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SEISMIC VULNERABILITY ASSESSMENT OF EXISTING BUILDINGS IN URBAN AREA

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Abstract

Dhaka city, for its geo-tectonic circumstances, is at high risk of the earthquake which has been intensified by the chaotic urban growth and poor construction of structures. Seismic risk assessment of urban areas includes analysis of the level of earthquake hazard of the building vulnerability and exposure. In case of a moderate to the robust level earthquake, the incurrence of damage might be enormously severe and extensive. This study will assess the seismic vulnerability of Ward no. 30 in Dhaka North City Corporation which is an area in the north part of the city and assumed as a probable risk area for any earthquake event as most of the area has been developed on low-land area and situated beside the river bank. Dhaka city has two city corporations- Dhaka North City Corporation and Dhaka South City Corporation. Ward 30 is one of the 36 wards in Dhaka North City Corporation, selected for study based on high number of households, mix of planned and unplanned area, availability of open space for temporary shelters and mixed land use. In this study analysis will be done according VR (Visual Rating) method using spatial analysis in ArcGIS to find the vulnerability of buildings so that further initiatives could be taken to reduce the negative impact of earthquake hazard of this area. Seismic vulnerability assessment of existing buildings may facilitate the required solutions and policy measures which may reduce the levels of structural damage, mass causality and financial loss of probable seismic hazards. The seismic performance index I_s will be calculated from the parameters of no of stories, building use, total floor area, wall area etc., which will calculate the column area ratio and the wall area ratio. After that from the secondary source the damage ratio will be collected. It will be compared with the seismic performance index I_s for further analysis to obtain the categories of the high-risk group and low risk group, moderate risk group of buildings.

Keywords: Visual Rating (VR) method; Seismic Performance Index; Vulnerability Assessment; Damage Ratio

1. Introduction

Bangladesh is no longer free from any possibilities of extreme earthquake. It is perhaps one of the country's most susceptible to possible earthquake risk and damage. Dhaka city is beneath the looming risk of cataclysmic earthquake. Some researchers suspected that if an earthquake with magnitude 6.5 occurs, about 60% structures of Dhaka city will be demolished [1, 2]. The earthquake threat at any vicinity relies upon on the seismic hazard as well as the vulnerability of its structures. The seismic hazard assessment considers the probability of earthquake of a specific magnitude or depth affecting a site, and the assessment of seismic hazard in any city requires appropriate consideration of the strength of possibly earthquakes in future [3]. Capital city Dhaka, is the most highly populated cities of the world. But its development is now not going planned. Due to fast urbanization process and excessive density of population it is susceptible to earthquake in latest years. So, the threat of extreme damage in Dhaka from earthquake is high [4, 5].

The assessment of the seismic hazard of urban areas is related to the degree of earthquake hazard, constructing vulnerability and level of exposure [6]. So seismic risk, building vulnerability is from all three variables, the one that assumes exceptional significance no longer solely due to the fact of its apparent physical consequences in the incidence of a seismic event, however due to the fact it is the potential aspect, for which the engineering research can intervene, enhance and even manage seismic behavior of existing buildings, decreasing the degree of vulnerability and therefore the degree of physical damage, life loss and economical loss [5, 7]. Development of vulnerability research in city areas can be performed aiming to identify building risk and minimize the seismic risk. The seismic hazard for Bangladesh has recently been quantified [8]. The seismic vulnerability, on the other hand, relies upon on the building practice in the city and is associated to quality of building inventory [9]. Vulnerability is described as the degree of loss to a given component or set of factors ensuing from the incidence of a natural catastrophe [10, 11]. For a densely populated city like Dhaka, the situation is greater at threat as the structures of the capital are built following the local practices and are now not much resistant to a robust natural hazard. Moreover, small to medium depth earthquake shook the capital a number of instances in these years [8]. The need to predict the seismic vulnerability of existing buildings has led to an enlarge interest on research dealing with the improvement of seismic vulnerability assessment of existing RC buildings.

Due to the concentration of both job amenities and different investments, Dhaka city has been experiencing a population boom of 6.5% every year [1, 12]. The city is recognized as an earthquake threat susceptible city due to geological and geomorphological set-up, indiscriminate and unplanned development of buildings. A study revealed that the Earthquake Vulnerability Index (EVI) of Dhaka city (1997) is 2nd amongst 20 vulnerable cities of the world [1]. The elements of estimating such vulnerability where the population density, unplanned urbanization, non-compliance of building codes, narrow road network, lack of preparedness of the responding organizations and insignificant consciousness amongst city dwellers and decision makers. In current times, the collapse or tilting of a proper quantity of high-rise buildings is taking place in Dhaka city due to non-engineered constructions of the buildings. Even Detailed Area Plan (DAP) of the city did not reflect on consideration of hazard sensitive land use planning [13].

2. Aim and Objective of the Study

The main aim of the study is to identify efficient and effective urban planning strategies to make cities safer and resilient against disaster specially for earthquake vulnerability assessment in the Dhaka city. For conducting this study following research question must be solved that "How the level of seismic vulnerability can be assessed in the study area?". To answer the research question the specific objectives of the study are as follows:

- To explore present scenario of study area.
- To assess the seismic risk of earthquake vulnerability in the study area.

3. Methodology

In this research, analysis was done according VR (Visual Rating) method using spatial analysis tool in ArcGIS to find the vulnerability of buildings so that further initiatives could be taken to reduce the negative impact of earthquake hazard of this area. The seismic performance index I_{vr} will be calculated from the parameters of no of stories, building use, total floor area, wall area, column area, span length, concrete wall ratio etc., which will calculate the column area ratio and the wall area ratio [1]. After that from the secondary source the damage ratio will be collected. It will be compared with the seismic performance index I_s for further analysis to obtain the categories of the high-risk group and low risk group, moderate risk group of buildings.

4. Visual Rating Method

The simplified seismic capacity index is calculated considering column area ratio, RC wall area ratio, masonry wall area ratio and their average shear strength. Since the proposed method is based on visual inspection, this visual rating method approximately estimates column area ratio, RC wall area ratio and masonry infill area ratio by more simplified way thorough visually investigation [14]. Therefore, the simplified seismic capacity index of existing buildings is referred as Visual Rating Index (I_{vr}) which is expressed by following Equation 1.

$$\mathrm{I_{VR}} = \frac{1}{\mathrm{n.w}}[\pi_c . \mathrm{I_c} + \pi_{inf} . \mathrm{I_{inf}} + \pi_{cw} . \mathrm{I_{cw}}] \qquad (1)$$

Where, $I_C = Column\ area\ ratio,\ I_C = \frac{A_c}{A_f} \approx \frac{b^2{}_c}{l_s^2}$

I_{Cw} =RC wall area ratio, $I_{Cw} = \frac{A_{cw}}{A_f} \approx \frac{t_{cw}}{l_s} . R_{cw}$

I_{inf} = masonry infill wall area ratio, $I_{inf} = \frac{A_{inf}}{A_f} \approx \frac{t_{inf}}{l_s} . R_{inf}$

So, the Visual Rating Index (I_{VR}), the equation can be written as follow as equation 2

$$I_{VR} = \frac{1}{n.w}[\ \pi_c(\frac{b_c^2}{l_s^2})\ +\ \pi_{inf}(\frac{t_{inf}}{l_s} . R_{inf}) + \pi_{cw}(\frac{t_{cw}}{l_s} . R_{cw})] \qquad (2)$$

n= number of stories of the building

w= Average unit weight per floor area

b_c=average column size

l_s = average span length

t_{inf}=thickness of masonry infill

R_{inf}=Masonry infill ratio

t_{cw}= thickness of concrete wall

R_{cw}=concrete wall ratio

After considering the influence of some strength modification parameters, the VR index in the Equation 3 can be expressed as:

$$I_{VR} = \frac{1}{n.w}[\ \pi_c(\frac{b^2{}_c}{l^2{}_s})\ +\ \pi_{inf}(\frac{t_{inf}}{I_s} . R_{inf}) + \pi_{cw}(\frac{t_{cw}}{I_s} . R_{cw})]\ F_{IV} . F_{IH} . F_D . F_Y \qquad (3)$$

Where, F_{IV}, F_{IH}, F_D and F_Y are the modification factors for existence of vertical irregularity, horizontal irregularity, and deterioration of concrete and year of construction respectively.

5. Existing Situation of the Study Area

The study area in Adabar ward no. 30 of Dhaka North City Corporation (DNCC) is situated in the middle of the Dhaka city and most densely populated with 1,86,639 people [15]. It is one of the most densely populated wards covering residential and commercial areas. Total buildings in this study area are 7,467 covering an area of 2,338 square meter [16]. By snow ball sampling on basis of building age and building height categories 37 buildings were analyzed for the vulnerability assessment.

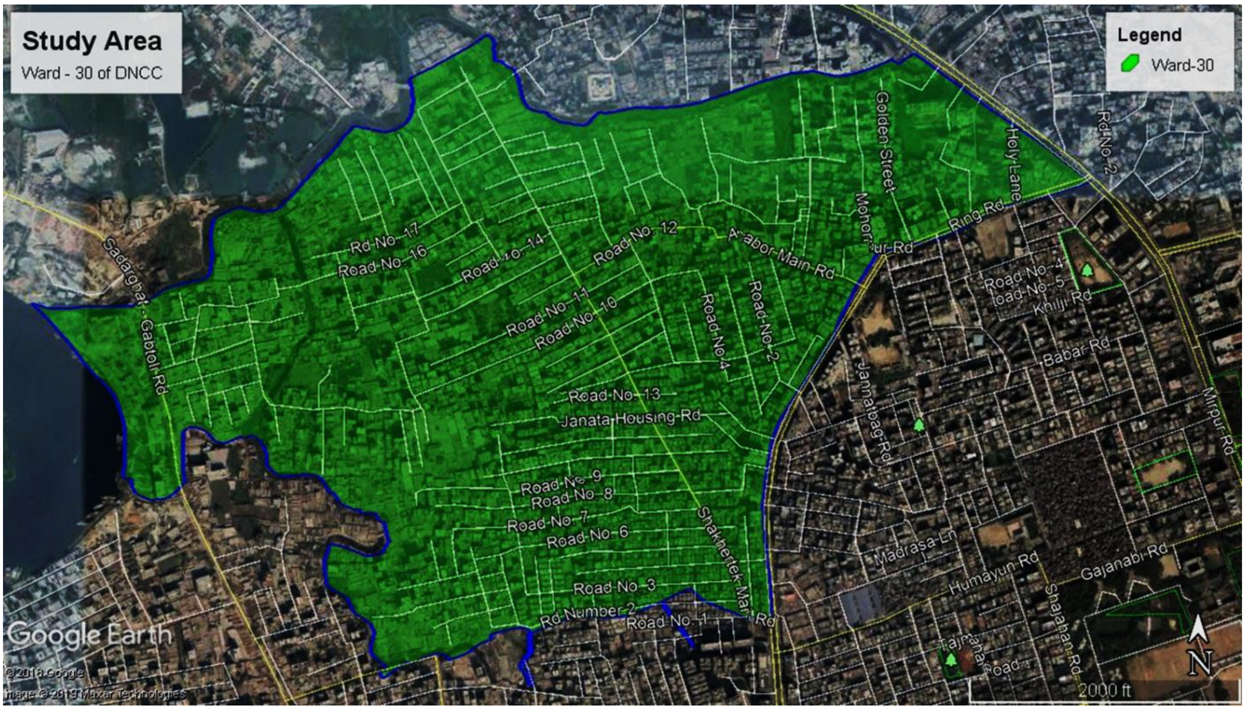

Fig. 1 – Location map of the study area

In the Visual Rating (VR) method which a modified visual screening method that is specially designed for implementing in the build-up environment of the assessment [14]. Maintaining the shortcomings of visual screening methods which not considering the variation of the cross-sectional area of structural elements (i.e. RC wall, column, masonry infill, etc.), the Visual Rating (VR) method has been selected to conduct this study. It is possible which structures are Pucca and the building height is between 2 storied to 6 storied. The use of the buildings is also mixed with a large variety like for residential, commercial, community facilities, industrials, mixed use and others.

The study area had been expanded haphazardly without considering disaster risk management issue. Specially, most of the low-lying areas adjacent to the ward no 30 are being filled which are most vulnerable for earthquake hazard like liquefaction. It has a high density of population which makes the area more vulnerable in terms of disaster like earthquake. As it is near the bank of the Buriganga river, the development was done filling the river side low land which is mixed with silty sand and soft soil. The different housing societies were developed after 1990s in this area which also indicates that most of the buildings were built during last two decades indicating rapid urbanization and development of this study area [17]. If it is possible to incorporate the soil characteristics with building vulnerability, this study could give a profound idea of vulnerability of the spatial aspect of the study area. Due to time limitation and shortage of soil data it was not possible to conduct the in-depth study.

From the Revised Detailed Area Plan (DAP) of Dhaka, prepared by Rajdhani Unnayan Kartipakkha (RAJUK) updated the Geographic Information System (GIS) database for the whole city. The base map was collected from that. From the following figure 2, it is clear that the study area has a good mixed storied building. Among those buildings, 37 buildings were assessed through snow bowling with the help of the local community leaders and the volunteers of disaster risk reduction and mitigation.

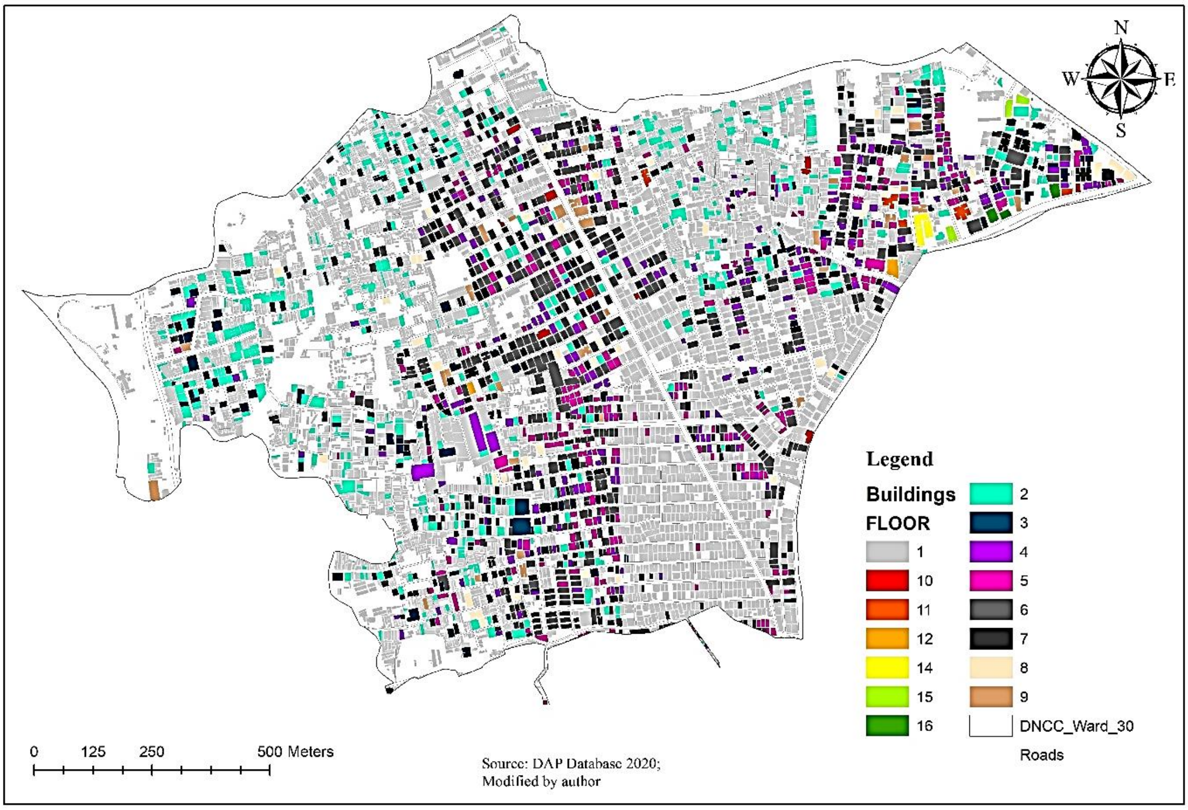

Fig. 2 – Existing Situation of buildings of the study area

6. Assessment of Seismic Vulnerability of the study area

The judgment criteria and ranges had been proposed according to the Visual Rating Index (I_{VR}) as shown in Table 1. In the proposed criteria, buildings are to be categorized into 5 (five) classes such as A, B, C, D, and E describing the different levels of seismic vulnerability depending on Visual Rating Index (I_{VR}) [14]. Category A and B indicate that the buildings located at these zones, are considered as less vulnerable buildings during earthquake. On the other hand, buildings located at category C, D and E are regarded as the most vulnerable buildings.

Table 1 – Boundaries for Visual Rating Method

Range of each categories	Categories	Description
$0.26 \leq I_{VR}$	*A*	No Possibility of Damage
$0.24 \leq I_{VR} < 0.26$	*B*	Light Possibility of Damage
$0.16 \leq I_{VR} < 0.24$	*C*	Less Possibility of Collapse to Damage
$0.10 \leq I_{VR} < 0.16$	*D*	Moderate Possibility of Collapse
$I_{VR} < 0.10$	*E*	High Possibility of Collapse

Source: Islam M S, Alwashali H, Sen D, Maeda M (2019)

Applying this method, the vulnerability index (I_{VR}) of the study area is as following figure 3 showing the ranges-

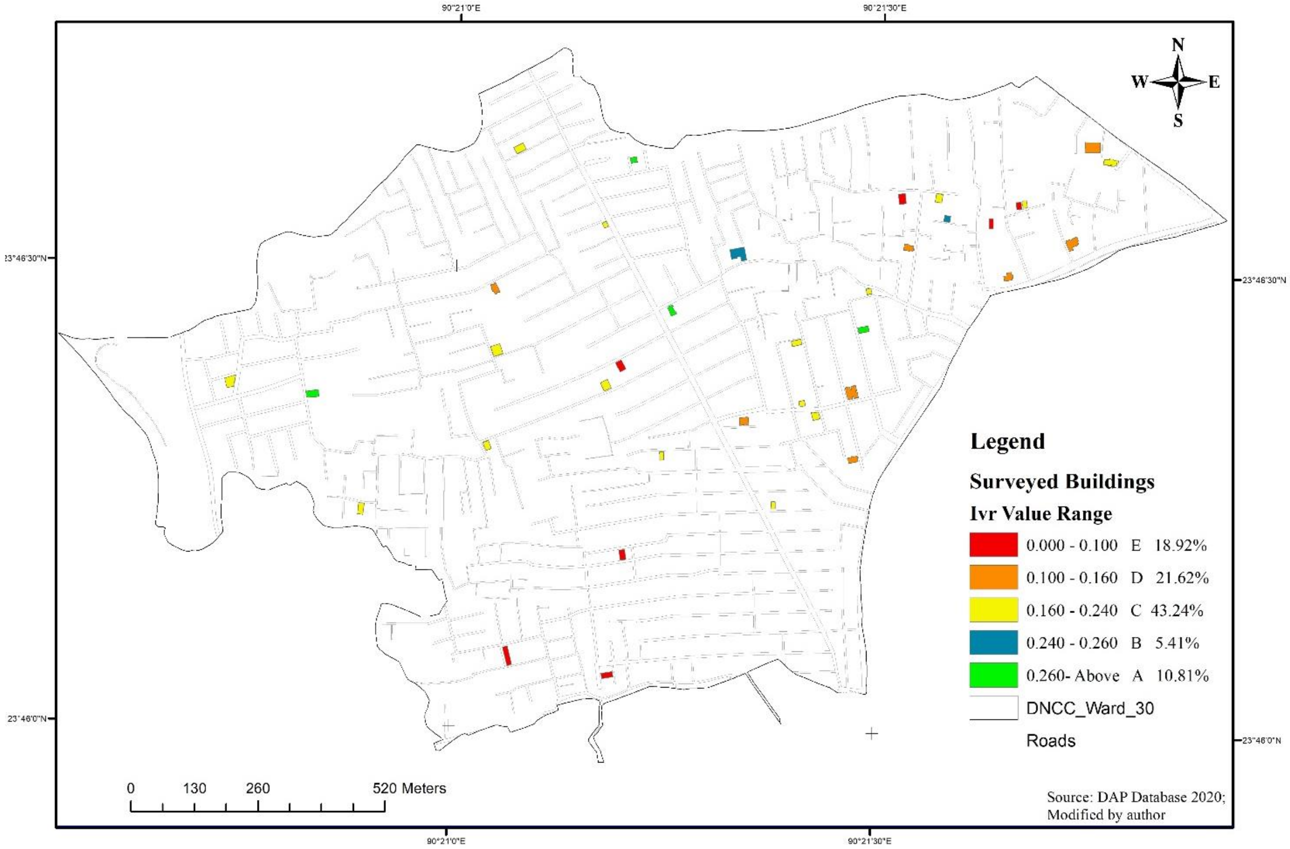

Fig. 3 – Map of Visual Rating Index of Ward-30 DNCC

The value of each boundary for each class are proposed based on simplified study and seismic evaluation of existing RC buildings in Bangladesh. The buildings with Visual Rating Index (I_{VR})less than 0.24, are classified as C, D and E and those buildings are regarded as might be the seismically vulnerable and might be have possibility to collapse during earthquake [14]. From the study about 43.24% buildings have less possibility of collapse, 21.62% buildings have moderate possibility of collapse. Besides, the existing buildings consisting of much lower Visual Rating Index (I_{VR}) (such as I_{VR}<0.10) are classified into E category, have been categorized as the most vulnerable buildings and those buildings are to be considered as higher priority for detail seismic evaluation comparing with other classes. Near about 10.81% buildings have the highest possibility of collapse during earthquake. On the other hand, the buildings with higher I_{VR} (I_{VR} is larger than 0.24) indicating that those buildings might not have severely possibility of damage during earthquake. Almost 5.41% buildings have been identified with light damage possibility and 10.81% has no damage possibility. Detail evaluation is not urgently required for those buildings with higher VR index.

7. Conclusion

Rapid urbanization without proper planning and unregulated population migration have created zones in Dhaka city where the earthquake hazard is quite elevated. In a disaster like a medium-sized earthquake in or around Dhaka, the catastrophic effects would be unthinkable. This paper examines housing structures and vulnerability factors in Dhaka city in order to facilitate earthquake preparations. This study presents significant findings to help identify housing structures towards earthquake vulnerability of Dhaka city which resulted that near 43.24% of buildings have less possibility of collapse but still vulnerable. It can be concluded that this study will provide valuable information about the building vulnerability of the Dhaka city to conduct in-depth study to contribute to the decision-making process and helping to achieve the goal of developing effective and efficient urban planning strategies for earthquake resiliency of urban areas.

8. Acknowledgement

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