Civil Engineering Beyond Limits 4 (2023) 1887
Civil Engineering Beyond Limits
journal home: www.acapublishing.com/journals/1/cebel
Research Article

Seismic Risk Assessment of Existing Buildings of HSTU Campus in Dinajpur

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Keywords

Earthquake,
Seismic events,
Seismic risk,
Seismic zone,
Turkish Method.

Abstract

Bangladesh is at high risk of earthquakes due to its geographic location. Earthquakes can cause widespread damage to buildings and infrastructure, as well as significant loss of life, due to the sudden release of energy in the form of seismic waves. Therefore, identifying and assessing the vulnerability of existing buildings is crucial for earthquake risk reduction. Hajee Mohammad Danesh Science and Technology University (HSTU) is situated just 13 kilometers from Dinajpur, which falls under zone II, a medium-risk zone according to the Bangladesh National Building Code (BNBC, 1993). This study aims to evaluate the seismic vulnerability of HSTU's existing buildings. A widely used seismic assessment technique, the Turkish two-level assessment procedure, was employed in this study to identify seismically vulnerable buildings. A total of 79 buildings were surveyed at level I, considering vulnerability parameters such as soft storey, heavy overhanging, pounding effect, topographic effect, short column, shape of building, number of storeys, apparent quality of building, and soil type. Based on these parameters, performance scores were assigned to each building, and they were classified into damage categories of safe, moderate, and unsafe at level I. Digital photographs of each building from at least two directions were taken for easy identification. All 79 buildings on the HSTU campus were found to be safe after the level I survey. Level II assessment was conducted on only one building to validate the level I findings, and it was classified as a low-risk structure. A significant outcome of this study is the identification of damage categories and the potential to reduce seismic risk at HSTU by creating a comprehensive building inventory.

1. Introduction

Earthquakes are sudden ground movements caused by the release of energy that builds up as tectonic plates move. These movements result from the movement of the earth's plates. The plates are constantly shifting, rubbing against each other, and pulling apart. When they get stuck, pressure builds up, and eventually, they slip past each other, releasing energy in the form of seismic waves. These seismic waves travel through the Earth and cause the ground to shake. Earthquakes have become a prevalent threat not only in Bangladesh but also across the globe. Developing nations like Bangladesh, situated in earthquake-prone regions, have witnessed seismic events in recent decades, particularly in densely populated areas, highlighting the vulnerability of these areas to significant human and economic losses. Bangladesh is primarily bordered by India, with a small portion adjoining Myanmar and the Bay of Bengal to the south. These neighboring regions indicate that Bangladesh is situated adjacent to the plate margins of India to the west, Burma to the south and east, and Eurasia to the east and north, areas where devastating earthquakes have occurred in the past. Currently, the Indian plate is moving towards central Asia at a rate of approximately 29-36 millimeters per year [1], while the Burma plate boundary absorbs approximately 12 to 24 millimeters per year of oblique India-Burma movement [2]. Furthermore, Bangladesh is traversed by several active faults, including the Jamuna Fault (JF), the Madhupur Fault (MF), the Bogura Fault (BGF), the Sylhet Fault (SF), and the Dauki Fault (DF). These faults are situated within tectonic blocks that have triggered earthquakes in recent history. However, the current generation of Bangladeshis has not experienced a major earthquake, leading to a general sense of complacency regarding earthquake risk. Consequently, incorporating seismic considerations into structural design, city planning, and infrastructure development is essential to mitigate future earthquake-related damage.

The current study focuses on the Hajee Mohammad Danesh Science and Technology University (HSTU) campus, situated 13 kilometers from Dinajpur city in northwestern Bangladesh. The campus is also located in proximity to the Dhepa River, a significant hydrological feature in the region. According to the Bangladesh National Building Code (BNBC) earthquake zonation map, the HSTU campus falls within Zone-II, indicating a moderate seismic risk. This implies that the region is susceptible to moderate-intensity earthquakes, which can inflict substantial damage to buildings and potentially lead to loss of life. Furthermore, the HSTU campus lies in close proximity to Saidpur town, which is traversed by a right-lateral strike-slip fault extending from Kakarbitta in Nepal to the northwest of Bangladesh [3]. This fault system is considered potentially active, as evidenced by the presence of a minor scarp in the southwest of Saidpur town, as identified through CORONA photo interpretation. The proximity to active faults and the moderate seismic risk associated with the region underscore the importance of earthquake preparedness and mitigation measures for the HSTU campus and the surrounding areas. Although the region has experienced major earthquakes in recent years, the general population, including those residing within the HSTU campus, exhibits a moderate level of awareness regarding earthquake preparedness. This highlights the need for enhanced earthquake education and awareness campaigns to foster a more resilient community.

The current study proposes a two-level seismic risk assessment procedure specifically tailored for low to medium-rise (less than seven stories) ordinary reinforced concrete buildings. This methodology is grounded in readily observable or measurable building parameters that can be systematically assessed during a comprehensive survey.

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Received 25 Nov 2023; Revised 25 Dec 2023; Accepted 25 Dec 2023
https://doi.org/10.36937/cebel.2023.1887

The selection of these parameters is crucial for establishing a correlation between ground motion intensity and the corresponding damage to the buildings. The overarching objective of risk assessment is to determine the probability of a specific damage level occurring in a given building type subjected to a scenario earthquake. Despite the existence of earthquake-resistant building codes promulgated by the Bangladesh government, these codes are often disregarded in the design of new structures, with only a few exceptions.

2. Methodology

Numerous methodologies exist for determining seismic risk assessment, including FEMA 154 (1988), FEMA 310 (1998), EURO CODE 8, New Zealand Guideline, Modified Turkish Method, NRC guideline, IITKGSDM method, Japan method, Indian method, and others. These methodologies share the common goal of evaluating the earthquake-related risk posed to buildings. For the present study focused on the HSTU campus, the Turkish Method of simple survey procedure was employed as the chosen assessment technique.

2.1. Turkish method

The Turkish Method of simple survey procedure, introduced by Sucuoglu and Yazgan in 2003 [4], is a two-level seismic assessment method that identifies buildings that are most vulnerable in a seismic event.

2.2. Seismic Vulnerability Assessment

Seismic vulnerability assessment methods can be categorized into three main groups based on their complexity:

Walk-down evaluation: This is the simplest level and does not require any analysis. It involves a survey based on readily observable structural and geotechnical parameters from the sidewalk. The goal is to prioritize buildings that require immediate intervention.

Preliminary Assessment Methodologies (PAM): This level is used when a more in-depth evaluation of building stocks is needed. It involves simplified analysis of the building based on various methods. Observers may enter the basement and ground floors to collect basic structural data.

Detailed Assessment Methodologies (DAM): This is the most complex level and involves detailed structural analysis using sophisticated computational methods. It is typically used for buildings that have been identified as potentially vulnerable through the PAM or for buildings that require specific retrofitting measures.

The study utilized a descriptive research method, utilizing secondary data, and followed a series of sequential steps:

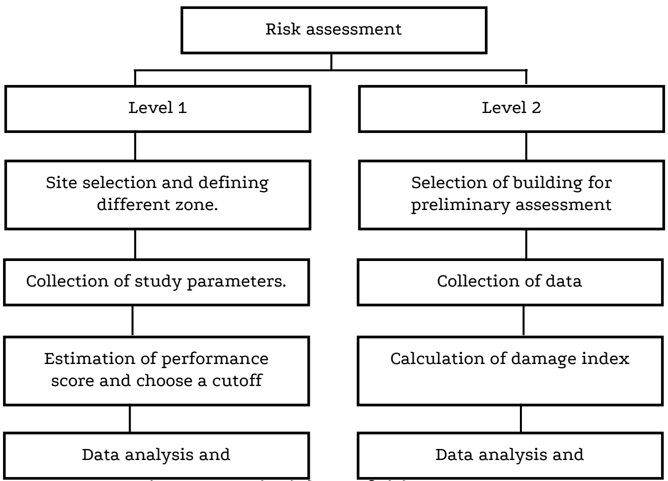

Figure 1. Methodology of risk assessment.

2.3. Level 1 Survey: The Walkdown Evaluation Procedure

The walkdown evaluation procedure is a simplified method for assessing the seismic vulnerability of buildings. It involves a visual inspection of the building's exterior to identify key features that may indicate structural weaknesses or susceptibility to earthquake damage.

Identification of Structural Vulnerability Parameters: Several building parameters are crucial for evaluating seismic vulnerability. These parameters provide insights into the building's structural integrity and its ability to withstand earthquake forces.

- Number of Stories (NS): Taller buildings generally experience greater seismic forces due to their increased exposure to ground shaking and wind loads.
- Soft stories (SS): The Turkish Code of Earthquake allows for a 15% difference in stiffness between a story with walls and one without walls. In contrast, BNBC defines a soft story as a story where the lateral stiffness is less than 70% (30% variation) of the stiffness of the story above.
- Heavy overhang (HO): In multistory reinforced concrete buildings, heavy balconies and overhanging levels transfer the mass centre upwards, increasing seismic lateral stresses and overturning moments during earthquakes. The overhang-like balcony shall not exceed 1.5 m in length, according to the Turkish Code of Earthquake and BNBC. However, overhang vulnerability can be subdivided according to its presence in buildings, such as one-sided, two-sided, and all sides overhang, and vulnerability ratings must be chosen accordingly.
- Short Columns (SC): When the ratio of a column's effective length to its shortest lateral dimension does not exceed 12, the column is said to be short. Frames with partial infills result in the construction of short columns, which experience significant damage since they are not built for the high shear forces caused by decreased heights caused by a major earthquake.
- Pounding Effects (PE): According to the Turkish technique, the building should be no closer than 4% of its height to an adjacent building. According to BNBC-2015, there is no requirement for a pounding gap between buildings up to 4 stories, a 1.5-meter pounding distance between 4 and 10 stories, and a 3-meter pounding gap above 10 stories. Pounding gap is only considered in Turkish approach for four-story buildings.
- Apparent Quality (AQ): The material utilized, workmanship during construction, and building upkeep status all indicate the apparent quality of a construction, which is rated as good, mediocre, or poor. A trained observer can estimate the apparent quality.
- Building on Slope: According to the Turkish method, buildings on sloping ground of more than 30 degrees may be vulnerable to earthquake load, which might trigger landslides. According to BNBC, buildings on slopes must not exceed 25% of the slope, which means that sloping ground should be no more than 15 degrees.
- Plan Irregularities: A variation from a rectangular layout with orthogonal axis systems in two directions is referred to as a building plan irregularity. Such variation from plan regularity causes inconsistencies in stiffness and strength distributions, which enhances the probability of damage localization in the presence of strong ground excitations. Buildings with plan errors attract additional stresses owing to torsion, causing irreversible damage to the structures.
- Liquefaction Vulnerability: Soil liquefaction can cause a variety of sub-structural failures during an earthquake and should be considered a primary sub-structural vulnerability of a building. If a building has zero or fewer super structural vulnerabilities but is built on liquefiable soil, the entire structure may collapse.

- Landslide Vulnerability: Earthquake ground shaking increases the likelihood of landslides in areas where the topography is prone to ground failure. When the earth is saturated with water, especially following heavy rainfall, the shaking causes more landslides than usual. As a result, this approach considers the sub-structural vulnerability parameter.

Base Score depends on local soil and Peak Ground Velocity (PGV): The strength of ground motion at a certain location is mostly determined by the distance between the causative fault and the local soil conditions. Because there is a good link between PGV and shear wave velocities of local soils [5], the PGV is used to represent ground motion intensity in this investigation. BNBC-2015 seismic zones can be represented in terms of the corresponding PGV ranges-

Zone I: 0<PGV<10 cm/s (PGA 0.12g)

Zone II: 10<PGV<20 cm/s (PGA 0.20g)

Zone III: 20<PGV<30 cm/s (PGA 0.28g)

Zone IV: 30<PGV<40 cm/s (PGA 0.36g).

Building Seismic Performance: The seismic performance score (PS) is calculated based on the seismic hazard zone, number of stories, and vulnerability parameters of a building. The Base Score (BS) is assigned based on the seismic hazard zone, and the Vulnerability Scores (VS) are assigned for each vulnerability parameter. The Penalty Score (PS) is calculated by multiplying the VS by the Vulnerability Score Multiplier (VSM) for each parameter and summing the results. The PS is then subtracted from the BS to obtain the final PS.

$$PS = (BS) - \Sigma\,(VSM) \times (VS) \quad (1)$$

Table 1. Vulnerability Score Multipliers [6]

Soft story	Does not exist=0, Exists=1
Heavy overhangs	Does not exist=0, Exists=1
Apparent quality	Good = 0, Moderate = 1, Poor =2
Short columns	Does not exist=0, Exists=1
Pounding effect	Does not exist=0, Exists=1
Topographic effects	Does not exist=0, Exists=1

Table 2. Base Scores and Vulnerability Scores [6]

NS	BS			VS					
	Zone I 60<PGV <80	Zone II 40<PGV <60	Zone III 20<PGV <40	SS	HO	AQ	SC	PE	TE
1 or 2	100	130	150	0	-5	-5	-5	0	0
3	90	120	140	-15	-10	-10	-5	-2	0
4	75	100	120	-20	-10	-10	-5	-3	-2
5	65	85	100	-25	-15	-15	-5	-3	-2
6 or 7	60	80	90	-30	-15	-15	-5	-3	-2

*TE = Topography effects

2.4. Level 2 Survey: Measurements at the ground story and basement

After level 1 survey, buildings falling into the moderate and high-risk levels can be subjected to a more detailed level 2 survey to determine their performance scores as explained in the following sections.

Minimum Normalized Lateral Stiffness Index (mnlstfi): The mnlstfi parameter represents the lateral rigidity of the ground story, which is typically the most critical story in terms of seismic resistance. This parameter is calculated using equation 2, which takes into account the properties of the columns and structural walls present at the ground story level.

$$mnlstfi = \min(I_{nx}, I_{ny}) \quad (2)$$

$$I_{nx} = \frac{\sum(I_{col})_x + \sum(I_{sw})_x}{\sum A_f} \times 1000 \quad (3)$$

$$I_{ny} = \frac{\sum(I_{col})_y + \sum(I_{sw})_y}{\sum A_f} \times 1000 \quad (4)$$

Where, $\sum(I_{col})_x$ is the summation of the moment of inertias of all columns about the centroidal y axes, and $\sum(I_{col})_y$ is the summation of the moment of inertias of all structural walls about the centroidal x axes. $\sum(I_{sw})_x$ is the summation of the moment of inertias of all structural walls about the centroidal x axes. $\sum(I_{sw})_y$ is the summation of the moment of inertias of all structural walls about the centroidal y axes. $\sum A_f$ is the total floor area above ground level.

Minimum Normalized Lateral Strength Index (mnlsi): The mnlsi parameter reflects the base shear capacity of the critical story, which is the story that experiences the highest level of seismic demand. To calculate, it is assumed that unreinforced masonry filler walls can only carry 10% of the shear force that a structural wall with the same cross-sectional area can withstand. The mnlsi parameter is determined using the provided equation (5).

$$\text{mnlsi} = \min(A_{nx}, A_{ny}) \quad (5)$$

$$A_{nx} = \frac{\sum(A_{col})_x + \sum(A_{sw})_x + 0.1\sum(A_{mw})_x}{\sum A_f} \times 1000 \quad (6)$$

$$A_{ny} = \frac{\sum(A_{col})_y + \sum(A_{sw})_y + 0.1\sum(A_{mw})_y}{\sum A_f} \times 1000 \quad (7)$$

For each column with a cross-sectional area denoted by A_{col}.

$$(A_{col})_x = K_x A_{col} (A_{col})_y = K_y A_{col} \quad (8)$$

$K_x = 1/2$, for square and circular columns
$K_x = 2/3$, for rectangular columns with bx>by
$K_x = 1/3$, for rectangular columns with bx<by and Ky=1-kx
For each shear wall with cross-sectional area denoted by Asw.

$$(A_{sw})_x = K_x A_{sw} (A_{sw})_y = K_y A_{colsw} \quad (9)$$

The value of Kx is 0 and 1 for masonry wall in y-axis (Ky=1-Kx) and for masonry wall in x-axis, respectively.

Normalized Redundancy Score (nrs): Insufficient continuous frames or an inadequate number of bays in a building system can result in uneven distribution of lateral loads to frame members. This is particularly concerning for frames that exhibit inelastic response during earthquakes, as they lack the necessary redundancy to handle the stress. Consequently, localized heavy damages are more likely to occur.

$$nrs = \frac{A_{tr}(nf_x - 1)(nf_y - 1)}{A_{gf}} \quad (10)$$

Where, A_{tr}, nf_x, nf,and A_{gf},are column tributary area, number of continuous frame lines in the critical storey in x directions, number of continuous frame lines in the critical storey in y directions, and ground storey area, respectively.

Soft Story Index (ssi): One of the main causes of soft story formation is the reduced number of partition walls on the ground floor compared to the upper stories.

$$ssi = \frac{H_1}{H_2} = \frac{first\ storey\ height}{second\ storey\ height} \quad (11)$$

Overhang Ratio (or): The region extending beyond the outermost frame lines on all sides of a conventional floor plan is referred to as the overhang area.

$$or = \frac{A_{over}}{A_{gf}} = \frac{summation\ of\ overhang\ area}{ground\ storey\ area} \quad (12)$$

3. Result and discussion

3.1. Level I survey.

3.1.1. Number of Stories

The most dominant damage generating parameter is the number of stories, which is defined as the total number of distinct floor systems above ground level where the moments of inertia and cross-sectional areas of the vertical elements are calculated. Almost most of the structures in the research zone are residential. In the instance of the Level I survey, 79 RC buildings on the HSTU campus were surveyed. There are one, two, three, four, and five-story buildings among the 79 structures. Buildings with more than seven stories are not countable under this method. There are 33 one-story buildings, 11 two-story buildings, 9 three-story buildings, 19 four-story structures, and 7 five-story buildings. The various numbers of stories are depicted in a bar diagram in Figure 2, and their percentages are depicted in a pie chart in Figure 3.

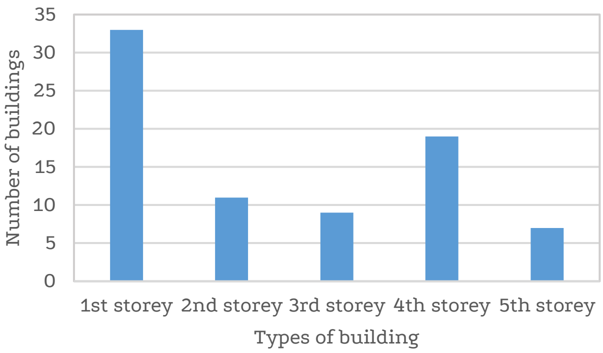

Figure 2. Different buildings building in study area

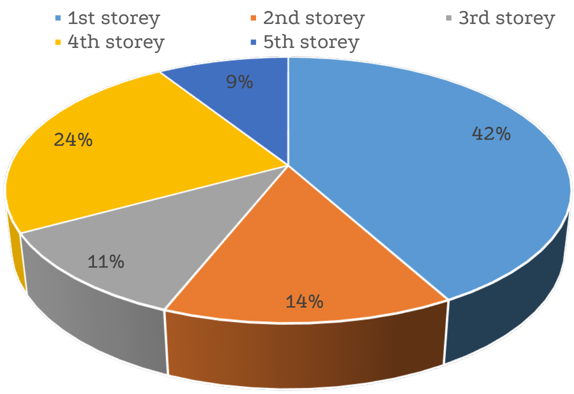

Figure 3. Percentage of different number of stories.

Figure 3 shows among total 79 buildings 42% are 1st storied, 14% are two storied, 11% are three storied, 24% four storied and 9% are five storied.

3.1.2. Soft Story

A soft story building is a multi-story structure with windows, broad doors, vast unobstructed commercial spaces, or other openings where a shear wall would ordinarily be necessary for stability due to earthquake engineering design. A soft story building is one that has 70% less stiffness than the floor above it. Only one building, a two-story building, was discovered to have a soft story problem out of the total of 79.

3.1.3. Heavy Overhanging

Heavy balconies and overhanging floors in multistory reinforced concrete buildings transfer the mass center upwards, resulting in increased seismic lateral stresses and overturning moments during earthquakes. In the event of a walk-down survey, heavy overhanging was considered for lengths greater than 4 feet. About 57% of buildings are four storied occupied to heavy overhangs problem (Figure 4).

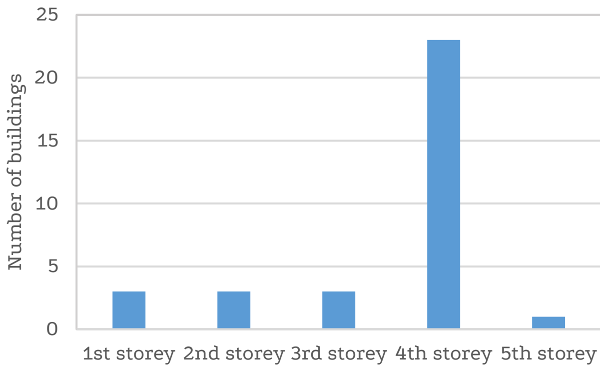

Figure 4. Buildings with overhanging.

3.1.4. Short Column

Frames with partial infills result in the construction of short columns, which experience significant damage since they are not built for the high shear forces caused by decreased heights caused by a major earthquake. Because of the existence of short columns, earthquakes can cause significant damage to many buildings. As illustrated in Figure 5, a total of 34 structures are discovered to be prone to short columns, with 8 being one story, 2 being two stories, 5 being three stories, 13 being four stories, and 6 being five stories. In the study region, many structures are occupied by short column problems, with 38% short columns in four-story buildings, 23% in one-story buildings, 6% in two-story buildings, and 18% in five-story buildings.

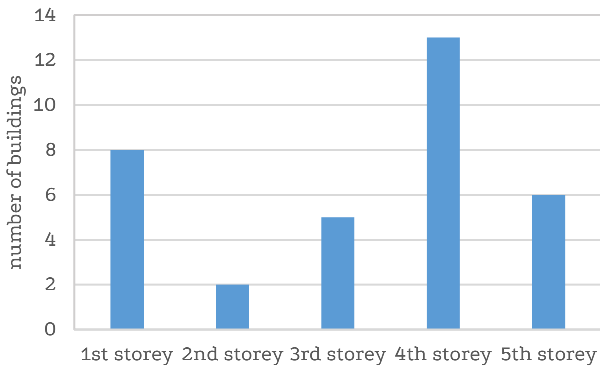

Figure 5. Number of buildings with short columns.

3.1.5. Pounding Possibilities

When there is insufficient space between nearby structures, this is referred to as pounding possibilities. Damage from pounding has been observed following practically every seismic event. During an earthquake, they pound each other due to differing vibration durations. We discovered no buildings with pounding potential in the study region.

3.1.6. Apparent Quality of the Structure

The apparent quality of a structure is determined by visual inspection and is classified as good, ordinary, or poor. According to a visual inspection of the HSTU campus, 77 of the 79 buildings have acceptable apparent quality, three have mediocre apparent quality, and one has low apparent quality. Here, 95% of the buildings have good apparent quality, 4% have mediocre apparent quality, and 1% have low apparent quality (Figure 6).

Figure 6. Apparent Quality of the Structure.

3.1.7. Overall Survey Parameters

According to the walk down evaluation survey, 23 of the 79 buildings have a heavy overhanging problem, 34 have a short column problem, and one has a soft story problem. Pounding options are not available in certain structures. In terms of apparent quality, 75 buildings are considered good, 3 structures are considered ordinary, and only 1 building is considered poor (Figure 7).

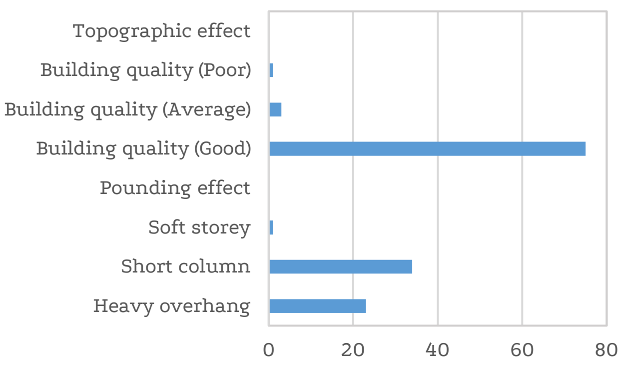

Figure 7. Vulnerability Parameters at Level I Survey

3.1.8. Summary of Level-I Survey

The walk down evaluation (level 1) survey work is divided into two sections. Building vulnerability parameters such as Heavy Overhang, Short Column, Soft Story, Pounding Effect, Building Quality, and Topographic Effect are discovered first, and then the buildings are classified as safe, moderate, or unsafe based on their seismic performance score, as shown in Figure 4.16, where all (79) buildings are classified as safe after level I work.

3.2. Level II Survey Example: R.C.C Building (ID-41)

Because all the structures were deemed to be safe in the Level I assessment, an attempt was made here to determine the vulnerability of one building. Figure 8 depicts a four-story residential (staff quarter) building on the HSTU Campus and its beam column configuration, which is a reinforced concrete construction finished with cast-in-situ reinforced concrete frames. This structure's roof and floor are reinforced concrete slabs. The plan of the building was collected for the inherent calculation. The plan and other data were kept confidential.

The following parameters are the basic estimation parameters which are calculated as below-

a. Number of Stories (n):

The total number of individual floor systems above the ground level is four. Therefore, n = 4.

b. Minimum Normalized Lateral Stiffness Index (mnlstfi):

This stiffness index indicates the lateral rigidity of the ground story, which is usually the most crucial story. For this computation, the columns and structural walls on the ground floor are taken into account. The mnlstfi parameter is calculated using equation 2.

The minimum value of total normalized moment of inertia of all members was found for Inx. Therefore, minimum normalized lateral stiffness index (mnlstfi) = 25.48.

c. Minimum Normalized Lateral Strength Index (mnlsi):

It indicates the crucial story's base shear capacity. In this index, unreinforced masonry filler walls are estimated to carry 10% of the shear stress that a structural wall with the same cross-sectional area may bear. Equation 5 is used to compute the mnlsi parameter. The calculated amount of the minimum normalized lateral strength index is (mnlsi) = 1.411

Figure 8. Exemplary building for Level II assessment.

d. Normalized Redundancy Score (nrs):

The degree of continuity of several frame lines is referred to as redundancy, which distributes lateral pressures across the structural system. Equation 10 is used to compute the nrs of a frame construction. It is calculated as 2.

e. Soft Story Index (ssi):

On the ground floor, there are typically fewer partition walls than on the upper storeys. This circumstance is one of the primary factors of soft tale development. Because the effects of masonry walls are factored into the mnlsi calculation, the soft story index is calculated using equation 11. It is found to be 1.

f. Overhang Ratio (or):

The region beyond the outermost frame lines on all sides is introduced as the overhang area in a conventional floor plan. Equation 12 can be used to get this ratio. The 'or' was found to be 0.045.

g. Performance Classification:

The performance levels of the building are evaluated using both the life safety performance classification (DILS) and the immediate occupancy performance classification (DIIO). The measures to take are outlined below.

The discriminating function in equation 13 is used to compute the damage index or damage score related to the life safety performance categorization (DILS).

$$DI_{LS} = 0.62n - 0.246mnlstfi - 0.182mnlsi - 0.699nrs + 3.269ssi + 2.278or - 4.905 \ldots\ldots\ldots\ldots\ldots (13).$$

This was found to be = $DI_{LS} = -6.96$

The discriminate function in equation 14 is used to construct the damage index or damage score related to the immediate occupancy performance classification (DIIO).

$$DI_{IO} = 0.808n - 0.334mnlstfi - 0.107mnlsi - 0.687nrs + 0.508ssi + 3.884or - 2.868 \ldots\ldots\ldots\ldots\ldots (14)$$

$$\therefore DI_{IO} = -9.15$$

Equation (15) was used to obtain the cutoff values for each performance categorisation. Table 3 is used to calculate the LSCVR and IOCVR values in Equation (16), which are based on the number of stories above ground level. The CMC values are obtained from Table 4 and are dependent on the building's proximity to the fault and the soil type at the site.

$$CV_{LS} = LS_{CVR} + |LS_{CVR}| \times (CMC - 1) \ldots\ldots\ldots\ldots\ldots (15)$$

$$\therefore CV_{LS} = 1.366$$

$$CV_{IO} = IO_{CVR} + |IO_{CVR}| \times (CMC - 1) \ldots\ldots\ldots\ldots\ldots (16)$$

$$\therefore CV_{IO} = 0.717$$

The comparison of CV and DI value performance grouplet of the building for life safety performance classification (LSPC) and immediate occupancy performance classification (IOPC) have been calculated. Here DILS < CVLS. So, performance grouping of the building for life safety performance classification (LSPC), PGLS=0 and DIIO<CVIO. So, performance grouping of the building for immediate occupancy performance classification (IOPC), PGIO=0 The indicator values of this building are “0” and “0”. So, this building lies in the “Low risk group”.

This also validates the findings of Level I assessment.

Table 3. Variation of LSCVR and IOCVR Values with Number of Stories (N)

N	LS_{CVR}	IO_{CVR}
3 or less	0.383	- 0.425
4	0.430	-0.609
5	0.495	-0.001
6	1.265	0.889
7	1.791	1.551

Table 4. Variation of CMC Values with Soil Type and Distance to Fault

Soil type	Shear wave velocity (m/s)	Distance to fault (KM)				
		0-4	5-8	9-15	16-26	>26
B	>760	0.778	0.824	0.928	1.128	1.538
C	360-760	0.864	1.000	1.240	1.642	2.414
D	180-360	0.970	1.180	1.530	2.099	3.177
E	<180	1.082	1.360	1.810	2.534	3.900

After a level I survey, all the buildings on the HSTU Campus were determined to be safe, and level II work was completed on one building alone for confirmation. It is seen that following level II work, the significant buildings are classified as safe or low risk.

4. Conclusion

The present condition of HSTU Campus in Dinajpur against earthquake is assessed by seismic vulnerability assessment method named Turkish method. The findings of this study are given below-

From this evaluation soft story in 1.27%, short columns in 43.04%, and heavy overhanging in 29.11%, pounding effect in 0% buildings have found among 79 buildings at level I survey. After the level-I survey, we found apparent building quality (Good) in 94.94% buildings, (Average) in 3.80% buildings and (Poor) in 1.27% buildings. Among 79 buildings all the buildings are found to be safe in terms of their Performance Score (PS) value after level I survey. Level II assessment has been conducted with only one building and it is for justification as all the buildings are found safe. Summarizing the level I, and level II assessment where no buildings act like unsafe reinforced concrete buildings in study area.

Declaration of Conflict of Interests

The authors declare that there is no conflict of interest. They have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1.] P. Bird, “An updated digital model of plate boundaries,” *Geochem. Geophys. Geosystems*, vol. 4, 2003.

[2.] R. Mallick, E. O. Lindsey, L. Feng, J. Hubbard, P. Banerjee, and E. M. Hill, “Active Convergence of the India-Burma-Sunda Plates Revealed by a New Continuous GPS Network,” *J. Geophys. Res. Solid Earth*, vol. 124, no. 3, pp. 3155–3171, 2019, doi: 10.1029/2018JB016480.

[3.] T. Nakata and Y. Kumahara, “Active faulting across the Himalaya and its significance in the collision tectonics,” *Act. Fault Res.*, vol. 20, pp. 7–16, 2002.

[4.] H. Sucuoglu and U. Yazgan, “Simple Survey Procedures for Seismic Risk Assessment in Urban Building Stocks,” *Seism. Assess. Rehabil. Exist. Build.*, pp. 97–118, 2003, doi: 10.1007/978-94-010-0021-5_7.

[5.] J. Edzwald and J. Tobiason, “Enhanced coagulation: US requirements and a broader view,” *Water Sci. Technol.*, vol. 40, no. 9, 1999.

[6.] A. Yakut, V. Aydogan, G. Ozcebe, and M. S. Yucemen, “Preliminary Seismic Vulnerability Assessment of Existing Reinforced Concrete Buildings in Turkey,” *Seism. Assess. Rehabil. Exist. Build.*, pp. 43–58, 2003, doi: 10.1007/978-94-010-0021-5_4.

How to Cite This Article

Mostazid, M. I., Parvi, M. S., Mahmud, A., and Nahar, N., Seismic Risk Assessment of Existing Buildings of HSTU Campus in Dinajpur, Civil Engineering Beyond Limits, 4(2023), 1887.
https://doi.org/10.36937/cebel.2023. 1887