A Statistical study on RC building stocks structural characteristics of Dhaka city for loss assessment application

A Thesis Submitted in Partial Fulfilment of the Requirements
For the Bachelor of Science Degree in

Civil & Environmental Engineering

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October, 2012

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The thesis entitled “A Statistical study on RC building stocks structural characteristics of Dhaka city for loss assessment application”, by Md. Rafi Sajjad, Zeeshan Yasir, Fuad Md. Moinul Haque, has been approved in partial fulfilment of the requirements for the Bachelor of Science Degree in Civil & Environmental Engineering.

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ABSTRACT

Dhaka is one of the most seismically hazardous cities in the world and several studies indicated Dhaka to have one of the highest values of earthquake disaster risk index (EDRI) mainly due to its inherent vulnerability of building infrastructure, high population density, and poor emergency response and recovery capability. Assessment of the seismic vulnerability of the building stock of Dhaka is of growing importance since such information is needed for reliable estimation of the losses that possible future earthquakes are likely to induce. The principal aim of this thesis is to provide statistical information on geometrical, functional and material properties of the Dhaka building stock for use in risk and loss assessment models, and other types of statistics or probability-based studies. To achieve this goal, the existing reinforced concrete (RC) building stock has been classified as dual (frame-wall) or frame structures. In addition to the statistical parameters such as mean values, standard deviations, etc., probability density functions and their goodness-of-fit have also been investigated for all types of parameters. Concrete properties of existing and recently constructed buildings and characteristics of Grade 40 and Grade 60 types of steel have also been documented.

Keywords: loss assessment, building stock, probability density function, goodness-of-fit.

ACKNOWLEDGEMENTS

We would like to express since gratitude to our thesis supervisor Asst. Prof. Mohammad Shafiqual Alam for his excellent and invaluable guidance and support throughout the duration of this study. Special thanks to Nakshabid Architects, The Structural Engineers Ltd., Eastern Housing Ltd., Bangladesh Plan and Design Ltd. & Tropical Homes Ltd. for providing structural and architectural drawing which lead to the development of building stock database and subsequently the structural characteristic statistics of Dhaka city.

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1 INTRODUCTION

1.1 Foreword

The principal aim of this thesis is to provide statistical information oF the Dhaka city building stock for use in risk and loss assessment models. Earthquake loss assessment modeling has become an increasingly important subject in recent years, driven by the needs of end users, which include both emergency planners and the insurance and reinsurance industries. Such models could also be used by national authorities in an iterative manner as the basis for cost–benefit analyses to identify appropriate loading and performance levels for retrofit programs. Earthquake loss models could also provide a rational basis, again through iterative cost–benefit studies, for establishing the levels of design motion and the structural performance criteria specified in seismic design codes, as an alternative to the use of arbitrarily selected return periods.

1.2 Background of Study

Over the past decades, urbanization in Bangladesh has been rapidly taking place without proper guidance. As a result many of the urban centers have developed haphazardly. These urban centers are fast growing and influence the economic developments of the country. It is therefore essential to have a realistic understanding on the nature, severity and consequences of likely damage/loss that a possible event of earthquake could cause. A strong earthquake affecting the major urban center like Dhaka may result in damage and destructions of massive proportions and may have disastrous consequences for the entire nation as it is the capital as well as political, cultural and economic center of Bangladesh and one of the major cities of South Asia.

Considering these reality, Alam M.S, 2008 carried out a sensitivity study of seismic loss model for Dhaka using DBELA as there was lack of sufficient input parameter data to the loss model during that period. Comprehensive Disaster Management Program (CDMP) under the Disaster Management Bureau of Government of Bangladesh (GoB) has recently (through 2008 to 2010) conducted seismic hazard and vulnerability assessment of major cities of Bangladesh, besides the individuals research efforts [Ansary et al. 2000; 2004; Ali et al., 1994] towards reduction of seismic risk.

A new Displacement Based Earthquake Loss Assessment, DBELA [Crowley et al. 2004] has recently been developed; this method allows for direct calibration of the required structural parameters in a loss model, thus leading to a straightforward customization of the model to the building stock characteristics.

There are numerous uncertainties associated with the input to earthquake loss models and consequently the results inevitably carry a high degree of uncertainty. Crowley et al. 2005 performed a systematic analysis of the impact of epistemic uncertainties in the ground motion and vulnerability elements of a model for estimating losses from a single earthquake scenario using the Displacement Based Earthquake Loss Assessment (DBELA) methodology; the main conclusion was that the parameters with the greatest impact are those related to the seismic capacity, and in particular the geometric properties, of the exposed building stock. This suggests that there is significant benefit to be obtained from investing time and effort in defining the vulnerability characteristics of the exposed building stock and this is therefore the aim of this paper. The majority of the building statistics that are presented in this paper are required to calibrate the DBELA method; however, the structural information presented herein could also be of use for the calibration of other risk assessment methodologies.

1.3 Outline of the Thesis

This thesis consists of five chapters.

The first chapter gives the background and description of this thesis.

Brief discussions of the main construction types used in Dhaka city are presented in chapter 2. The chapter also provides an general overview of RCC buildings in Dhaka in terms of building use, number of storey, construction year etc based on Comprehensive Disaster Management Program[CDMP,2009] survey.

In chapter 3 a detailed evaluation of structural characteristic of building stock of Dhaka city are presented on the basis of database prepared from architectural and structural drawing collected from different sources.

The properties of building materials (concrete & steel) used in Dhaka city are discussed in Chapter 4.
In the final chapter, conclusions drawn from this study are presented and some suggestions for future work are provided.

2 AN OVERVIEW OF DHAKA CITY BUILDING STOCK

2.1 Common Construction types

Dhaka is a totally urban city. Several building technologies are used here for construction purpose. The most commonly found building categories are:

(1) reinforced-concrete frame buildings with partition walls;
(2) brick masonry (with cement mortar) buildings with reinforced concrete roofs;
(3) informal brick masonry buildings (which may or may not use cement mortar);
(4) buildings made of other materials such as tin sheets, thatch, mud, wood and other light weight elements.

2.1.1 Engineered constructions

Buildings which are constructed under the supervision of qualified engineers are categorized as engineered constructions. Reinforced-concrete frame buildings with partition walls and brick masonry (with cement mortar) buildings with reinforced concrete roofs are considered as engineered construction. But in Dhaka city it is often found that several reinforced concrete and brick masonry buildings have been constructed without the supervision of a qualified engineer. So this type of construction is not considered as engineered construction as they lack proper design and structural strength.

Since Dhaka is an old city, several engineered constructions are also very old. These buildings have already exceeded their useful service life and several of them have deteriorated badly. These buildings, even though classified as engineered structures, are not expected to perform as well as the newer similar constructions during scenario earthquakes. Several engineered construction categories are briefly described in the following section.

(a) Frame Building

These types of structures are supported mainly by a frame of wood, steel, or reinforced concrete rather than by load-bearing walls. Rigid frames have fixed joints that enable the frames to resist lateral forces. Steel's strength, when used in steel framing, makes it possible to produce buildings with longer spans. Concrete frames impart greater rigidity and continuity. A large proportion of residential and commercial building in Dhaka city is constructed by frame structure. Most of them are between in 3-7 storeys.

Figure 2.1. RCC frame building.

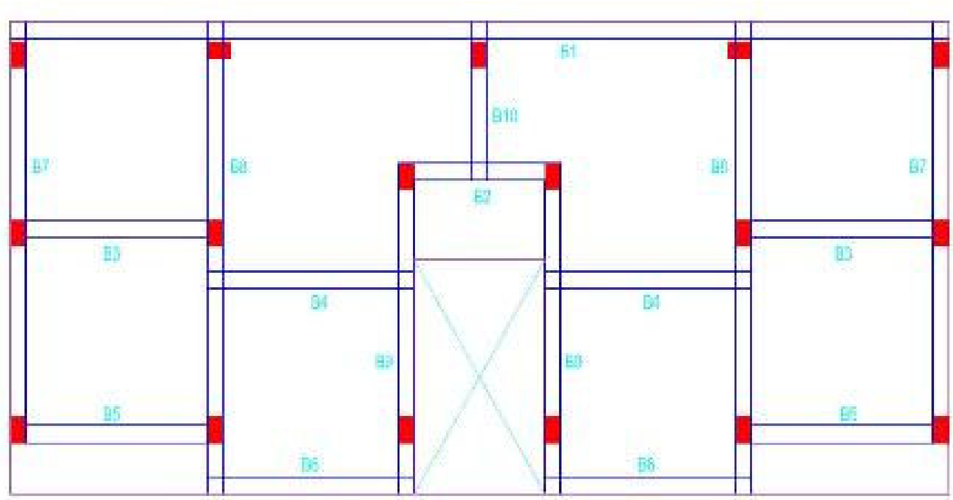


Figure 2.2. A typical floor plan of a RCC frame building.

(b) Frame with structural wall

Lateral forces caused by wind, earthquake, and uneven settlement loads, in addition to the weight of structure and occupants, create powerful twisting (torsional) forces. These forces can literally tear (shear) a building apart. Reinforcing a frame by attaching or placing a rigid structural wall inside it maintains the shape of the frame and prevents rotation at the joints. Structural walls are especially important in high-rise buildings subject to lateral wind and seismic forces. The use of structural wall has traditionally formed a large part of residential construction in Dhaka city.

Figure 2.3.Frame with structural wall building.

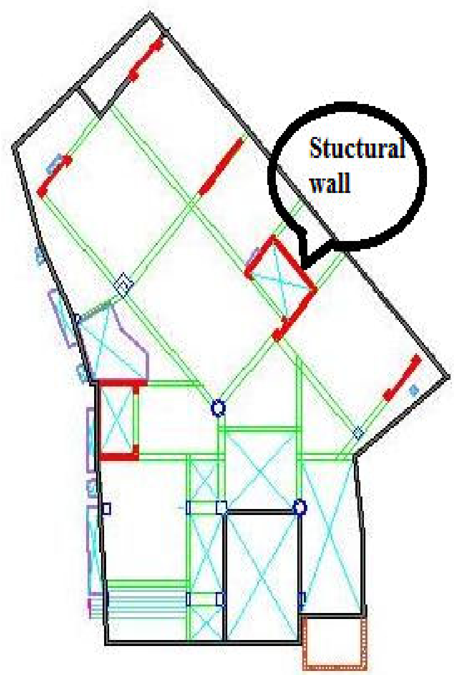


Figure 2.4. A typical floor plan of a RCC frame with structural building.

(c) Pre-cast Concrete Building

Single storey precast concrete buildings are generally used for manufacturing and warehouse operation in Dhaka. Precast concrete construction has performed rather badly under earthquake loading [Arslan *et al.*, 2006].Common source of damage include spalling at the connection between precast components and plastic hinging of the precast column. Precast concrete offers a competitive building solution based on low cost, long term economic benefit, lower maintenance, overall minimum operating cost as well as future reuse when the occupancy of the building changes. The concept of precast (also known as "prefabricated") construction includes those buildings where the majority of structural components are standardized and produced in plants in a location away from the building, and then transported to the site for assembly. These components are manufactured by industrial methods based on mass production in order to build a large number of buildings in a short time at low cost.

Figure 2.5. Pre-cast Concrete Building.

2.1.2 Non Engineered construction

Buildings which are not constructed under the supervision of qualified engineers are categorized as non-engineered constructions. Informal brick masonry buildings (which may or may not use cement mortar) and buildings made of other materials such as tin sheets, thatch, mud, wood and other light weight elements are considered as non-engineered construction which comprises about 65% of the buildings in Dhaka [Al-Husaini, 2003]. These buildings are not properly designed and may also be of poor quality. In the absence of legal enforcement of building codes in the country and lack of earthquake awareness, most of the buildings have been constructed without proper earthquake consideration, just designed for gravity load

Unreinforced Brick Masonry (URM) is the most common non engineered construction found in the city. A building survey, funded by Bangladesh Ministry of Science and Technology research grant, in parts of Sutrapur, Lalbag and west Dhanmondi reveals a concentration of multi-storied URM buildings in the older parts of the city. While the percentage of URM buildings in Sutrapur area of the old city was found to be around 65%, the same in the relatively new west Dhanmondi was found to be around 42% [Al-Hussaini, 2003].

(a) One storey tin shed building

This is a one-story brick masonry house of fired bricks with cement or lime mortar; roof is either GI sheet or another material. These houses are also very common around the city. This construction type has been in practice for less than 100 years [WHE, Report#91].

(a) One storey tin shed building. **(b) Frame building.**

Figure 2.6. Non Engineered construction.

(b) Frame building

This type of building is constructed without help of engineer. Building code is not at all followed for this type of construction. They are not properly designed and of poor quality, which results in short life span. During earthquake they may result serious hazard.

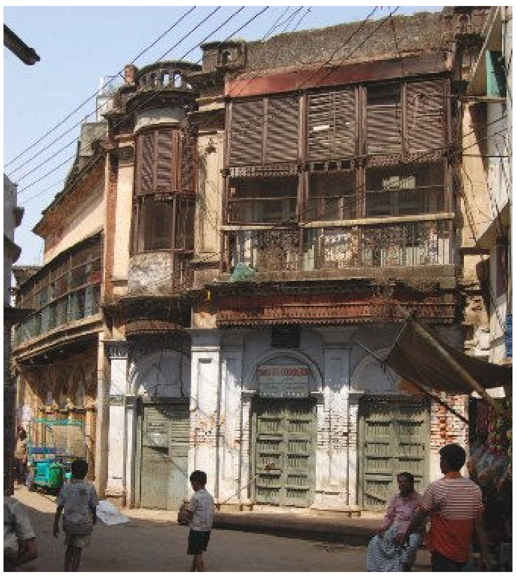


Figure 2.7. Informal brick masonry building & Tin sheets building.

2.2 General Building stock statistics for Dhaka city

In this study, the building survey carried out by CDMP during 2008-2009 periods is used to give an overall overview of the general building stock inventory in Dhaka city. The surveys were classified into 3 levels: level-1, level-2, and level-3. Total 8,741buildings have been surveyed for level-1in Dhaka city, which was conducted by side walk and questionnaires. The information obtained from the survey during level-1, at the level of 'Thana' (the smallest municipality unit) includes: construction type, building use, number of storeys, age of the building, structural type, presence of soft storey etc. About 10% of these buildings were selected for the level-2 survey on random basis. Level-2 survey acquired detailed measurements of columns, structural walls, floor areas which are prerequisite for any in-depth seismic loss assessment of a typical building. At level-3 survey dynamic behavior of 50 RC buildings were investigated through different tests using Ferro scanner, Vibration shaker, Schmidt hammer etc. [CDMP, 2009].

Figure 2.8. A view of the Dhaka city skyline.

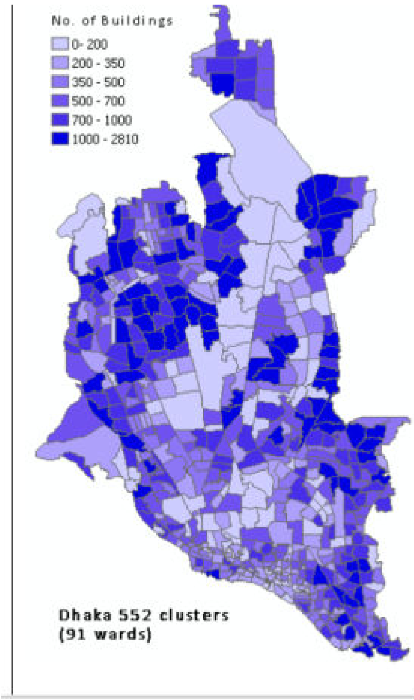


Figure 2.9. Building distribution map of Dhaka city.

2.2.1 Construction Type

The CDMP survey classifies the Dhaka city construction type broadly into two categories: Engineered construction and Non-engineered construction. These categories are then subdivided into three systems: framed, load-bearing wall and others. The frame systems are then subdivided according to the frame material and the infill material; the load-bearing wall systems are distinguished by wall material; and among the ‘other’ systems there are two main construction types (Tin shed, bamboo structure & steel roof truss with column). The proportion of buildings in each construction category based on level-1 survey is presented in Table 2.1.

Table 2.1. The percentage of each construction type in Dhaka city

	Bearing System	***Construction type classification***	***Number***	***Percentage (%)***	***Percentage (%)***
Engineered Construction	Frame	RC, insignificant volume of infill	183	2.1	66.1
		RC, significant volume of infill	5260	60.2	
		RC, slab-column construction	294	3.4	
		Structural steel, metal cladding	3	0.0	
	Frame+ Structural Wall	RC, lift core & structural wall	36	0.4	
Non Engineered	Frame	RC, lightly reinforced non engineered	937	10.7	33.9
	Bearing Wall	Clay Brick wall, concrete slab	1835	21.0	
		Clay Brick wall, steel roof truss	8	0.1	
	Other	Steel roof truss with steel column	16	0.2	
		Steel roof truss with concrete column	6	0.1	
		Tin shed	139	1.6	
		Bamboo structure	23	0.3	

2.2.2 Building Use

The use of the buildings is divided into three categories in the surveys: residential, mostly residential and mostly commercial. 'Mostly residential' buildings are likely to be apartment buildings with shops at the ground floor, whilst 'mostly commercial' buildings are assumed to be office or industrial buildings. This distinction between building usage is important in an earthquake loss model in order to make predictions on the number of casualties. In addition, RC frames which are 'mostly residential' (which are assumed to have shops at the ground floor) are likely to have stiffness irregularities with height and thus estimations of the proportion of buildings which will develop soft-storey can be made.

2.2.3 No of Storey

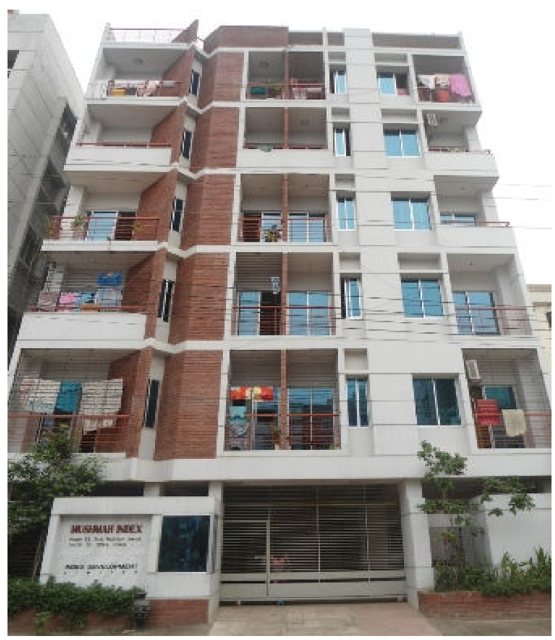
In the CDMP survey, the buildings are further classified into the number of storeys; each building has been placed into one of the following storey number categories: 1~ 3, 4 ~7 and greater than 8 storey.

2.2.4 Construction Year

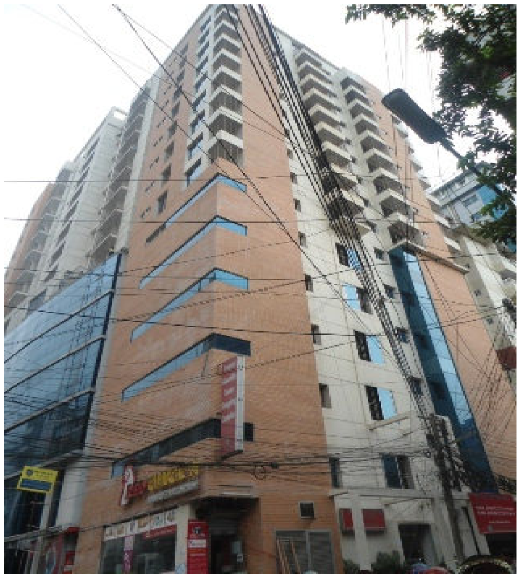
The construction year has also been recorded in the survey using the range between prior 1980 to 2010, by grouping this range into decades. This information may be important for assessing the vulnerability of the building stock, as the construction year can be used to find whether there was any structural design code that was in effect at the time of construction. Bangladesh National Building Code (BNBC) was first drafted in 1993 but not formally reviewed and updated until recently in 2010. In 2006 the Building Construction Act was amended to include a new section 18 A, empowering the government to promulgate the building code as a legally binding document for the first time in the history of Bangladesh [Salma A. Shafi, 2010].

In this regard, it is noteworthy that many buildings in Dhaka city have been constructed illegally without conforming to building codes; furthermore, even in those cases where codes have been used to some extent, they are likely to exhibit a lack of critical seismic design concept (e.g. capacity design) and it may be assumed that a negligible portion of the building stock recorded in the survey has been designed and built in accordance with adequate seismic detailing as per code requirements.

(a) Low-rise residential building



(b) Mid-rise residential building



(c) High-rise mostly residential building

(d) High-rise mostly commercial building

Figure 2.10.Typical Dhaka city reinforced concrete frame buildings.

2.2.5 Summary Statistics

CDMP survey shows that in Dhaka city , the two most common construction type for existing buildings are RC frames (with clay brick infill) and bearing wall construction with clay brick masonry. In Fig.2.12, the frequency data for the most common construction types is given, with the usage of each building type. Most of the buildings in Dhaka city are residential.

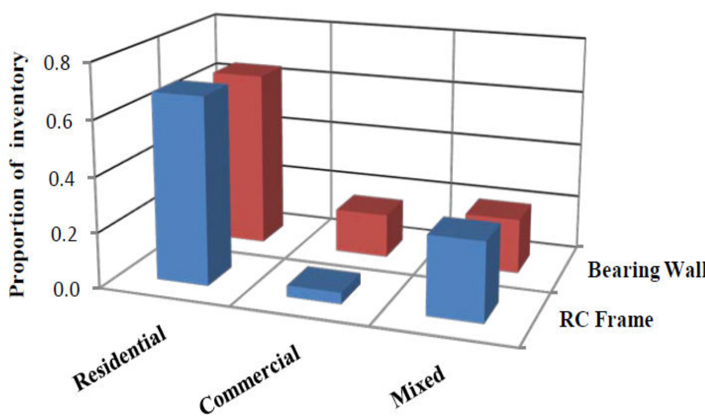


Figure 2.11. Proportion of the inventory divided into building use and construction type

Fig. 2.13 is a frequency distribution of construction year for RC frame and bearing wall buildings representing the increase in the use of RC frames in last 30 years (especially in the last 10 years) whilst bearing wall construction peaked before 1980s. (but are not used now).

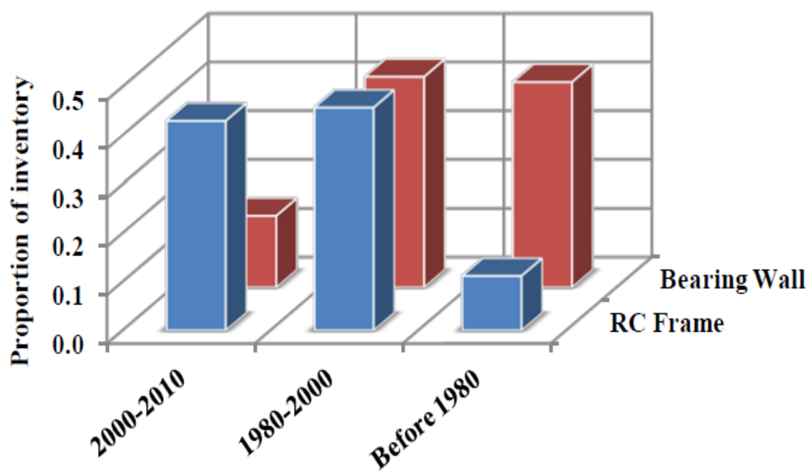


Figure 2.12 Proportion of RC frame building & Bearing wall building in-terms of construction year.

Fig. 2.14 shows the frequency distribution of the number of storeys for RC frame and bearing wall. The result shows that, for masonry construction the proportion of buildings decreases with increasing number of storeys. It is related to the structural characteristics of these building types: bearing wall /masonry is not good for construction of tall buildings.

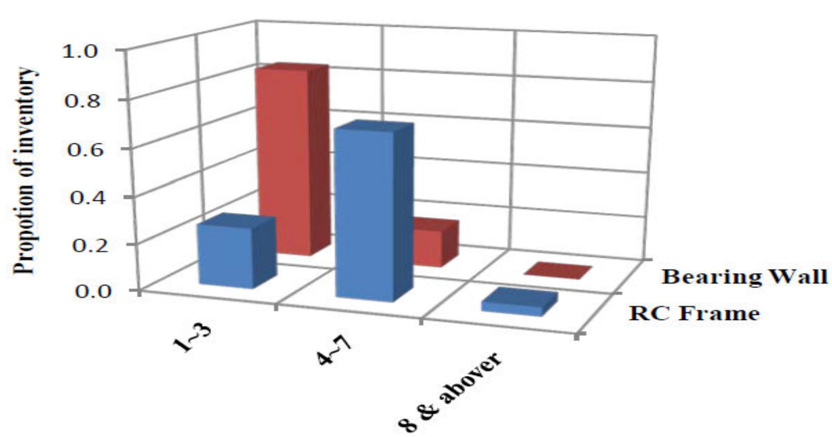


Figure 2.13. Proportion of RC frame building & Bearing wall with different storey numbers.

3 DETAILED EVALUATION OF STRUCTURAL CHARACTERISTIC

3.1 Description of the database

About two-third of the building stock in Dhaka city is either RC frame or dual construction type (Table 2.1) and is particularly vulnerable to the demands from earthquake. Thus, from the loss modeling point of view, RC building should be given particular attention. For this reason, in addition to data presented in the previous section which provides an overall view of the building stock in Dhaka based on CDMP 2008~2009 survey, about 66 RC buildings from the region have been studied in order to classify the characteristics of this type of construction in more detail. Statistics related to various parameters such as beam depth, floor area, storey height etc., are presented for possible use in earthquake loss modeling.

The building database has been created with building drawings (architectural & structural) obtained from different private developers, Design farms & from personal communication with design professionals. Particular attention has been paid so that buildings from different parts (at Thana level) of the Dhaka city are well represented.

In this thesis, it was not possible to use the whole sample of buildings (i.e. 66) to define the statistics of all of the parameters presented herein, since these buildings have been gathered from different sources, with each one presenting different categories of data. For instance, 62 buildings have been used in total to define the column depth distribution whilst 48 buildings have been employed to define the floor area characteristics.

3.2 Statistical approach

In the following sections, for most of the structural properties, histograms are presented which give the frequency of observed measurements of that particular property. A statistical distribution of normal, lognormal, exponential or gamma has been assigned to each property depending on the goodness-of-fit. All parameters have been examined in terms of the number of data, number of buildings, mean values, coefficient of variation, the best fit distribution type, goodness-of-fit test (chi-square test) results. The $\chi 2$ test simply means that the $\chi 2$, which is a function of the difference between the observed and expected frequencies, should be less than one of the $\chi 2$ percent point functions for significance levels of 10%, 5% or 1%. A 10% satisfaction means a better fit as compared to the 5% or 1% satisfaction levels.

In the graph presented in this report, the y axis generally represents the number of occurrences of a given parameter; however, in comparison cases where the numbers of samples are not equal, the y axis is transformed into the frequency of the data and is normalized by the total number of data.

3.3 Storey properties

Storey properties have been defined based on height and area. Storey heights are classified by both the regular storey height and the ratio of the ground floor height to the regular-storey height in order to study the frequency of occurrence of soft storeys. Of the 66 buildings studied, it has been found that almost 90% of the building exhibit a storey height of 10 ft. So, it was not possible to fit any distribution to the storey height parameter and storey height for Dhaka city building may be considered as deterministic value of 10 ft. Though no variation in storey height could be observed that will lead to soft storey identification, it is noted that 53out of the 66 buildings has an open ground storey (either for parking/ commercial activity).So, it is obvious that more than 80% of the total sample building will exhibit soft-storey phenomenon.

The statistics related to the floor area of RC buildings has also been investigated in terms of ground floor area and regular floor area. The evaluation of 48 sample buildings has produced a mean ground floor area of 3842 ft2 with large coefficient of variation of 83.9%. The suggested distribution is a log-normal distribution with 5% satisfaction of the $\chi 2$ test (see Figure 3.1).

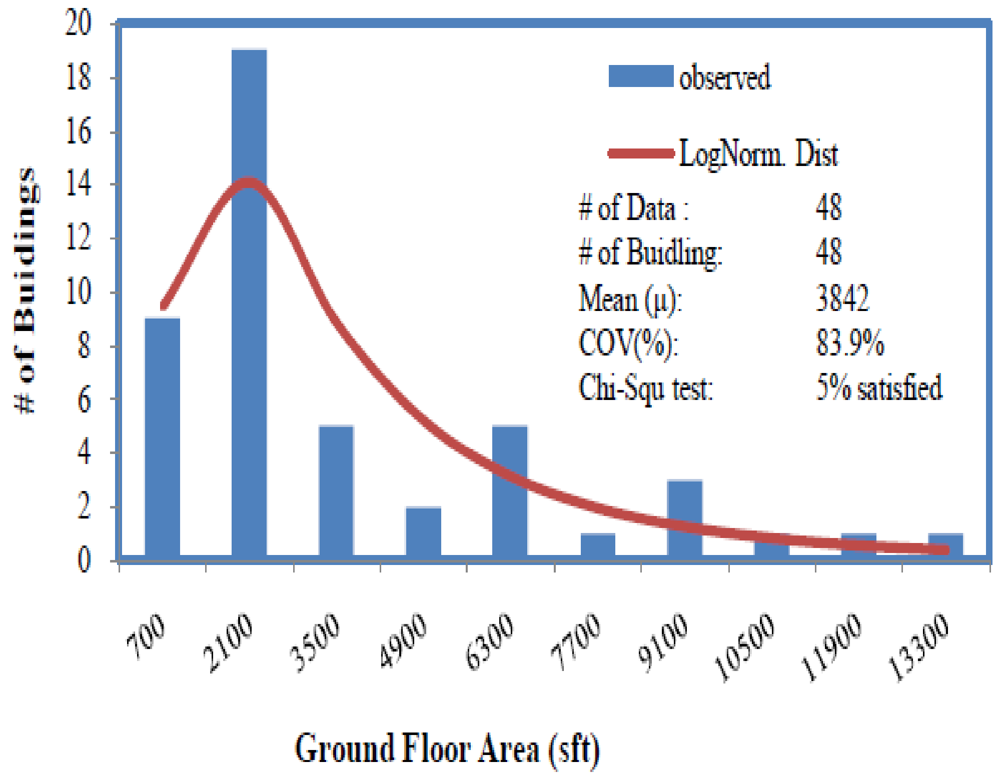


Figure 3.1. Distribution of ground floor area for all RC buildings in the database

Since one of the characteristics of the Dhaka city building stock is the presence of over-hangings (41% according to CDMP,2009), an attempt was made to find out the increase of the floor area from the ground floor to the first floor. But quite expectedly it was found that almost all the sample buildings have uniform floor area throughout the building height. The data were extracted from the drawings submitted to the regulatory authority (for obtaining permission for construction) and in most cases they differ markedly from the working drawing (drawing used in building site for actual construction). However during implementation phase the approved drawing is partially modified in most cases where some extra areas are added beyond the periphery frames which lead to heavy over-hangings.

3.4 Structural elements

The structural parameters of RC buildings which have been studied in this section include column depth, beam depth, beam length, structural wall length and thickness and slab thickness.

3.4.1 Columns

The column depth parameter has been defined by choosing between 2 and 5 representative frames for each building and the dimensions of the columns which are assumed to provide the main structural resistance in each principal direction of the building have been reported; the inclusion of the dimension of the weaker columns in a given direction leads to a large coefficient of variation of about 60% and considering that these columns contribute title to the strength in a given direction, they have been ignored in the column dimension calculations. For each of the sample buildings, the main structural frames in both axis of the building have been identified in order to extract information on the column sizes. Figure 3.2 can be used to illustrate how the frames and associated columns were chosen.

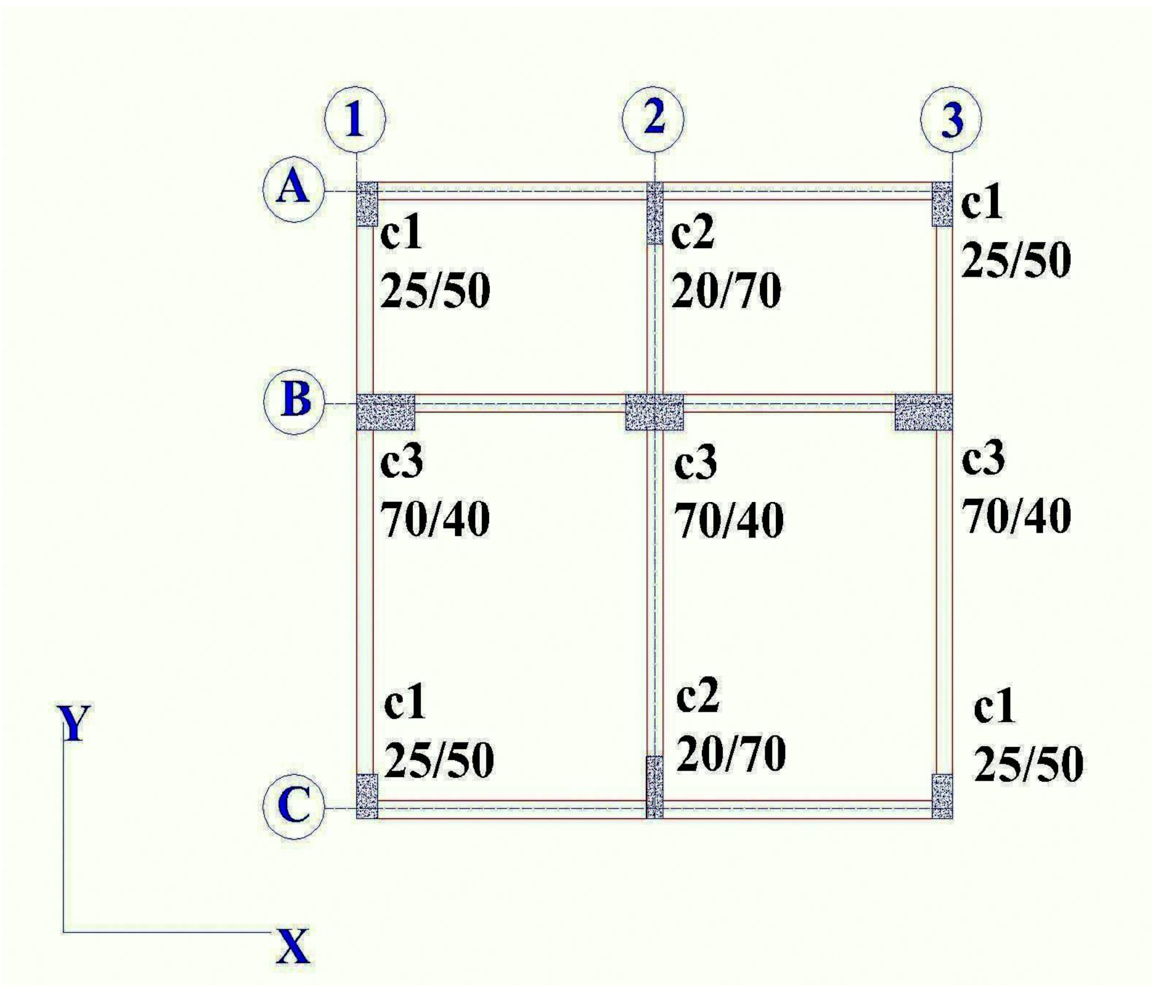


Figure3.2.Example plan of building to illustrate the choice of dominant frames associated column in the X and Y direction of a building.

In this example, in the X direction, the frame along B gridline would be selected as being the dominant structural frame, while in the Y direction the frame along gridline 2 would be considered. The statistics that would be extracted from this example are reported in Table 3.1. In many buildings more than one frame in each direction has been considered; however this simple example can be presented by a single frame along each axis.

Table 3.1. Column section statistics obtained from the example building in figure 3.2.

Frame	Number of occurrence of column depth		
	40 cm	60 cm	70 cm
X- direction			3
Y- direction	1		2

A detailed explanation of the recorded column depth data with respect to the total number of storeys is presented in Table 3.2. The purpose of considering the column depth statistics separately for buildings with different numbers of storeys is to represent the significant effect of the number of storeys on the ground floor column dimensions due to the increased gravity load.

Table 3.2. Detailed statistics for column depth parameters.

# of storeys	# of data	# of buildings	Mean (in)	COV (%)	Suggested distribution	$\chi2$ test result
3~5	28	11	13.9	23.6	Log-normal	5%
6	87	31	15.6	33	Log-normal	1%
>6	21	10	19.3	36	Log-normal	10%

3.4.2 Beam

Beams have also been investigated in terms of their length and depth values. The beam length is generally affected by architectural requirements; thus, the beam length distribution is evaluated for all types of buildings since it is unlikely to be affected by code requirements or framing type. Herein, 431 beams have been studied from 59 different buildings and the beam length distribution has been found to be a normal distribution with a mean length of 15.4ft and a coefficient of variation of 29.2%. The χ2 test has not been satisfied (see Fig. 3.3).

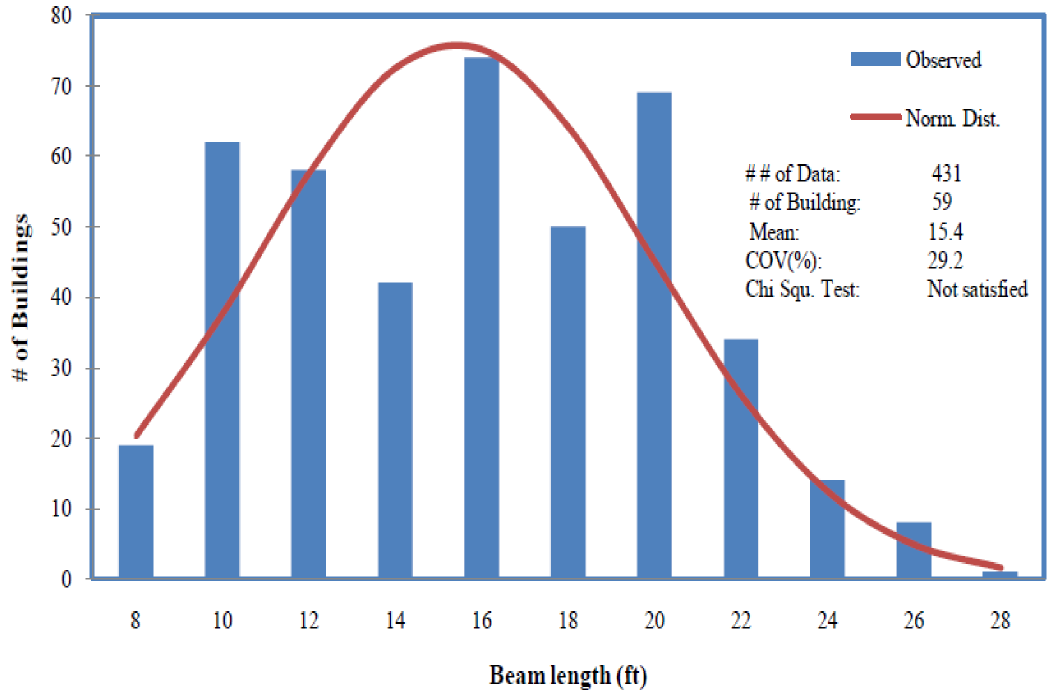


Figure 3.3. Beam length distribution for all RC buildings in the database.

The study also intended to figure out the influence of floor type (beam-column system, flat plate) on the beam depth. Unfortunately, there is only one building with flat plate system in the data base and rests are beam-column system. So, it was not possible to study the influence of floor system on the beam depth. The 393 beam depth data of 59 different buildings have been found to follow log-normal distribution with a mean of 19 inch and coefficient of variation of 16.5% .The χ2 test has not been satisfied.

3.4.3 RC Structural Walls

The thickness and length parameters of RC walls have been studied herein. It has been found that 12 buildings out of 66 buildings studied in the database have dual system (frame & structural wall) and they are mostly buildings having more than 6 storey height.

The Bangladesh National Building Code (BNBC) of 1993 defines the smallest structural thickness to be not be less than $1/25^{th}$ of the supported height or length, whichever is shorter, nor less than 125 mm (5 inch). 51 structural walls of 12 dual system buildings studied herein reveals that structural wall length follows log-normal distribution with mean length of 8.1 ft and coefficient of variation of 49.4%. The $\chi 2$ test has been satisfied for 1% level of satisfaction (see Fig. 3.4).

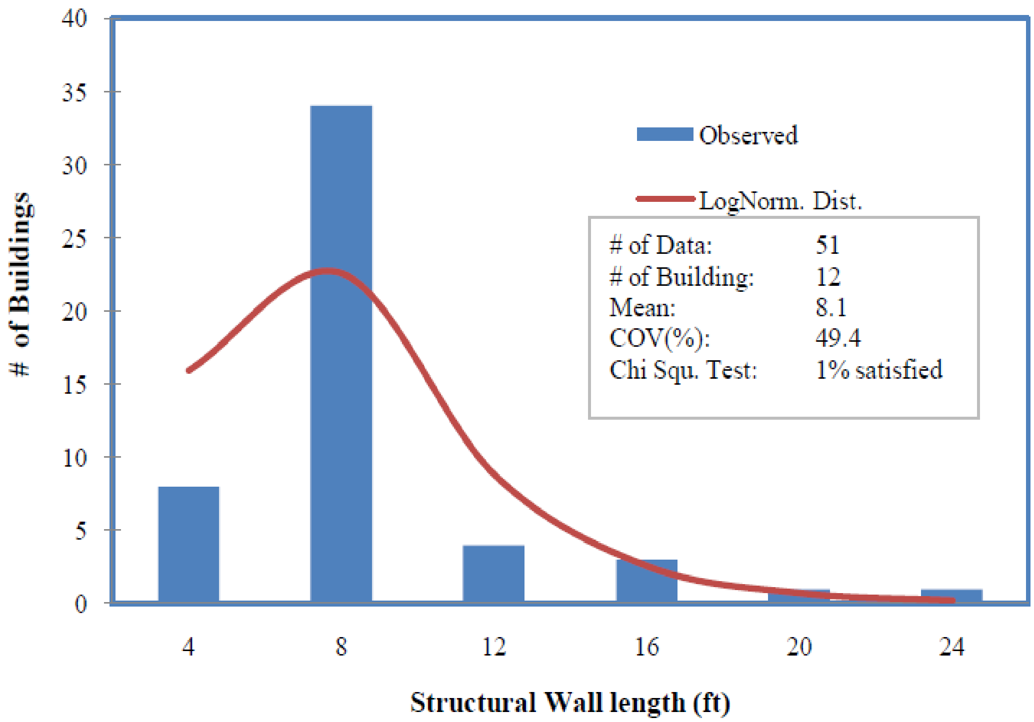


Figure 3.4. Structural wall length distribution for all RC buildings in the database.

The structural wall thickness statistics observed for the sample buildings revealed that 87% (41 out of 47) of thickness data are 10 inch and hence the wall thickness may be considered as deterministic value of 10 inch.

3.4.4 Slab

Slabs are also RC members of the system and they may be included in the loss assessment or other evaluation measures. After studying 66 beam-column structures, the mean slab thickness has been found to be 5.4 inch with a coefficient of variation of 16.5%. The suggested distribution is normal, and the result of the $\chi 2$ test is 10% satisfaction level. In case of flat plate structure, beams are actually embedded within the slab which results in increased slab thickness.

4 Material properties of RC building stock

4.1 Concrete compressive strength

Many desirable properties of concrete such as high compressive strength, excellent durability and fire resistance contributed toward its wide range of applicability throughout the world. The most advantageous and unique feature of concrete is that it can be produced using locally available ingredients as aggregates. Therefore, in countries where steel is not readily available, as in Bangladesh, concrete is the most used construction material. However the advantage of using local materials as concrete ingredients has its own demerits as well. Because of the variations in properties of locally available aggregates, the properties of concrete may vary widely. Although plant mixed concrete is gaining popularity day by day, and in many big projects concrete is produced in a centrally located plant, in small projects concrete is still produced and laid in the field [Wadud, Z et al. 2001]

The properties of the concrete used in the Dhaka city building stock have been evaluated in terms of the 28 days concrete compressive strength. For this purpose, concrete cylinder test data have been collected from Bureau of Research, Testing and Consultation (BRTC) of Bangladesh University of Engineering & Technology (BUET). The concrete characteristic compressive strength distribution of the stock has been evaluated using a larger dataset of 1005 samples from Dhaka city, and the results are shown in Fig. 4.1 and Fig 4.2. It should be noted that the majority of these samples were taken from the buildings which were constructed by mixed-on-site concrete and aggregate used mostly is stone chips with occasional use of brick chips. The mean strength for beam and slab construction were found to be 3.45 ksi and for column to be 4.1 ksi. The standard deviation for beam and slab compressive strength is approximately 0.9 ksi which follows gamma distribution with χ^2 test result of 5% satisfaction level. On the other hand, column test result exhibits a normal distribution with a standard deviation of approximately 1 ksi and the χ^2 test result satisfies 5% satisfaction level.

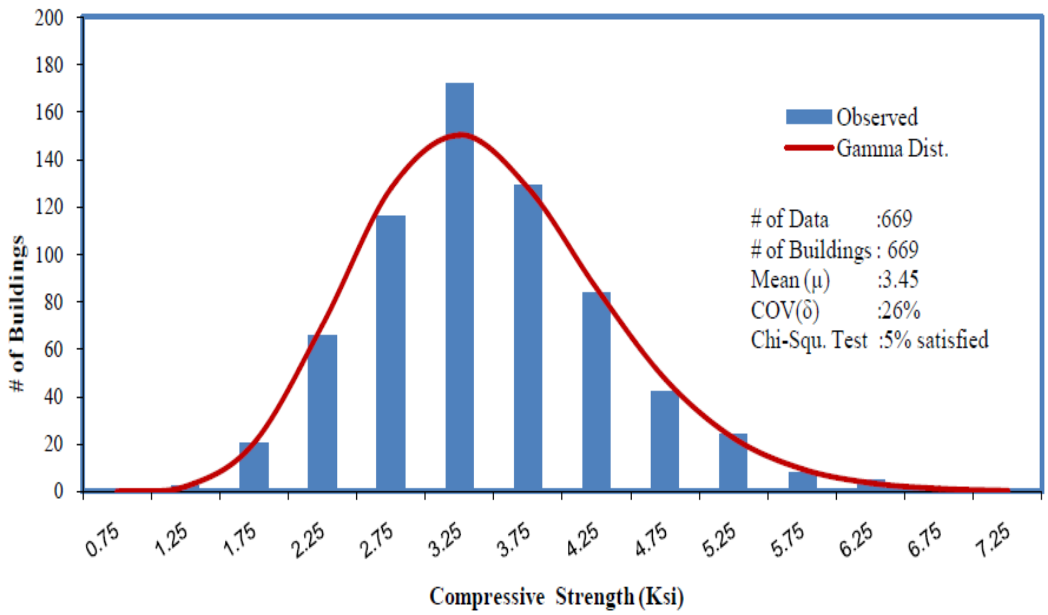


Figure 4.1. Distribution of characteristic 28 days compressive strength of beam and slab of RC buildings in Dhaka.

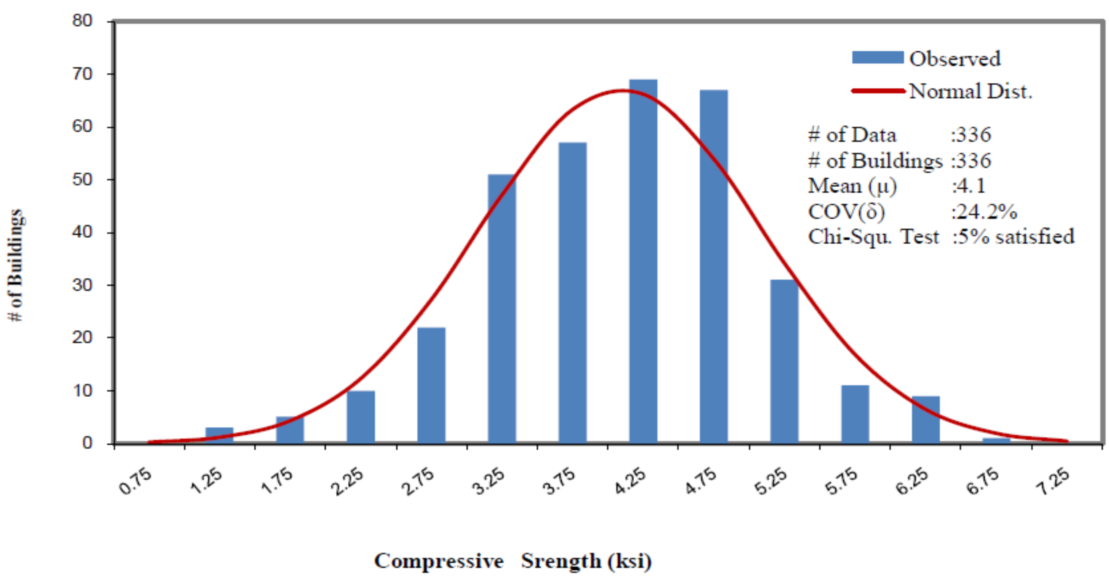


Figure 4.2. Distribution of characteristic 28 days compressive strength of columns of RC buildings in Dhaka.

4.2 Steel

Two different steel types have been used extensively in Bangladesh over the past 40 years; Grade 40 (fy=40 ksi) and Grade 60 ((fy=60 ksi) with recent but steady increased use of Grade 75(fy=75 ksi) steel. There is growing interest within the reinforced concrete industry in using higher strength reinforcing steel for certain applications. This interest is driven primarily by relief of congestion; particularly in buildings assigned a high seismic design category.

The statistical results of Grade 40 and Grade 60 steel are presented in Table 4.1. These results are based on rebar test data gathered from BRTC,BUET over 4 years period from 2006 to 2010.

Table 4.1. Detailed statistics for commonly used steel in RC buildings

Grade of steel	# of data	Mean (ksi)	COV (%)	Suggested distribution	$\chi 2$ test result
40	341	51.5	17.6	Log-normal	Not satisfied
60	710	66	9	Gamma	Not satisfied

5 CONCLUSION

Dhaka, the capital of Bangladesh, is a mega city and one of the major cities of south Asia. It is the political, cultural and economic center of Bangladesh. Bangladesh, being located close to the plate margins of the Indian and Eurasian plates, is susceptible to earthquakes. Though Bangladesh didn't experienced major earthquakes in recent decades, Bilham et al. [2001]pointed out there is a 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. So, the need to carry out a seismic loss assessment study of Dhaka is extremely import in the context of the design of insurance and reinsurance schemes and in the planning of urban/regional-scale emergency response, disaster planning and earthquake protection/retrofitting schemes.

The building survey carried out by Comprehensive Disaster Management Programme (CDMP) of Government of Bangladesh (GoB) during 2008-2009 [CDMP 2009] is used to present general building stock statistics of Dhaka city. The result of the survey has shown that the majority of the buildings are reinforced concrete building (76.4%) and masonry bearing wall structure (23.3%). The reinforced concrete building stock in the Dhaka city ranges mainly between 3 to 7 storeys which are used as residential, mostly residential buildings and mostly commercial purposes.

Besides the general building stock statistic presented, an attempt was undertaken to study structural characteristics of the RC building in Dhaka city based on a database of 66 buildings structural and architectural drawing which have been gathered from different source. The database has been used to study the statistics of the structural properties of the building stock (e.g. storey height, floor area, column, beam, wall and slab dimensions) in detail and the material properties used in the construction of the buildings.

One of the main limitations of the present study is that the characteristics of the existing building stock have been basically defined according to the data obtained from the structural and architectural drawings of the real building projects. Although the buildings had the permit of construction from regulatory authority, there might be some, at least slight, differences compared to the real building constructions.

In view of these limitations the following developments are envisaged:

- About 10% of the buildings in the database would be randomly selected for field verification. This would lead to the identification of degree of discrepancy between approved drawings and on field construction.
- There is an increased trend of constructing flat plate buildings, especially for midrise residential buildings but they are poorly represented in the current database. So additional building drawings of this category would be collected and analysed.
- Structural irregularities such as code defined horizontal and vertical irregularities result in poor performance of the buildings during earthquakes. So, these irregularities (torsional irregularities, floor discontinuities etc.) would be investigated.

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APPENDIX

Table A1 : Description of different building parameters

POSITION	SLOPE	1	Yes
		2	No
	NEIGHBOUR	1	Independent
		2	Dependent from one side
		3	Dependent from two sides
	DILATATION	1	Yes
		2	No
		3	Undetermined
	STORY LEVEL	1	Same
		2	Different
IRREQULARITIES	A1	1	Yes
		2	No
	A2	1	Yes
		2	No
	A3	1	Yes
		2	No
	A4	1	Yes
		2	No
	B1	1	Yes
		2	No
	B2	1	Yes
		2	No
	B3	1	Yes
		2	No
SYSTEM TYPE	R/C Frame	1	
	R/C Frame+Shear Walls	2	
	Masonry	3	
INFILL MATERIAL	Hollow Brick	1	
	Solid Brick	2	
	Concrete Briquet	3	
	Other	4	
MATERIAL OF BASEMENT WALL	Stone	1	
	R/C Wall	2	
	Solid Brick	3	
	Concrete Briquet	4	
	Other	5	

Table A1 : Description of different building parameters (contd..)

FLOOR TYPE	Slabs with beam between all sides	1
	Flat slab	2
	Flat Plate	3
	Joist slab	4
	other	5
STRUCTURAL SYSTEM TYPE	Reinforced Concrete Frame	RCF
	RC Frame with Shear Wall	RCSW
	Masonry	Masonry
	Mixed-Masonry and RC frame	Masonry-RCF
	Tunnel Form-Shear Walls	Tunnel Form

Table A2: General Information of RC Building Stocks in database

Building no	Building id	address	Construction year	Developer/owner	No of story
1	UTT-1	Road-2 , Sector -13 , Uttara, Dhaka	2007	Eastern Housing	
2	TEZ-1	80/1 Indira Road Frmgte Dhaka	2007	Prodential Construction	6
3	TEZ-2	80/1 Indira Road Frmgte Dhaka	2007	Prodential Construction	
4		Dhaka	2007		5
5	UTT-2	Utara Model Town ,Dhaka	2007	Rupayan housing estate ltd.	6
6	GUL-1	Ng At A-24, Niketon, Gulshan, Dhaka	2005	Md. Masud sheikh	6
7	MIR-1	Plot-347,Mirpur-15,Dhaka		Mr.md. Faridur rahman	4
8	MIR-2	P. No-246, plot no-437, mirpurdohs, dhaka cantonment,mirpur, dhaka.	2007	Captain Nizam Uddin Ahmed	8
9		Dhaka	2008	Prudential Consultents	4
10	MOHA-1	Mohammadpur,Dhaka	2008	Mr. Md. Humayun kabir	5
11	BAN-1	Shafi textile ltd. House :64 road:17 block:e banani dhaka	2008	Binyash	13
12	MIR-3	Plot#63&64 Block-C ,Mirpur ,Dhaka	2007	Md. Motiur rahman sikder	6
13	MOHA-2	Mohammadpur ,Dhaka	2008	Prudential	6
14		Dhaka	2007		3
15	MOHA-3	Mohammadpur Dhaka	2007	Nikhil	6
16	SAV-1	Bipial, Savar,Dhaka.	2008	Prudential Consultants	4
17	MOHA-4	Block -C,Tajmahal Road Mohammadpur Dhaka	2008	Nagar Design & Development	6
18	BAN-2	Plot 20, Road 5, Nikunjo 1, Dhaka	2008	Md Abdul Jabbar Akond	3
19	BASU-1	Plot 401, Block F, Bashundhora Residential Area, Dhaka		Md Abu Baker Siddique	6
20		Dhaka			6
21	GUL-2	House 11a, Road 99, Gulshan 2, Dhaka	2006	Vision Home Ltd	6
22	MOHA-5	Plot-01, Babur Road, Mohammedpur, Dhaka	2007	Md Moazzem Hossain	4
23	RAM-1	Block -G ,Road-2,Bonosree	2009	Prudential Consultants	4
24		Dhaka			
25	UTT-3	Sector-11 Road-27 Utara, Dhaka	2008	Elegance Developer	6
26		Siddik Bazar	2007	Imperial Real State	
27	MOD-1	357/15/A Modhubag		Md Mussa Khan	6
28		Dhaka		Md Shofuqul Islam	6

Table A2: General Information of RC Building Stocks in database (contid…)

Building no	Building id	Address	Construction year	Developer/owner	No of story
29	RAM-2	Rampura,Dhaka		Al-arafa builders ltd.	5
30	MOHA-6	Mohammadpur Dhaka	2005	Building Design System	5
31	MIR-4	Plot16 Road32 Pallabi Dhaka		Al-arafa builders ltd.	6
32	MIR-5	Mirpur Dhaka		Md Asraf Uddin	4
33		Plot#12 Road#29rupnagar Residential Area Dhaka		Md. Nurul amin	6
34	MIR-6	Housing #2 Road#15 Mirpur Road Dhaka	2009	Anas Property Ltd	6
35	UTT-4	Sector 11, Uttara, Dhaka	2006	Mr. Shafiqur rahman	
36	BAD-1	Ja -80 Plot-72 Moddle Badda,Dhaka		Md. Amin ullah	6
37	UTT-4	Road-2 , Sector -13 , Uttara, Dhaka	2007	Eastern Housing	6
38	DHAN-1	50/1 Dhanmondi R/A		Eastern Housing	6
39	DHAN-2	46/4a Dhanmondi	2002	Eastern Housing	6
40	POL-1	67/9 Kakrail,Dhaka	2004	Eastern Housing	15
41	POL-2	67/9 Kakrail,Dhaka	1999	Eastern Housing	20
42	GUL-3	Plot no. C-64,at nikaton,gulshan		Eastern Housing	8
43	GUL-4	House no 29, road no. 43 gulshan dhaka	2003	Eastern Housing	6
44	GUL-5	Plot No -10,Block-B,Road No-23a Banani Dhaka		Eastern Housing	6
45		106 Central Road Dhaka		Eastern Housing	6
46	DHAN-3	Plot-741 Saat Masjid Road Dhanmondi Dhaka	2004	Eastern Housing	5
47	GUL-6	Plot-B3 ,Block-B Nikaton Dhaka		Eastern Housing	6
48	GUL-7	Plot-A47,Block A Nikaton Dhaka		Eastern Housing	6
49	GUL-8	Plot-A47,Block A Nikaton Dhaka		Eastern Housing	6
50	GUL-9	Plot no. 35,road no. 37 gulshan dhaka	2002	Eastern Housing	6
51	GUL-10	Plot No-A/140,Block-A Nikaton Dhaka	2003	Eastern Housing	6
52	MOT-1	Plot -011 No- 342 , Ward 31, Ps - Motijheel , North Komlapur, Dhaka	2011	Eastern Housing	18
53	TEZ-3	Greenroad, Panthapath	2007	Eastern Housing	15
54	MOHA-7	Plot - 215, Shahjahan Road, Block C , Mohammad Pur , Mouza Dakhin Adabor	2009	Eastern Housing	14
55	BASU-2	No-564.block-f. Basundara dhaka		Dr.Md.Luthfur Rahman, Dhaka	6
56	MOHA-8	Plot 2801 Babor Road Dhaka	2008	Md.Ishtique Ahmed	6
57		45-A Lalbag Dhaka		Tipu	6
58		Anamika Concord		Concord	13
59	GUL-11	House no. 2, block-d, road no. 23/a, banani, dhaka.		Mr.Jalal Ahmmed Karim.	6

Table A2 : General Information of RC Building Stocks in database (contd…)

Building no	Building id	Address	Construction year	Developer/owner	No of story
60	MOHA-9	Plot -14/12 Babor Road Mohammadpur ,Dhaka		Ekushey homes ltd.	6
61		Chandramollika	2007		
62	BASU-3	Plot no:-214, block no:-g, bashundhara r/a baridhara, gulshan, dhaka.		Akter Hossin	6
63	UTT-5	C.S#211,S.A(Motation)1429,R.S-6684,Mouza-Baunia,Uttara, Dhaka.		Amir Hossain Rouf	6
64	GUL-12	Jahanara Palace,Plot No-76,Road No-15,Block -C Banani			8
65	POL-3	plot-80,kakrail avenue ,dhaka	2005	rupayan housing estate ltd.	17
66	RAM-3	JA-18(Plot No:72),Moddle Badda, Dhaka.		Md.Amin Ullah Chowdhury	6

Table A3 : Storey properties of RC Building Stocks in database

BuildingNo	Story Heights (Ft)					Floor Areas (Sqft)				
	1st Basement	2nd Basement	Ground	Mezzanine	Normal	1st Basement	2nd	Ground	Mezzanine	Normal
1			9.5		10			3891.2		3891.2
2			10		10			2533		2533
3			10		10			1342.5		1342.5
4			10		10			1775		1775
5			10		10			2396.3		2396.3
6			9		10			2509		2513
7			10		10			732		732
8					10					1873
9										
10			7		10			2090		2090
11			10		10			11158		12528
12			10		10			996		969
13			10		10			1384		1384
14			10		10			2550.7		2550.7
15			10		10			2549.7		1549.7
16			10		10			11395		11395
17			10		10			2471		2471
18					9.5					980
19					10					1184
20					10					1731
21			9.5		10			5723.511		7667.236
22			10		10			2396		2445.75
23					10					1060
24					10					1736
25			10		10			3477		3622.325
26					10					2541
27					10					1442
28					10					2300
29					10					3036
30			10		10			794		794
31			10		10			1616		1616
32			10		10			1903		2206
33			10		10			929		929
34			10		10			2430		2430
35					10					2480
36			10		10			1373		1373

Table A3 : Storey properties of RC Building Stocks in database(contd..)

Building	Story Heights (Ft)					Floor Areas (Sqft)				
No	1st Basement	2nd Basement	Ground	Mezzanine	Normal	1st Basement	2nd Basement	Ground	Mezzanine	Normal
37			9.5		10			3891.2		3891.2
38			12		10			5241.5		5697
39			12		10			6823.08		6313.5
40			10.5		10	5310.168		5694		4235.19
41	9.25		12.75		9.75					
42			9		10			3479		2669
43			11.5		9.75			11420		9322
44			11		10			7059		7059
45			13		9.75			17212.5		17212.5
46			10		10			7059.763		6883.029
47			10		10			3577.08		3577.08
48			10.5		10			2845.71		2845.71
49			10		10			2443		2443
50			10.5		9.75			6507.57		6507.57
51			10		10			2439.5		2439.5
52	10		16		10	13955.22		16948.71		14899.71
53			10.67		9.5			9528		8158
54			15		9.75	2370		5189		4248.675
55			10		10			1903		1903
56			10		10			1398.6		1398.6
57			10		10			871		871
58	9		10		10	8932		8916		9235
59	9		10		10	2708		3081		3081
60			10		10			2360		2360
61			10		10			2512		2512
62			10		10			1538		1538
63			9.5		9.5			1551		1551
64	9		12		11			2970		3910
65	8.75		9.75		9.75	3681.4		5001.6		5385.6
66			10		10			1574		1589

Table A.3: Storey properties of RC Building Stocks in database (contd..)

Building No.	Slab thickness (in)	System Type	Infill Material	Material of Basement Wall	Floor Type
1	5	2	2	2	1
2	5	1	2		1
3	4.5	1	2		1
4	4	1	2		1
5	6	1	2		1
6	5	1	2		1
7	6.5	1	2		1
8	5	2	2	2	1
9	4	1	2		1
10	5	1	2		1
11	6	2	2	2	1
12	4	1	2		1
13	5	1	2		1
14	5	1	2		1
15	5	1	2		1
16	6	1	2		1
17	5	1	2		1
18	5	1	2		1
19	5	1	2		1
20	5	1	2		1
21	5	1	2		1
22	5	1	2		2
23	5	1	2		2
24	5	1	2		1
25	5	1	2		1
26	5	1	2		1
27	5	1	2		1
28	5	1	2		1
29	5	1	2		1
30	5	1	2		1
31	5	1	2		1
32	5	1	2		1
33	5	1	2		1
34	5	1	2		1
35	10	1	2		1
36	5	1	2		1
37	5	2	2	2	1

Table A.3: Storey properties of RC Building Stocks in database (contd..)

Building no	Slab thickness (in)	System Type	Infill Material	Material of Basement Wall	Floor Type
38	7	1	2		1
39	7	1	2		1
40	6	2	2	2	1
41	5	1	2		1
42	5	1	2		1
43	5	1	2		1
44	7	1	2	2	1
45	6	1	2		1
46	6	1	2		1
47	5	1	2		1
48	6	1	2		1
49	5	1	2		1
50	6	2	2	2	1
51	6	2	2	2	1
52	5	1	2		1
53	5	2	2	2	1
54	7	2	2	2	1
55	6	1	2		1
56	6	1	2		1
57	6	1	2		1
58	5.5	2	2	2	1
59	5	1	2		1
60	6	1	2		3
61	5	1	2		1
62	5	1	2		1
63	6	1	2		1
64	6	2	2	2	1
65	6	2	2	2	1
66	6	1	2		1

Table A4 : Structural elements information of RC Building Stock in database

Building No	# of Column depth occurrence																																	
	X-dir (inch)																	Y-dir (inch)																
	10	12	14	15	16	17	18	20	21	22	24	25	29	30	33	36	40	10	12	14	15	16	17	18	20	21	22	24	25	28	30	33	36	40
1	2			4														4			2													
2	6	2		2														4			2			2	2									
3	6		2															3		2		2		1										
4	4	4	3	2			2											11			2			2										
5	1		4	2				3			3							12							1									
6	13			1				3										4			2				10				1					
7	10			1														5	4															
8	4			4				6										6			6				2									
9																																		
10	8		3				1											4	2	2				3			1							
11		2					2	18								4														16			8	
12	4			2			2	2										7			2			1										
13	7	2			2													4	3	2				2										
14		8	15		1		10												8	15		1		10										
15	6	4	4															6	6		2													
16				9						29											10						19							
17	4	2		4								2						12																
18	1	4		3														7						1										
19	1	2						3				3						9																
20		4				2					5		2					2	11															
21											8			2		2			12															
22				2			2	1											2		2													
23	11	4																8	4		3													
24																																		
25																																		
26	10			4				5										10			3				5				2					
27	3	2		6				1										11			1													
28	12			1			3											4			3			4	5									
29	16			3														3	3		7				6									
30	7	2																2	4		2			1										
31	10			2																	8			4										
32		9		1															5		2		3											
33	8			3														2	2		7													
34	6			6				6										12	2		2				2									

Table A4 : Structural elements information of RC Building Stock in database (contd..)

Building No	# of Column depth occurrence																																	
	X-dir (inch)																	Y-dir (inch)																
	10	12	14	15	16	17	18	20	21	22	24	25	29	30	33	36	40	10	12	14	15	16	17	18	20	21	22	24	25	28	30	33	36	40
35	6			8				4										6			7				5									
36	4			4				2										6						4										
37	2			4														4			2													
38		4						8																	8			8						
39		3						8											7						8									
40															5																	2		
41																																		
42								8										4			4													
43	10							4										4							10									
44				2				4										6																
45																																		
46	3			4				9										8			15													
47	2			10			2	2										3			13													
48	8			3				1										2	2		10				1									
49	6			4														6			12				2									
50																		20	4															
51	4			5								2						2			4				6				4					
52		4						8																	8			8						
53		24																								1					11		12	
54				4				1				7									2				6				4					
55	4			4			1	1										6			2			2										
56	11						2											2			8			3										
57	11			1														1			11													
58			17					2			1			2						5					4			11			2			
59																																		
60	1			8			4											12						1										
61	10			4				5										10			2				8				2					
62		1		2				3				3							8						1									
63	3			10				4										14			3													
64		7						1											2	1				2	2								1	
65								8	2																									10
66	4			3				2										4						5										

Table A4 : Structural elements information of RC Building Stock in database (contd..)

Building No	Column depth pair																								# of Continuous Frame	
	1		2		3		4		5		6		7		8		9		10		11		12			
1	15	10	15	10	15	10	15	10	10	15	10	15													1	0
2	12	10	15	10	10	18	10	15																	2	1
3	14	10	16	10	16	10	14	10																	2	1
4	12	10	10	15	12	10																			4	2
5	15	10	10	20	20	10	15	10																	2	1
6	10	15	10	15	10	20	10	20	15	10															3	2
7	10	10	12	10	12	10	10	10																		
8	15	20	15	20	20	10	20	10																	3	2
9	10	18	10	18	18	10	22	10																		
10	14	10	10	18	10	14	10	14	10	12															1	4
11	20	28	20	28	20	28	20	28	20	28															4	2
12	15	10	18	10	15	10																			2	3
13																									2	2
14	12	12	14	14	14	14																			5	3
15	10	15	10	15	15	10	15	10																	3	2
16	22	15	22	15	22	15	22	15	22	15	15	15													6	5
17	12	15	12	18	12	18	12	18	12	15															4	3
18	12	10	15	10	15	10	12	10																	1	2
19	20	10	10	26	10	20	10	25	10	20															2	2
20	12	12	24	12	18	12	12	10	12	10															2	3
21	25	12	25	12	25	12	25	12	25	12	25	12													2	0
22	15	10	18	10	20	10	18	10	15	10															1	1
23	12	10	10	15	10	15	12	10																	2	5
24																									0	2
25																									2	7
26	15	10	20	10	10	20	10	20	10	15															2	3
27	12	10	15	10	15	10	15	10	12	10															2	2
28	18	10	20	10	20	10	18	10																	3	2
29	10	12	10	15	10	15	10	15	10	12															3	4
30	12	10	10	15	10	15	12	10																	2	2
31	10	15	10	15	10	15	10	15																	2	4
32	12	12	12	18	12	18	12	12																	3	2
33	10	15	15	10	15	10	10	15																	3	2

Table A4 : Structural elements information of RC Building Stock in database (contd..)

Building No	Column depth pair																								# of Continuous Frame	
	1		2		3		4		5		6		7		8		9		10		11		12			
34	12	12	20	10	20	10	12	12																	4	2
35	10	20	20	10	20	10	10	20																	5	1
36	18	10	10	18	15	10	10	18	15	10															2	3
37	15	10	15	10	15	10	15	10	10	15	10	15													1	0
38	10	20	10	20	10	24	10	24	20	10	20	10													2	4
39	10	15	10	15	10	20	10	20	10	22	10	22													2	4
40																									2	2
41																										
42	20	10	20	10	20	15	20	15																	3	2
43	10	20	10	20	10	20	10	20	10	20	10	20	20	10	20	10	20	10	20	10	20	10	20	10	2	0
44	15	10	15	10	20	10	20	10	20	10	20	10													1	0
45																										
46	10	15	10	15	10	20	15	15	15	15															4	4
47	10	15	10	15	15	10	15	10																	1	7
48	10	15	10	15	10	15	10	15	10	15	10	15													3	1
49	10	15	10	15	10	15	10	15	10	10	10	10													4	2
50	10	20	10	20	10	20	10	20	10	24	10	24													0	4
51	10	15	10	15	15	10	15	10																	4	2
52																									4	4
53	12	36	12	36	12	36	12	36	12	28	12	28													1	3
54	15	25	20	15	25	20	25	20																	3	0
55	10	15	10	15	20	10																			1	1
56	10	15	10	15	10	18																			2	2
57	10	15	10	15	15	10																			3	4
58	14	14	14	20	14	24	14	24	14	24	14	24	14	24											2	3
59																										
60	10	12	10	15	10	15	15	10																	2	2
61	10	18	10	18	10	25																			2	3
62	12	20	15	12	20	12																			2	2
63	10	15	15	10	15	10	15	10																	3	3
64	12	12	12	15	12	18	12	36																	1	2
65	20	40	20	40	20	40	20	45	20	45															2	0
66	10	18	10	18	20	10																			1	3

Table A4 : Structural elements information of RC Building Stock in database (contd..)

Building No	# of beam length occurrence																			
	X-dir (ft)																			
	7	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**28**
1	18	18							18											
2					12				14											
3									16	16										
4		15						15												
5			21				21	21												
6				21							20									
7																				
8		20	20											20						
9	18									18			18	18						
10										15				16						
11								24				24				24				
12						14					14									
13																				
14																20				
15		20																		
16													18							
17								18	18											
18						18	18		18											
19	15	15			15				18											
20		16						16		16				16						
21									20		20	20								
22					18							18								
23	18			18																
24																				
25																				
26				18			18													
27					15		15	15												
28		18									18									
29					18				18											
30	18			18																
31									18							18				
32							15					18								
33		18	18				18													
34					18	18			18											
35						18			18			18					24			
36				18							18		18							
37	18	18							18											

Table A4 : Structural elements information of RC Building Stock in database (contd..)

Building No	# of beam length occurrence																			
	X-dir (ft)																			
	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	28
38																				
39																				
40																				
41																				
42																				
43		21								21		21	21							
44	21										21							21		
45																				
46																				
47																				
48																				
49																				
50																				
51																				
52																				
53																				
54				21					21	21										
55																				
56																				
57																				
58																				
59																				
60																				
61																				
62																				
63																				
64																				
65									21	21										
66																				

Table A4 : Structural elements information of RC Building Stock in database (contd..)

Building No	# of beam length occurrence																	
	Y-dir (ft)																	
	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	25
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
16																		
17																		
18																		
19																		
20																		
21																		
22																		
23																		
24																		
25																		
26																		
27																		
28																		
29																		
30																		
31																		
32																		
33																		
34																		
35																		
36																		
37																		
38		15		15					15									
39	18		18									18						
40																		
41																		
42					24					24								
43																		
44																		
45																		
46			24			24					24							24
47										18								
48	18			18					18									
49	18			18	18				18									
50		21			21					21								
51		24																24
52																		
53		21								21								

Table A4 : Structural elements information of RC Building Stock in database (contd..)

Building No	# of beam length occurrence																	
	Y-dir (ft)																	
	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	25
54																		
55							18											
56				18					18									
57				15		15												
58			18						18	18			18					
59																		
60		21	21			21												
61											18		18					
62									18									
63			18	18														
64							18	18	18									
65																		
66						18												

Table A4 : Structural elements information of RC Building Stock in database (contd..)

Building Number	# of beam depth occurrence																											
	X-dir (inch)														Y-dir(inch)													
		10	12	14	15	16	18	19	20	21	22	24	25	29		10	12	14	15	16	18	19	20	21	22	24	25	29
1							5								1													
2			2			3	1								3					2								
3						4									3					2								
4				2	2		4								4				4		4							
5										7					1									2				
6									12						3								3					
7																												
8							4		3						3						2		4					
9							3								3		3		1		2							
10							3								3		2		4		2							
11															4													
12															2	10												
13		2					2		2						3	2					2							
14									20						1								14					
15					2		2								2				1		4		1					
16													17	14	3													25
17					6				2						2				2				4					
18							3								1						4							
19					2		2								3				3		4							
20				4		2			2						3			2		2			2					
21								11							2													
22							4								2						3							
23					2		6								2				4		6							
24																												
25																												
26					4		4								3				2		4							
27					8										1				4									
28							10								2						6							
29							12								1						12							
30					2		3								2				2		2							
31							6								4						8							
32					3		3								2				1		5							
33							8								1						4							
34							12								1						8							
35										4		4			2											4		

Table A4 : Structural elements information of RC Building Stock in database (contd..)

Building Number	# of beam depth occurrence																											
	X-dir (inch)															Y-dir(inch)												
36							6								1						5							
37							5								1													
38										8					3				16									
39							8								3				16									
40																												
41																												
42												4			2											6		
43										14					3													
44										5					3													
45																												
46							14								1						8							
47															1													
48											9				1										3			
49							14								1						4							
50															3						25							
51							2								2											6		
52					4					4					2				8					8				
53										11					1									5				
54										4					2													
55							4								1						2							
56							6								1						4							
57					6										1				5									
58							16								1						3							
59																												
60							4								2						9							
61							7								1						5							
62							5								2						4							
63					6		6								3									7				
64							2								3						6							
65										8					3													
66							2								1						5							

Table A4 : Structural elements information of RC Building Stock in database (contd..)

Building No	# of beam width occurrence								Structural wall length																			
	X-dir(inch)					Y-dir (in)			X-dir (inch)											Y-dir (inch)								
	10	12	15	20	21	10	12	15	15	24	55	72	92	100	110	174	200	220	307	18	34	48	72	80	98	110	124	146
1	5																											
2	6					2																						
3	4					2																						
4	8					8																						
5						9																						
6	15																											
7																												
8	7					6							1												2			
9	3					5																						
10	3					8																						
11														2			1	1								1	1	
12						10																						
13	6					4																						
14	20					14																						
15	4					6																						
16			31					25																				
17	8					6																						
18	3					4																						
19	4					7																						
20		8					6																					
21		11																										
22		4					3																					
23	8					10																						
24																												
25																												
26	8					10																						
27	8					4																						
28	10					6																						
29		12					12																					

Table A4 : Structural elements information of RC Building Stock in database (contd..)

Building No	# of beam width occurrence								Structural wall length																			
	X-dir(inch)					Y-dir (in)			X-dir (inch)											Y-dir (inch)								
	10	12	15	20	21	10	12	15	15	24	55	72	92	100	110	174	200	220	307	18	34	48	72	80	98	110	124	146
30	5					4																						
31	6					8																						
32	6					6																						
33	8					4																						
34	12					8																						
35	12					4																						
36	6					5																						
37	5																											
38	8					16																						
39	8					16																						
40									5		1	2				1					2	1	5		2			
41																												
42	4					6																						
43	14																											
44	5																											
45																												
46	14					8																						
47																												
48	9					3																						
49	14					4																						
50						25					1														1			
51	2					6					2													1				
52	8					16																						
53	11					2				2					2										2	1		1
54	4								2																		2	
55	4					2																						
56	6					4																						
57	6					5																						
58	8	8				3						1	1	1							1				1	1		
59																												
60	4					9																						
61	7					5																						
62	5					4																						
63	12					7																						
64	2					6				2			1											2				
65	8											1		2		1			1	1			1	1	2			
66	2					5																						

Table A4 : Structural elements information of RC Building Stock in database (contd..)

Building No	Structural Wall width					
	X			Y		
	10	14	15	5	10	15
1						
2						
3						
4						
5						
6						
7						
8	2				1	
9						
10						
11	2				4	
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						
32						
33						
34						
35						
36						
37						
38						

Building No	Structural Wall width					
	X			y		
	10	14	15	5	10	15
39						
40						
41						
42						
43						
44						
45						
46						
47						
48						
49	1				1	
50	1			2		
51						
52	4				4	
53	2				2	
54						
55						
56						
57	3				3	
58						
59						
60						
61						
62						
63	2				3	
64	2	1	2		3	2
65						
66						

Table A.5: Classification of Building Structural Types (CDMP Report 2009)

Sl No.	Structure Type	Label	Height		Description
			Name	Stories	
1	C1	C1L	Low-Rise	1-3	Concrete moment frames are buildings with reinforced concrete columns and beams and designed by engineers. The building in this class contains no significant volume of wall that contributes to total stiffness of the building
		C1M	Mid-Rise	4-7	
		C1H	High-Rise	8+	
2	C2	C2L	Low-Rise	1-3	Concrete Shear Walls are buildings that lateral force resisting system are mainly from shear walls. The examples for shear wall are including lift core and structural wall.
		C2M	Mid-Rise	4-7	
		C2H	High-Rise	8+	
3	C3	C3L	Low-Rise	1-3	Concrete frame with masonry infill walls are buildings with reinforced concrete columns and beams and designed by engineers. The building in this class contains the significant amount of masonry in filled wall that contribute to total stiffness of the building.
		C3M	Mid-Rise	4-7	
		C3H	High-Rise	8+	
4	C4	C4L	Low-Rise	1-3	Concrete Slab-Column Frames are reinforced concrete building which its lateral force resisting system consisted of slab and column.
		C4M	Mid-Rise	4-7	
		C4H	High-Rise	8+	
5	S1	S1L	Low-Rise	1-3	Steel Moment Frame are similar to concrete moment frame however columns and beams are made of steel instead of reinforced concrete
		S1M	Mid-Rise	4-7	
		S1H	High-Rise	8+	
6	S3	S3	Low-Rise	1	Steel truss with steel column consists of the roof truss and the steel column. Gravity load of the roof truss are transferred to ground by steel column. The weak link of this structure usually found in the connection between roof truss and steel column.
7	LC	LCL	Low-Rise	1-3	Lightly reinforced concrete frames are those reinforce concrete building that contains the minimum structural members to sustain the gravity loading. These buildings are not usually designed by engineer. The main characteristics of these building are small column sizes (usually 9-10") and heavily overhanging.
		LCM	Mid-Rise	4-7	
		LCH	High-Rise	8+	
8	BC	BCL	Low-Rise	1-3	Brick in cement mortar masonry with concrete floor are masonry buildings with concrete slab and structural masonry wall and no confined reinforced concrete column.
		BCM	Mid-Rise	4-7	
9	BF	BFL	Low-Rise	1-3	Brick in cement mortar masonry with flexible roof are similar to the one with concrete floor. However, due to lacking of rigid diaphragm that confines the masonry wall, its seismic behavior is considerer poorer.
10	STC	STC	Low-Rise	1	Steel truss with concrete column consists of the roof truss and the concrete column. Gravity load of the roof truss are transferred to ground by concrete column. The weak link of this structure usually found in the connection between roof truss and concrete column.
11	STM	STM	Low-Rise	1	Steel truss with masonry wall consists of the roof truss and the masonry wall. Gravity load of the roof truss are transferred to ground by masonry wall. The weak link of this structure usually found in the connection between roof truss and masonry wall.
12	TSL	TSL	Low-Rise	1-3	Tin shed is minimum standard structure constructed by tin shed for wall and roof.
13	BAL	BAL	Low-Rise	1-3	Bamboo refers to building which use bamboo as structural component to resist both the lateral and gravity loads.

Table A.5 :Building Occupancy Classes(CDMP Report 2009)

Sl No.	Occupancy	Description
1	RES1	These shall include any building, detached from neighboring buildings by distances required by code and having independent access which is used for private dwelling by members of a single family
2	RES2	These shall include any building in which one or more families are housed, specifically built for minimum standard accommodation of lower income families, in which the minimum requirements for hygiene and safety are maintained for example multi-storied complexes, cluster houses and rehabilitation housing or housing undertaken by private low income groups approved by the authority
3	RES3	Include any building or portion there of or group of buildings in which living quarters are provided for more than one family, living independently of each other, with independent cooking facility for each family. Flats or apartments may be located in walk up buildings, high rise buildings or in housing complexes
4	RES4	Include any building or group of buildings under single management in which sleeping and living accommodation, with or without dining facilities but without cooking facilities for individuals is provided for hire on transient or permanent basis. Example, hotels, motels, rest house, lodging house, inns and clubs
5	RES5	Include any building in which sleeping and living accommodations are provided for groups of unrelated persons with or without common dining facilities and with common cooking facilities under management control or with individual or group cooking facilities. Examples, mess houses, dormitories, boarding houses, hostels and students' halls of residence.
6	RES6	These are sub-standard housings
7	COM1	Include any building or portion thereof used for purpose of display and sale of merchandise, either wholesale or retail or without incidental storage and service facilities with an area not exceeding 300 sq m. Example; large shops, markets, departmental stores, super markets and hyper markets.
8	COM2	Include any building or portion thereof used for purpose of display and sale of merchandise, either wholesale or retail or without incidental storage and service facilities with an area more than 300 sq. m. Example; large shops, markets, departmental stores, super markets and hyper markets.
9	COM3	These are personal and repair services shop. Examples; photocopy shop, automobile workshop etc.
10	COM4	These are professional or technical services offices
11	COM5	These are financial institutions or organizations. Examples; banks, money exchange etc.
12	COM6	Include any building or portion thereof used for purpose of providing essential medical facilities having surgery, emergency and casualty treatment areas which is equipped and designated to handle post disaster emergency and is required to remain operational after disaster.
13	COM7	Include any building or portion thereof used single management in which general and specialized medical, surgical and other treatment is provided to persons sufferings from physical limitations because of health. Example; medical office or clinic.
14	COM8	These buildings are entertainment and recreation facilities. Example: restaurants, bars, snooker club etc.
15	COM9	These buildings are theaters
16	COM10	These are mixed occupancy buildings such as residential with commercial uses.
17	IND1	Buildings are heavy industrial factories. Example: large rubber industry, plastic factory and car industry.
18	IND2	Buildings include light industry. Example; small textile & garments factory, jewelry industry.
19	IND3	Buildings include food, drugs or chemicals industries. Example; soft drink, ice cream, pharmaceuticals etc.
20	IND4	Buildings metals or minerals processing factories. Example: iron & steel industry, brick or cement factories.
21	IND5	The buildings are high technology industries. Example; computer or electrical apparatus factories.
22	IND6	These are buildings under construction.
23	REL1	These are religious buildings like mosques, churches, temples and other non-profit associations.
24	GOV1	These are government general service buildings such as government office like post office or municipal building.
25	GOV2	These are government emergency service buildings such as government office like police or fire service.
26	EDU1	These buildings are grade schools, religious schools or libraries.
27	EDU2	These are college or university buildings

Table A.6 :Correlation Matrix of structural type and building occupancy in Dhaka(CDMP Report 2009)

Occ	Engineered buildings													NON -ENGINEERED BUILDINGS												TOTAL
	C1L	C1M	C1H	C2L	C2M	C2H	C3L	C3M	C3H	CC4L	C4M	C4H	S1L	LCL	LCM	LCH	BCL	BCM	BFL	BLL	TSL	BAL	STM	STC	S3	
RES1	2						60	2		4	1			11	1		60	2	91	3	10	2				249
RES2A		1					238	79		2				81	20		153	6	256	7	31	4				878
RES2B		2		1	1		143	833	2	8	11			38	140	1	49	46	53	1	4	1				1334
RES2C							1	18	3					3	7		1	6	2							41
RES3A	1	2			1	1	254	684	1	9	56			48	92		103	102	20							1374
RES3B		7			3	1	15	937	31	1	95	7			21			52								1170
RES3C			1		1	2	1	160	61		8	12			8			4								258
RES3D								3	12			2														17
RES4	1	3					2	5									1		2							14
RES5							10	21			2				5		2	3	6		5					54
RES6							1										5		38		55	9				108
COM1	7	4					20	4		1	1			20	10		30		182	2	13	2			7	303
COM2	1	9	6				8	12	2		2	1		1	8		1	1	11				1			64
COM3							4	1						1					3	1	3		2		3	18
COM4	2	2				2	25	26	2	1	1		1	5	2		12	5	5					1		92
COM5	2			1	1		1			1	1	1					2									10
COM6		1	2		2	2	2	12	2		2				1		2	2			1					31
COM7							9	3						3	1		4									20
COM8	1						12	3			2			4			7		8	2	1	1				41
COM9							1	1						1	1		1									5
COM10	11	54	13		5	5	307	875	43	5	28	8		133	215	1	141	58	116	15	2	1				2036
IND1		3	2				10	21	6			1		2	2		1	1	13		2		2	2	1	69
IND2	1	2					5	7	1				1	4	1		3		28		1		2		2	58
IND3								4						1					2							7
IND4														1			1		4		1			1	2	10
IND5							1	1																		2
IND6	1	1				2	9	30	2	3	9	2			1											60
AGR1							5	3	1				1	5	1		3		10	1	6	2	1	2	1	42
REL1	16	10					58	14						12	5		11		11		3					140
GOV1	2	3			2	2	18	12	4		2	1		5			10	4	9	1		1				76
GOV2							5	2						1			3		1							12
EDU1		1					42	23						8	3		16	3	6		1					103
EDU2		1	5		1		11	12	1	1	2			2			5		3							44
TOTAL	48	106	29	2	17	17	1278	3808	174	36	223	35	3	390	545	2	627	295	880	33	139	23	8	6	16	8740