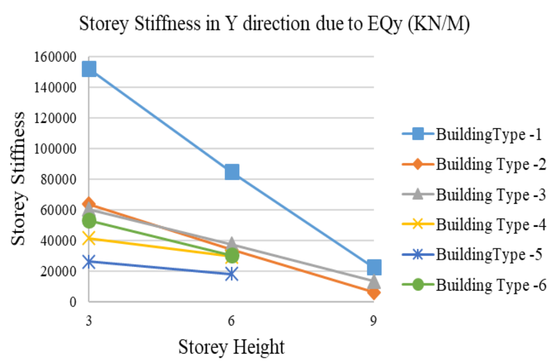

Figure 11: Storey Stiffness in Y direction due to EQy

A soft story is defined as having a lateral-force-resisting system stiffness that is either less than 70% of the stiffness of the lateral-force-resisting system in an adjacent story above or below, or less than 80% of the average lateral-force-resisting system stiffness of the three adjacent stories. Therefore, all buildings in this case have sufficient stiffness in their adjacent stories.

Storey Displacement

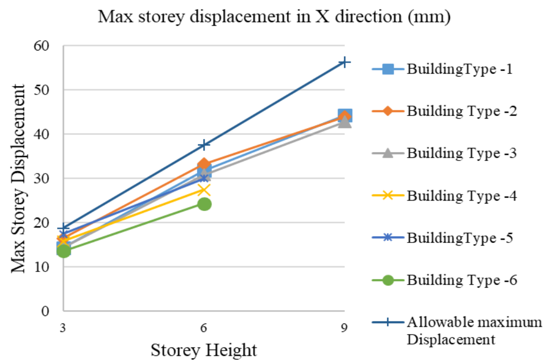

Figure 12: Max storey displacement in X direction

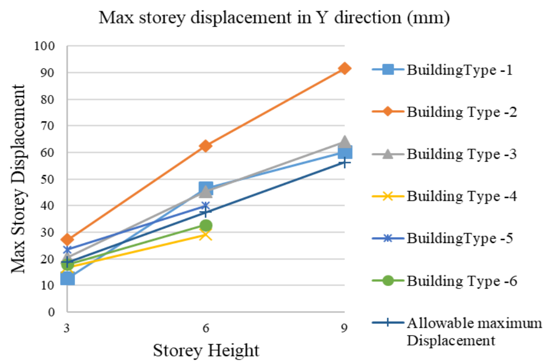

Figure 13: Max storey displacement in Y direction

The graphs shown above illustrate the maximum storey displacement values in Institutional RC buildings, along with the allowable maximum displacement as stated in NBC, Ref (Cl 5.6.3). All of the buildings, except the building type -4 and type -6, are surpass the permissible displacement.

INTERPRETATION OF REASULT

The main output of a pushover analysis is in terms of response demand versus capacity. If the demand curve intersects the capacity curve near the elastic range (Figure 14), then the structure has a good resistance. If the demand curve intersects the capacity curve with little reserve of strength and deformation capacity, Figure 14 (b), then it can be concluded that the building structure will behave poorly during the imposed seismic excitation and need to be retrofitted to avoid future major damage or collapse.

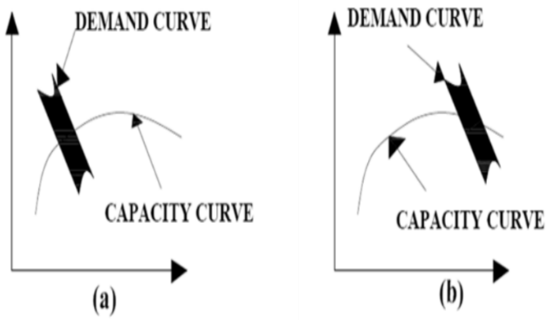

Figure 14: Typical seismic Demand vs. Capacity (a) Safe design (b) Unsafe design. (irjet.net)

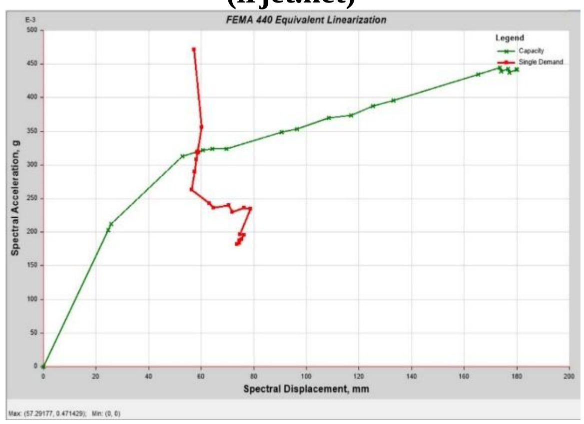

Figure 15: Seismic Demand vs. Capacity Curve for Building Type -1 in PAx

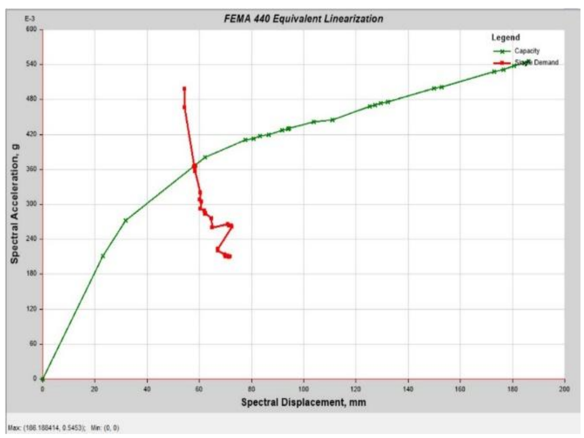

Figure 16: Seismic Demand vs. Capacity Curve for Building Type -1 in PAy.

It can be observed from the given curves that the intersection of the demand curve and the capacity curve occurs close to the elastic range, which falls within the level of immediate occupancy. As a result, retrofitting is not required for building type -1.

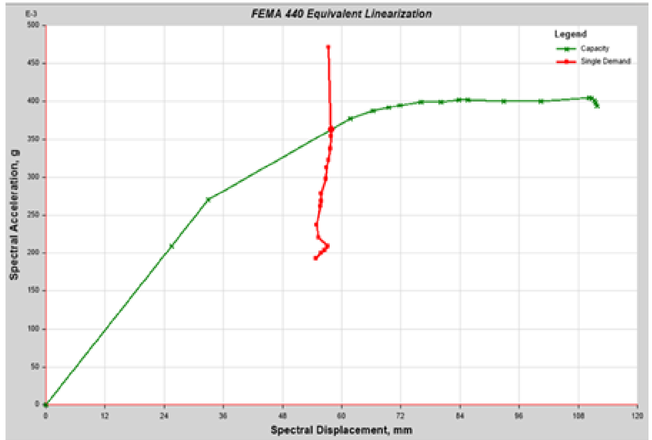

Figure 17: Seismic Demand vs Capacity Curve for Building Type -2 in PAx.

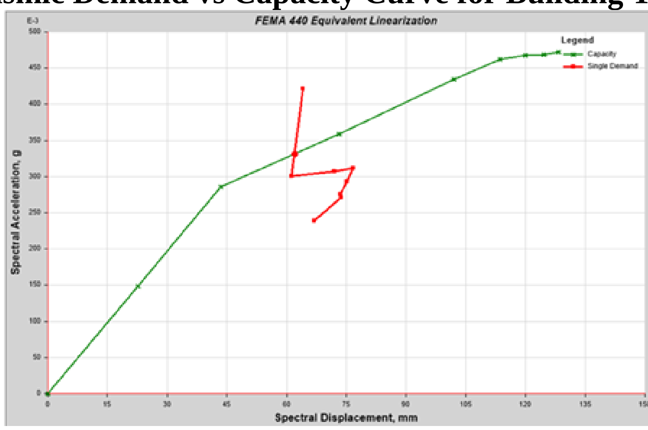

Figure 18: Seismic Demand vs Capacity Curve for Building Type -2 in PAy.

It can be observed from the curves that the intersection of the demand curve and the capacity curve is far away from the elastic range and well beyond the level of immediate occupancy. Hence, retrofitting is required for building type -2.

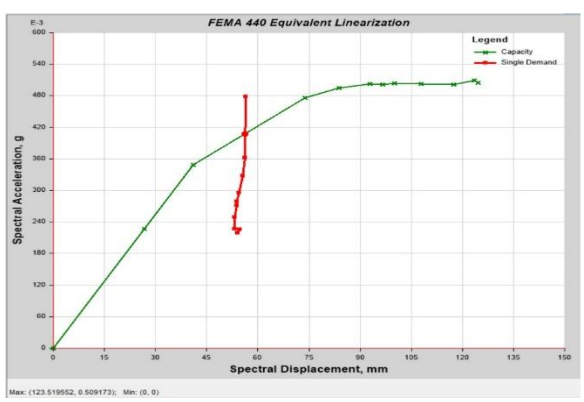

Figure 19: Seismic Demand vs. Capacity Curve for Building Type -3 in PAx

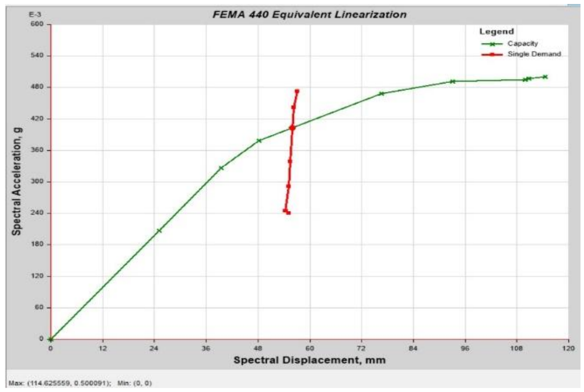

Figure 20: Seismic Demand vs. Capacity Curve for Building Type -3 in PAy.

It can be observed from the given curves that the intersection of the demand curve and the capacity curve occurs close to the elastic range, which falls within the level of immediate occupancy. As a result, retrofitting is not required for building type -3.

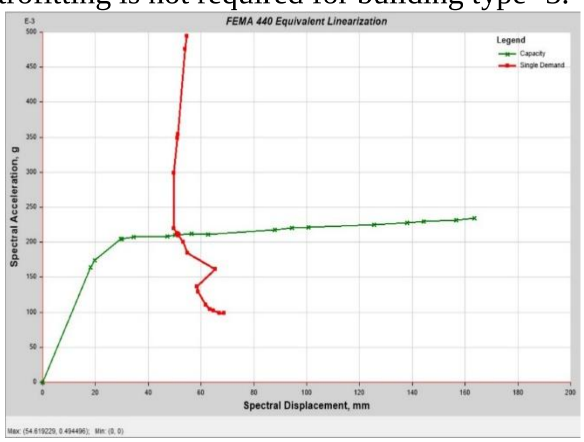

Figure 21: Seismic Demand vs. Capacity Curve for Building Type -4 in PAx.

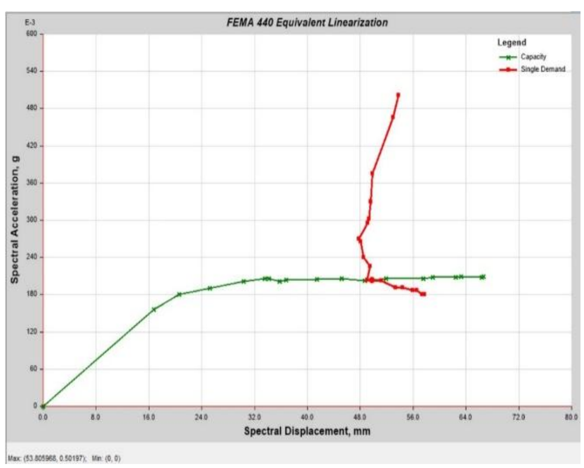

Figure 22: Seismic Demand vs. Capacity Curve for Building Type -4 in PAy.

It can be observed from the curves that the intersection of the demand curve and the capacity curve is far away from the elastic range and well beyond the level of immediate occupancy. Hence, retrofitting is required for building type -4.

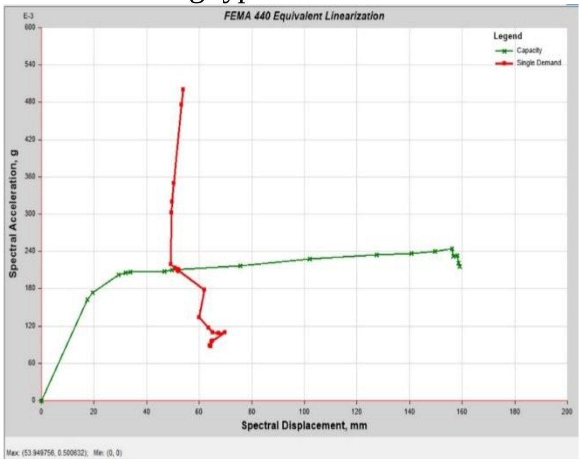

Figure 23: Seismic Demand vs. Capacity Curve for Building Type -5 in PAx.

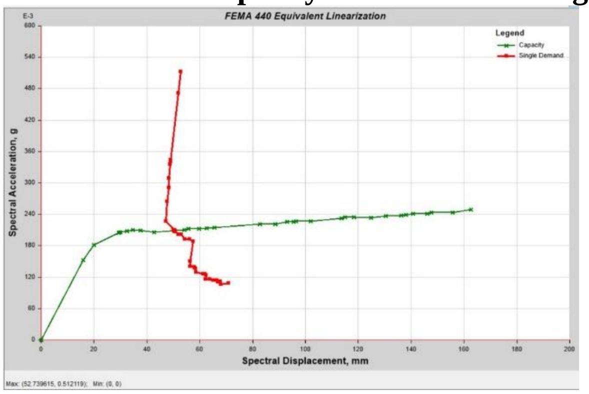

Figure 24: Seismic Demand vs. Capacity Curve for Building Type -5 in PAy.

It can be observed from the curves that the intersection of the demand curve and the capacity curve is far away from the elastic range and well beyond the level of immediate occupancy. Hence, retrofitting is required for building type -5.

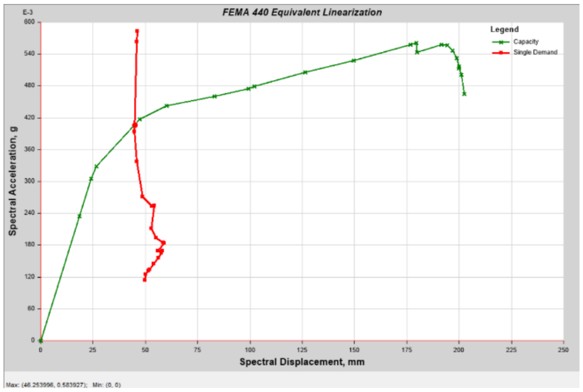

Figure 25: Seismic Demand vs. Capacity Curve for Building Type -6 in PAx.

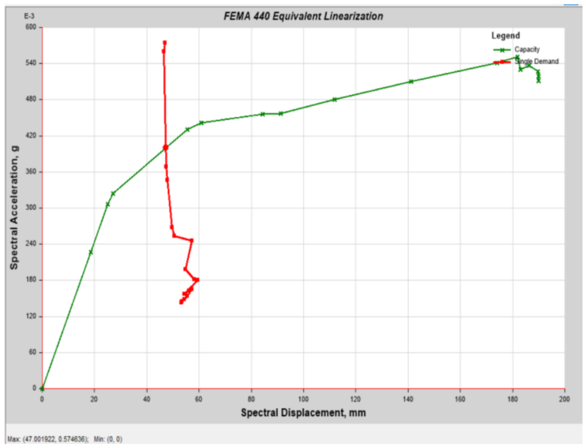

Figure 26: Seismic Demand vs. Capacity Curve for Building Type -6 in PAy.

It can be observed from the given curves that the intersection of the demand curve and the capacity curve occurs close to the elastic range, which falls within the level of immediate occupancy. As a result, retrofitting is not required for building type -6.

Strengthening Measure

The implementation of shear walls in specific areas of a building's structural system results in a change in its performance level. The following comparison of outcomes demonstrates the reinforcement of institutional buildings.

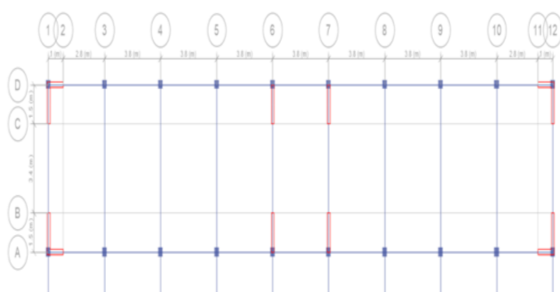

Figure 27: plan of building type -2 after inserting Shear wall.

Comparison In Base Shear

Below is a comparison of the building's analysis for base shear in both the existing case and after strengthening.

TABLE 9: COMPARISON OF BASE SHEAR OF BUILDING.

Types of Building	Base Shear (KN)	
	Existing	After Strengthen
Type -2	1178.7789	1244.28

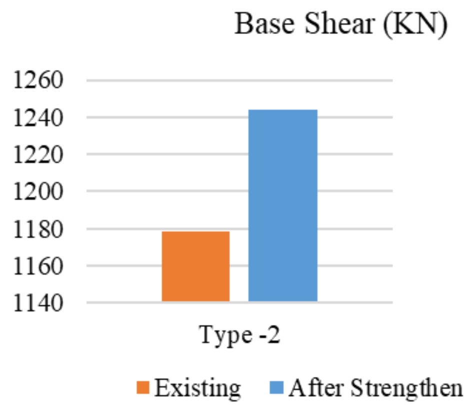

Figure 28: Comparison of Base Shear of Building.

Comparison in Time Period

Below is a comparison of the building's analysis for time period in both the existing case and after strengthening.

TABLE 10: COMPARISON OF TIME PERIOD OF BUILDINGS

Types of Building	Time Period (Sec)	
	Existing	After strengthen
Type -2	0.855	0.391

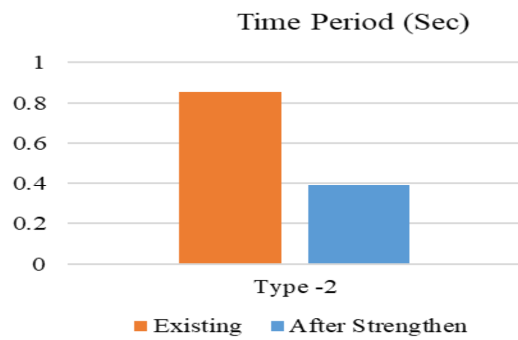

Figure 29: Comparison of Time Period of Buildings

After the strengthening of the building time period are less than the existing Condition.

Comparison in Storey Drift

For building type-2, the storey drift values in the x and y directions due to EQx and EQy were analyzed and tabulated to compare the values before and after the building was strengthened.

TABLE 11: COMPARISON OF MAX STOREY DRIFT IN X DIRECTION DUE TO EQX

Max storey drift in X direction due to EQx			
Storey Height	Type -2 existing	Type - 2 after strengthen	Allowable Drift
3	0.00549	0.000962	0.00625

6	0.00571	0.001857	0.00625
9	0.00356	0.002723	0.00625

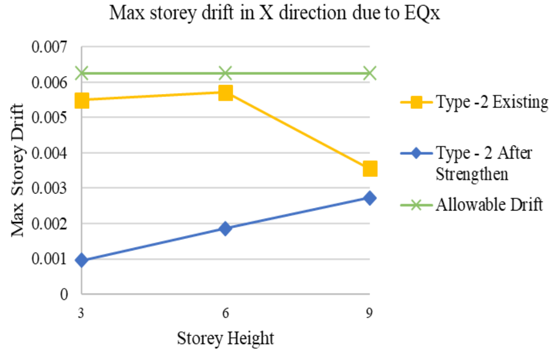

Figure 30: Comparison of Max storey drift in X direction due to EQx

TABLE 12: COMPARISON MAX STOREY DRIFT IN Y DIRECTION DUE TO EQY

Max storey drift in Y direction due to Eqy			
Storey Height	Type -2 Existing	Type - 2 After Strengthen	Allowable Drift
3	0.00907	0.000415	0.00625
6	0.01178	0.000807	0.00625
9	0.00966	0.003553	0.00625

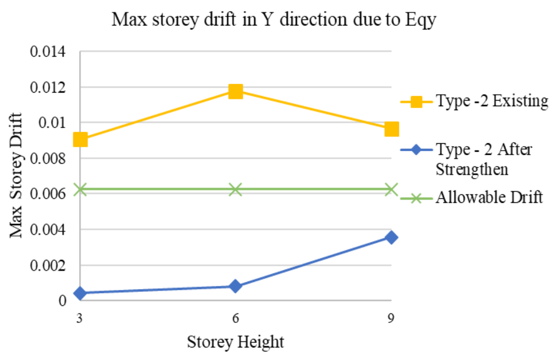

Figure 31: Comparison of Max storey drift in Y direction due to EQy

The graphs shown above illustrate the highest recorded drift values in Institutional RC buildings, along with the drift limit specified by NBC, Ref (Cl 5.6.3). For type-2 buildings, the maximum storey drift after the strengthening is within the allowable limit.

Comparison in Storey Stiffness

For building type-2, the storey Stiffness values in the x and y directions due to EQx and EQy were analyzed and tabulated to compare the values before and after the building was strengthening.

TABLE 13: COMPARISON OF STOREY STIFFNESS IN X DIRECTION DUE TO EQX (KN/M)

Storey Stiffness in X direction due to EQx (KN/M)		
Storey Height	Type -2 Existing	Type -2 After Strengthen
3	12321.876	433482.577
6	48565.795	167159.784
9	11970.78	15689.932

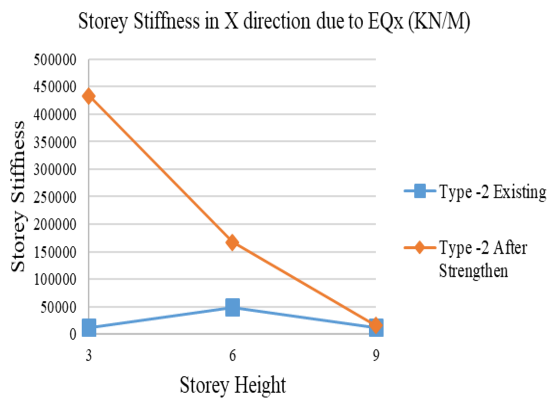

Figure 32: Comparison of Storey Stiffness in X direction due to Eqx

TABLE 14: COMPARISON OF STOREY STIFFNESS IN Y DIRECTION DUE TO EQY

Storey Stiffness in Y direction due to EQy (KN/M)		
Storey Height	Type -2 Existing	Type -2 After Strengthen
3	63814.067	1291379.087
6	34007.534	475932.787
9	6241.107	12362.789

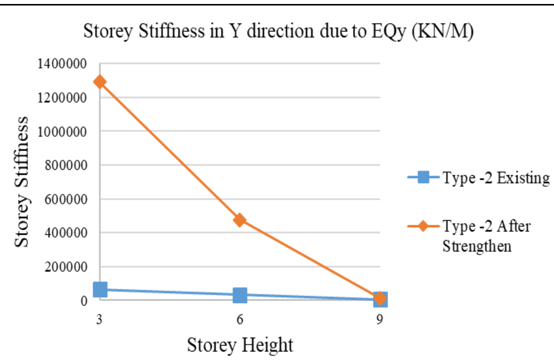

Figure 33: Comparison of Storey Stiffness in Y direction due to EQy

A soft story is defined as having a lateral-force-resisting system stiffness that is either less than 70% of the stiffness of the lateral-force-resisting system in an adjacent story above or below, or less than 80% of the average lateral-force-resisting system stiffness of the three adjacent stories. Therefore, building types -2 in this case have sufficient stiffness in their adjacent stories.

Comparison in Storey Displacement

For building type-2, the storey displacement values in the x and y directions due to EQx and EQy were analyzed and tabulated to compare the values before and after the building was strengthening.

TABLE 15: COMPARISON OF MAX STOREY DISPLACEMENT IN X DIRECTION

Max storey displacement in X direction (mm)			
Storey Height	Type -2 Existing	Type -2 After Strengthen	Allowable maximum Displacement
3	16.495	2.886	18.75
6	33.273	8.474	37.5
9	43.854	16.603	56.25

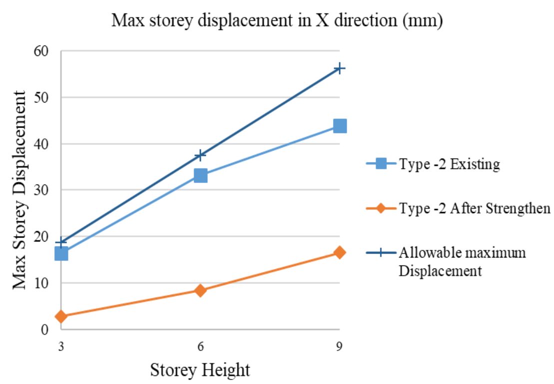

Figure 34: Comparison of Max storey displacement in X direction

TABLE 16: COMPARISON OF MAX STOREY DISPLACEMENT IN Y DIRECTION

Max storey displacement in Y direction (mm)			
Storey Height	Type -2 Existing	Type -2 After Strengthen	Allowable maximum Displacement
3	27.192	1.244	18.75
6	62.543	3.74	37.50
9	91.519	14.298	56.25

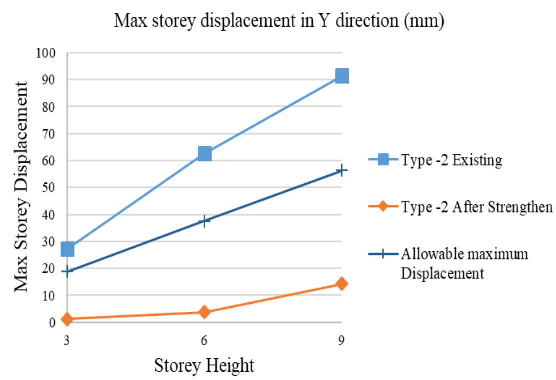

Figure 35: Comparison of Max storey displacement in Y direction

The graph indicates that the story displacement values for building type -2 in existing and after strengthen condition. In existing condition, the story displacement is surpassing the allowable maximum displacement while after the strengthening the building story displacement value is within the acceptable limit.

CONCLUSIONS

The conclusions from this study are summarized as follows:

1. Based on the results above, it has been determined that out of the six types of buildings, three do not require strengthening, while the remaining four are requiring strengthening.
2. The intersection of the Seismic demand curve and the Capacity curve occurs close to the elastic range, which falls within the level of immediate occupancy. As a result, it is not necessary to retrofit building type-1, type-3 and type -6.
3. Based on the Demand Capacity curves, it can be observed that the intersection of the seismic demand curve and the Capacity curve occurs far from the elastic range, which is also beyond the immediate occupancy level. Therefore, building types -2, -4, and -5 require retrofitting.
4. Shear walls are an efficient method for strengthening the structure and enhancing its performance level in the aforementioned types of buildings.

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