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EVALUTION OF BUILDING'S VULNERABILITY TO EARTHQUAKE IN OLD PART OF SYLHET AND CONSTRUCTION SAFETY RULES

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Abstract: *Sylhet is the northeastern region of Bangladesh and probability of earthquake in Sylhet is higher than other areas of this zone. Among 27 wards, Ward no. 14 is one of the important largest Wards in Sylhet city and a densely populated one. It was clear from the survey works, 42.8% buildings are belongs to Building with RCC frame; 54.03% buildings are Masonry buildings. Another interesting finding is 325 houses fall in the category of Houses with resident 1-10. The occurrence of an earthquake of PGA value 0.9g on ward no. 14 causes massive loss of lives and damage to buildings. Depending on the time of the day 147 to 603 people may be killed due to structural collapse and the buildings of worth approximately TK.32.00 core may be damaged.*

Keywords: *Earthquake, PGA, economical evaluation, building types.*

1. Introduction

Bangladesh is one of the most earthquake prone countries in the world. Specialists are expecting a severe earthquake in this area in near future, which will cause a serious human casualty, damages of infrastructure and other losses. By the initiative of Bangladesh Government, a seismic zoning map of Bangladesh was prepared in 1993 [1], where the country was divided into three zones. The most severe zone is the zone no. 3, which includes the north and northeastern parts of the country.

Sylhet is the northeastern region of Bangladesh and probability of earthquake in Sylhet is higher than other areas of this zone. But most of the population and policy makers do not perceive seismic risk to be important.

The loss of life and property can be reduced to a considerable degree by the adaptation and implementation of proper planning, improved structural design and construction procedures. Geologically Bangladesh is vulnerable to earthquake. In north of Bangladesh, there is a joining point of two plates- Indian plate and Eurasian plate. In east of Bangladesh, there is a joining point of two plates- Barmiz plate and Indian plate. Indian plate is moving in north east direction and barmiz plate is moving in north-west direction. So, the tectonic evaluation of Bangladesh can be explained as a result of collision of the north moving Indian plate with the Eurasian plate. The whole Indian subcontinent is situated on the junction of these two plates. There are several fault zones active in this junction area, which are the sources of earthquake [2]. In this paper an attempt has been taken to estimate the damage in this zone due to earthquake to make the people and Government aware about the earthquake.

2. Methodology

The methodology followed for damage estimation is presented in the flow chart shown in the figure 1.

2.1. Selection of Site for Survey

To survey the whole city is almost impossible within a limited time especially for two students. Considering this time constrain and lack of economic support we have surveyed a representative ward of Sylhet city. Ward no.

Our selected study area Ward no. 14 is one of the important largest Wards in Sylhet city and a densely populated one. In the North of the ward Zindabazar is situated and the southern part is bounded by Surma River. The west side of the ward extends from Taltola to Shakh ghat. The East the boundary of this ward is

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extended to Upashar. For shake of convenience, the whole ward was divided into nine areas. These areas are Amjad Ali Road, Bondor Bazar, Charar par, Dc Office,Kali Ghat, Kamal ghor,Kasto ghor, Lal digirt Par and Mohanjon Potti.

2.2. Building Classification

All buildings have been classified into five types based on their definition in European Macro seismic Scale [4]. Table 1 shows the description of each typology.

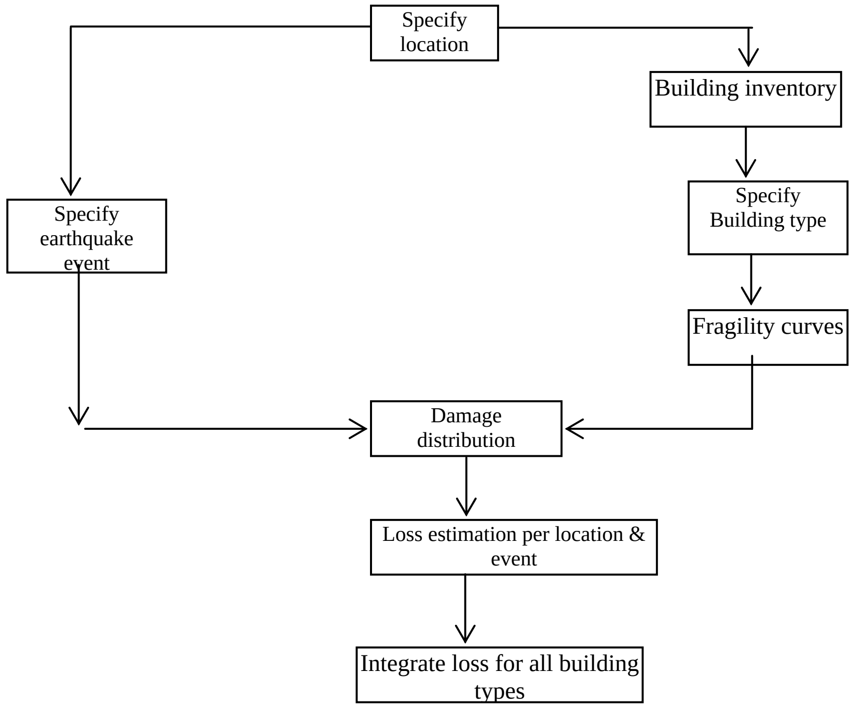

Fig 1. Flowchart of damage estimation methodology [3]

Tab. 1. Description of each building typology

No.	Types	Description
1	EMSB1	1- storied brick masonry of fired bricks with cement or lime mortar; roof is either of GI sheet or other materials
2	EMSB2	2-storied or taller brick masonry of fired bricks with cements or lime mortar; roof is generally made of RCC slab. Some weak and old reinforced concrete frame.
3	EMSC	Reinforced concrete frame with low ductility; designed for vertical load only.
4	EMSD	Reinforced concrete frame with moderate ductility; designed for both vertical and horizontal loads.
5	EMSF	Mainly bamboo, wooden and steel structures.

3. Data Collection and Analysis

Estimating human casualty and economic loss requires a wide variety of data. In this study the seismic vulnerability has been carried out by using the data of building stock and behavior of different types of buildings. As enough seismic information for Sylhet is not available, we have to collect necessary data for Sylhet city. Table 2 shows distribution of different types of buildings in ward no.14.

3.1. Building Inventory Survey

Completion of our survey work involves questionnaire survey and visual inspection. All the buildings in the survey area have been surveyed with a questionnaire based on type of building, shape of building, age of building, area of building, facilities of building such as electricity, water supply, stair etc [5, 6].

Tab. 2. Distribution of different types of buildings in ward no.14.

	EMSB1	EMSB2	EMSC	EMSD	EMSF	Total
Amjad Ali Road	12	5	38	5	0	60
Bondor bazaar	30	16	32	1	1	80
Charar par	34	1	28	0	1	64
Kali Ghat	35	9	22	0	0	66
Kamal ghor	18	2	11	0	0	31
Kasto ghor	56	1	17	0	1	75
Dc office	12	2	16	2	3	35
Lal dighir par	19	22	33	3	3	80
Mohajon potti	29	16	32	0	3	80
Total	245	74	229	11	12	571

Source: [3]

3.2. Seismic Vulnerability and Safety Measures

The present population of Sylhet city is about 6 lakhs. As a result of high migration rate, this number is increasing day by day. So, the city is growing at a high rate and obviously, without proper planning. New slums and high-rise buildings are making the city very crowded. This situation is common for other town of Sylhet region. In the cities of Sylhet region, there are mainly three types of houses: i) buildings with RCC frame and brick walls ii) masonry buildings iii) houses constructed of other materials like CI sheet, bamboo, wood, thash, mud etc. Recently the Department of Civil and Environmental Engineering of Shahjalal University of Science and Technology, Sylhet performed a survey in Sylhet city. The findings of the survey in word-7 of Sylhet Municipality on 571 houses are given in table-3.

Tab. 3. The findings of the survey in Old part of Sylhet (commercial area)

Parameters	% of houses				
Type of houses	*Building with RCC frame*	*Masonry buildings*	*Houses constructed of other materials*		
	42.8 %	54.03 %	3.17 %		
Story	*1 storied buildings*	*2 storied buildings*	*3 and above storied buildings*		
	54.7 %	36.6 %	8.7 %		
Shape of the house	*Rectangular, square and box*	**L** *shape*	**I** *shape*	*Other shapes*	
	94.4%	2.03 %	3.7 %	0 %	
Age of the houses	*0-10 years*	*11-20 years*	*21-30 years*	*Above 30 years*	
	19.7 %	28.3%	23.7 %	28.3 %	
Foundation type	*Foot*	*Wall*	*Pile*	*Raft*	*Without foundation*
	38.7 %	57.6%	1 %	0 %	2.7 %
Resident number	*Houses with resident 1-10*	*Houses with resident above 10*			
	32 %	68 %			
Gas supply	*Houses with gas supply*	*Houses without gas supply*			
	63 %	37 %			
Electricity	*Houses with electricity*	*Houses without electricity*			
	100 %	0 %			
Telephone	*Houses with telephone*	*Houses without telephone*			
	54 %	46 %			

The seismic vulnerability depends on the construction practice in the city and is related to quality of building stock. In Sylhet, a larger proportion of buildings are very old. On the other hand, most of the new buildings are unplanned and designed without considering earthquake risk. Consequently, the buildings of Sylhet city are vulnerable to earthquake. The number of houses that can be damaged due to earthquake of intensity EMS VIII, IX, X in Sylhet city based on previous earthquake occurred in this region is given in the table- 4. According to the Figure 2 in Ward no.14 Mohazonpotti, Laldegirpar and Bondor are the most vulnerable areas to the destruction of earthquake because there are a lot of buildings, which have constructed more then 50 years ago and moreover, some are expired.

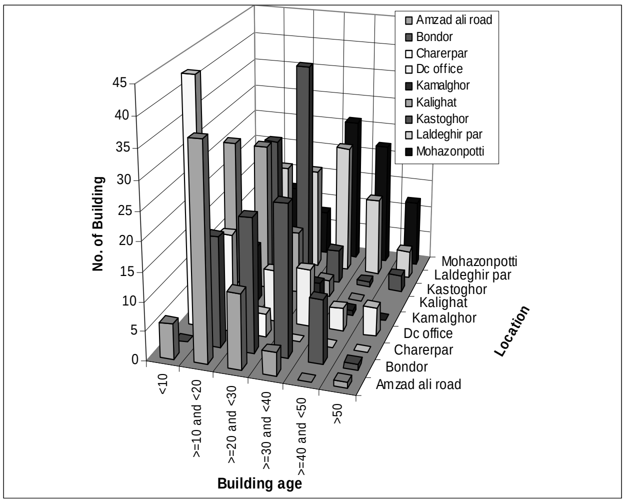

Fig 2. Building age, Location, No. of Buildings

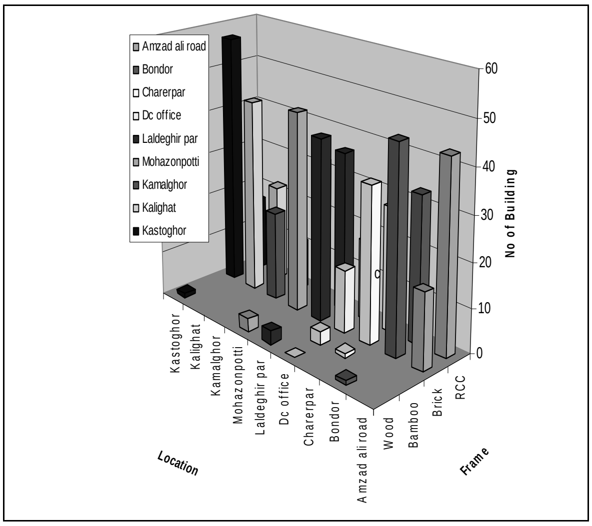

Fig 3. Frame, Location, No. of Buildings

According to the Figure 3 in Ward no.14 Kastoghor, Mohazonpotti, Laldegirpar and Bondor are the most susceptible areas to the damage of earthquake because there are a lot of buildings, which have constructed with brick masonry.

3.3. Damage Calculation and Human Casualty

Earthquakes are natural hazards under which disasters are mainly caused by damage to or collapse of buildings and other manmade structures. In this study primarily building damage is estimated and then human casualty.

3.3.1 Vulnerability Function

Earthquake damage depends upon many parameters, including intensity, duration, frequency of ground motion, geologic and soil condition, quality of construction etc. For estimating building damage use of fragility curve is the usual practice. But no fragility curve has yet been developed for Bangladesh. The fragility curve in figure 4 for Indian buildings prepared by Arya [7] and calibrated by Ansary [8] for buildings in Dhaka has been used in this study to estimate the building damage as the experts think that the Indian and Nepalese curves are most suitable for Bangladeshi buildings.

Following figure shows the fragility curve for EMSB1, EMSB2, EMSC, EMSD and EMSF type structure.

3.3.2. Building Damage

Most buildings that are found in Sylhet are non-engineered. These structures are typically designed and for constructed by people with out appropriate technical qualifications. Most such buildings are designed without any detailed analysis and may also be a poor quality.

Some non-engineered buildings are made from brick masonry with light weight roof. The performance of these buildings is expected to be at par with the corresponding engineered buildings since most such constructions have also used cement mortar. Most other non-engineered buildings are made of light informal materials such as thatch, wood, GI sheets and mud. These buildings are naturally expected to behave very poorly due to an earthquake.

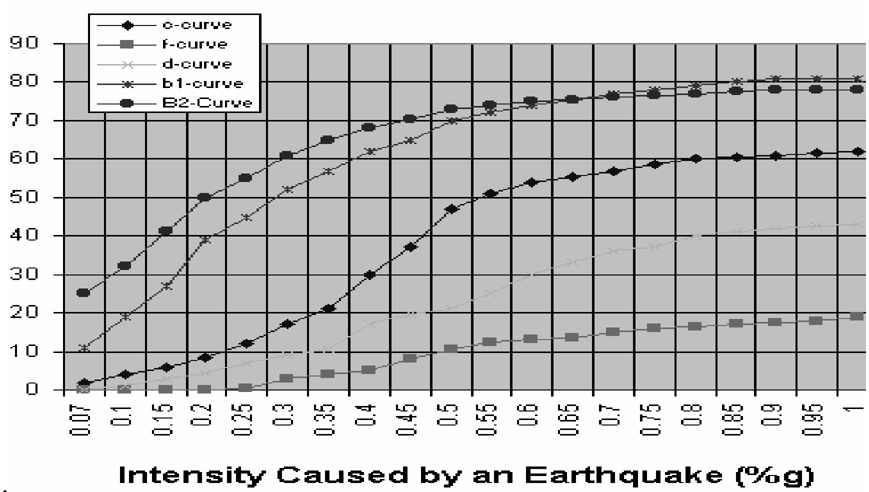

Fig 4. Fragility curve for different building types based on EMS intensity

However due to the lightweight nature of these structures, they are expected to trap fewer people, leading to lower casualty. A similar phenomenon has also been observed after 1993 Killari and 2001 Gujarat earthquakes in India where the loss of life among the poorest section of inhabitants, who mainly lived in thatch houses, have been found to be the lower. Some traditional non-engineered houses in Sylhet are unique in their feature from the rest of the country. They are made of bamboo mats plastered with lime having either bamboo or wooden poles as supports. These are called Assam and Sylhet region as earthquake resistant structures.

From the isoseismic maps of some of the damaging earthquakes in this region it can be deduced that the intensity of a large earthquake in Sylhet may be 0.9g. In this study building damage has been estimated for PGA value 0.8g, 0.9g and 1.0g. From the fragility curve calibrated for a return period of 475 years, the percentage of damage for different types of buildings at PGA value 0.8(%g), 0.9(%g) and 1.0(%g) given in the table 4. Estimated damage of different types of buildings for PGA value 0.8(%g), 0.9(%g) and 1.0(%g) is shown in the Table 5.

Tab. 4. Damage ratio for different types of buildings at different earthquake intensity

Type of Building	**Damage Ratio at Various PGA value (%g)**		
	0.8	**0.9**	**1.0**
EMSB1	0.79	0.8	0.81
EMSB2	0.75	0.76	0.77
EMSC	0.6	0.61	0.62
EMSD	0.4	0.42	0.43
EMSF	0.16	0.17	0.18

Tab. 5. Probable damage due to earthquake (no. of houses) in Ward number -7

Type of house	**Probable no. of houses when the Intensity of earthquake is :**		
	0.8 PGA	***0.9 PGA***	***1.0 PGA***
Buildings with RCC frame and brick wall	141	145	147
Masonry buildings with RCC roof	55	56	57
Masonry buildings with CI sheet roof	194	196	198
Houses constructed with mud, bamboo, wood, CI sheet etc.	2	3	2

3.4. Human Casualty

In order to assess the human casualty levels due to the earthquake, the estimates of average fatality and injury levels are used. By using mortality prediction model for different categories of structures human casualty has been estimated in this study. This prediction model is based on investigation of casualty due to several major earthquakes occurred in this century [9]. According to this model, the total number of people that may be killed due to damage of each type of building can be represented as follows:

$$Ks_b=D_b*[M1_b*M2_b*M3_b*M4_b]$$

Where D_b is the total number of damaged structures of building type b, $M1_b$ is the occupant density rate. In this study the value of M1b is taken as 10 persons per building, which is calculated from the data collected by questionnaire survey. $M2_b$ is the occupancy of buildings at the time of the earthquake. The occupancy cycle proposed by Coburn and Spence [10] is used here. The value of $M2_b$ is taken 0.62, 0.42and 0.8 for morning, noon and midnight respectively. $M3_b$ is proportion of occupants who are trapped by the collapse of buildings, which depends on the type of buildings. For EMSB1 and EMSC type buildings the value of this factor is taken 10%, 20% and 40% for PGA value 0.8(%g), 0.9(%g) and 1.0(%g) respectively. For EMSB2 type the value of the factor $M3_b$ is taken as 20%, 40%and 80% for PGA value 0.8g, 0.9g and 1.0g respectively.

For EMSD type this value is taken as 5%, 10% and 20% for PGA value 0.8(%g), 0.9(%g) and 1.0(%g) respectively. For EMSF type this value is taken as 3%, 5% and 10% for PGA value 0.8(%g), 0.9(%g) and 1.0(%g) respectively. Based on the quantitative information available from several earthquakes (Coburn et al., 1992), $M4_b$ has been taken as 40% for EMSB2, EMSC and EMSD type buildings, 20% for EMSB1 type and 10 % for EMSF type buildings for estimating killed population. Again $M4_b$ has been taken as 50% for EMSB2, EMSC and EMSD, 30% for EMSB1 and 10% for EMSF type buildings for estimating injured population. Human casualty at morning, noon and midnight for different intensity is shown in the Table 6, 7 and 8 respectively.

Tab. 6. Estimation of human casualty level at morning for PGA value 0.8(%g), 0.9(%g) and 1.0(%g)

PGA value (%)	Building Type	Db	M1b	M2b	M3b	M4b	Kb	Total killed Population
0.8g	EMSB1	194	10	0.62	0.10	0.20	24	85
	EMSB2	55	10	0.62	0.20	0.40	27	
	EMSC	137	10	0.62	0.10	0.40	34	
	EMSD	4	10	0.62	0.05	0.40	0	
	EMSF	1	10	0.62	0.03	0.10	0	
0.9g	EMSB1	196	10	0.62	0.20	0.20	49	175
	EMSB2	56	10	0.62	0.40	0.40	56	
	EMSC	140	10	0.62	0.20	0.40	69	
	EMSD	5	10	0.62	0.10	0.40	1	
	EMSF	2	10	0.62	0.05	0.10	0	
1.0g	EMSB1	198	10	0.62	0.40	0.20	98	354
	EMSB2	57	10	0.62	0.80	0.40	113	
	EMSC	142	10	0.62	0.40	0.40	141	
	EMSD	5	10	0.62	0.20	0.40	2	
	EMSF	2	10	0.62	0.10	0.10	0	

Tab. 7. Estimation of human casualty level at noon for PGA value 0.8(%g), 0.9(%g) and 1.0(%g)

PGA value (%)	Building Type	Db	M1b	M2b	M3b	M4b	Kb	Total killed Population
0.8g	EMSB1	194	10	0.42	0.10	0.20	16	57
	EMSB2	55	10	0.42	0.20	0.40	18	
	EMSC	137	10	0.42	0.10	0.40	23	
	EMSD	4	10	0.42	0.05	0.40	0	
	EMSF	1	10	0.42	0.03	0.10	0	
0.9g	EMSB1	196	10	0.42	0.20	0.20	33	119
	EMSB2	56	10	0.42	0.40	0.40	38	
	EMSC	140	10	0.42	0.20	0.40	47	
	EMSD	5	10	0.42	0.10	0.40	1	
	EMSF	2	10	0.42	0.05	0.10	0	
1.0g	EMSB1	198	10	0.42	0.40	0.20	67	241
	EMSB2	57	10	0.42	0.80	0.40	77	
	EMSC	142	10	0.42	0.40	0.40	95	
	EMSD	5	10	0.42	0.20	0.40	2	
	EMSF	2	10	0.42	0.10	0.10	0	

Tab. 8. Estimation of human casualty level at midnight for PGA value 0.8g, 0.9g and 1.0g

PGA value (%)	Building Type	Db	M1b	M2b	M3b	M4b	Kb	Total killed Population
0.8g	EMSB1	194	10	0.80	0.10	0.20	31	111
	EMSB2	55	10	0.80	0.20	0.40	35	
	EMSC	137	10	0.80	0.10	0.40	44	
	EMSD	4	10	0.80	0.05	0.40	1	
	EMSF	1	10	0.80	0.03	0.10	0	
0.9g	EMSB1	196	10	0.80	0.20	0.20	63	329
	EMSB2	56	10	0.80	0.40	0.40	174	
	EMSC	140	10	0.80	0.20	0.40	90	
	EMSD	5	10	0.80	0.10	0.40	2	
	EMSF	2	10	0.80	0.05	0.10	0	
1.0g	EMSB1	198	10	0.80	0.40	0.20	127	458
	EMSB2	57	10	0.80	0.80	0.40	146	
	EMSC	142	10	0.80	0.40	0.40	182	
	EMSD	5	10	0.80	0.20	0.40	3	
	EMSF	2	10	0.80	0.10	0.10	0	

Similarly estimation of injured people at morning, noon and midnight due to earthquake for PGA value 0.8(%g), 0.9(%g) and 1.0(%g) was done. Total fatalities and injured population is shown in table 9.

Tab. 9. Estimated number of fatalities and injuries due to earthquake of PGA value 0.8(%g), 0.9(%g) and 1.0(%g) in Old Sylhet

PGA value (%)	Time of occurrence in the day	Number of fatality	Number of injury
0.8g	Morning	85	113
	Noon	57	76
	Midnight	111	147
0.9g	Morning	175	231
	Noon	119	156
	Midnight	329	298
1.0g	Morning	354	467
	Noon	241	317
	Midnight	458	603

3.5. Economic Loss Estimation

There are many more direct and indirect losses due to an earthquake, such as losses due to lifelines, business interruption losses, rental losses, relocation losses business interruption losses, transport industry loss, lifeline leakage losses, debris removal cost etc. More detail analysis is required to ascertain those losses. Since the building damage constitutes the major economic loss due to an earthquake, hence economic loss due to building damage is estimated in this study. The method followed for estimating economic loss is calculating weighted floor space for the whole ward and obtaining total floor space of the damaged buildings then multiplying the floor space by construction cost per unit floor area.

In this study, for full damage the construction cost is taken as TK.600 per square feet, and for the Partial damage, the construction cost is taken as TK.180 per square feet. The weighted floor space has been calculated by Computer Program in Visual Basic developed by **Rahman** and **Islam** using the following equations developed by **Ansary** (2003).

$$Aj = \frac{\sum_{i=1}^{5} N_i A_i}{\sum_{i=1}^{5} N_i}$$

$$A_{ward} = \frac{\sum_{j=1}^{7}((\sum_{i=1}^{5} N_i) A_j)}{\sum_{j=1}^{7}(\sum_{i=1}^{5} N_i)}$$

Where, A_j =weighted area for each story type (j=1,2,3,4, and >5 story)

Ai= middle value of an area in a particular range

Ni=number of buildings corresponding to Ai

A_{ward} = weighted floor space for the ward

From the story and building area distribution for the buildings of old of Sylhet given in the table 10, weighted floor area has been calculated by using above equations.

Tab. 10. Storey and building area distribution for old part of Sylhet

No. of storey	Building area (sft.)						
	500 (0-500)	1000 (501-1000)	1500 (1001-1500)	2000 (1501-2000)	2500 (2001-2500)	3500 (>2500)	Sum
1	18	127	93	21	13	37	309
2	4	19	56	41	12	33	165
3	1	5	26	7	6	12	57
4	0	1	11	7	7	7	33
>5	0	0	2	0	4	1	7
Sum	23	152	188	76	42	90	571

3.6. Seismic Effects on Structures

The following occurrences happen during earthquake:

1. The whole building including contents are shaken from the position of rest
2. The earthquake motion results into vibration of the building along its all three axes
3. The movement is reversible in direction. The number of cycles per second depends on the characteristics of earthquake as well as the structure
4. Additional vertical load effect is caused on beams and columns due to vertical vibrations. Being reversible, at certain instant of time the effective load is increased, at others it is decreased
5. The supporting members, walls or columns which were carrying only vertical loads before the earthquake, have now to carry horizontal bending and shearing effects as well
6. The dumping in the building system has the effect to reduce the effective accelerations on the masses and higher the dumping greater is the reduction
7. The dynamic and damage behavior of a building is a function of the stiffness and strength characteristics of the structural elements.

Precautionary measures from architectural and engineering point of view:

1. **Urban planning**: Urban planning is very important for minimizing the losses from earthquake. The condition of most of the roads of Sylhet city is not suitable for post earthquake rescue and other activities. Every road should be wider and connected with at least two other roads for frequent movement of rescue vehicles, ambulances and fire service etc. Proper distance between two buildings must be maintained.
2. **Emergency exit**: Every building must have more than one exit and every multistoried building must have more than one stairwells for emergency use.
3. **Simplicity**: The simplest structures have the greatest chance of survival. Torsional effects due to earthquake are less in simple/ regular structures than in complex/ irregular structures.
4. **Symmetry**: Symmetry is important in both directions in plan, as well as in elevations. Lack of symmetry produces torsional effects. All elements including stairwells and lift shafts must be placed in proper way to maintain the symmetry. Otherwise the center of rigidity (mass) shifts

substantially from the center of story shear, resulting ground floor subjected to floor rotation as well as floor translation.

5. **Length in plan**: Buildings, which are long in plan, experience greater variation in ground movement and soil conditions over their length than shorter ones. So, it is always better to construct buildings with smaller length in plan. Long buildings can be divided into some small parts, so that the whole building will not be affected by earthquake.
6. **Shape in elevation**: Very slender structures and those with sudden changes in width should be avoided in earthquake prone areas. Very slender buildings have high column forces and foundation stability may difficult to achieve. The ratio of height and width of a building equal to or less than 4 is preferred. Sudden changes in width of a building generally imply a step in the dynamic response characteristics of the building at that height.

Therefore, the following measures can be taken to reduce the losses:

- Proper soil investigations must be carried out
- Proper foundation for the structural system depending upon soil parameters should be selected
- Strong foundation and weak superstructure philosophy can be followed
- Pile foundation or ground improvement techniques should be provided for liquefaction zones.

3.6.1. Provisions for RCC Frame Building Design

R.C.C is the most popular building materials at the present day. Beams and columns act integrally in this type of building. According to BNBC**,** 6mm dia up to 5m beam length and beyond 8mm dia, Hock bent 135^0 and be extended sufficiently maximum spacing half beam depth but at end "2d" distance spacing is d/4 or 8 times bar dia. For column, size should be minimum 300mm, for column length less than 4m and beam length less than 5mm, the size maybe 200mm. Tie spacing in column should be 75mm to 100mm and tie bend should be 135^0 and extended greater than 75mm.

As Sylhet is earthquake prone area, the designers must follow the earthquake provisions mentioned in BNBC (Bangladesh National Building Code -1993). Here are some suggestions to follow for earthquake resistant building design:

1. **Soft story**: Most of the high-rise buildings of Sylhet city stand on only columns at their ground story for providing car parking facility. For the absence of shear walls, the ground story appears to be a soft story subjecting the building vulnerable to earthquake very seriously. Ground story is subjected to highest story-shear force and bending moment developed due to earthquake induced horizontal forces. If this story (or any story at lower level) is weaker than upper stories, a column sway mechanism can develop with high local ductility demands on columns, which may beyond their ductility capacity. It causes failure of the whole building. The vulnerability due to soft story may be minimized by supplying adequate quantity of RC shear walls and/ or RC bracings and by using base isolation system in the ground story.
2. Masonry infilled RC frames: Most of the buildings in Sylhet are constructed with masonry infills in their RC frames. Masonry infill is usually consists of solid bricks supported only by sand cement mortar. When the frames are subjected to shaking due to earthquake, diagonal tensile spitting, diagonal crushing, sliding and separation of all infills may occur simultaneously. Besides, the total weight of the building becomes higher when solid bricks are used. It is dangerous, because horizontal force due to earthquake is directly proportional to the weight of the building. Using lighter hollow bricks or blocks for infills may reduce these vulnerabilities. These bricks or blocks can be strengthened and secured by using rebars. Wire or bamboo mesh may also be used to secure the infilled materials in RC frames.
3. Weak beam strong column: Weak beam strong column technology should be used to design a seismic resistant frame, because, i) plastic hinges that are developed at the beam-ends, have larger rotational capacities than at column ends ii) mechanism involving beam hinges have larger energy absorption capacity iii) collapse of a beam results a localized failure, but collapse of a column may cause the total failure of the building iv) columns are more difficult to repair than beams.
4. Uniform and continuous distribution of strength and stiffness: In an earthquake resistant building there should be uniform and continuous distribution of strength and stiffness. For that:
   - All load bearing members must be uniformly distributed
   - All columns and walls should be continuous and without offset vertically
   - All beams must be without offset
   - Columns and beams should be co-axial
   - Reinforced concrete beams and columns must have almost the same width
   - Principal members must not change their sections suddenly
   - The structure should be as continuous and monolithic as possible.
5. Some other measures:
   - It is better to use high strength steel (f_y= 60000 psi)
   - Compression steel should be used
   - Adequate stirrups should be used to ensure that shear failure does not precede flexural failure
   - Proper detailing of anchorage, splicing etc. should be considered.
   - For complex structural system, appropriate 3-D earthquake analysis is needed for design

3.6.2. Provisions for Masonry Building Design

To ensure good performance of masonry building it requires

- All walls must be tied by rebar horizontally
- All walls must be tied with roof and foundation and create box type reinforcement system.
- Construction of more than 4 storied masonry buildings should be avoided in Sylhet region. The following measures can be taken to construct masonry buildings:

- Minimum width of the walls should be 10 inches

- Continuous lintel should be used
- Hollow bricks are preferable instead of solid bricks
- Bars may be used in hollow bricks to strengthen the walls
- Modified RC columns can be used in corners and near the doors and windows of solid brick buildings
- Using wire mesh also can strengthen the walls [11-13].

3.6.3. Old buildings strengthening technique

It has already been mentioned that there are many old buildings in Sylhet city that are very much vulnerable to earthquake. Most of them are masonry. Following measures can strengthen these buildings:

- Removing the plasters on walls and using wire meshes
- Removing vertically some bricks from walls specially in corners and near the doors and windows and constructing there column- like RCC elements
- Constructing similarly lintel- like RCC elements
- Using bracings

4. Conclusion

Proper planning and setup of earthquake center with GPS system are essential for Sylhet. As earthquake in Sylhet region is inevitable. So, people should take the maximum preparation to minimize the losses due to earthquake. Proper planning, designing and constructing buildings and other infrastructures are the best preparations to manage the disaster. People's awareness about impacts and remedies of earthquake should be increased. Government, NGOs, specialists, journalists, media people and all of us should work together for that just from today.

It is not an easy task to assess probable seismic damage precisely without economic support and authorization from the proper authority. However, the database created in this work lays the foundation for dealing with seismic hazard analysis. We have worked on old part of Sylhet which is a very important commercial area in Sylhet city. In order to get a precise estimation of human casualty and economic loss data should be collected from the entire city. It is also essential to accumulate data every 10 or 15 years in order to update the casualty level.

Due to lack of data on indirect losses incurred by an earthquake, only building damage has been estimated here. In case of further study it will be wise to accumulate information on indirect losses, such as losses due to business interruption losses, relocation losses, transport industry loss, lifeline leakage loss, debris removal costs etc

From our study it is observed that the occurrence of an earthquake of PGA value 0.9g on **ward no. 14** may causes massive loss of lives and damage to buildings. Depending on the time of the day 147 to 603 people may be killed due to structural collapse and the buildings of worth approximately TK.32.00 core may be damaged.

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