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Urban Settlement Risk in the Moderate Seismic Zone of Bangladesh

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Introduction

Earthquakes of varying magnitude are regularly experienced throughout the world. These are most disastrous of all the natural calamities as they affect large areas causing death, injuries and destruction of physical resources on a massive scale. A severe earthquake can realease 10000times more energy than the first atomic bomb (MEF, 2010). Severe earthquake is considered as one of the most frightening and destruction phenomenon of nature. Severe earthquake has occurred in Bangladesh in the past. Since 1869, the country has experienced seven severe earthquakes; each had a magnitude of 7.0 or greater on the Richter scale (Ali & Choudhury, 2001). Out of these, the Bengal earthquake in 1885 and the Srimangal earthquake in 1918 had their epicenters within the country (Paul & Bhuiyan 2010). Earthquake epicenters inside Bangladesh are indicative of the propagation of fractures from seismically active zones, making the entire country potentially vulnerable to earthquakes (Khan *et al.*, 2000). The term urban settlement is used in the study is based on a functional approach to denote a settlement in which the majority of the works force pursues urban occupations; *i.e.,* secondary or tertiary. These are occupations which are concerned with such things as manufacturing, retailing, wholesaling, finance, transport and education. Repeat of severe earthquakes which appears to be quite likely can now cause great devastation. Even moderate earthquakes close to the urban settlements may cause great havoc.

Objectives and Methodology

The objectives of the present study are to know about the urban settlement that may exist in the moderate seismic zone of Bangladesh and perceive their risk to earthquake hazard. Distribution pattern of urban settlement and their hierarchy have been identified by applying *Nearest Neighbor Index*

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evolved by Clark and Evans (1954) and *Centrality Score* respectively. Risk of urban settlement to earthquake hazard has been observed from 385 samples by applying stratified random sampling technique in different Order of urban settlements where the owners of the house were the only respondets.

$$R_n = \frac{\overline{Dobs}}{\overline{Dran}} \quad Where, R_n = \text{nearest neighbor index;}$$

$$\overline{Dobs} = \frac{\sum x}{N} \; ; \quad \overline{Dran} = \frac{1}{2\sqrt{\frac{N}{A}}}$$

Where, $\sum x$ = distance between every single settlement and its nearest neighbor; N = number of settlements; A = total area of Moderate Seismic Zone in Bangladesh

Earthquake Scenario in Bangladesh

Earthquakes occur due to movements along the faults that have evolved through geological and tectonic processes. Recently, Bilham *et al.* (2001) pointed out that there is high possibility that a huge earthquake will occur around the Himalayan region based on the difference between energy accumulation in this region and historical earthquake occurrence. Bangladesh is close to the meeting point of the Indian, Eurasian and Burma (Myanmar) plates. The magnitude 7.0 or above on the Richter scale earthquake occurred (Table 1) during the last 150 years had their epicenters distance from Dhaka in between 150- 780 km. (Ansary, 2001; Ali & Choudhury, 2001). The most devastating Earthquake was Great Indian Earthquake and the distance was only 230 km from Dhaka. The depth of focus of these epicenters was more or less 70 km (Bolt, 1987; Ali & Choudhury, 2001).

Table 1: Major Earthquakes in Bangladesh the Last 150 Years

Date	Name of Earthquake	Magnitude (Richter)	Distance of Epicenter from Dhaka (KM)
January 10, 1869	Cachar Earthquake	7.5	250
July 14, 1885	Bengal Earthquake	7.0	170
June 12, 1897	Great Indian Earthquake	8.7	230
July 8, 1918	Srimangal Earthquake	7.6	150
July 3, 1930	Dhubri Earthquake	7.1	250
January 15, 1934	Bihar-Nepal Earthquake	8.3	510
August 15, 1950	Assam Earthquake	8.5	780

Source: *Ali & Choudhury, 2001*

According to a seismic zoning map prepared by BUET, 43 percent areas in Bangladesh are rated high risk, 41 percent moderate and 16 percent low. In the zoning map of 1993 which was included in the BNBC, 26 percent of the country was high risk, 38 percent moderate and 36 percent low in terms of earthquake vulnerability. Major seismic sources for the Bangladesh are Assam fault zone, Tripura fault zone, Sub-Dauki fault zone and Bogra fault zone. These faults are capable of producing earthquakes of magnitudes 8.0, 7.0, 7.3 and 7.0 Richter respectively (Bolt, 1987).

Urban Settlement in the Study Area

Considering *Pourashava* as urban settlement 48 urban settlements found in the study area. Seventy per cent of the total urban population; *i.e.*, 18893903 person lives in *Pourashavas* (BBS, 2008), where the study area covers about 44% of the total *Pourashavas*' population having about 22% of the total urban settlements of Bangladesh. The value of nearest-neighbor "R_n" is found 0.13 which explain that the distribution patterns of urban settlements are "near clustered" (Fig.1).

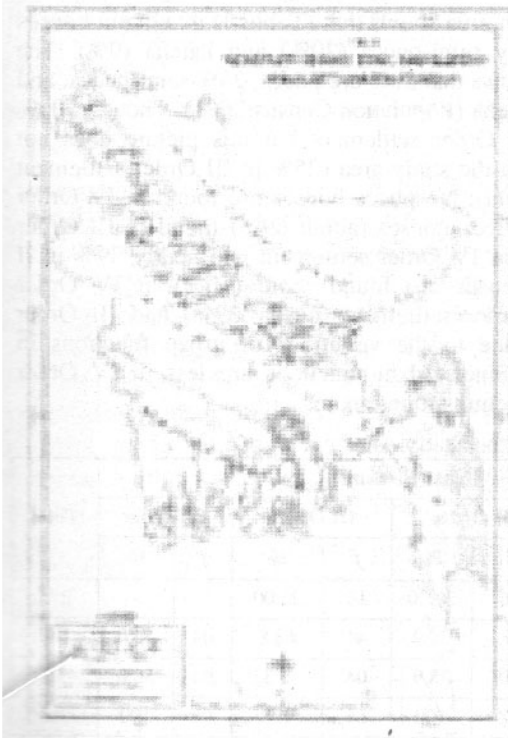
In respect of all selected settlements, details of population, functions, amenities and administrative status have been analyzed for hierarchy of urban settlement. The threshold population for each function has been worked out by entry-point (the population at which the function appears first time when all the selected settlements are arranged in and ascending order of population). To find out the entry-point of function algorithms are made. Since the entry point of all functions varied from unit to unit due to differential population size of the settlements and the spread of the functions over an area, the entry point or threshold is worked out separately for all the urban settlements in the study area. A score of one is given for every 1,000-threshold population. Numerically score values assigned to population, amenities and administrative status are such as to be convenient for purposes of quantification.

Following hierarchy of urban settlements found (Fig. 1) on the basis of centrality score: I Order (having score >5000), II Order (having score 650-450), III Order (having score 449-250) and IV Order (having score <250). Composite centrality score shows that only Dhaka City Corporation found in the I Order hierarchy with a population size of 5327306 and centrality score 5808.33. It is the only mega city and capital city of Bangladesh and is the undisputed urban leader in Bangladesh. In II Order hierarchy there are 9 urban settlements; *viz.*, Dinajpur, Narayanganj, Tongi, Savar, Gazipur, Bogra, Tangail, Brahmanbaria,and Sirajganj. These urban settlements act as predominant regional centers serve their surroundings as well as other centers of higher magnitude. Thirty one urban settlements found in III Order hierarchy with centrality score 449-250 namely, Kadamrasul,

Narsingdi, Rangamati, Naogaon, Joypurhat, Manikganj, Ghorashal, Shahjadpur, Thakurgaon, Daudkandi, Parbatipur, Gopalpur, Madhabdi, Shariakandi, Nabinagar, Ullahpara, Mirzapur, Akhaura, Pirganj, Birampur, Dhupchanchia, Kalihati, Kasba, Gurudaspur, Sherpur, Ghatail, Khagrachhari, Bhangura, Kazipur, Bochaganj, and Akkelpur. All of these urban settlements have spatial existence in the area to serve the population of the surrounding area to a maximum extent. Seven urban settlements; viz., Bhuanpur, Hakimpur, Santahar, Panchbibi, Fulbari, Faridpur, and Patnitala are contained in IV Order hierarchy with centrality score below 250.

Risk of Urban Settlement to Earthquake Hazard

Risk of urban settlement to earthquake hazard in the study area has been assessed on housing structure, building height, construction year, involvement of home builders, number of exit door in the house, nearest open space, accessibility of fire bridget, and considering whether building construction rule followed.



House Ownership and Housing Structure in the Study Area

House ownership in the study area (Table 2) depicts that maximum of the respondents (67.0%) own the full ownership and remaining i.e. 33% own the partial ownership. Hundred percent full ownership found in II, III, and IV Order Settlement where as only 47.3% found in I Order Settlement, because as considering unit cost it is very difficult in getting access to land in the city where people could build their own dwelling. The land value of I Order Settlement increased at rates 60 to 90 percent faster than the customer prize index in eighties (Choudhury 1992).

Table 2: House Ownership of the Sample Household in Study Area

Urban Settlement	Ownership				
	Full		Partial		Total
	f	% within the settlement	*f*	% within the settlement	
I Order	114	47.3	127	52.7	241
II Order	72	100	0	0	72
III Order	64	100	0	0	64
IV Order	8	100	0	0	8
Total	258	-	127	-	385

Source : *Field Survey, 2010*

The housing structure in urban area shows that (Table 3) maximum houses are pucca (71%) followed by semi-pucca (20%) and katcha (9%). The national figure of the same shows that 22% are pucca, 23% semi-pucca, and 55% housing structure are katcha (Population Census 2001). Though 100% pucca houses are found in I Order settlement but this picture does not remain same in everywhere in the study area (25% in III Order settlement and 22% in II Order settlement). No pucca houses are found in IV Order settlement. Maximum semi-pucca houses (about 69%) found in III Order settlement followed by 50% in IV Order settlement and nearly 39% in II Order settlement. Katcha houses are found more (50%) in IV Order settlement followed by II Order settlement (nearly 39%) and III Order settlement (6.3%). This is due to the variations of urban functions in different Order settlements. Since urban functions are less in IV Order settlement katcha housing structures found more.

Table 3: Housing Structure in the Study Area

Housing Structure	Urban Settlement								Total
	I Order		II Order		III Order		IV Order		
	f	%	*f*	%	*f*	%	*f*	%	
Pucca	241	100	16	22.20	16	25.00	-	-	273
Semi-pucca	-	-	28	38.9	44	68.8	04	50.0	76
Katcha	-	-	28	38.9	04	6.3	04	50.0	36
Total	241	100	72	100	64	100	08	100	385

Source : *Field Survey, 2010*

Note: Semi-pucca means floor pucca, wall pucca/tin, roof pucca/tin. Katcha means mud floor, wall tin/fence, roof tin/fence).

Building Height: Building height of the pucca houses in the study area (Table 4) reveals that 71% are low laying and 29% are high-rise. Hundred percent of the high-rise building found in I Order Settlement due to the huge population and very rapid growing nature of the city which attracts people to migrate from the rural and other cities. In order to release the pressure of over population and congestion in the inner-city areas of Dhaka, high-rise buildings are constructed.

Table 4: Building Height in the Study Area

Building Height	Urban Settlement								Total
	I Order		II Order		III Order		IV Order		
	f	%	*f*	%	*f*	%	*f*	%	
Low laying	161	66.80	16	100.0	16	100.0	00	00	193
High rise	80	33.19	00	00	00	00	00	00	80
Total	241	100.0	16	100.0	16	100.0	00	00	273

Note: High rise building means 7 storied and above as per BNBC, 1993

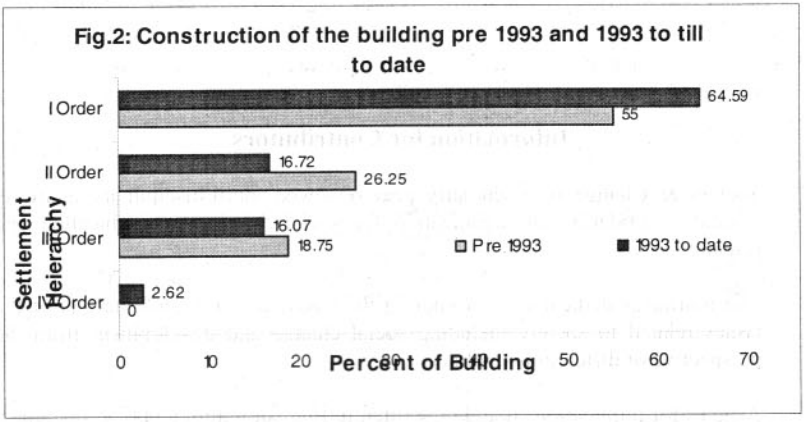
Source : Field Survey, 2010

Construction Year: Housing and Building Research Institution (HBRI) granted a housing policy named BNBC (Bangladesh National Building Code) in 1993. Considering Bangladesh National Building Code (BNBC) plan, 1993 as a marked year for the study, it is found that nearly 19% buildings constructed before 1993 in I Order settlement, and more than 81% constructed in 1993 to till to-date (Table 5 & Fig.2). Though maximum buildings are constructed after 1993 in all hierarchy of urban settlement but comparatively more buildings (31.3%) are found constructed before 1993 in II Order urban settlement and 12.5% are in III Order settlement. The buildings built before 1993 are seem to be under risk, since there was no housing policy like BNBC before 1993.

Table 5: Construction Year of the Building in the Study Area

Construction Year	Urban Settlement								Total
	I Order		II Order		III Order		IV Order		
	f	%	*f*	%	*f*	%	*f*	%	
Before 1993	44	18.26	5	31.25	2	12.5	-	-	51
1993 to till todate	197	81.74	11	68.75	14	87.5	-	-	222
Total	241	100.0	16	100	16	100.0	-	-	273

Source : *Field Survey, 2010*



Involvement of Home Builders: Twenty years ago there were fewer than five companies in Bangladesh engaged in developing apartments while today there are more than 200 developers. At present there are 80 such developers working in Dhaka City who are members of REHB. But there are many other companies/individuals engaged in such development in smaller scale and selling apartments to friends and relatives only. Involvement of home builders for housing construction found only in the I Order settlement of the study area and that also not more than 24% of the total sampled houses (Table 6). The housing situation in Dhaka (I Order Settlement) is characterized by a huge shortage in housing stock. It is very difficult in getting access to land in the city where they could build their own dwelling.

Table 6: Home Builders of the Sample Household in the Study Area

Home Builders	Urban Settlement								Total
	I Order		II Order		III Order		IV Order		
	f	%	*f*	%	*f*	%	*f*	%	
Owner	150	62.2	72	100	64	100	8	100	294
Developer	91	37.8	-	-	-	-	-	-	91
Total	244	100	72	100	64	100	8	100	385

Source : *Field Survey, 2010*

Number of Exit Door at Home: The exit door is important to exit from residential unit during and after occurrence of an earthquake. Most residential buildings in the study area have only one door at each home (Table 7); *i.e.,* about 62%. Having two, three, and four exit door occupies 29.1 %, 7.3% and 2.0% respectively in the study area. Only one exit door at

home found more in the I Order settlement (about 92% of the total houses of I Order settlement) due to save floor space followed by II Order settlement (about 17% of the total houses of II Order settlement), and III Order settlement (about 6% of the total houses of III Order settlement). In reality, it will be very difficult for residents to exit from most apartment building in case of emergencies because of use one exit door and iron grill for safety purposes.

Table 7: Number of Exit Door of the Sample Household in the Study Area

Number of Exit Door	Urban Settlement								Total
	I Order		II Order		III Order		IV Order		
	f	%	*f*	%	*f*	%	*f*	%	
1	221	91.7	12	16.7	4	6.3	-	-	237
2	20	8.3	48	66.7	36	56.3	8	100	112
3	-	-	8	11.1	20	31.3	-	-	28
4	-	-	4	5.6	4	6.3	-	-	8
Total	241	100	72	100	64	100	08	100	385

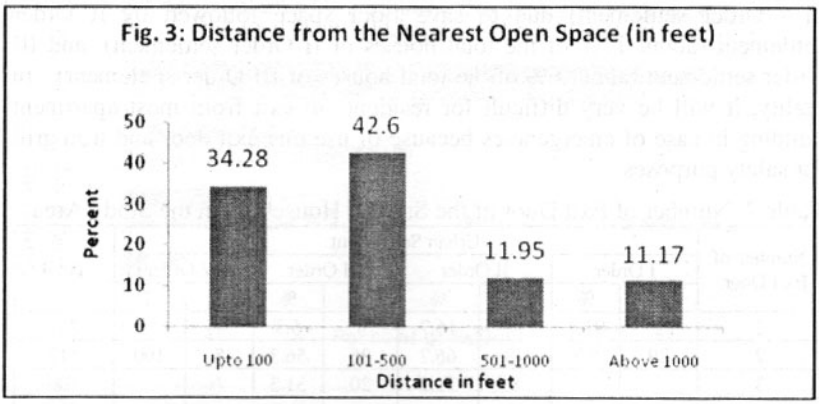
Source : Field Survey, 2010

Nearest Open Space: Open space is very important to take shelter during and after occurrence of earthquake. Thus having nearest open space is considered to be less risk for a house than not having nearest open space. Having open space within the radius of 100 feet found 34% of the total houses and which found more in II Order settlement (52% of the total houses in the study area), 43% of the houses having open space within the radius of 100-500 feet and 12% of the houses having open space within the radius of 500-1000feet (Table 8 & Fig. 3). Only 3% of the total houses are found in I Order settlement having nearest open space within the radius of 100 feet.

Table 8: Nearest Open space from the House in the Study Area

Range (in feet)	Urban Settlement								Total	
	I Order		II Order		III Order		IV Order			
	f	%	*f*	%	*f*	%	*f*	%	*f*	%
> 100	4	1.65	68	94.44	52	81.25	8	100	132	34.28
100 - 500	148	61.41	4	5.56	12	18.75	-	-	164	42.60
501 – 1000	46	19.09	-	-	-	-	-	-	46	11.95
1000+	43	17.84	-	-	-	-	-	-	43	11.17
Total	241	100	72	100	64	100	8	100	385	100

Source : *Field Survey, 2010*



Accessibility of Fire Bridget: According to BNBC every high rise (seven storied and above) building should have at least 30 feet wide road for accessibility of Fire Bridget vehicles (BNBC 1993). Since cent percent of the high-rise building found in I Order settlement (discussed earlier in Table 4) accessibility of Fire Bridget as per BNBC are observed in I Order settlement only. Maximum high rise buildings (91%) have accessibility of Fire Bridget in the I Order settlement. Only 9% of the high rise buildings are not accessible of which maximum are located in Old Dhaka. The width of road in the unregulated residential areas are less than 13 feet wide, some even less than 10 feet. And most of the not accessible roads are in III Order Settlement which is not well connected by road.

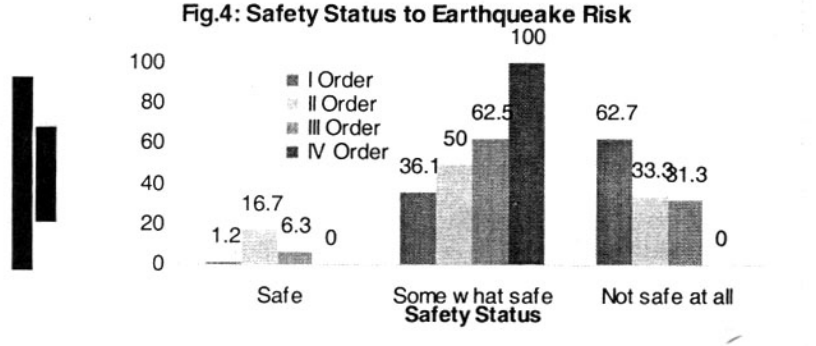
Building Construction Rule Followed: With a view to bringing in control and ensuring a uniform standard of building construction practice in the country, the Bangladesh National Building Code (BNBC) was prepared in 1993 under the aegis of the Ministry of Housing and Public Works. BNBC is a 1000 page detailed document specifying safe and acceptable practices in all aspects of building design and construction for various uses or occupancy. Bangladesh National Building Code (BNBC) prepared in 1993 has ten distinct parts addressing different aspects of building construction and building services. Though most of the respondents in the study area are aware about BNBC (71.9%) but the percentage of following the same is not satisfactory. Maximum of the respondents who are aware regarding building construction rule are found in I Order settlement because most of the high rise buildings found in here. The owner of the high rise buildings has little respect either for rule or environmental sustainability. Most parts of Dhaka have been built informally by individuals without any planning guide line or more recently by private land developers or real estate companies.

Peoples` Perception Regarding the Safetiness to Earthquake Hazard: As many as 50.6 percent of all respondents believed that they and their families are not safe at all from earthquake risk. Fourty four percent believe that they are some what safe and very few respondents (4.9%) believed that they are safe from earthquake risk (Table 9 & Fig. 4).

Table 9: Peoples Perception Regarding the Safetiness to Earthquake Hazard

Situations	Urban Settlement									
	I Order		II Order		III Order		IV Order		Total	
	f	%	*f*	%	*f*	%	*f*	%	*f*	%
Safe	3	1.2	12	16.7	4	6.3	0	0	19	4.9
Some what safe	87	36.1	36	50.0	40	62.5	8	100.0	171	44.4
Not safe at all	151	62.7	24	33.3	20	31.3	0	0	195	50.6
Total	241	100	72	100	64	100	8	100	385	100

Source : Field Survey, 2010



Conclusion

It can be concluded from the analysis that urban settlement in the study area are under risk to earthquake hazard. Although the earthquake tremors cannot be stopped or reduced, the human casualties and loss of properties can be reduced. Since urban settlements are built up area, immediate action should be taken to reduce risk by making an inventory of all old buildings which are vulnerable to earthquake, and either repair or evacuate occupants from those buildings and that has to be done on the basis of hierarchy of urban settlement. Mapping risk areas to earthquake hazard, building awareness programme, and constructing building as per the guidelines of the BNBC urban settlement risk can be reduced dramatically.

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