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Seismic Vulnerability Assessment of Existing Building Stocks at Chandgaon in Chittagong city, Bangladesh

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Abstract: The draft of Bangladesh National Building Code (BNBC)-2012 has been updated the seismic coefficient of 0.28g (with Zone III) for Chittagong region, which is larger than the previous of 0.15g (with Zone II). Chittagong is the largest port city and commercial capital of Bangladesh, which has many development activities as like of planned residential areas. Although BNBC code is up-to-date with earthquake provisions since 1993 with interpreting several new clauses and provisions, but in case of pre-code revision structures it is quite unsafe. Thus it is quite impossible to reduce earthquake damage without considering the safety of pre-code revision structures. In this regards earthquake vulnerability of Chandgaon Residential Area(R/A) has been assessed on the basis of potential structural vulnerability of more than 300 buildings. Initial results reveal that there have large varieties of construction practices, however, predominantly RCC structures were found. RVS score of these structures reveal that in general buildings are of minimum quality and further evaluation and strengthening of buildings is recommended. Walk down evaluation encountered several factors which were responsible for comparatively lower range of vulnerability scores.

Keywords: Chandgaon, BNBC, RVS, FEMA, Soft Story, Short Column

1. Introduction

For providing seismic safety in building structures need to ensure their conformance to the current seismic design codes which is a valid approach for new buildings. However majority of the existing buildings in seismic environments do not satisfy modern code requirements. The need to predict the seismic vulnerability of existing buildings has led to an increase interest on research dealing with the development of seismic vulnerability assessment of existing RC buildings. In case of Bangladesh which is possibly one of the country's most vulnerable to potential earthquake threat and damage. An earthquake of even medium magnitude on Richter scale can produce a mass damage without any previous notice in major cities of the country, particularly Dhaka and Chittagong.

Earthquake vulnerability of any place largely depends on its geology and topography, population density, building density and quality, and finally the coping strategy of its people and it shows clear spatial variations.

The location of Bangladesh close to the boundary of two active plates: the Indian plate in the west and the Eurasian plate in the east and north. As a result the country is always under a potential threat to earthquake at any magnitude at any time, which might cause catastrophic death tolls in less than a minute. In the basic seismic zoning map of Bangladesh Chittagong region has been shown under Zone II with basic seismic coefficient of 0.15 [1], but recent repeated shocking around this region indicating the possibilities of potential threat of even much higher intensity than projected.

According to report of Professor Roger Bilham and Peter Molnar of Colorado University huge amount of pressure is created under two kilometer wide Himalayan fault which can produce earthquake of magnitude 8.1 to 8.3 (in RS) at any time [5]. If this will happen, about two lack people will die and fifty million will be injured and affected.

According to Global Hazard Assessment Program (GSHAP), the most hazardous division in Bangladesh is the Port City Chittagong. About 80-90 percent of buildings and physical infrastructures in Chittagong are vulnerable to future massive earthquake measuring RS 6-7 magnitudes, as most of these were not designed to withstand against seismic load.

Hilly terrain of this city corporation area may create huge land slide during a heavy earthquake. As, most of the building contain sloppy ground around them. Asian Disaster

Preparation Center (ADPC) Seismic Hazards assessment has carried out at the Chittagong City Corporation Area of some buildings and found many vulnerable existing buildings. Now further evaluation of the seismic resistance and the assessment of possible damage are quite imperative in order to take preventive measures and reduce the potential damage to civil engineering structures and loss of human lives during possible future earthquakes. Several studies on seismic vulnerability assessment have been carried out at Chittagong City Corporation, but those performed by the consideration of showing the region at zone II of seismic zoning map of BNBC. But new update of national building code (BNBC) proposed this region at zone III with a seismic coefficient value of 0.28g [Fig. 2]. Thus a pilot application in a residential area named by Chandgaon Residential Area (R/A) of Chittagong City Corporation has been conducted which is situated on the banks of Karnaphuli River and is a most densely populated area of the city. Seismic risks of RC structures were evaluated and the concerned authority will be noticed of the probable disaster by providing these data.

1.1. Status of Earthquakes in and around Bangladesh

Bangladesh is surrounded by the regions of high seismicity which include the Himalayan Arc and Shillong Plateau in the north, the Burmese Arc*,* Arakan Yoma anticlinorium 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. These weak regions are believed to provide the necessary zones for movements within the basin area. In the generalized tectonic map of Bangladesh the distribution of epicenters is found to be linear along the Dauki Fault system and random in other regions of Bangladesh. The investigation of the map demonstrates that the epicenters are lying in the weak zones comprising surface or subsurface faults. Most of the events are of moderate rank (magnitude 4-6) and lie at a shallow depth, which suggests that the recent movements occurred in the sediments overlying the basement rocks. In the northeastern region (SURMA BASIN), major events are controlled by the Dauki Fault system. The events located in and around the ADHUPUR TRACT also indicate shallow displacement in the faults separating the block from the ALLUVIUM. The first seismic zoning map of the subcontinent was compiled by the Geological Survey of India in 1935.

The Bangladesh Meteorological Department adopted a seismic zoning map in 1972. In 1977, the Government of Bangladesh constituted a Committee of Experts to examine the seismic problem and make appropriate recommendations. The Committee proposed a zoning map of Bangladesh in the same year.

1.2. Geologic and Tectonic Set-Up

Tectonically, Bangladesh lies in the northeastern Indian plate near the edge of the Indian carton and at the junction of three tectonic plates – the Indian plate, the Eurasian plate and the Burmese micro plate. These form two boundaries where plates converge the India- Eurasia plate boundary to the north forming the Himalaya Arc and the India-Burma plate boundary to the east forming the Burma Arc (Fig. 1).

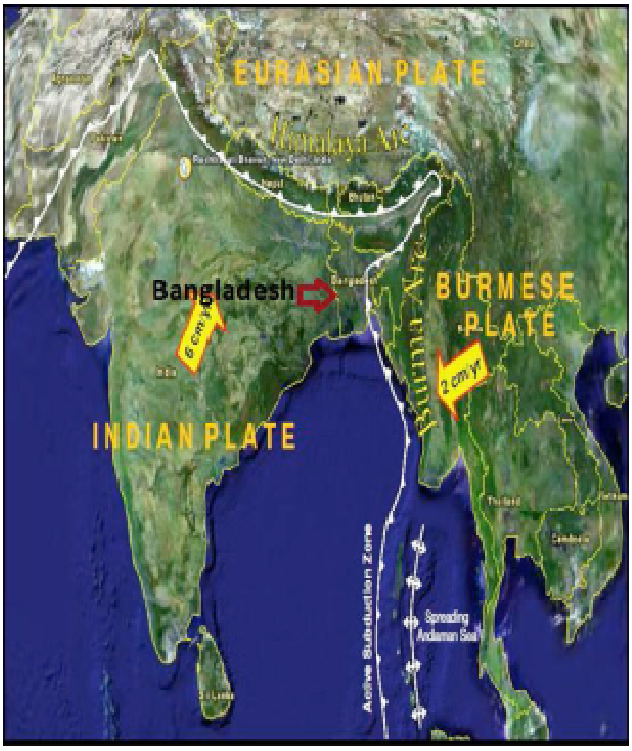

Figure 1. *Regional Tectonic Setup of Bangladesh with respect to Plate [20]*

The Indian plate is moving ~6 cm/yr in a northeast direction and sub ducting under the Eurasian (45 mm/yr) and the Burmese (35 mm/yr) plates in the north and east, respectively [2, 3]. This continuous motion is taken up by active faults. Active faults of regional scale capable of generating moderate to great earthquakes are present in and around Bangladesh. These include the Dauki fault, about 300 km long trending east-west and located along the southern edge of Shillong Plateau (Meghalaya- Bangladesh border), the 150 km long Madhupur fault trending north- south situated between Madhupur Tract and Jamuna flood plain, Assam-Sylhet fault, about 300 km long trending north-east-south-west located in the southern Surma basin and the Chittagong-Myanmar plate boundary fault, about 800 km long runs parallel to Chittagong-Myanmar coast (Fig. 2).

The Chittagong- Myanmar plate boundary continues south to Sumatra where it ruptured in the disastrous 26 December 2004 Mw 9.3 earthquake [4]. These faults are the surface expression of fault systems that underlie the northern and eastern parts of Bangladesh. Another tectonic element, the Himalayan Arc‘ is characterized by three well defined fault systems (HFT, MBT and MCT) that are 2500 km long stretching from northwest syntaxial bend in Pakistan in the west to northeast syntaxial bend in Assam in the east. It poses a great threat to Bangladesh as significant damaging historical earthquakes have occurred in this seismic belt [5, 6 & 7].

1.3. Seismic Sources of Bangladesh

Bolt (1987) analyzed the different seismic sources in and around Bangladesh and arrived at conclusion related to maximum likely earthquake magnitude [8]. The magnitudes of earthquake suggested by Bolt (1987) in Table 1 are the maximum magnitude generated in these tectonic blocks as recorded in the historical seismic catalogue. The historical seismic catalogue of the region covers approximately 250 years of recent seismicity of the region and such a meager data base does not provide a true picture of the seismicity of the tectonic provinces. For example, the Assam and the Tripura fault zones contain significant faults capable of producing magnitude 8.6 and 8.0 earthquakes, respectively, in the future. Similarly, earthquakes with maximum magnitude of 7.5 in Sub-Dauki fault zone and in Bogra fault zone are not unlikely events.

Table 1. *Seismic Sources of Potential Earthquake [8]*

Location	Maximum Likely Magnitude
(i)	(ii)
Assam fault	8.0
Tripura Fault	7.0
Sub-Dauki Fault	7.3
Bogra Fault	7.0

1.4. Earthquake Zone Co-Efficient

Fig. 2 presents the proposed seismic zoning map for Bangladesh based on PGA values for a return period of 2475 years. The country is divided into four seismic zones with zone coefficient Z equal to 0.12 (Zone 1), 0.2 (Zone 2), 0.28 (Zone 3) and 0.36 (Zone 4). In previous Bangladesh National Building Code (BNBC) of 1993 there were three (3) zones. As mention earlier in BNBC 1993 the zone co-efficient of Chittagong was 0.15 [1]. But in newer adopted code of BNBC 2010 it would be proposed to 0.28 which like to be nearly doubled of previous coefficient thus making the zone prone to be highly risk against Earthquake [9, 10]. The red circle zone is the zone of the study area which indicates the Zone III with a basic seismic co-efficient of 0.28 [Fig. 2].

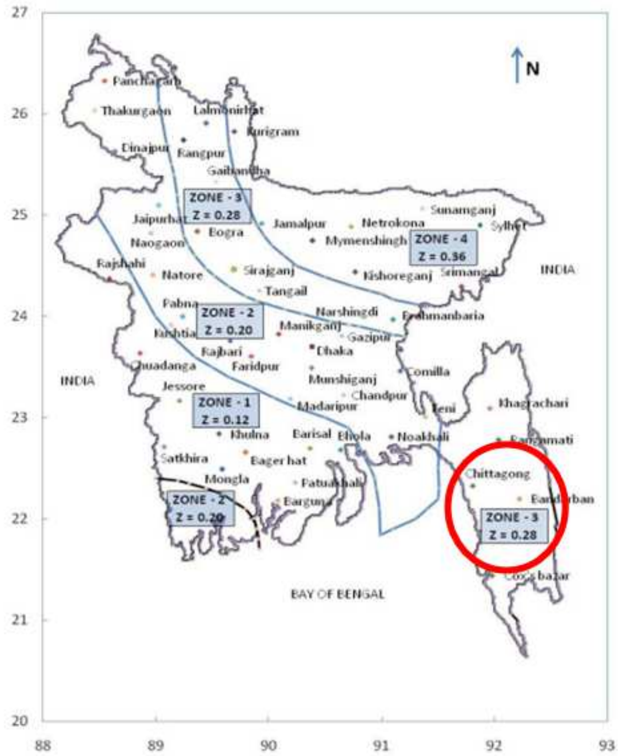

Figure 2. *Update Earthquake Zoning Map of Bangladesh [9, 10]*

1.5. Seismicity Records of Chittagong

Chittagong is the second largest city of Bangladesh which is located in a strategic geographic position at the south-eastern part of the country, contributes a lot in the national economy acting as a commercial hub being connected with the busiest sea- port. The city is exposed mostly tropical storm surges and earthquake. Moreover Chittagong City Corporation (CCC) area is situated approximately 70 km from the fault zone in Bangladesh-Myanmar Boarder. Historical information reveals that earthquakes of magnitude between 6 and 7 have been occurred around the city in the past [11].

For last two decades there were encountered about 8 major earthquake around the city as 1997- Bandarban (M 6.1), 1999- Moheshkhali (M 5.1), 2009- Chandanaish (M 5.2) earthquake etc. (Table 2). These earthquakes caused enormous amount of damages with causalities (Table 2)

Table 2. *Lists of Recent Earthquakes around the Region*

Date of Occurrence	Epicenter of Earthquake	Epicentral Distance, km	Magnitude (Mb)	Causalities
(i)	(ii)	(iii)	(iv)	(v)
21-11- 1997	Bandarban (Myanmar Border)	65	6.1	20 killed
22-07- 1999	Moheshkhali	184	5.1	6 Killed
19-12- 2001	Dhaka (Manikganj)	285	4.2	20 injured
22-07- 2005	Rangamati	37	5.5	2 killed
13-12- 2009	Chittagong	45	5.2	N/A
10-11- 2010	Chandpur	125	4.8	N/A
03-05- 2011	Comilla	115	4.6	N/A

2. Description of Study Area

The study area is Chandgaon R/A at ward no.4 of Chittagong City Corporation situated on the bank of Karnaphuli River. Ward no. 4 is the most densely populated (131,212) ward of Chittagong city and have a residential building value of 129 million US dollar [12]. Chandgaon have a population near 30,000 and more than 400 buildings [13]. The global positioning of Chandgaon is around the 91° 52’ 10” N and 22° 21’ 40” S (Fig. 3).

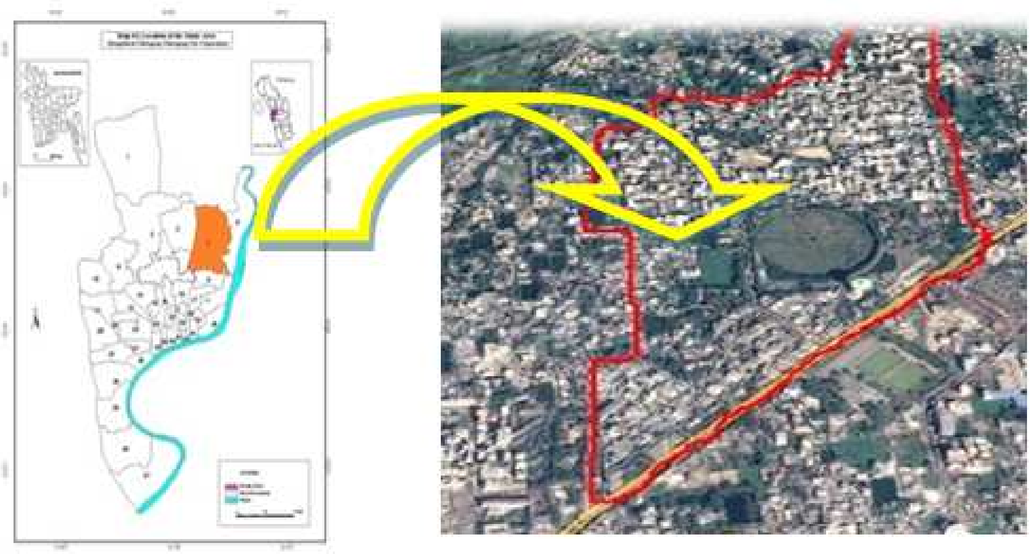

Figure 3. *Satellite View of Chandgaon R/A; Source: CCC and Google map, 2014*

3. Methodology

3.1. Methods of Seismic Vulnerability Assessment

Rapid Visual Screening (RVS) method was originally developed by the Applied Technology Council (ATC) in the late 1980’s and published in 1988 in the FEMA 154 [14] report. It is a "sidewalk survey" approach that enabled users to classify surveyed buildings into two categories: those acceptable as to “risk to life safety” or those that may be seismically hazardous and should be evaluated in more detail. The Turkish Simple Survey procedure is a two level risk assessment procedure which has been proposed on the basis of statistical correlations obtained by Sucuoglu and Yazgan (2003) [15]. The first level incorporates recording of building parameters from the street side and in the second level, these are extended by structural parameters measured by entering into the ground storey.

Although there have no method developed in Bangladesh but some efforts found in India towards developing RVS methods. In this study the method of vulnerability assessment limited to the walk down survey (level-I). Two basic procedures employed in this study. One was the RVS of FEMA 154 [14] and another had done based on the RVS forms proposed by Sudhir K Jain et al. [16, 17] for Indian conditions.

3.2. Rapid Visual Screening (RVS)

Data collection form of RVS (FEMA 154) includes space for documenting building identification information, including its use and size, a photograph of the building, sketches, and documentation of pertinent data related to seismic performance, including the development of a numeric seismic hazard score. There are three types of form in FEMA 154 [14]. The form for high seismicity region has been used to carry out the research work. Basic Structural Hazard Scores based on Lateral Force Resisting System for various building types are provided on the form, and the screener circles the appropriate one. The screener modifies the Basic Structural Hazard Score by identifying and circling Score Modifiers related to observed performance attributes, by adding (or subtracting) them a final Structural Score, ‘S’ is obtained.

3.3. Indian Method of Evaluation

Indian evaluation method is based on few parameters of RCC and Masonry building. The parameters of the RCC buildings are building height, frame action, pounding effect, structural irregularity etc. as shown in Table 3. The scoring system adopted in this research is for seismic zone V in Indian seismic zoning map as the value of zone coefficient is relevant to the updated zone coefficient of Chittagong region as proposed by Dr. T.M. Al-Hussaini [9]. A “cut-off” performance score of 50 has been suggested for the study.

On the basis of parameters shown in Table 3, Performance Score (PS) of the buildings has been calculated by using the values of Base Score (BS), Vulnerability Score (VS) and Vulnerability Score Modifiers (VSM). The formula of the performance score is given as:

$$PS = (BS) - \Sigma\,[(VSM) \times (VS)] \qquad (1)$$

Where, BS = Base Score; VSM = Vulnerability Score Modifiers; VS = Vulnerability Score

The corresponding storey wise value of Vulnerability Score (VS) for different parameters compiled at Table 3. The BS value of zone V (= 0.36) of Indian seismic zoning map was selected as the Base Score (BS) due to the consideration of maximum risk and the coefficient value (= 0.36) is quite nearer to the value of study area (= 0.28). Table 3 shows the storey wise distribution of Base Score (BS). The value of Vulnerability Score Modifiers (VSM) of equation 1 also described at Table 5.

Table 3. *Vulnerability Scores (VS) for RCC Building [16, 17]*

No of Stories	1or 2	3	4	5	>5
Vulnerability Factors	**Vulnerability Scores**				
(i)	**(ii)**	**(iii)**	**(iv)**	**(v)**	**(vi)**
Soft Stories	0	-15	-20	-25	-30
Vertical Irregularities	-10	-10	-10	-10	-10
Plan Irregularities	-5	-5	-5	-5	-5
Heavy Overhanging	-5	-10	-10	-15	-15
Apparent Quality	-5	-10	-10	-15	-15
Short Column	-5	-5	-5	-5	-5
Pounding Effects	0	-2	-3	-3	-3
Soil Condition	10	10	10	10	10
Frame Action	10	10	10	10	10
Water Tank at Roof	0	-3	-4	-5	-5
Location of Water Tank	0	-3	-4	-5	-5
Basement-Full/Partial	0	3	4	5	5

Table 4. *Base Scores (BS) for RCC Building [16, 17]*

Number of Stories	Base Scores
(i)	**(ii)**
1 or 2	100
3	90
4	75
5	65
More than 5	60

Table 5. *Vulnerability Score Modifiers (VSM) for RCC Building [16, 17]*

Vulnerability Factors	Vulnerability Score Modifiers (VSM)		
(i)	**(ii)**	**(iii)**	**(iv)**
Soft Stories	Absent =0	Present =1	---
Vertical Irregularities	Absent =0	Present =1	---
Plan Irregularities	None =0	Moderate =1	Extreme =2
Heavy Overhanging	Absent =0	Present =1	---
Apparent Quality	Good =0	Moderate =1	Poor =2
Short Column	Absent =0	Present =1	---
Pounding Effects	Absent =0	Unaligned floors =2	Poor apparent quality of adjacent building =2
Soil Condition	Medium =0	Hard =1	Soft = -1
Frame Action	Absent =0	Present =1	Not sure =0
Roof Water Tank Capacity	Absent =0	<5000 L =0.5	>5000L =1.0
Location of Water Tank	Symmetric =0	Asymmetric =l	---
Basement-Full/Partial	Absent =0	Present =1	---

Based on the scores of RVS, some percentage of structures will be selected for preliminary evaluation and further for detailed evaluation. RVS is useful when the number of buildings to be evaluated is large and even non-engineers may collect data and assign scores.

4. General Description of Building

The study comprised of a detailed survey on 310 buildings of Chandgaon R/A. Although largest percentage (95%) of buildings are of residential occupancy but other types of occupancy like mosque, school (3%) and offices (2%) also present here. The structural systems are mainly encompassed of two types, one is the Moment Resisting Frame (MRF) and another is the Unreinforced Masonry Wall Infill Frame (URM) from the categories provided at RVS form. It was found from the study that about 99% building belongs to the category of URM-infill and only 1% belongs to the category of MRF.

4.1. Age of Buildings

The age of the building is attributed at both of the methods used in the study. From this information the building can be classified as range of four significant stage of development of BNBC code according to Table 6.

Study found that about 68% buildings built at applicative stage of code and 14% built at legislative stage (Fig. 4). But the main vulnerable objectives were 10% buildings built at precode and 8% at primitive stage. According to this finding Chandgaon can be termed as a newly developed residential area.

Table 6. *Stages of Building Age based on the development period of BNBC*

Stage	Range of Year Built	Remarks
(i)	(ii)	(iii)
Precode	< 1993	Code was proposed
Primitive	1993 – 1996	Updated for 1st time
Applicative	1996 – 2006	Updated for 2nd time
Legislative	> 2006	After the year of 2006

4.2. Vertical Height of Buildings

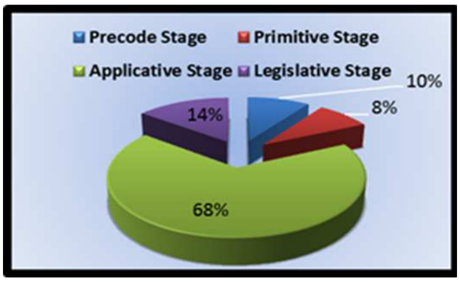

Figure 4. *Different Stages of Building Age*

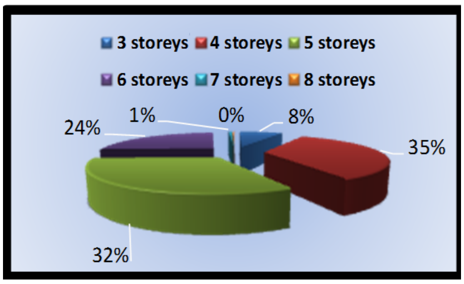

Figure 5. *Vertical Height of Buildings*

The vertical height of the building limited to 8 storeys. Figure 5 shows that majority of the buildings are 4storied (35%) and 5 storied (32%) where 24% buildings are 6 storied. A smallest percentage of 0 to 1% buildings are 7 to 8 storied (Fig. 5). Thus it can be said that Chandgaon area is occupied by low to medium rise building rather than the most vulnerable high rise structure.

5. Vulnerability Factors

5.1. Structural Irregularities

Structural irregularity is the combination of two vulnerability factors: plan irregularity and vertical irregularity. The criteria based definition of plan and vertical irregularities mentioned at both the FEMA and BNBC regulations [1, 14]. The Euro code 2008 showed a precise analysis of plan and vertical irregularities by showing the marginal values of setback in elevation and slope at contour [19].

The study found that the plan and vertical irregularities possess by only small percentages of building. These factors were encountered for a maximum of 7 and 6 numbers of four storied building of the Chandgaon area (Table 4).

5.2. Storey Drift Parameters

Major storey drift parameters are soft storey and pounding effects. A soft story usually exists in a building when one particular story, usually employed as a commercial space, has less stiffness and strength compared to the other stories [15]. In this study soft story problem encountered for 37, 55 and 64 buildings of 4, 5 and 6 storied respectively (Table 4). Soft story problem found as major vulnerability factor of the buildings (53.7%) of Chandgaon area.

When there is no sufficient clearance between adjacent buildings, they pound each other during an earthquake as a result of different vibration periods. Uneven floor levels aggravate the effect of pounding [15]. Pounding effects was found only for 2.2% buildings of Chandgaon area (Table 4). Short column is another factor which can be formed at frames with partial infill which sustain heavy damage since they are not designed for the high shear forces due to shortened heights that will result from a strong earthquake [15]. Here short column, heavy overhanging and poor apparent quality found for 2.6%, 0.97 and 1.94% building respectively (Table 7).

Table 7. *Vulnerability Factors Found in the Study*

	Vulnerability Parameters							Roof Water Tank Capacity		Position of Roof Water Tank	
	VI	PI	SC	HO	SS	PAQ	PE	≥ 5000 liter	< 5000 liter	Unsymmetrical	Symmetrical
	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)	(x)	(xi)
	Number of Buildings										
3 Storied	2	1	0	0	7	0	0	0	24	23	1
4 Storied	7	6	5	3	37	5	2	99	8	103	5
5 Storied	3	3	3	0	55	1	2	73	27	88	12
6 Storied	1	1	0	0	64	0	3	68	8	24	6
7 Storied	0	0	0	0	2	0	0	2	0	2	0
8 Storied	0	0	0	0	1	0	0	2	0	1	0
Total =	13	11	8	3	166	6	7	244	67	241	24
Percentage =	4.2	3.6	2.6	0.97	53.7	1.94	2.2	79	21.68	78	7.77

VI= Vertical Irregularities, PI= Plan Irregularities, SC= Short Column, HO= Heavy Overhanging, SS= Soft Storey, PAQ= Poor Apparent Quality, PE= Pounding Effects

In case of roof water tank, largest percentage (about 79%) of building possess a tank of more than 5000 liter capacity and 78% building have a tank located at an unsymmetrical position with respect to roof plan of the building (Table 4).

6. Results and Discussion

6.1. Assessment by RVS

As mentioned earlier, total number of 310 Buildings have been analyzed using Rapid Visual Screening (RVS) method. Considering Chittagong as a high Seismic Risk zone, the cut off value was determined as 2.0. The results show that no score for any building was found to touch the cut off value according to FEMA method and all of them require further detailed analysis for vulnerability to determine the level of actual risk. Table 8 shows summary of the RVS score for different storied buildings.

In fact the basic score for RC building in FEMA-RVS is only 1.6 (less than the cut off), which becomes smaller after being modified by the negative parameters. This is one of the reasons for the FEMA RVS score to be less.

Table 8. *Final Scores of RVS*

	Score Range			
	S≤0.4	0.4<S<0.7	0.7<S<1.2	1.2<S<2
	Number of Buildings			
3 Storied	4	0	14	6
4 Storied	9	0	78	21
5 Storied	3	0	79	18
6 Storied	0	0	59	17
7 Storied	0	0	1	1
Total =	16	0	231	63
Percentage =	5	0	75	20

The parameters contributing the scoring system are mainly, the height, irregularities of the buildings and type of the soil underneath. The parameters “Pre Code” and “Post Benchmark” remained inapplicable in the scoring. On a general view, the soil type of Chandgaon has been considered as Stiff, so this modifier also remains constant in the whole process.

6.2. Assessment by Indian Method

Here, the assessment has been performed considering the soil zonation of Chittagong in Zone-V of Indian method which PGA (Peak Ground Acceleration) value is analogous to Zone-III (Chittagong) of updated BNBC earthquake zoning map.

In this method much more variation in final scores has been observed as not only the basic score but also the influences of vulnerability parameters are very much dependent on the height of the building.

In fact the positive or negative score modifications due to vulnerability parameters are weighted multiplications based on their existence and number of stories of the buildings. As a result the score becomes high for low rise buildings in spite of presence of negatively influential vulnerability parameters. Due to these dependent variations, it is comparatively tougher task here to classify the damage probabilities with minute specifications, as that of RVS-FEMA method, only from final scores. Rather it is easier to indicate an overall view on safety of the building comparing the final score with the cut off value and observing their relative difference.

Fig. 6 reflects that about 50% buildings from 6 storied and verily 5%, 1% from 5 and 4 storied scored less than 25 which less than the “cut-off” score, according to the survey. All of the 7 and 8 storied buildings scored less than 25. The building with a score of 0 to 25 might be possessed to the most critical state of vulnerability and must be investigated further. Fig. 6 also reveals that more than 50% of 5 storied and 80% of 6 storied building have a score less than 50 (the “cutoff score”). These buildings also should be assessed in details. Thus rest of the buildings does not need further detailing on vulnerability assessment, or they can be termed as safe.

When the performance scores of the buildings have been placed against building story, it was found that few 4 storied and more than 80% of 3 storied buildings scored above 75 (Fig. 6) and all the buildings scoring greater than 50 (Fig. 6) were low to midrise (3 to 5 storied). The observed general trend is that the taller the buildings the higher the presence of negative parameters and thus the lower becomes the scores.

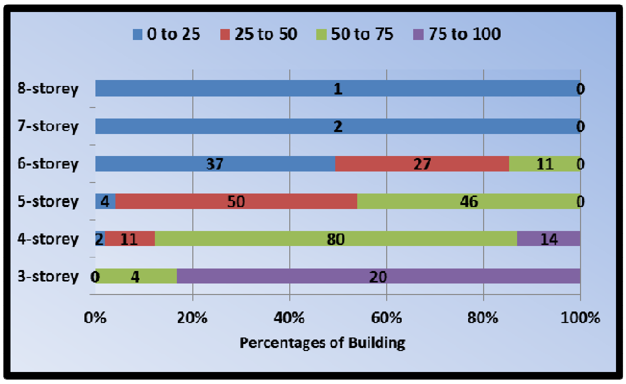

Figure 6. *Performance Score of Assessment by Indian Method*

7. Conclusions

The occurrence of earthquakes is a part of the natural process in the earth's geophysical system. The earthquake tremors cannot be stopped or reduced and the causalities and damages are caused mainly due to the collapse of the infrastructures. The infrastructures of different areas will not be equally vulnerable to any earthquake. In this research, an attempt has been made to develop firsthand vulnerability assessment for Chandgaon Residential Area (R/A).These works are expected to be useful for especially pre-disaster planning and capital investment planning.

In the present research, an inventory with huge information of the building features has been made for residential buildings of Chandgaon area. The vulnerability of the buildings has been assessed so that the buildings prone to earthquake can be identified and repair, restoration or evacuation plans can be prepared easily. The results of the vulnerability analyses can also be useful for providing guidance in the construction of seismic resistant buildings.

While, it is not possible and also not economic to abandon all the vulnerable structures, future buildings and structures in the area are recommended to be brought under strict building code as well as to be constructed according to the land use planning zoning ordinances so that earthquake vulnerability of the region can be mitigated.

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