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Earthquake vulnerability assessment in schools and colleges of Tangail municipality

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Abstract

Assessing school and college vulnerability to earthquakes can be regarded as an ill-structured problem i.e. a problem for which there is no unique, identifiable and objectively optimal solution. The study was conducted to assess the earthquake vulnerability of the schools and colleges in Tangail municipality. The study investigated the present condition of the buildings or infrastructures of the schools and colleges where some buildings or infrastructures were highly vulnerable due to old age and the rest were vulnerable due to their plan or vertical irregularity. The study showed that 58.82% infrastructures made by concrete were non-engineered and the old concrete-frame buildings were vulnerable to earthquake. If they collapse due to any seismic event, they will be comparatively more lethal and will take higher percentage of lives than the masonry structures. The study demonstrated that 15.69% school buildings were older than 30 years, 21.57% was vertically irregular and 31.37% infrastructures showed plan irregularity. By analyzing the above circumstances, 64.71% school buildings/ infrastructures are needed to detailed evaluation as early as possible to safe children and people from earthquake hazards.

Keywords: Earthquake, vulnerability, plan irregularity, vertical irregularity

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1. Introduction

Bangladesh is the most vulnerable to several natural disasters due to its geographical location, and every year natural calamities upset people's lives in some parts of the country. The destructive disasters concerned here are the occurrences of earthquake, flood, cyclone and storm surge, flash flood, drought, tornado, riverbank erosion and land slide (UNEP, 2001). Earthquake, the trembling or shaking movement of the earth is the most discussed topic among them. It is a form of energy of wave motion, which originates in a limited region and then spreads out in all directions from the source of disturbance (Banglapedia, 2008). The

1897 Great Indian earthquake with a magnitude of 8.7 affected almost whole of the Bangladesh. Damages were very severe particularly in Sylhet, Rangpur and Mymensingh. In the city of Dhaka, most of the brick masonry buildings either collapsed or were severely damaged (Oldham, 1899). Bangladesh is surrounded by the regions of high seismicity which include the Himalayan Arc and Shillong Plateau the north, the Burmese Arc, Arakan Yoma anticlinorium's in the east and complex Naga-Disang-Jaflong thrust zones in the northeast. It is also the site of the Dauki Fault system along with numerous subsurface active faults and a flexure zone called Hinge Zone (SAARC, 2011). These weak regions are believed to provide the necessary zones for movements within the basin area. According to Sharfuddin (2001), both the seismic hazard analysis and the establishment of seismic maps were made difficult in Bangladesh due to the lack of homogenous, accurate and complete data. The 1993 Bangladesh national building code has adopted a seismic zoning map consisting of three seismic zones, with zone coefficients of 0.25 (Zone 3 in the north and north-east), 0.15 (Zone 2 in the middle, north-west and south-east) and 0.075 (Zone 1 in the south west). This zoning map is based on peak ground accelerations estimated by Hattori (1979) for a return period of 200 years, where Modhupur fault is situated in Zone 2 which is not so far from the Tangail municipality (Ali and Choudhury, 1994). It is about only 40 km away from the fault, so it can be said that the infrastructure of Tangail municipality is highly vulnerable to earthquake.

There are three government colleges, seven non-government colleges, three government high school, thirty non-government high schools, one hundred and sixteen government primary schools, thirty five non-government primary schools, twelve madrasa in Tangail municipality but majority of them are very old (Banglapedia, 2008). Most of the existing schools and colleges' buildings are 2 or 3 storied reinforced concrete frame buildings with infill brick walls and 1 storied brick masonry building with reinforced concrete roofs and uses cement mortar in most of the cases. For this reason, a moderate level earthquake may create a huge damage to property and valuable lives. That is why this earthquake risk assessment was done to evaluate the existing condition of the schools and colleges in this region. School safety was given a major focus by the United Nations International Strategy on Disaster Reduction (UNISDR) when the 2006-2007 World Disaster Reduction Campaign was devoted to the theme Disaster Reduction Begins at School. This theme was chosen by United Nations International Strategy on Disaster Reduction (UNISDR) because (a) it is in line with the Priority 3 of the Hyogo Framework for Action 2005-2015: "Use knowledge, innovation and education to build a culture of safety and resilience at all levels, and (b) schools are the best venues for forging durable collective values; and therefore suitable for building a culture of prevention and disaster resilience (UNISDR, 2009).

From Bangladesh's perspective, school infrastructures are the most vulnerable during disasters due to poor construction, lack of proper maintenance and many other issues related to the schools and colleges. Moreover, as a result of the rapid urbanization and over population in urban areas, schools and colleges are growing in an unplanned way to accommodate students in the education system. As a result, vulnerability is increasing in education sector and safety of the students is becoming questionable day by day. Considering all these, school safety has become an issue of major priorities to make schools safer for the well being of our next generation. In the study, the earthquake vulnerability of schools and colleges in this region was identified to evaluate the existing condition of the schools and colleges.

2. Materials and Methods

The study was conducted to know the earthquake vulnerability assessment of schools and colleges at Tangail municipality in Tangail district, Bangladesh. Tangail municipality is the central part and the most crowded area of Tangail district. For completing the study, 51 educational institutions including 20 primary schools, 17 high schools, 2 madrasa and 12 colleges in Tangail municipality was selected because most of the schools and colleges are situated in urban areas where population density is so high. These infrastructures are vulnerable to earthquake due to rapid urbanization and also as the educational institutions are not following the building code and many of them are more than 100 years old. Moreover, the institutions are just 40 km away from the Modhupur fault which is an active fault.

The research work was done on the basis of Rapid Visual Screening (RVS) of Buildings for Potential Seismic Hazards (PSH) method. To perform with this method, at first a data collection form was selected which known as FEMA-154 data collection form (Fig. 1). The data collection form was completed for each building screened through execution of the following steps: a) verifying and updating the building identification information, b) walking around the building to identify its size and shape, and sketching a plan and elevation view on the data collection form, c) determining and documenting occupancy, d) determining soil type, e) identifying the seismic lateral-load resisting system (entering the building, if possible, to facilitate this process) and circling the related Basic Structural Hazard Score on the data collection form, f) Seismic Performance Attribute Score Modifiers (e.g., number of storeys, design date, and soil type on the data collection form), g) determining the final score, S (by adjusting the basic structural hazard score with the score modifiers identified in step g) and deciding if a detailed evaluation is required, and h) photographing the building and attaching the photo to, or indicating a photo reference number on, the form. The masonry building structures have more than seven storeys, and those schools that have no permanent educational building were excluded from the present assessment.

3. Results and Discussions

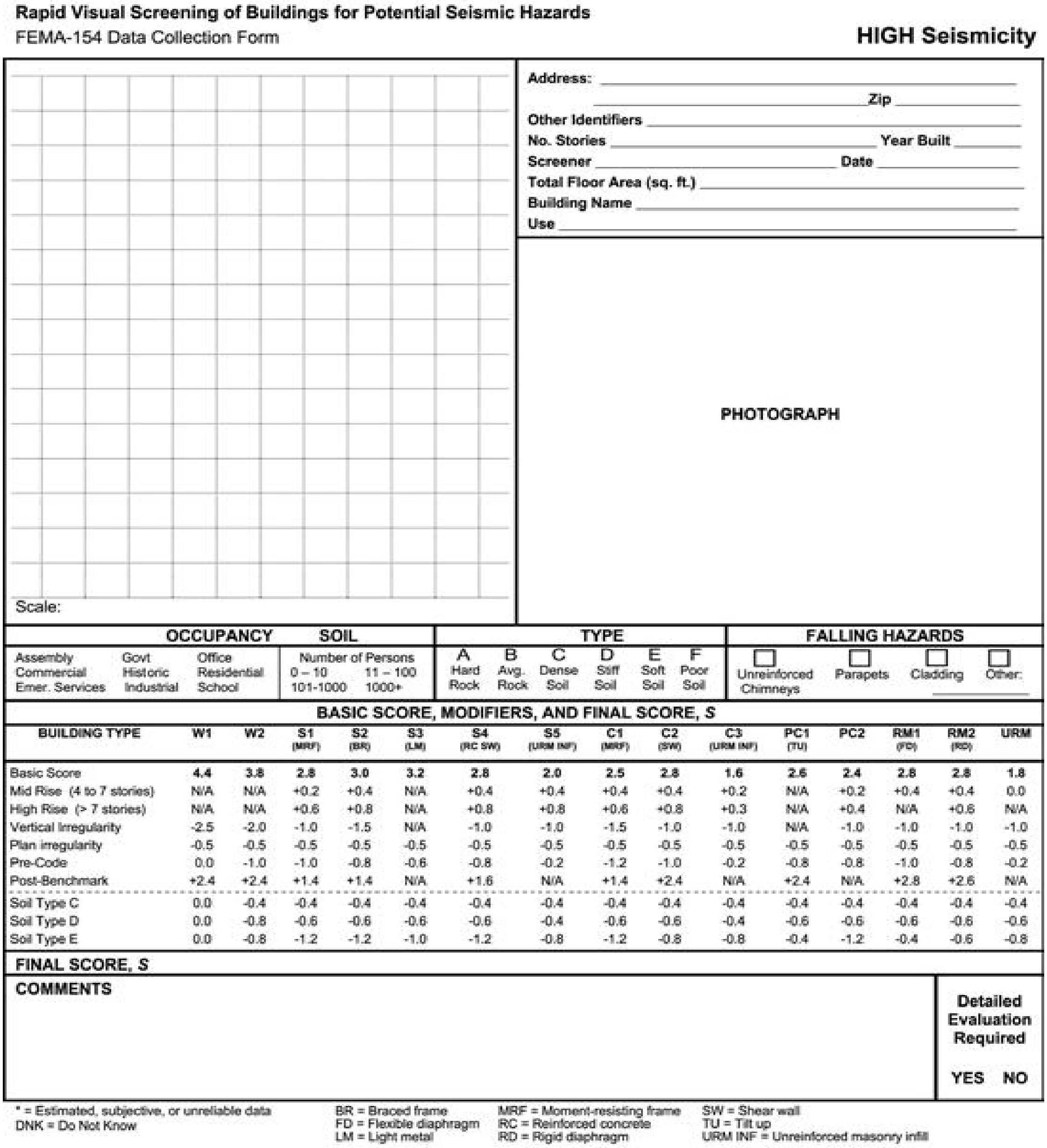
3.1 Types of Infrastructures

In the study, three types of infrastructures were found: wooden, concrete and masonry. Among them 23.52, 58.82 and 17.65% were wooden, concrete and masonry, respectively. The percentages goes higher towards the concrete building because people thought that it is more reliable against various types of disasters and has a sustainable utilization, but it is also found that low quality or old construction may also be great deadly for school student (Fig. 2). According to OECD (2004), a primary school in San Giuliano, Italy, collapsed during Earthquake, killing 29 children and one teacher in 2002.

It is observed from the study that numbers of wooden buildings are not modest amount in this area which is comparatively safer than old concrete and masonry construction. Thus, strong infrastructure plays important role as an earthquake resistor and reduce damage during earthquake.

3.2 Epoch (age) of Infrastructures

Most of the school buildings of the study area were very old. Many of them, e.g. Santosh Zanbhi High School, were built in British Period. From the study, 7 (13.73%) buildings were less than 10 years old, 19 (37.25%) buildings were less than 20 years old, 17 (33.33%) buildings were less than 30 years old and 8 (15.69) buildings were found more than 30 years old. Hays et *al*. (1998) found that with the passage of time buildings loss their lateral resistance and turn into more vulnerable to an earthquake. It is revealed from the study that 15.69% visited educational institutions were built about more than 30 years ago that have followed low construction standards (Fig. 3). They are vulnerable to earthquake and age related decay compel then to fall a victim to seismic vibration. Many of older buildings also showed vertical and plan irregularity whereas some of the new buildings and infrastructures have also not been sited, designed, and constructed with adequate enforcement of modern, state-of-the-art building regulations, lifeline standards, and land use ordinances.


Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA-154 Data Collection Form

HIGH Seismicity

Address: ____________________
____________________ Zip ________
Other Identifiers ____________________
No. Stories ____________________ Year Built ________
Screener ____________________ Date ________
Total Floor Area (sq. ft.) ____________________
Building Name ____________________
Use ____________________

PHOTOGRAPH

Scale:

OCCUPANCY			SOIL	TYPE	FALLING HAZARDS
Assembly Commercial Emer. Services	Govt Historic Industrial	Office Residential School	Number of Persons 0 – 10 11 – 100 101-1000 1000+	A Hard Rock B Avg. Rock C Dense Soil D Stiff Soil E Soft Soil F Poor Soil	☐ Unreinforced Chimneys ☐ Parapets ☐ Cladding ☐ Other:

BASIC SCORE, MODIFIERS, AND FINAL SCORE, S

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	4.4	3.8	2.8	3.0	3.2	2.8	2.0	2.5	2.8	1.6	2.6	2.4	2.8	2.8	1.8
Mid Rise (4 to 7 stories)	N/A	N/A	+0.2	+0.4	N/A	+0.4	+0.4	+0.4	+0.4	+0.2	N/A	+0.2	+0.4	+0.4	0.0
High Rise (> 7 stories)	N/A	N/A	+0.6	+0.8	N/A	+0.8	+0.8	+0.6	+0.8	+0.3	N/A	+0.4	N/A	+0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.0	-1.5	N/A	-1.0	-1.0	-1.5	-1.0	-1.0	N/A	-1.0	-1.0	-1.0	-1.0
Plan irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0.0	-1.0	-1.0	-0.8	-0.6	-0.8	-0.2	-1.2	-1.0	-0.2	-0.8	-0.8	-1.0	-0.8	-0.2
Post-Benchmark	+2.4	+2.4	+1.4	+1.4	N/A	+1.6	N/A	+1.4	+2.4	N/A	+2.4	N/A	+2.8	+2.6	N/A
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.4	-0.6	-0.6	-0.4	-0.6	-0.6	-0.6	-0.6	-0.6
Soil Type E	0.0	-0.8	-1.2	-1.2	-1.0	-1.2	-0.8	-1.2	-0.8	-0.8	-0.4	-1.2	-0.4	-0.6	-0.8
FINAL SCORE, S															

COMMENTS

Detailed Evaluation Required
YES NO

* = Estimated, subjective, or unreliable data
DNK = Do Not Know
BR = Braced frame
FD = Flexible diaphragm
LM = Light metal
MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm
SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

Fig. 1. FEMA-154 data collection form used in the study (FEMA, 2002)

3.3 Number of Storeys of the Infrastructures

Height of the building is important as it is directly related to the weight of the structures and their response to ground motion. The natural frequency of building is low for tall buildings and high for short buildings. From the study it is revealed that 37.25, 23.53, 21.57 and 11.76% infrastructures were 1, 2, 3 and 4 and above 4 stored, respectively (Fig. 4). Short buildings tend to collapse or experience damage when amplification is higher in high frequency domain and tall buildings experience damage when amplification is higher in low frequency domain that means the safety of building depends on its resonance.

According to BIS (2002), one and two storeys buildings have physical frequency of 10 and 5, respectively, whereas 3 to 5 storeys buildings have frequency of 2.

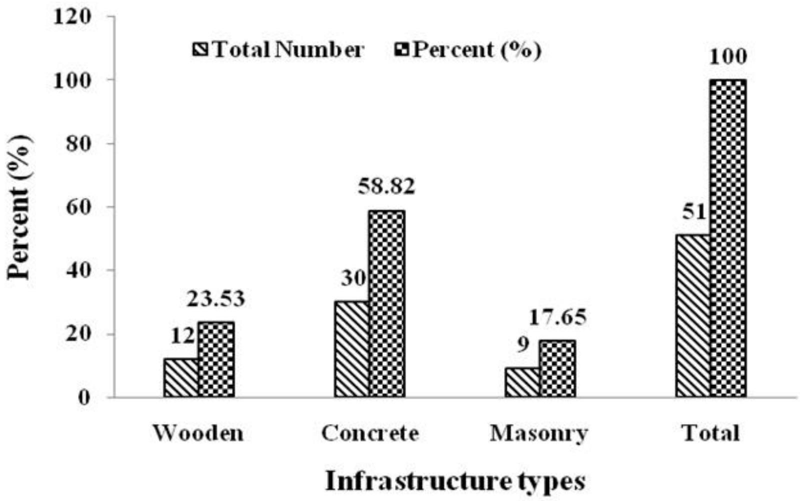


Fig. 2. Types of infrastructures of schools and colleges in Tangail municipality

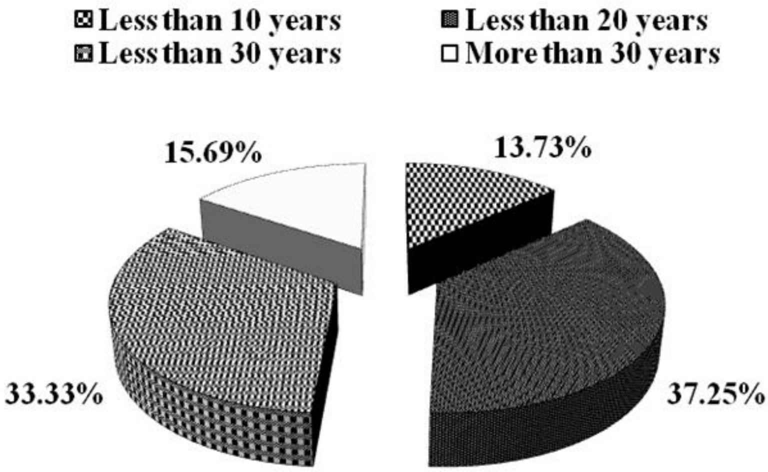


Fig. 3. Epoch (age) of the infrastructures of schools and colleges in Tangail municipality

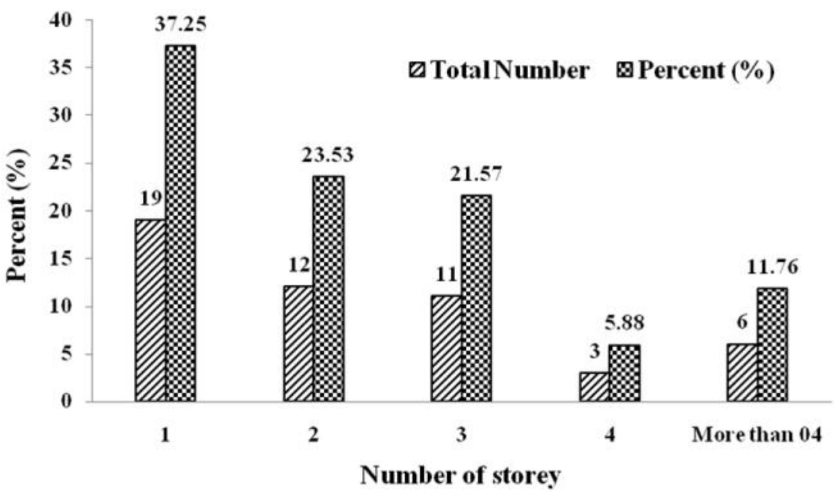


Fig. 4. Storeys of the infrastructures of schools and colleges in Tangail municipality

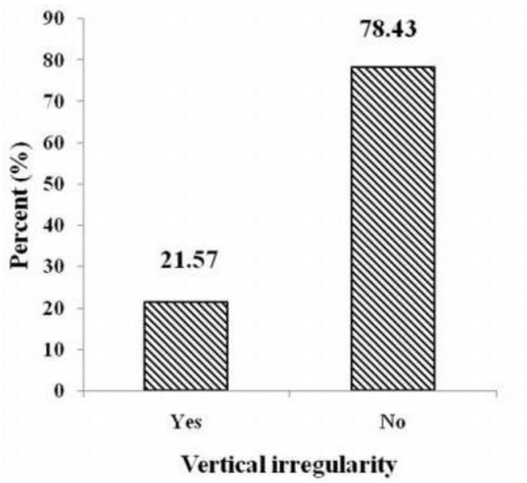
3.4 Plan Irregularity

The buildings appearing to be E, L, T, U, or + shaped show plan irregularity, whereas square shaped building has no plan irregularity for what they are more strong in structure. From the study it was found that 31.37% of the infrastructures had plan irregularity which may fall in as victim to earthquake and other 68.63% had no plan irregularity (Fig. 5). Plan irregularity often results in shape irregularity. It is an unfavorable feature of buildings. The shapes determine the probability of damage in specific parts or storeys of a building which may even cause collapse.

According to Herrera and Soberón (2008), it is observed from seismic events during 1980 to 2008 that the building damaged causes due to plan irregularities. McCrum (2012) found that the effect of strength eccentricity on the seismic response of plan irregular structures needs further investigation and increasing the strength of a lateral force resisting element in the infrastructure.

3.5 Vertical Irregularity

Structures having significant physical discontinuities in vertical configuration or in their lateral force resisting systems are termed as vertically irregular structure. Vertical irregularity plays an important role in the earthquake vulnerability detection of the buildings.



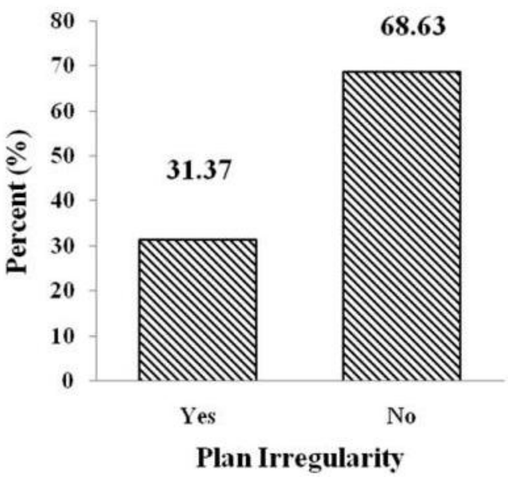


Fig. 5. Plan irregularity of the infrastructures of schools and colleges (left) and the vertical irregularity of the studied infrastructures (right)

FEMA (2012) showed that vertical irregularity includes buildings with setbacks, hillside buildings, and buildings with soft storeys. The observed 21.57% infrastructures have vertical irregularity that results from the uneven distribution of mass, strength or stiffness along the elevation of a building structure and other 78.43% infrastructures have no vertical irregularity (Fig. 6). Mass irregularity results from a sudden change in mass between adjacent floors, such as mechanical plant on the roof of a structure, where stiffness irregularity results from a sudden change in stiffness between adjacent floors, such as setbacks in the elevation of a building. SAARC report (2011) explained that vertical irregularity particularly is considered a serious weakness and the corresponding score modifier is negative for all building types with a recommendation for detailed evaluation.

3.6 Detailed Evaluation

On the basis of the final score, S, it is measured that detailed evaluation of the infrastructure is needed or not. If the value is 2 or more than 2 then no need to detailed evaluation. But if the value is less than 2, then the infrastructure should be evaluated in details (the value varies from country to country). According to Wang and Goettel (2007), a final score, S, of 2.0 means that the calculated probability of building collapsed at the maximum considered earthquake is 10^{-2} or 0.01 i.e., 1% chance of collapse, where a building with a final score of 3.0 has a factor of 10 times lower probability of collapse than does a building with a final score of 2.0. Similarly, a building with a final score of 1.0 is 10 times more likely to collapse than a building with a final score of 2.0. From the study, 33 out of 51 infrastructures (64.71%) were needed for detailed evaluation due to low final score of S and vertical irregularity with plan irregularity, and others 18 (35.29%) infrastructures didn't need detailed evaluation (Fig. 6). According to SAARC report (2011), if any of these irregularities (plan and vertical irregularity) are noticed, the building may undergo much more severe damage even up to Grade 4 or 5 and should be recommended for detailed.

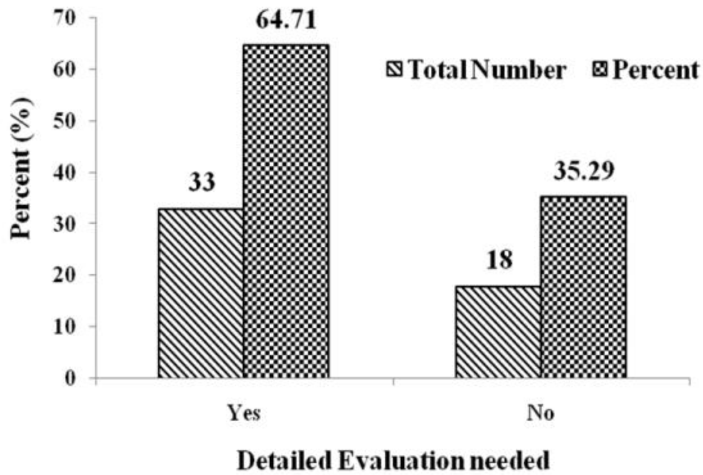


Fig. 6. Detailed evaluations of the infrastructures is needed or not to needed

4. Conclusions

Some of the schools and colleges in Tangail municipality were new and earthquake resistant. In contrast more than half of the buildings were made of concrete, but most of the buildings were ancient and visually they need further evaluation, some of them were built in British Period. Modern engineering concrete-framed buildings were generally safer than non engineering infrastructures because old buildings are devoid of modern engineering technology for what their architectural longevity is vulnerable as they sometimes collapse due to earthquake or other natural forces. The ultimate result of the fault line in architectural activity is considerably more lethal which kills higher percentage of people than masonry structures. The worst victims will be the school and college students. The observation found that the majority of the buildings were more than 20 years old and were not appropriately followed plan irregularity and vertical irregularity.

Seismic Performance Attributes Score Modifiers showed that most of the infrastructures were needed detailed evaluation to reduce the vulnerability of earthquake and vulnerable buildings or infrastructures should be replaced by new earthquake resisting buildings; and occupancy load would be maintained in every building.

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