Journal of Bangladesh Institute of Planners ISSN 2075-9363
Vol. 10, 2017 (Printed in December 2019), pp. 89-104, © Bangladesh Institute of Planners

An Analysis of Structure, Fire and Social Vulnerabilities of Chittagong City Corporation Area due to Earthquake Hazard

**Md. Rakibul Hasan Kauser*
Joy Kumer Saha**
Debasish Roy Raja*****

Abstract

Chittagong city is the second largest city of Bangladesh. Due to rapid rate of urbanization and unplanned growth of urban centers, disasters like earthquake have become a menace for Chittagong. Most of the structures are owner built, non-engineered in nature and structurally vulnerable for earthquake. Ward no 29 (South Agrabad) which acts as CBD of Chittagong was selected for earthquake vulnerability assessment. A total of 86 buildings were selected by Simple random sampling procedure keeping the confidence level at 90%. Structure vulnerability assessment has been analyzed by a FEMA-RVS method, fire hazards vulnerability assessment has been done with the help of method developed by ADPC (2004) and social vulnerability assessment was done with the help of method developed by World Bank (2014). Finally, structure, fire and social vulnerabilities were integrated by composite vulnerability score developed by Rahman et al. (2015). From the analysis, it has been found that most of the structures are very highly vulnerable to earthquake and fire hazard and low social impacts are observed against earthquake. The findings of the research can be used to prioritize risk mitigation investments, measures to strengthen the emergency preparedness and response mechanisms for reducing the losses and damages due to future earthquake events.

Introduction

Earthquake is now a burning issue, because of its frequent occurrences all over the world. Recently, it has occurred in Nepal named Gorkha earthquake, 2015 and Japan named Kumamoto earthquake, 2016 with magnitude of 7.5 and 7.0 respectively (USGS, 2016). Bangladesh is not free from any possibilities of severe earthquake, because of its geotectonic set-up. It is located along two of the active plate boundaries suggesting high probabilities of damaging future earthquakes (Sultana et. al, 2013). From the historical record, it is found that hundred (100) moderate to large earthquakes occurred in Bangladesh since 1900, where more than sixty-five (65) events occurred after 1960 (Sultana et. all, 2013 and Sarraz.et. all, 2015). Chittagong and its surrounding region has been shown under Zone II in the basic seismic zoning map of Bangladesh (BNBC, 1993), but recent repeated shocking around this region indicating the possibilities of potential threat of even much higher intensity than projected (Sarraz.et. al, 2015). Moreover Chittagong City Corporation (CCC) area is situated approximately 70 km from the fault

* Lecturer, Department of Urban and Regional Planning, Chittagong University of Engineering and Technology (CUET), Chittagong - 4349, Bangladesh. E-mail: mdrhkauser@gmail.com

** Site Operation Officer, Save the Children, Cox-bazar.

*** Assistant Professor, Department of Urban and Regional Planning, Chittagong University of Engineering and Technology (CUET), Chittagong - 4349, Bangladesh.
E-mail: rdebasishroy@gamil.com

zone in Bangladesh-Myanmar Boarder. Historical information reveals that earthquakes of magnitude between 6 and 7 have occurred around the city in the past decade (Alam. et. al, 2008). Detail description of damages caused by these earthquakes is described in Table 1.

Table 1: List of Recent Earthquake and Extent of Damage in Chittagong Region

Date of Occurrence	Epicenter of Earthquake	Magnitude	Extent of Damage
December, 1830	N/A	N/A	Most of the houses were severely cracked.
October , 1842	N/A	N/A	Minor losses of resources
1865	N/A	N/A	Most of the buildings were severely cracked.
21-11-1997	Bandarban - Myanmar	6.1	Sinking of two underground floors of a five storied building and 32 people were dead.
22-07-1999	Moheskhali	5.1	7 persons died and 24 persons were injured, 1292 houses were fully damaged with 5662 partially, 10 cyclone centers, other structures were damaged. The estimated loss was about 14 million taka.
19-12-2001	Dhaka (Manikganj)	4.2	20 people were injured.
22-07-2005	Rangamati	5.5	Two people died.
03-05-2011	Comilla	4.6	N/A

Source: Sarraz.et. al, 2015

There are various factors which contribute to the earthquake vulnerability in the urban areas of Bangladesh (Akhter, 2010). Due to rapid rate of urbanization and unplanned growth of urban centers, disasters like earthquake have become a menace for Chittagong. Most of the structures are owner built, non-engineered in nature and structurally vulnerable for earthquake and are built to gain profit within a short time span through increasing commercial floor space without any essential structural measures to make it earthquake resistant (Masud, 2007). On the other hand, 80-90% buildings and physical infrastructures in Chittagong are vulnerable to future massive earthquakes, as most of these were not designed to withstand this (Bhuiyan et al., 2006). From the study of CDMP, it is found that 168,150 buildings will be at least moderately damaged. This is over 92.00% of the total number of buildings in the Chittagong city (CDMP, 2009).

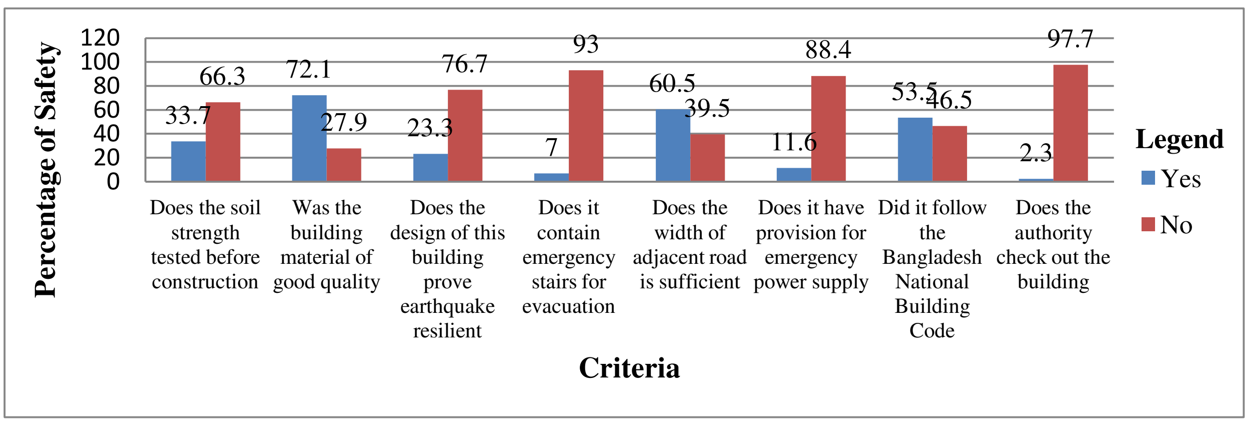
On the other hand, many physical infrastructures and buildings, such as sea port, airport, EPZ (Export processing zone), refineries, power station, industries etc. at Chittagong, were constructed 10, 20, 50, 100 and 200 years ago without considering seismic safety provisions. These buildings are more vulnerable to fire hazard (Bhuiyan et al., 2006). In recent fire in Chittagong, one was killed, five were injured and a huge loss of properties was incurred destroying more than 200 shops (Dhaka Tribune, 2018 and The Daily Star, 2017). Several types of secondary hazards have happened due to earthquake such as surface fault rupture, ground failure, tsunami run-up; regional tectonic deformations, earthquake induced flooding, fire and explosions (Rahman et. al, 2015). From the study of CDMP, it is found that 428 buildings in the Chittagong city is highly vulnerable to fire hazard due to earthquake (CDMP, 2009). In case of social vulnerability, around 240,300 peoples are vulnerable due to earthquake hazard. On the other hand, 3,111 million dollars of building related economic loss is estimated in Chittagong City Corporation Area (CDMP, 2009).

Remarkable amount of study has been conducted on earthquake induced structure hazard, but a little amount of study has been conducted on earthquake induced fire or social hazard on Chittagong. In this research, structure, fire and social vulnerability of Chittagong City Corporation Area due to earthquake hazard have been analyzed in a comprehensive way. Finally, the main objective of this paper is to assess structure fire and social vulnerability of a selected ward of Chittagong City Corporation.

In this paper, the methodology of three different vulnerability assessments, such as structure vulnerability assessment, fire vulnerability assessment and social vulnerability assessment has been described. The methodology of combining the results found from three different vulnerabilities has been described by developing composite vulnerability score. Then the results have been analyzed and represented in the form of graph, chart and table. The composite vulnerability score describes the overall vulnerability of the study area.

Selection of Study Area

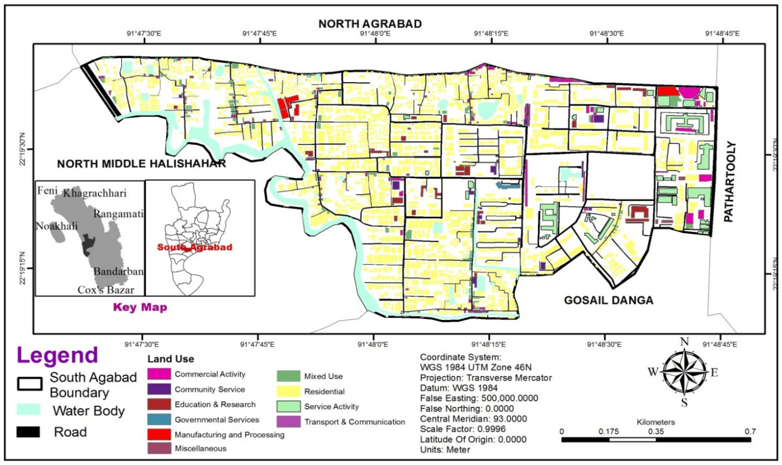
From the study of CDMP (2009), Masud (2007) and Kauser et al. (2017) showed that South Agrabad (ward no 27) fall into the high seismic hazard zone. Agrabad is considered as a Central Business District (CBD) of Chittagong city and eastern part of the area (west of Sk. Mujib road) has been considered as a Special Commercial Area in DPZ-2 and western part of Sheikh Mujib road of Agrabad in DPZ-3 was declared as special commercial area in Chittagong area (CMMP-1995). On the other hand, 46681 people are living in per sq. km in South Agrabad (ward no 27). More precisely, 47 people are living in per sq. meter in South Agrabad (BBS, 2011).



Source: Field Survey, 2016

Figure 1: Percentage of earthquake safety measure of different factors

From the field survey, it has been found that in most of the cases, there is minimum earthquake safety measure present in the South Agrabad area. So, considering this hazard and economic importance, South Agrabad is selected for vulnerability assessment.



Source: Prepared by author.

Figure 2: Location map of study area

Figure 3: Workshop for the surveyor in September 2016.

Methodology

Sampling and Data Collection

Primary data has been collected through a field survey in September 2016. Before conducting the field survey, a workshop has been arranged for the surveyor in September 2016. The total number of buildings of South Agrabad (Ward no 27) is 2,908 (CDA, 2009). To conduct both physical and social surveys, samples of 86 buildings have been selected by Simple random sampling procedure keeping the confidence level at 90% (Gupta & Gupta, 2006). Stratification of sample has been chosen according to the percentage of construction type, number of storey and structure use of buildings. Survey of buildings has been conducted to find out the existing condition of structure vulnerability and fire hazard vulnerability assessment. Socio economic survey of the same buildings has been conducted to assess social vulnerability. Table 2 shows the distribution of sample buildings. Secondary data has been collected from journals & Bangladesh Bureau of Statistics (BBS).

Table 2: Distribution of sample structures as per construction type, number of storey and structure use

Type / Use	kacha	Semi pacca	Pucca										Total
			1	2	3	4	5	6	7	8	11	15	
Residential	6	10	0	1	2	5	4	5	1	1	0	0	35
Commercial	4	4	2	1	0	4	4	1	0	0	0	1	18
Community	0	1	0	0	1	1	0	0	0	0	0	0	2
Education	0	2	1	1	1	0	0	0	0	0	0	0	6
Government	0	0	0	0	0	0	0	0	0	0	0	0	0
Manufacturing	0	0	0	0	0	1	2	0	0	0	0	0	3
Miscellaneous	1	1	0	1	0	0	0	0	0	0	0	0	4
Mixed Use	2	3	0	1	0	1	1	0	0	0	0	0	8
Service	0	1	2	1	0	1	2	1	0	0	1	0	10
Transport	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	13	24	5	6	4	13	13	8	1	1	1	1	86
	13	22	51										

Source: Prepared by author based on CDA, 2009

Structure Vulnerability Assessment

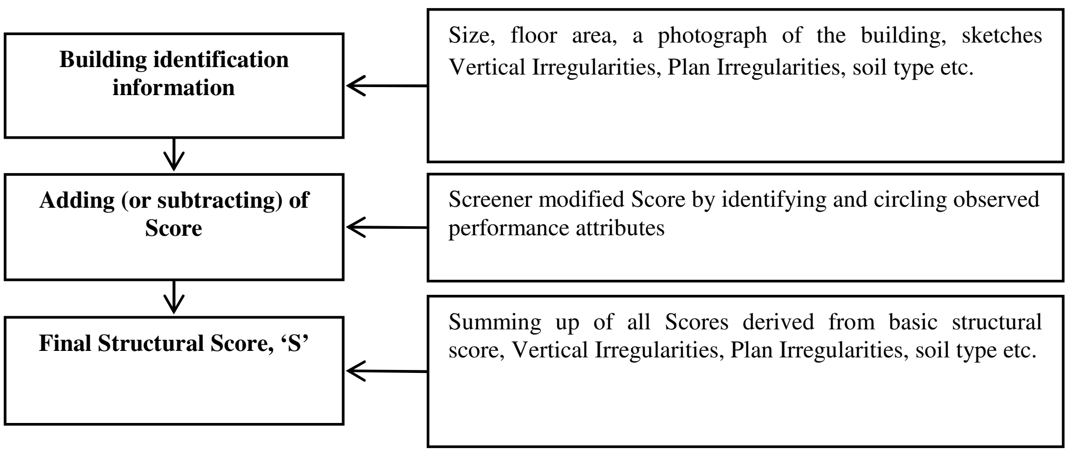
On the basis of magnitude and location, earthquake can produce primary and secondary hazard such as liquefaction, surface fault rupture, ground failure, surface fault rupture, regional tectonic deformations and earthquake-induced flooding, fire and explosions etc. Urban earthquake cause lot of damages to built environment, the informal settlement in urban areas, large numbers of poorly built dwellings and infrastructure etc. Urban vulnerability assessment describes the degree to which socioeconomic pattern and physical infrastructures in urban areas are either susceptible or resilient to the impact of natural hazards (Bhuiyan et al., 2006 and Rahman et. al, 2015). There are several methods which are compared in Table 3.

Table 3: Comparison of seismic evaluation methods

Undamaged Buildings	**FEMA P-154**	**ASCE/SEI 41 Tier 1**	**ASCE/SEI 41 Tier 2**	**ASCE/SEI 41 Tier 3 FEMA P-807 FEMA P-58 HAZUS**
Earthquake-Damaged Buildings	ATC-20 Rapid	ATC-20 Detailed	FEMA 352 ATC-52-4	FEMA 306 ATC-52-4
Time Required	Minutes	Hours	Days	Weeks
Relative Cost	$	$$	$$$	$$$$
Qualifications	Properly trained building professionals	Structural engineers experienced in seismic evaluation and design		

Source: FEMA, 2015

So, Structure vulnerability assessment has been calculated by FEMA-Rapid Visual Screening (RVS) method in this research. This RVS method is developed by Federal Emergency Management Agency (FEMA) of United State of America. To conduct RVS survey, FEMA 154 Data collection form for high seismicity has been used for this purpose which is applicable for Bangladesh (Sarraz et. al, 2015 and Rahman et. al, 2015). There are several types of parameters of scoring of FEMA-RVS which are space for documenting building identification information, such as a photograph of the building, its size and use, floor area, sketches of building plan, Vertical Irregularities, Plan Irregularities, elevation and documentation of pertinent data related to seismic performance including soil type and expected ground shaking levels in the region as well as the seismic design and construction practices for the city or region. Basic procedure for obtaining final Structural Score, 'S' is given in Figure 4. This 'S' score represents the RVS score. Data has been collected by RVS in September 2016.



Source: Prepared by author.

Figure 4: Flow chart of preparing RVS score for structure vulnerability assessment

Fire Hazard Vulnerability Assessment

Fire hazard vulnerability assessment has been done by developing FVS score (Fire hazard Vulnerability Score). FVS is carried out with the help of methodology developed by ADPC for developing countries of Asia under the Lao PDR Urban Disaster Mitigation Project. In that project, fire vulnerability has been done by using factors like accessibility construction type, floor area, number of stories, fire source in building and fire source around building (Rahman et al., 2015). Data has been collected by a household survey in September 2016. To develop FVS of sample building required weightage of these indicators so that no factor exerts an influence beyond its determined weight. This weightage is developed by Rahman et al. (2015) for Dhaka City in their study. The socio-economic and cultural condition, structure made martials, techniques and standards are same in Chittagong city. So, considering this situation the weightage which was developed for Dhaka city can be applicable for Chittagong city. Table 4 presents Fire hazard vulnerability indicators and weights. FVS of every sample building was calculated using the following formula by Rahman et al. (2015):

FVS = Construction Type × 0.140 + Number of storey × 0.113 + Floor Area × 0.070 + Fire source in building × 0.327 + Fire source around building × 0.091+ Accessibility × 0.259……………………………………………………………………….………………… (1)

Table 4: Fire hazard vulnerability indicators and weights

Factors	**Value**			**Weight**
Construction Type	Pucca - 1	Semipucca - 2	Kutcha - 3	0.140
Number of story	Up to 1-storey Low - 1	2-5 story Moderate - 2	6 and above story High – 3	0.113
Floor Area	Up to 1000 sq. ft. Low - 1	1001 sq. ft.–2000 sq. ft. Moderate - 2	2001 sq. and above High – 3	0.070
Fire source in building	No – 0	Residential sources* - 1	Hazardous sources** - 2	0.327
Fire source around building	No - 0	Yes - 1		0.091
Accessibility	Code – 0 Road >=10 ft.	Code – 1 Road < 10ft		0.259

*Residential Source: Gas Stove; **Hazardous Source: Chemical, plastic, paper, electric generator

Source: World Bank, 2014; Rahman et all, 2015

Social Vulnerability Assessment

Social vulnerability has been analyzed by developing the Social Vulnerability SVS Score (Social Vulnerability Score). World Bank developed Social Vulnerability Score for Dhaka City in order to develop Urban Disaster Risk Index under Bangladesh Urban Earthquake Resilience Project in 2014 (World Bank, 2014). For SVS study, factors like population density, gender, age below 5, age 65 and over, disability, illiteracy and disability are used (Rahman et al., 2015). Data has been collected by a household survey in September 2016. The weighted value of each factor was derived from the study of World Bank (2014) for Dhaka City. The socio-economic and cultural conditions are same in Chittagong city. So, considering this situation, the weightage which was developed for Dhaka city can be applicable for Chittagong city. Table 5 presents the social vulnerability indicators and weights. Social vulnerability score (SVS) of each sample building was calculated using the following formula:

SVS = Population density×0.3 + Gender×0.05 + Age below 5×0.17 + Age 65 and over×0.11 + Disability×0.34 + Illiterate×0.03 …………………..…………………………………..…. (2)

Table 5: Social vulnerability indicators and weights

Indicator	Formula	Weight
Population density	= Total population in building/Total floor area of building in square feet	0.30
Gender	= Number of female/number of male	0.05
Age below 5	= Number of children/Total population in building	0.17
Age 65 and over	= Number of elderly/Total population in building	0.11
Disability	= Number of disable/Total population in building	0.34
Illiterate	= Number of illiterate/Total population in building	0.03
	Total	1.00

Source: World Bank, 2014 and Rahman et. al, 2015

Development of Composite Vulnerability Score

RVS (Rapid Visual Screening score for Structure Vulnerability), FVS (Fire Vulnerability Score) and SVS (Social Vulnerability Score) are in different scale, it is necessary to convert them into a common scale for calculation. So, earthquake vulnerability is analyzed by developing Composite vulnerability score. The methodology of Composite vulnerability score is developed from the study of Cardona et al. (2005) and Rahman et al. (2015). The composite score of vulnerability is the combination of RVS score, FVS and SVS. After interpolating RVS data range is differing from 0.4 to 3.27 where lower values mean high vulnerability and higher value mean low vulnerability. FVS data range is differing from where 0.69 to 1.67 lower values mean low vulnerability and higher value mean high vulnerability and SVS data range is differing from 0.01 to 0.47 lower value mean low vulnerability and higher value mean high vulnerability. PVS (Physical vulnerability score) of each building was calculated using structure vulnerability score and fire vulnerability score. The CVS (composite vulnerability score) of a building is the combination of PVS (physical vulnerability score) and SVS (social vulnerability score). Figure 5 presents the vulnerability assessment procedure and Table 6 presents common vulnerability category of earthquake vulnerability. Composite vulnerability score (CVS) is given by the formula:

CVS = PVS (1+ SVS)…………………………….. (3) (Cardona et. al. 2005)

Here,

PVS= Physical Vulnerability Score and SVS= Social Vulnerability Score

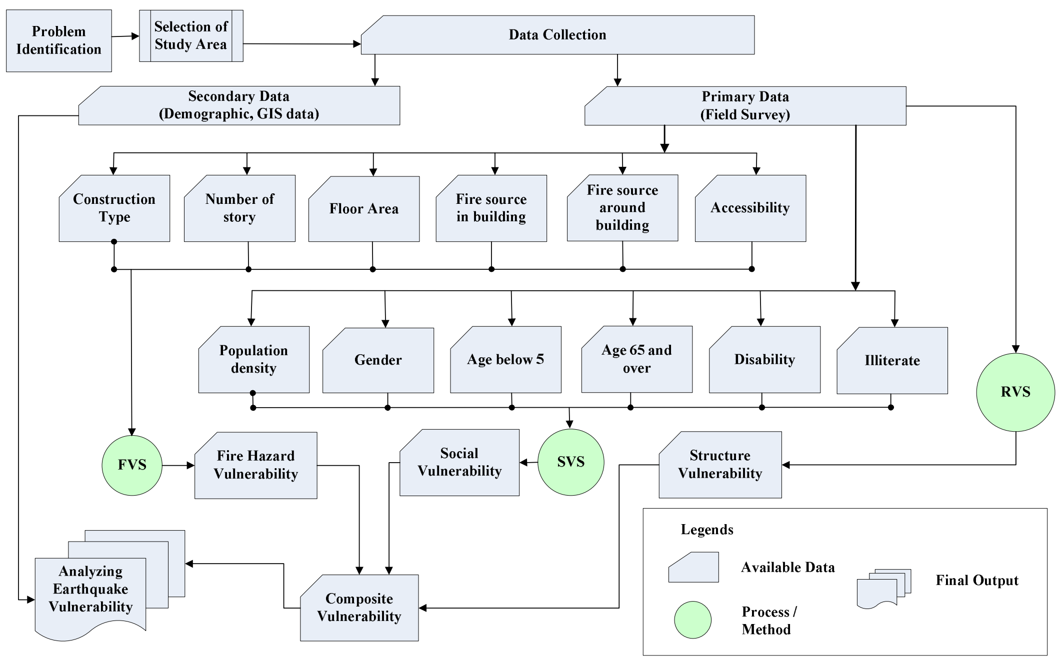
Physical Vulnerability Score (PVS) is given by:

PVS = 0.6*Structure Vulnerability score + 0.4* Fire Vulnerability score …………… (4)

Table 6: Common vulnerability category

Vulnerability category	New Scale	RVS score	FVS score	SVS score
Very Low Vulnerability	0.20	2.8 - 3.4	0.463 – 0.7046	0.001 – 0.0986
Low Vulnerability	0.40	2.2 – 2.8	0.704601 – 0.94620	0.0.8601 – 0.19620
Moderate Vulnerability	0.60	1.6 – 2.2	0.94621 – 1.1878	0.196201 – 0.2938
High Vulnerability	0.80	1 – 1.6	1.1878 – 1.4294	0.293801 – 0.391400
Very High Vulnerability	1.00	0.4 – 1.6	1.42941 – 1.67100	0.391401 – 0.489

Source: Prepared by author



Source: Prepared by author

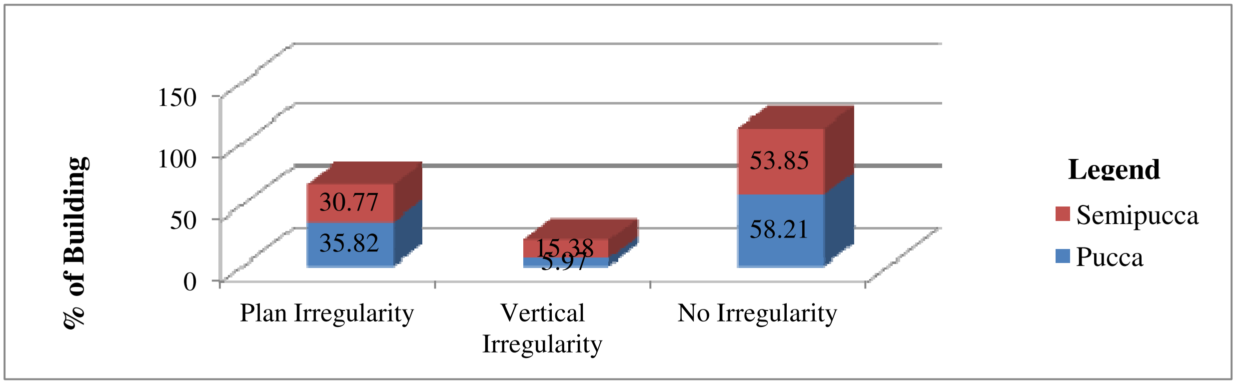
Figure 5: Flow chart of preparing earthquake vulnerability assessment

Results and Findings

South Agrabad (ward no 27) is selected for earthquake vulnerability assessment on the basis of hazard and economic importance. Structure vulnerability assessment has been analyzed by a FEMA-RVS, fire hazards vulnerability assessment is done with the help of method developed by ADPC (2004) and social vulnerability assessment is done with the help of method developed by World Bank (2014). Finally, structure, fire and social vulnerabilities are integrated by composite vulnerability score developed by Rahman et al. (2015). The results and findings of the above mentioned vulnerability analyses are discussed here.

Structure Vulnerability Assessment

Percentage of Irregularities in the Building

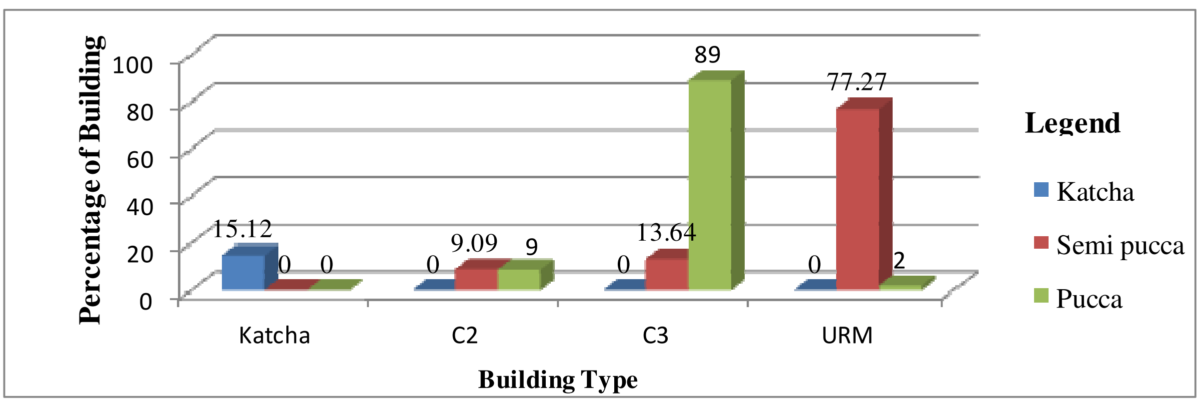


Source: Field Survey, 2016

Figure 6: Percentage of Irregularities in the building

From the analysis, it is found that in South Agrabad, 53.85 percent semi pucca buildings have no irregularity, 30.77 percent semi pucca buildings have plan irregularity and 15.38 percent semi pucca buildings have vertical irregularity. It is also found that 58.21 percent pucca buildings have no irregularity, 35.82 percent pucca buildings have plan irregularity and 5.97 percent pucca buildings have vertical irregularity (Figure 6).

Building Type

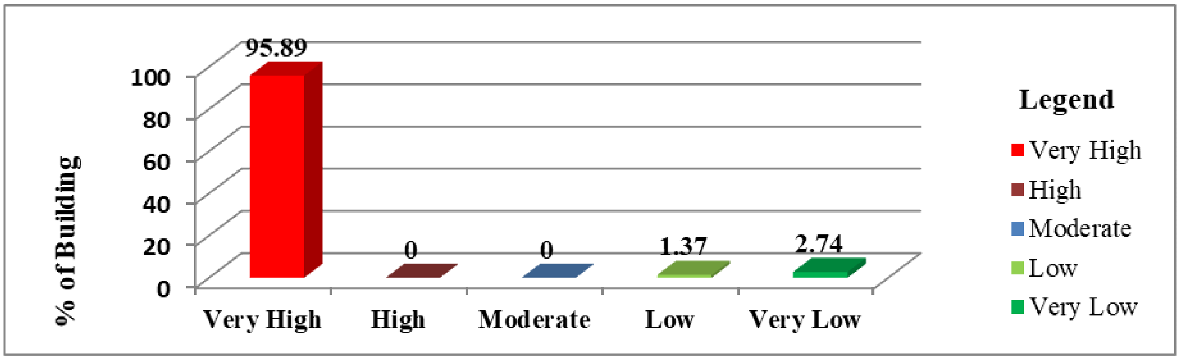


Source: Field Survey, 2016

Figure 7: Type of Buildings in South Agrabad Area

From the field survey, it is found that almost all semi pucca buildings are found as URM type buildings which are 77.27 percent. It is also found that almost 89 percent pucca buildings are found as C3 type buildings, 9 percent pucca buildings are found as C2 type building. It is found from the field survey that there are 15.12 percent katcha buildings (Figure 7).

Vulnerability Assessment of Building According to RVS Score



Source: Field Survey, 2016

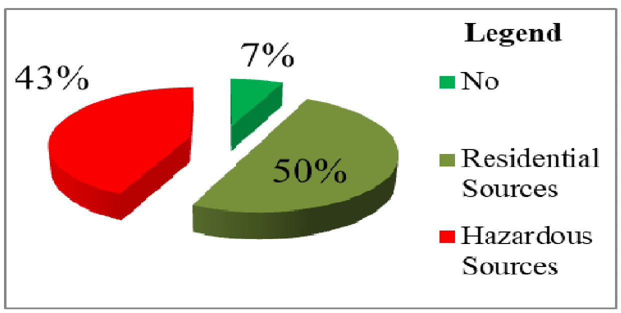
Figure 8: Vulnerability Assessment of Building According to RVS Score

It is found from the structure vulnerability of the buildings according to RVS score that almost 96 percent buildings of the South Agrabad are very highly vulnerable, only few percent of the buildings are low and very low vulnerable which are almost 2 and 3 percent respectively and no buildings are found as high and moderate vulnerable (Figure 8).

Fire Vulnerability Assessment

Fire Source in the Buildings

One of the most important factors of occurring fire hazard is the presence of fire hazard in the building. By making the review of fire hazard related journals, articles and papers, it has been understood that the sources of fire are chemical, plastic, leather, generator and gas stove. Among them, first four types are hazardous sources and last one is residential source. After analyzing the surveyed buildings it has been found that 43% of the buildings have hazardous sources, 50% of the buildings have residential sources and rest 7% of the buildings have no fire sources (Figure 9).

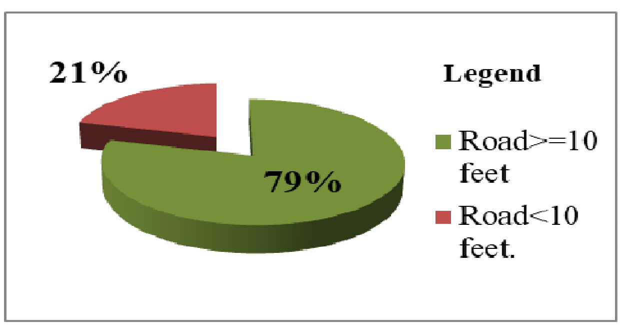


Source: Field Survey, 2016

Figure 9: Fire Sources in the Buildings

Fire Source around the Building

Another most important factor of fire hazard is the existence of fire sources around or outside the building. Fire sources around or outside the building may be



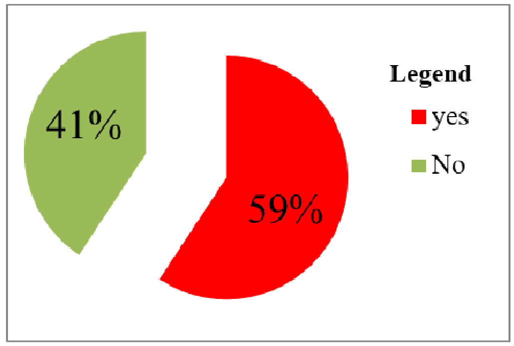
Source: Field Survey, 2016

Figure 10: Fire sources around the building

transformer, electric pole or fire influencing materials etc. From the field survey, it has been found that 59% buildings have fire sources around the building and 41% do not have fire sources around the building.

Accessibility

Accessibility is another most important factor of fire hazard vulnerability. Here accessibility refers to the sufficient width of the road that supports or helps the vehicle such as fire brigade or ambulance giving easy access to the affected building in the emergency case. From the field survey, it has been found that 79% buildings have access road which is greater than or equal to 10 feet and only 21% buildings have access road which is less than 10 feet in width.

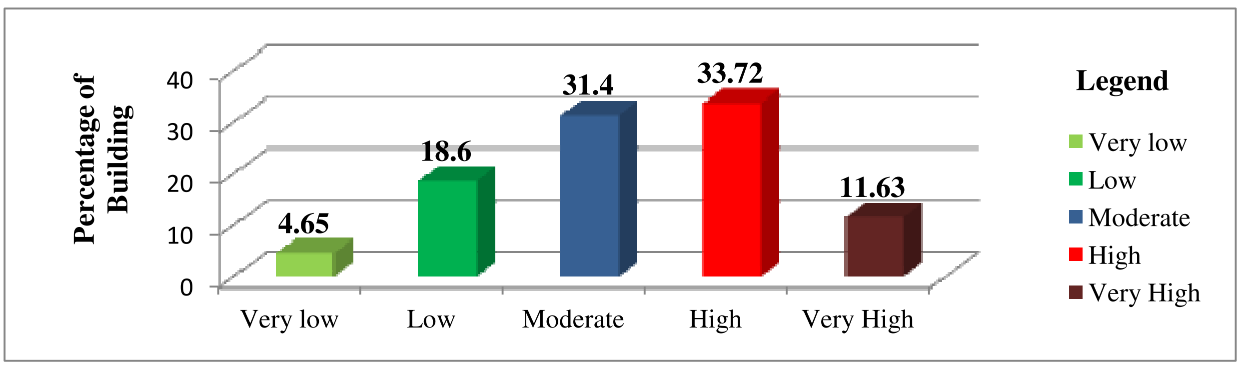


Source: Field Survey, 2016

Figure 11: Accessibility around the building

Vulnerability Assessment of Building According to FVS

From the fire hazard vulnerability assessment, it is found that most of the buildings are highly vulnerable and moderate vulnerable to fire hazard which are 33.72 and 31.4 percent respectively. It is also found that 11.63 percent buildings are very high and 18.6 percent buildings are low vulnerable to fire hazard (Figure 12).



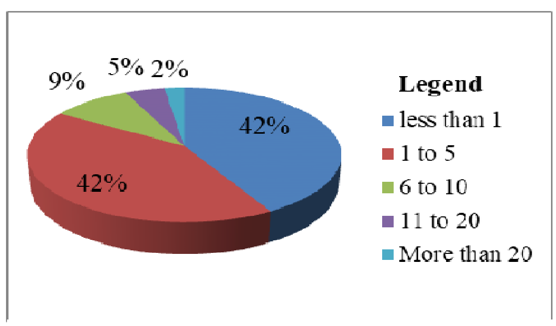
Source: Field Survey, 2016

Figure 12: Vulnerability Assessment of Building according to FVS

Social Vulnerability Assessment

Percentage of Building Having Children Age below Five Years

From the field survey it has been found that 42% buildings have less than one or within one to five children of age below five year, 9% buildings have children of age below five year within 6-10, 5% buildings have within 11-20 numbers of children and rest 2% have more than 20

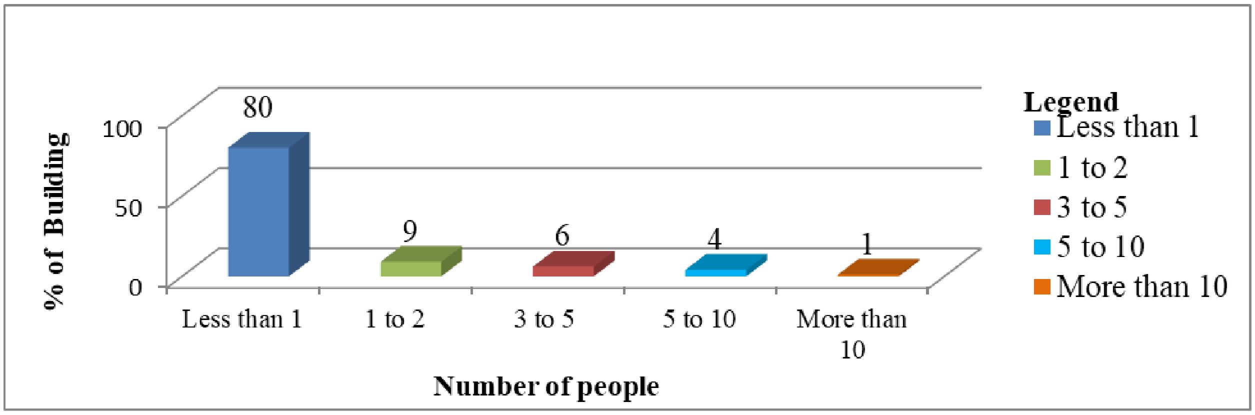


Source: Field Survey, 2016

Figure 13: Percentage of building having Children Age <5 years

children age below five years (Figure 13).

Percentage of Building Having Disable People



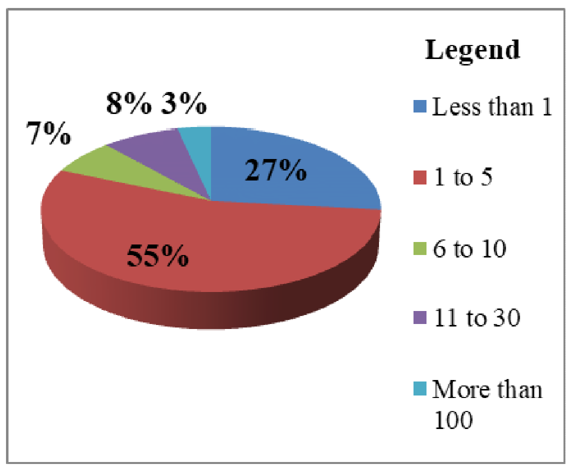
Source: Field Survey, 2016

Figure 14: Percentage of building having disable people

From the field survey, it has been found that 80% buildings have less than one disable people, 9% and 6% buildings have 1-2 and 3-5 numbers of disable people and rest of the buildings have 5-10 or more than 10 numbers of disable people (Figure 14).

Percentage of Building Having Elderly People Age above 65 Year

From the field survey, it has been found that 53% buildings have 1 to 5 number of people age equal or above 65 year, 27% buildings have less than one person age equal or above 65 year, 8% and 7% of the buildings have 11-30 and 6-10 numbers of people age equal or 65 year and only 3% of that have people more than 100.

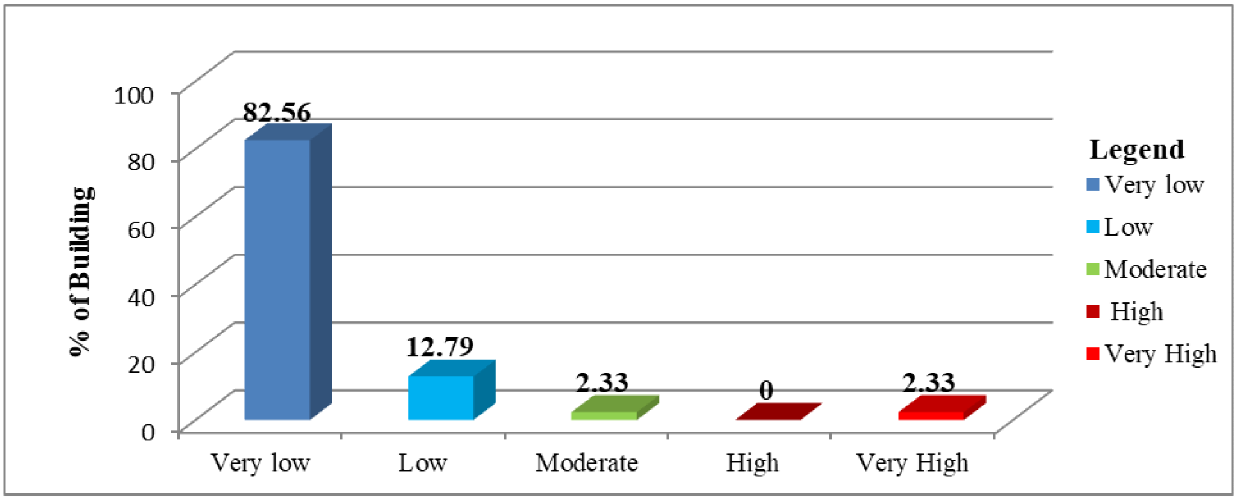


Source: Field Survey, 2016

Figure 15: Percentage of building having Elderly People Age >=65

Vulnerability Assessment of Building According to SVS

From social vulnerability analysis, it is found that almost all the buildings are very low vulnerable and low vulnerable, only few percent of the buildings are moderate and very high vulnerable which are both 2.33 percent and no buildings are found as high vulnerable (Figure 16).

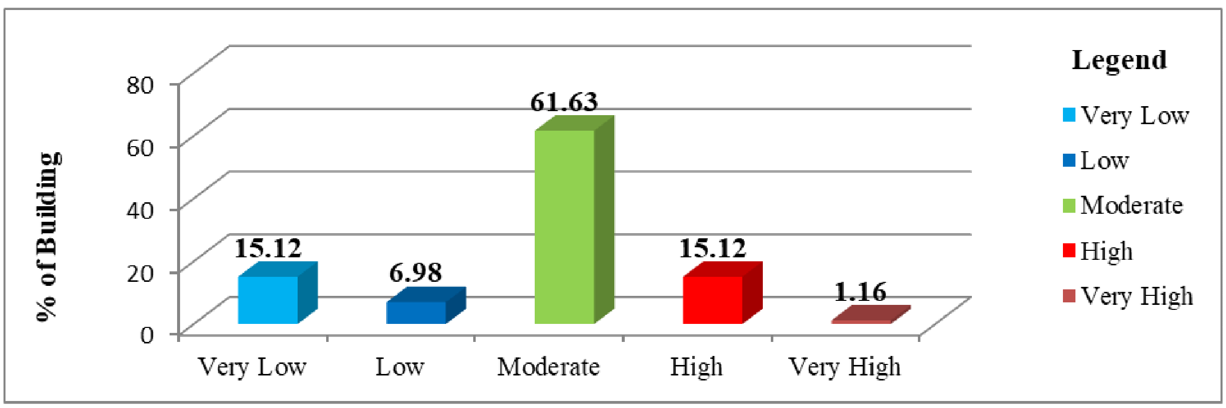


Source: Field Survey, 2016

Figure 16: Vulnerability Assessment of Building according to SVS

Vulnerability Assessment of Building according to Composite Vulnerability Score

From the composite vulnerability assessment (PVS+SVS) it is found that most of the buildings in South Agrabad are moderate vulnerable which is almost 62 percent, few percent of the buildings are high and very low vulnerable which are both 15.12 percent and 1.16 percent buildings are found as very high vulnerable (Figure 17).



Source: Field Survey, 2016

Figure 17: Vulnerability Assessment of Building according to CVS

Major Findings

After making earthquake vulnerability assessment in ward no 27 (South Agrabad) of CCC, the structure vulnerability analysis of the buildings according to RVS score is found that almost 96 percent buildings of the South Agrabad are very high vulnerable, only few percent of the buildings are low and very low vulnerable. From the fire hazard vulnerability assessment, it is found that most of the buildings are high vulnerable and moderate vulnerable to fire hazard which are 33.72 and 31.4 percent respectively. After analyzing Social vulnerability, it is found that almost all the buildings are low vulnerable, only few percent of the buildings are moderate and very high vulnerable. From the composite vulnerability assessment, it is found that most of the buildings in South Agrabad are moderate vulnerable which is almost 62 percent, few percent of the buildings are high and very low vulnerable, which are both 15.12 percent and 1.16 percent buildings are found as very high vulnerable

Conclusion

The vulnerability assessment is a well-known tool of decision-making of specific issues for responding and adapting to the effects of hazard by taking stakeholders options. Vulnerability assessment of earthquake is done in a selected area in CCC by incorporating structure, fire and social vulnerability. The buildings and physical infrastructures in Chittagong are vulnerable to future massive earthquakes, as most of this was not designed to withstand this. The study has been carried out to a small portion of CCC. If the methodology is applied in the whole ward as well as other wards, it will help the policy makers to prioritize special consideration area or hotspot for disaster management. Finally, findings of this study would benefit engineers, city planners, emergency personnel, government officials and anyone who may be concerned with the potential consequences of seismic activity in Chittagong. This research can be used to prioritize risk mitigation investments, measures to strengthen the emergency preparedness and response mechanisms for reducing the losses and damages due to future earthquake events.

Acknowledgement: *This paper is a part of research work of Undergraduate Thesis conducted by the first and second authors under the supervision of third author. Chittagong University of Engineering and Technology (CUET) funded the research as a part of author's Undergraduate Degree in Urban and Regional Planning. We are thankful for the cooperation and help extended by the junior of 12 Batch, 13 Batch and 14 Batch of the department for conducting RVS and Household Survey.*

References

Alam, M.J.B and Baroi, G.N. 2004. Fire hazard categorization and risk assessment for Dhaka city in GIS framework, *Journal of Civil Engineering (IEB)*, Volume 32 (1), Page 35 -45.

Akhter S.H. 2010. Earthquakes of Dhaka. In Environment of Capital Dhaka - Plants Wildlife Gardens Parks Air Water and Earthquake. M.A. Islam (Ed.). Asiatic Society of Bangladesh. pp. 401-426.

BBS. 2011. Bangladesh Bureau of Statistics, Bangladesh Population Census: Chittagong Community Series, Planning Commission, Ministry of Planning, Dhaka.

Bhuiyan M. A. R, Alam M. J, Roy T. and Barua A. K. 2006. Generation of Liquefaction Potential Map for Chittagong City Area, Bangladesh.4th International Conference on Earthquake Engineering. Paper No. 283. Taipei, Taiwan

BNBC. 1993. "Bangladesh National Building Code-1993", House and Building Research Institute, Dhaka, Bangladesh.

Cardona, O. D. 2005. Indicators of Disaster Risk and Risk Management, summery report, *Program for Latin America and the Caribbean*, Inter-American Development Bank, Washington D.C.

CDA. 2009. *Digital Data base of Chittagong City Corporation Area.* Chittagong Development Authority, Chittagong.

CDMP. 2009. Earthquake Risk Assessment of Dhaka, Chittagong and Sylhet City Corporation Area, Comprehensive Disaster Management Programme (CDMP), Ministry of Food and Disaster Management, Government of the People's Republic of Bangladesh

CMMP. 1995. Structure Plan, Chittagong Metropolitan Master Plan, Chittagong Development Authority, Chittagong.

Dhaka Tribune, 2018. *Fire destroys 200 shanties in Chittagong*. [online] Available at: https://www.dhakatribune.com/bangladesh/nation/2018/02/19/fire-destroys-200-shanties-chittagong/ [Accessed 15 May 2018].

FEMA. 2015. Rapid Visual Screening of Buildings for Potential Seismic Hazards, A Handbook, FEMA 154, Federal Emergency Management Agency, Edition 3.

Gupta, S. P. and Gupta, M. P. 2006. Business Statistics, New Delhi: Sultan Chand & Sons.

Kauser, M. R. H., Saha, J. K., and Raja, D. R. 2017. 'A GIS based approach of seismic microzonation of Chittagong city corporation area, Bangladesh', paper presented in the International Conference on Disaster Risk Mitigation, (ICDRM) 2017, organized by BUET-JIPSU, Dhaka, Bangladesh, September 23 - 24, 2017.

Masud A.M. 2007. Earthquake Risk Analysis for Chittagong City, Unpublished Muster thesis, Department of Civil Engineering, Bangladesh University of Engineering and Technology.

Rahman, N., Ansary, M., & Islam, I. 2015. GIS based mapping of vulnerability to earthquake and fire hazard in Dhaka city, Bangladesh. *International Journal of Disaster Risk Reduction*.

Sarraz A., Ali M. K. and Das D. C. 2015. Seismic Vulnerability Assessment of Existing Building Stocks at Chandgaon in Chittagong City, *Bangladesh. American Journal of Civil Engineering*. Vol. 3, No. 1, pp. 1-8. doi: 10.11648/j.ajce.20150301.11.

Sultana, S., Rahman, U., Saika, U. 2013. Earthquake, Cause Susceptibility And Risk Mitigation in Bangladesh. *ARPN Journal of Earth Sciences,* VOL. 2, NO.2, 2013, 70-73.

The Daily Star. 2017. *One killed, five injured in Ctg fire*. [online]. Available at: https://www.thedailystar.net/backpage/one-killed-five-injured-ctg-fires-1487917 [Accessed 15 Dec. 2017].

World Bank. 2014. Dhaka Earthquake Risk Guidebook, Bangladesh Urban Earthquake Resilience Project, Earthquakes and Megacities.

USGS. 2016. *Recent earthquake history*. *Earthquake.usgs.gov*. Retrieved 8 September 2016, from https://earthquake.usgs.gov/ *Recent*/*earthquake*/*history* /