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BANGLADESH NETWORK
OFFICE FOR URBAN SAFETY

INTERNATIONAL CENTER FOR
URBAN SAFETY ENGINEERING

INSTITUTE OF INDUSTRIAL SCIENCE
THE UNIVERSITY OF TOKYO

# BNUS ANNUAL REPORT - 2010

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ISBN4-903661-49-0

*Serial Number 54*

BANGLADESH NETWORK
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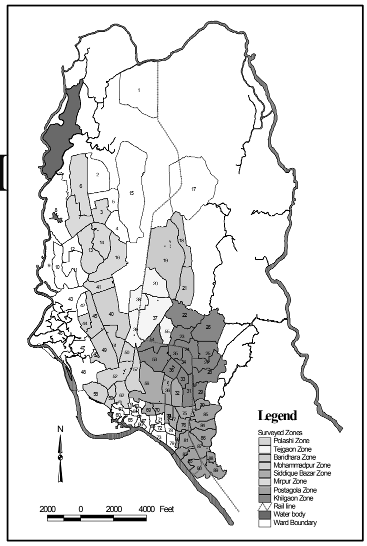
# BNUS ANNUAL REPORT-2010

## BANGLADESH NETWORK OFFICE FOR URBAN SAFETY




**BUET, DHAKA, BANGLADESH**

**Prepared By:**

**Mehedi Ahmed Ansary**

# CONTENTS

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# PART-I

# DIAGNOSIS OF THE SEISMIC VULNERABILITY OF BUILDINGS AT DHAKA USING NON-DESTRUCTIVE TESTING

## BANGLADESH NETWORK OFFICE FOR URBAN SAFETY (BNUS), BUET, DHAKA

**Prepared By: Saidur Rahman**

**Mehedi Ahmed Ansary**

1. INTRODUCTION

The purpose of this study is to analyze the seismic vulnerability of buildings at various locations in Dhaka city. In order to do this, checking structural elements in light of seismic design and analysis of resonance phenomena between building and soil on the basis of natural frequency has been executed. Therefore, two non-destructive tests have been carried out in this project. In addition, the seismic evaluation of buildings according to the first level of screening procedure of the Japanese RC building seismic evaluation provision has also been performed.

Ferroscanner, the electromagnetic detector to record image of reinforcements in concrete up to 100 mm depth, is the efficient device for the identification of reinforcement if there is no found basic design document or having contradiction to design in this building. Column and Lift Core are the most important elements in any structural system. This is why the above two structural elements along with slabs have been surveyed properly using Ferroscanner. In this survey, detection of reinforcement includes number of reinforcement, spacing of reinforcement, bar number and cover over the reinforcement. Eighty three buildings have been selected at six locations in Dhaka city as shown in Figure 1. These are Old Dhaka, BUET campus, Lalmatia, Mirpur, Banani and Uttara.

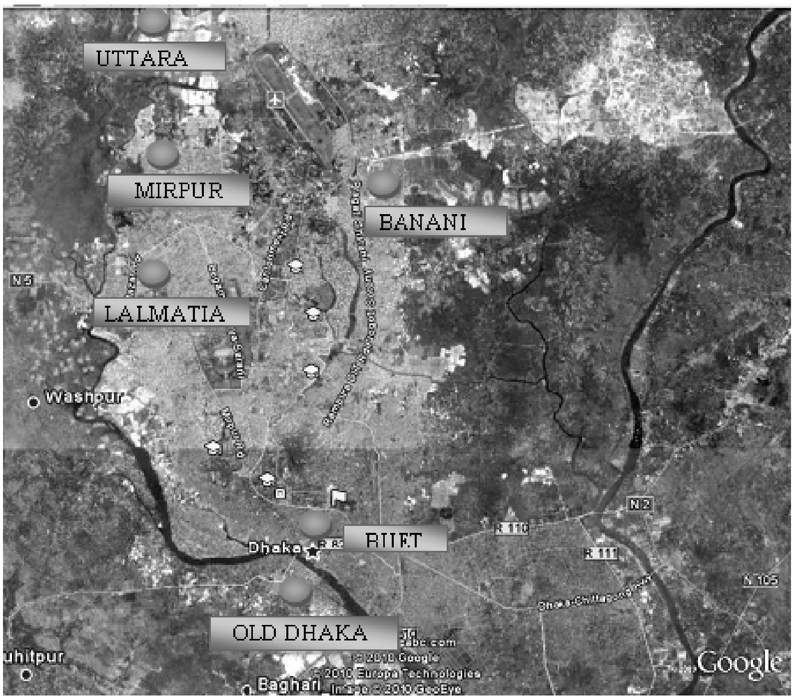


Figure 1: Survey site at Dhaka city (Source: Google map)

In addition, Microtremor is also used to record the fundamental frequency and period of those buildings and soil. The dynamic properties are the important factor for seismic design. Response of building mainly depends on the characteristics of both excitation forces and dynamic properties of buildings.


Figure 2: Seismic Microzonation Map for Dhaka City (After Rahman, 2005)

This is why the natural frequency and period is taken on the top of the roof of those building to identify the dynamic properties of buildings. Furthermore, the vibration characteristics in soil are different from building. Hard soil gives high frequency and soft soil gives low frequency. A structure may experience a vibration period at which it oscillates in the earthquake vibration motion and will tend to response to that. Natural frequency of structure is obtained based on the spectral ratio of horizontal component of the building to that of ground. Meanwhile, practical application of Microtremor in the field of engineering has advanced tremendously. One of the powerful and simplest applications of Microtremor observation is in seismic micro zoning (see Figure 2).

From the data analysis of these building, most of the building are vulnerable due to moderate seismic activity. In Old Dhaka, the majority of buildings are not constructed according to proper seismic design code. Some of these buildings are likely to be damaged because of lower intensity of earthquake. In BUET campus, about twenty nine buildings natural period are not close to that of soil. So, they are out of danger of resonance and natural period of the remaining twenty one buildings are close to that of soil, so their seismic response can be considerably amplified. Results obtained from Ferroscan are not satisfactory. Variation of cover and spacing of lateral ties in columns and stirrups in beam from design are above acceptable limit. The buildings of three places like Lalmatia, Mirpur and Uttara are vulnerable due to medium seismic force. There is a significant variation in reinforcement in those buildings. Some of them are vulnerable due to resonance.

## 2. CHECKING OF STRUCTURAL ELEMENTS USING FERROSCAN

Ferro-scanner, which detects reinforcements in concrete, is efficient device for the detection of structural elements in a concrete building. There are many methods for the diagnosis of the rebar arrangement like Electromagnetic method, X-ray measurement, and High energy X-ray CT Scan and Radar inspection. In our survey, Electromagnetic method in Ferroscanner has been utilized in the surveyed building.

When electric current run through a coil of the apparatus, magnetic field is formed. Electric current is produced in the reinforcement bar because of the magnetic field. The field induces electric current in the secondary coil to be measured. When electric current runs through a coil of the electro-magnetic sensor, magnetic flux is measured. Electromotive force of coil changes due to magnetic flux. Thickness of clear cover or diameter of the reinforcement bar can be estimated from magnetic flux change. Induced magnetic field depends on the distance between sensor and reinforcement. When bars are too close, it becomes difficult to identify the numbers of bar. The rebar detection ranges usually 120-150mm depending on bar size and maximum depth is 180mm. Depth measurement ranges 100-140 mm depending in bar size. However, depth accuracy is ±2.5 mm for most bars at common depth.

The Hilti PS 200 is a system used for high-end reinforcement detection. The important elements of the system are the scanner, the monitor and the software. Scanner (PS 200 S) is used to scan the reinforced concrete element whereas Monitor (PS 200 M) is used to show the bar and to analyze on site (see figure 3(a)).

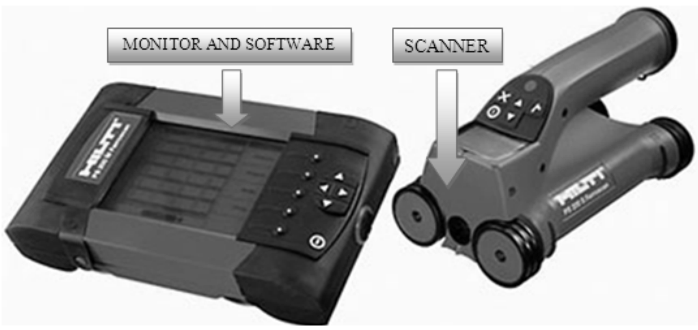


Figure 3(a): PS 200 Ferroscan system

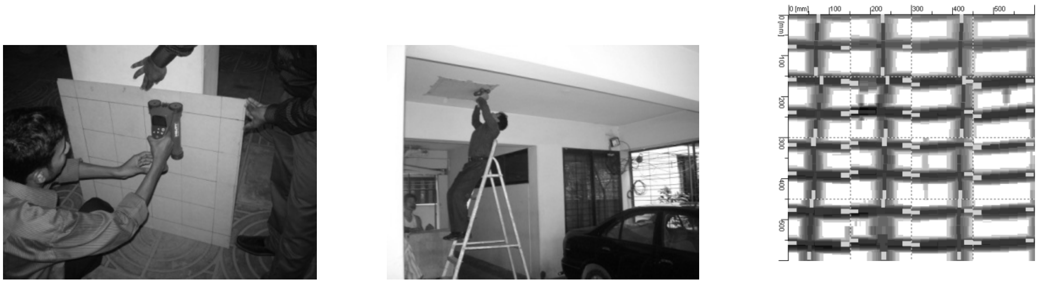

Figure 3(b): Column and slab checking using Ferroscan

For Ferroscan observation the team identified the column and marked them in drawing as well as in the structural part of the building. Then they scan it carefully with the scanner and store the data. The collected raw data were analyzed with help of the Ferroscan software. Sometimes hardboard has been used to execute the scan efficiently. Figure 3(b) shows the process of Ferroscan and the reinforcement data in Villa Vatia.

## 3. MICROTREMOR OBSERVATION

For Microtremor observation, sensors have been fixed on the floor of building at the beginning. The sensor has been placed on the basis of long side and short side of building. Three sensors have been located at different places to find out structural stiffness and natural period.

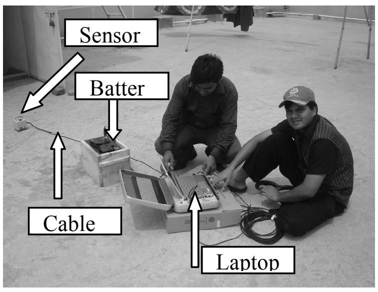


Figure 4: Microtremor data recording at Ameralo, Banani

One sensor has been fixed at the top of the building, one at the free field near the building and other at any floor level of building. In this survey, approximately 60,000 data points with sampling frequency 100 have been recorded. Sometimes observation of the two building has been taken to save time. After taking the observation with the help of a program the time domain velocity data is converted to frequency domain data and find out the natural period of the buildings. Microtremor measurement instrument is shown below in Figure 4.

Soil characteristics can be assessed by Microtremor measurement. Hard soil gives high frequency and soft soil gives long period. A structure may experience a vibration period at which it oscillates in the earthquake vibration motion and will tend to response to that. Natural frequency of structure is obtained based on the spectral ration of horizontal component of the building to that of ground. The velocity spectrums along three directions and response spectrums at different time interval in KING SHOPTAK RAJONIGANDA (MIRPUR) are shown in Figure 4.

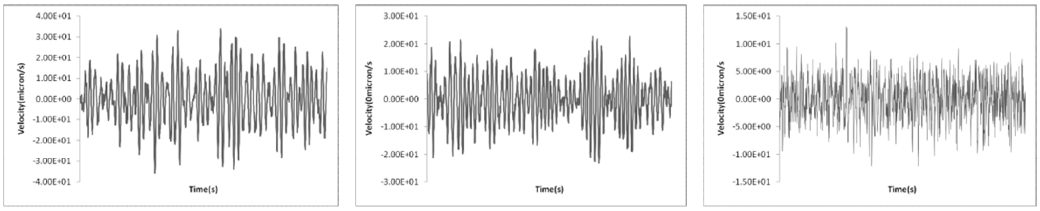


Figure 5: Velocity time history at X, Y and Z direction

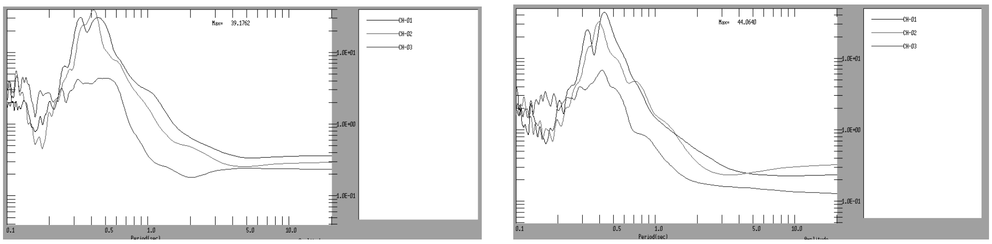

Figure 6: Fourier spectrums of two time intervals of 20 seconds each (from 90 to 110 seconds and from 400 to 420 seconds, according to data recording)

Wave propagation mechanism of Microtremor and its relation with ground vibration characteristics were studied from the beginning of Microtremor studies (Aki, 1957; Kanai and Tanaka, 1961). There are two types of Microtremor observations. These are point and array observations of microtremors (Ansary et al., 1996). From the array observation of Microtremor of period greater than 1 sec, Rayleigh-wave and Love-wave originating from natural sources, such as sea wave, variation of air and wind pressure can be recognized. On the other hand, short-period Microtremor of period less than 1 sec is thought to be generated by artificial noises such as traffic vehicles, industrial plants, household appliances, etc. Some researches (Sato et al., 1991; Tokimatsu and Miyadera, 1992; Tokimatsu et al., 1994) have showed that microtremors are mainly composed of Rayleight-wave and some (Nakamura, 1989; Wakamatsu and Yasui, 1995) have showed that short-period Microtremor bears resemblance to shear-wave characteristics. Nevertheless, Microtremor can also be dominated by Love–wave (Tamura et al., 1993). Recently, Suzuki et al. (1995) have applied Microtremor measurements to the estimation of earthquake ground motions based on a hypothesis that the amplitude ratio defined by Nakamura can be regarded identical with half of the amplification factor from bedrock to the ground surface. However, the real generation and nature of microtremors have not yet been established.

## 4. **DATA ANALYSIS**

In this study, about eighty three buildings have been checked on various points of view, such as structural element checking using Ferroscan, resonance and stiffness criteria using Microtremor, and the first level of screening procedure of Japanese RC building seismic evaluation provisions (2001).

Table 1 shows the probability of resonance in surveyed places. On the other hand, Table 2 gives the structural vulnerability of building on the basis of Ferroscan. In addition to these, Table 3 and Table 4 represent Seismic index of structure $I_S$ and of non-structural elements $I_N$.

The most of the building in BUET campus are vulnerable in consideration of resonance because the predominant period of these buildings is close to that of the soil. However, some of them are unlikely to cause resonance phenomena. But there is structural disparity from various points of view in according to our National Building Code (BNBC, 1993). The building has major structural irregularities such as soft story, re-entrant corner, torsional irregularity, soft story and story mass irregularity. Moreover, variation of clear cover is high. Spacing of lateral ties in column is not as per code.

The buildings in Old Dhaka are likely to be occurred severe seismic hazard. Most of the building, residential as well as religious purposes, is not built according to BNBC (1993). In those areas, resonance phenomena are not analyzed, but, structural vulnerability has been investigated properly. Variation of clear cover is high in most of the building. Spacing of lateral ties in column is not as per code. But, there are a few buildings in those areas which are quite good in consideration of seismic activities. However, majority of the buildings are vulnerable not only for the seismic activity, but also fire or any other hazard.

The building in others areas, like Banani, Mirpur, Lalmatia and Uttara, are vulnerable due structural irregularity as well as resonance. But, there are a few buildings in those areas which are quite good in consideration of two important seismic activities. Furthermore, the construction quality of those buildings is not very well. Some buildings are not constructed according to our National Building Code.

**Table 1: Microtremor data**

| **Building Name and Location** | **Storey of Building** | **T= N/10** | **Observed period (sec)** | | **Site period (sec)** | | **Probability of Resonance** |
|---|---|---|---|---|---|---|---|
| | | | X-direction | Y-direction | X-direction | Y-direction | |
| AMARELO H#77/B, R#3, BLOCK #F, BANANNI | 6 | 0.6 | 0.44 | 0.35 | 0.2 | 0.2 | No |

| Building Name and Location | Storey of Building | T= N/10 | Observed period (sec) | | Site period (sec) | | Probability of Resonance |
|---|---|---|---|---|---|---|---|
| | | | X-direction | Y-direction | X-direction | Y-direction | |
| King Shoptak Rajoniganda, 2<br>2/C, AVENUE-3, PLOT-3, HAZI ROAD, MIRPUR-2 | 7 | 0.7 | 0.34 | 0.45 | 0.25 | 0.25 | No |
| MI-NIBASH<br>H# 1/3, R#19,BLOCK#B, SECTION #10, MIRPUR, DHAKA-1216 | 9 | 0.9 | 0.32 | 0.39 | 0.30 | 0.30 | YES |
| NHB<br>15/3, Ibrahimpur,Mipur-14 | 6 | 0.6 | 0.41 | 0.43 | 0.30 | 0.30 | No |
| RIDGE VALLEY<br>H#29, R#7, BLOCK#F, BANANI MODEL TOWN | 10 | 1 | 0.51 | 0.30 | 0.25 | 0.25 | No |
| VILLA VATIA<br>H#3/8, BLOCK#E,LALMATIA, DHAKA-1207 | 7 | 0.7 | 0.35 | 0.37 | 0.20 | 0.20 | No |
| SUVASTU SARINA<br>H#1/4,BLOCK#F,LAL-MATIA, DHAKA-1207 | 8 | 0.8 | 0.31 | 0.43 | 0.20 | 0.20 | No |
| TOTAL GODHULI<br>PLOT-16, SECTOR-10, ROAD-11, UTTARA R/A, DHAKA | 6 | 0.6 | 0.5 | 0.3 | 0.26 | 0.26 | YES |
| IFCDR Building<br>BUET CAMPUS | 4 | 0.4 | 0.5 | 0.5 | 0.7 | 0.65 | No |
| Eleven Storey Tower Building<br>BUET CAMPUS | 11 | 1.1 | 0.4 | 0.4 | 0.3 | 0.3 | No |
| Civil Engineering Building<br>BUET CAMPUS | 7 | 0.7 | 0.26 | 0.39 | 0.5 | 0.33 | No |
| EME Building | 7 | 0.7 | 0.37 | 0.37 | 0.25 | 0.25 | YES |

| Building Name and Location | Storey of Building | T= N/10 | Observed period (sec) | | Site period (sec) | | Probability of Resonance |
|---|---|---|---|---|---|---|---|
| | | | X-direction | Y-direction | X-direction | Y-direction | |
| BUET CAMPUS | | | | | | | |
| Library Building BUET CAMPUS | 5 | 0.5 | 0.33 | 0.36 | 0.25 | 0.26 | No |
| Architecture Building BUET CAMPUS | 5 | 0.5 | 0.26 | 0.38 | 0.4 | 0.4 | YES |
| URP Building BUET CAMPUS | 5 | 0.5 | 0.27 | 0.3 | 0.4 | 0.4 | YES |
| ARC Building BUET CAMPUS | 5 | 0.5 | 0.18 | 0.3 | 0.5 | 0.26 | No |
| New Academic Building BUET CAMPUS | 12 | 1.2 | 0.27 | 0.18 | 0.32 | 0.35 | No |
| Controller of Examination building BUET CAMPUS | 5 | 0.5 | NA | NA | 0.3 | 0.35 | YES |
| Engg. University School Building BUET CAMPUS | 4 | 0.4 | NA | NA | NA | 0.52 | YES |
| Titumir Hall BUET CAMPUS | 4 | 0.4 | 0.24 | 0.27 | 0.38 | 0.52 | NO |
| Sher-e-Bangla Hall BUET CAMPUS | 4 | 0.4 | 0.32 | 0.27 | 0.38 | 0.31 | YES |
| Dr. M.A. Rashid Hall BUET CAMPUS | 4 | 0.4 | 0.32 | 0.32 | 0.32 | 0.38 | YES |
| Building Number 47 BUET CAMPUS | 6 | 0.6 | 0.39 | 0.34 | 0.38 | 0.32 | YES |
| Building Number 62 BUET CAMPUS | 6 | 0.6 | 0.32 | 0.28 | 0.3 | 0.3 | YES |
| Fire Service Station (Head Office, Dhaka) BUET CAMPUS | 6 | 0.6 | 0.4 | 0.38 | 0.3 | 0.3 | YES |
| Ban Bhaban Main Building BUET CAMPUS | 5 | 0.5 | 0.3 | 0.3 | 0.3 | 0.23 | YES |
| Fire Service Station, Lalbag BUET CAMPUS | 4 | 0.4 | 0.27 | 0.25 | 0.07 | 0.06 | YES |

| **Building Name and Location** | **Storey of Building** | **T= N/10** | **Observed period (sec)** | | **Site period (sec)** | | **Probability of Resonance** |
|---|---|---|---|---|---|---|---|
| | | | X-direction | Y-direction | X-direction | Y-direction | |
| Shahid Smirity Hall middle Building BUET CAMPUS | 4 | 0.4 | 0.3 | 0.28 | 0.18 | 0.07 | YES |
| Shahid Smrity Hall north Building BUET CAMPUS | 5 | 0.5 | 0.2 | 0.2 | 0.32 | 0.3 | No |

Note: X = Long direction and Y = Short direction

**Table 2: Data analysis (Ferroscan)**

| **Building Name and Location** | **Adequacy of Reinforcement** | | | **Structural Vulnerability** |
|---|---|---|---|---|
| | **Column** | **Slab** | **Beam/shear wall** | |
| TEACHERS' QUARTER 47/1-6, BUET campus | not ok | ok | not tested | moderate |
| AMARELO H#77/B, R#3, BLOCK #F, BANANNI | ok | ok | not tested | moderate |
| King Shoptak Rajoniganda, 2 2/C, AVENUE-3, PLOT-3, HAZI ROAD, MIRPUR-2 | not ok | ok | not tested | moderate |
| MI-NIBASH H# 1/3, R#19,BLOCK#B, SECTION #10, MIRPUR, DHAKA-1216 | not ok | not ok | not tested | high |
| NHB 15_3 15/3, Ibrahimpur,Mipur-14 | not ok | not ok | not tested | high |
| RIDGE VALLEY H#29, R#7, BLOCK#F, BANANI MODEL TOWN | ok | ok | not ok | moderate |
| VILLA VATIA H#3/8, BLOCK#E, LALMATIA, DHAKA-1207 | not ok | ok | not tested | moderate |
| SUVASTU SARINA H#1/4,BLOCK#F, | ok | ok | not tested | moderate |

| **Building Name and Location** | **Adequacy of Reinforcement** | | | **Structural Vulnerability** |
|---|---|---|---|---|
| LALMATIA, DHAKA-1207 | | | | |
| TOTAL GODHULI PLOT-16, SECTOR-10, ROAD-11, UTTARA R/A, DHAKA | not ok | ok | not ok | high |
| Islampur Jame Mosque 57, 58; Islampur road | not ok | not tested | not tested | high |
| Jhubbu Khanam Jame Mosque 24, Islampur road | not ok | not tested | not tested | High |
| Kamranga Jame Mosque Zindabahar 1st Lane | not ok | not ok | not ok | high |
| Mahuttuli Jame Mosque 55,Sharat Chandra Chakrobarti Road | not ok | not tested | not tested | high |
| Malibagh(Bangshal) Peyala Mosque Bongshal Road | ok | not ok | not tested | moderate |
| Kosaituli Old Jame Mosque 26/27, K.P. Ghosh Street | ok | ok | not tested | moderate |
| Bangshal RokonUddin Jame Mosque Bongshal Road | not ok | ok | not tested | moderate |
| Anondomoyee Girls's High School 17,18 ,Kazi Muddin Siddque Street | ok | not ok | not tested | moderate |
| Haybotnagar Primary School 13,'Haibat Nagar Dewan | not ok | ok | not tested | moderate |
| Jummon Community Centre 19-1,19-2(I),'Hazi Abdur Rashid Lane | Not ok | not ok | not tested | moderate |
| Mokimbaza school | ok | not tested | not tested | quite good |
| Mahuttuli primary School 27, Sharat Chandra Chakrobarti Road | not ok | ok | not tested | moderate |

| **Building Name and Location** | **Adequacy of Reinforcement** | | | **Structural Vulnerability** |
|---|---|---|---|---|
| Nobab Yousuf Market Mosque<br>Nobab Eusuf Road | not ok | not ok | not ok | high |
| ShahjadaMia Jame Mosque<br>24, Shahjada Mia Lane | not ok | ok | not tested | moderate |
| Jindabahar Jame Mosque<br>54, Zindabahar 1st Lane | not ok | not ok | not ok | high |
| Maulana Mosque<br>97/98, K.P. Ghosh Street | not ok | ok | not tested | moderate |
| Shahjadi Begum Jame Mosque<br>45, Bagdasha Lane | ok | not ok | not tested | moderate |
| Samsabad Boro Mosque<br>K.P. Ghosh Street | ok | not ok | not tested | moderate |
| Kosaituli panchayet Committee and School<br>9, Kazi Muddin Siddque Street | ok | ok | not tested | moderate |
| Babubazar Ghat Jame Mosque<br>Ray Eshar Chandra Ghosh | ok | ok | not tested | moderate |
| Ahmed Bawani School and College<br>3/4, K.P. Ghosh Street | not ok | ok | not tested | moderate |
| Samsabad Primary School<br>79, K.P. Ghosh Street | not ok | ok | not ok | moderate |
| Kona Party Centre<br>11-12,S.C.C Road | not ok | not ok | not ok | high |
| Ahmedabad school<br>3/4, K.P. Ghosh Street | not ok | ok | | moderate |
| Mosjid-e-Baitul-Mamur<br>69 French Road, Mosjid-e-Baitul-Mamur | ok | not ok | not tested | moderate |
| IFCDR Building<br>BUET CAMPUS | ok | ok | not ok | moderate |
| Eleven Storey Tower Building<br>BUET CAMPUS | not ok | ok | not ok | moderate |

| **Building Name and Location** | **Adequacy of Reinforcement** | | | **Structural Vulnerability** |
|---|---|---|---|---|
| Civil Engineering Building BUET CAMPUS | not ok | ok | not ok | moderate |
| EME Building BUET CAMPUS | not ok | ok | not ok | moderate |
| Library Building BUET CAMPUS | not ok | ok | not tested | moderate |
| Architecture Building BUET CAMPUS | not ok | ok | not ok | moderate |
| URP Building BUET CAMPUS | not ok | ok | not ok | moderate |
| ARC Building BUET CAMPUS | not ok | ok | not ok | moderate |
| New Academic Building BUET CAMPUS | not ok | ok | not ok | moderate |
| Controller of Examination building BUET CAMPUS | not ok | ok | not ok | high |
| Engg. University School Building BUET CAMPUS | not ok | not tested | not ok | moderate |
| Titumir Hall BUET CAMPUS | not ok | not ok | not ok | moderate |
| Sher-e-Bangla Hall BUET CAMPUS | not ok | not ok | not ok | moderate |
| Dr. M.A. Rashid Hall BUET CAMPUS | not ok | not ok | not ok | moderate |
| Building Number 47 BUET CAMPUS | ok | not tested | ok | moderate |
| Building Number 62 BUET CAMPUS | ok | ok | ok | moderate |
| Fire Service Station (Head Office, Dhaka) BUET CAMPUS | not ok | not ok | not ok | moderate |
| Ban Bhaban Main Building BUET CAMPUS | ok | not tested | not ok | moderate |
| Ban Bhaban Extended Portion BUET CAMPUS | ok | not tested | not ok | high |

| Building Name and Location | Adequacy of Reinforcement | | | Structural Vulnerability |
|---|---|---|---|---|
| Fire Service Station, Lalbag BUET CAMPUS | ok | not ok | not tested | moderate |
| ahsan-Ullah hall BUET CAMPUS | not ok | not ok | not ok | high |
| Shahid Smirity Hall middle Building BUET CAMPUS | not ok | ok | ok | moderate |
| Shahid Smrity Hall north Building BUET CAMPUS | not ok | ok | ok | moderate |

## 5. SEISMIC EVALUATION FOLLOWING THE FIRST LEVEL OF SCREENING PROCEDURE

The provisions of the Standard of Japanese RC building evaluation (2001) is applied to seismic evaluation of existing reinforced concrete buildings of Dhaka. The seismic evaluation is done based on both site inspection and structural calculation to represent the seismic performance of a building in terms of seismic index of structure $I_S$ and seismic index of non-structural elements $I_N$. The seismic safety of the building shall be judged based on standard for judgment on seismic safety wherein seismic performance demands are prescribed.

The standard is applied to the seismic evaluation and the verification of seismic retrofitting of existing low-rise and medium-rise reinforced concrete buildings. Three levels of screening procedures, namely the first, the second, and the third level screening procedures, are available for the seismic evaluation according to this standard. In the present study first level of screening procedure is used.

The seismic index of structure $I_S$ can be calculated at each story and in each principal horizontal direction of a building. Here the index has been calculated for a typical story in weak direction. The seismic index of structure includes basic seismic index of structure $E_O$, irregularity index $S_D$ and time index T. The basic seismic index of structure $E_O$ evaluates the basic seismic performance of the building. It is calculated at each story and each direction based on the ultimate strength, failure mode and ductility of the building. These effects are considered by applying the strength index C, the ductility index F and the effective strength factor $\alpha$. The vertical structural members are classified into three categories as column, extremely short columns and wall, according to the provision. The strength index in the first level of screening procedure is calculated approximately using the cross sectional area of walls and columns. The irregularity index $S_D$ and time index T are used commonly for all stories and directions in the first level of screening procedure. The irregularity index $S_D$ is to modify the basic seismic index of structure $E_O$ by quantifying the effects of the shape complexity and the stiffness unbalance distribution, and the seismic performance of a structure with engineering judgment. The time index T evaluates the effects of the structural defects such as cracking, deflection, aging and like on the seismic performance of a structure. Seismic index of non-structural elements $I_N$ is to judge the safety of human lives or the security of evacuation routes against the fall-down or the spall-off of non-structural elements, especially external walls. $I_N$ shall be calculated by following the procedures provided for the first level screening procedure for each wall in each story. In current seismic evaluation $I_N$ is calculated for the walls based on the representative condition present in a specific story of a building. The seismic index of non-structural elements includes construction index and human risk index which shall be adopted for the external walls considering the most vulnerable construction method, that is, which gives the maximum value of the construction index, among the walls concerned. The construction index is calculated from conformability index and deterioration index. The conformability index is determined in combination of ductility grade of the primary structure and ductility grade of non-structural elements. The deterioration index is based on aging and past damages. The human risk index is based on the condition of usage below the external wall and the existence of guard such as the eaves, set back and the like.

Seismic safety of a building shall be judged by comprehensive assessment based on the seismic evaluations separately conducted on the structure and non-structural elements. Seismic safety of structure is judged by comparing the seismic index of structure and the seismic demand index of structure $I_{SO}$. The building may be assessed to be safe if the building possesses the seismic capacity required against the expected earthquake motions. Otherwise the building should be assessed to be uncertain in seismic safety. The seismic demand index of structure $I_{SO}$ is calculated for first level of screening, based on the basic seismic demand index of structure $E_S$ taken as 0.8, zone index Z as 1.2 (Rahman G.F., 2004), ground index as 1.0 and usage index as 1.0, regardless of the story in the building.

The index calculated for the seismic evaluation of a few selected buildings is enumerated in Table 3 and comment on their safety judgment is shown in Table 4.

**Table 3: Seismic index of structure $I_S$ and of non-structural elements $I_N$**

| Building | No. of Stories, n | No of Story for Evaluation, i | $E_O$ | $S_D$ | T | $I_S$ | B | H | $I_N$ |
|---|---|---|---|---|---|---|---|---|---|
| IFCDR Building | 4 | 2 | 0.602 | 1.2 | 0.9 | 0.65 | 0.8 | 0.5 | 0.6 |
| Titumir Hall | 4 | 2 | 0.458 | 1.14 | 0.8 | 0.42 | 0.8 | 0.5 | 0.6 |
| New Academic Building | 12 | 2 | 1.494 | 1.14 | 1 | 1.70 | 0.8 | 0.5 | 0.6 |
| M A Rashid Hall | 5 | 2 | 0.702 | 1.14 | 0.8 | 0.64 | 0.8 | 0.5 | 0.6 |
| Library Building | 4 | 2 | 1.148 | 1.14 | 0.8 | 1.05 | 0.8 | 0.5 | 0.6 |
| ARC Building | 4 | 2 | 0.761 | 1.2 | 1 | 0.91 | 0.8 | 0.5 | 0.6 |
| Civil Engineering Building | 7 | 2 | 0.902 | 1.14 | 0.8 | 0.82 | 0.8 | 0.5 | 0.6 |

**Table 4: Comment on safety judgment**

| Building | No of Stories, n | Seismic Index of Structure, $I_S$ | Seismic Index of Non-Structural Elements, $I_N$ | Seismic Demand Index of Structure, $I_{SO}$ | Safety Judgment |
|---|---|---|---|---|---|
| IFCDR Building | 4 | 0.65 | 0.6 | 0.96 | Uncertain |
| Titumir Hall | 4 | 0.42 | 0.6 | 0.96 | Uncertain |
| New Academic Building | 12 | 1.70 | 0.6 | 0.96 | Safe |
| M A Rashid Hall | 5 | 0.64 | 0.6 | 0.96 | Uncertain |
| Library Building | 4 | 1.05 | 0.6 | 0.96 | Safe |
| ARC Building | 4 | 0.91 | 0.6 | 0.96 | Uncertain |
| Civil Engineering Building | 7 | 0.82 | 0.6 | 0.96 | Uncertain |

## 6. CONCLUSIONS

In this study, the seismic vulnerability of low and medium-rise reinforced concrete buildings within six major locations of Dhaka city was investigated. The seismic evaluation has been accomplished by performing two non-destructive tests, Ferroscan and Microtremor measurements and also following the Japanese RC building seismic evaluation provision. The inspection was done by observing the structural elements and building configuration along with the resonance phenomena of the building.

Total 84 buildings have been selected for the study. Most of the buildings in BUET campus are vulnerable in consideration of resonance. Those buildings have major structural irregularities such as soft story, re-entrant corner, torsional irregularity, and mass irregularity. The poor structural quality has been identified in most of the building in Old Dhaka. These buildings have the most probability to face seismic hazard. Consequently, it could be greater threat for the people of these areas. The buildings in other areas, like Banani, Mirpur, Lalmatia and Uttara, are vulnerable due to structural irregularity as well as resonance.

On the other hand, the vulnerability assessment of the seven arbitrary buildings has been performed according to the first level of screening procedure of the Japanese provision. Among these buildings, two buildings may be declared as safe on the basis of seismic safety of structural elements since they own the required seismic capacity against the expected earthquake motions. While other five buildings may be evaluated as uncertain in seismic safety and detail analysis is required to confirm this situation.

Therefore, in light of study, it may be recommended that proper planning and better construction quality are required in future building to combat the seismic activity as well as fire hazard. Moreover, retrofitting technique for the risky buildings in these places.

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# PART-II

# EVALUATION OF FIRE FIGHTING SYSTEM AT HIGH-RISE BUILDINGS IN DHAKA CITY


**BANGLADESH NETWORK OFFICE FOR URBAN SAFETY (BNUS), BUET, DHAKA**

**Prepared By: Tanjina Afrin, Sharmin Ara**

**Mehedi Ahmed Ansary**

## 1. BACKGROUND

A fire hazard is any situation in which there is a greater than normal risk of harm to people or property due to fire. Urban fires have devastating impact on communities. Unplanned urbanization and rapid industrialization are the major causes of huge number of fire related accidents in Dhaka city and increase the vulnerability of the country's major population and economic centers. Dense building concentrations, narrow roads, flammable building materials and electrical system as well as the lack of resources to raise awareness and response skills have resulted in a growing risk of large scale, multiple structure fires.

Fire incidents are very common in Dhaka city, especially in relatively densely populated areas. The damage of property and loss of human life are intensified by different factors. The extent of loss due to fire incidents has an increasing trend and it is shown in Figure 1.

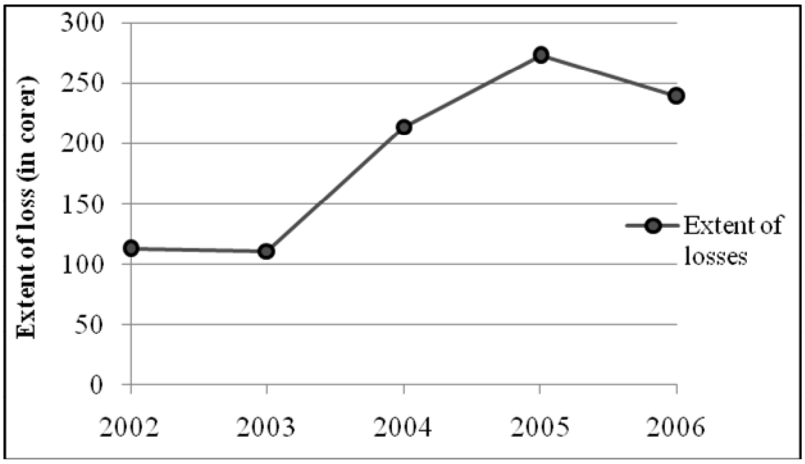



Figure 1: Extent of losses due to fire hazards in different years

A developing country like Bangladesh cannot afford the huge amount of loss caused by fire accidents every year. Moreover, fire incidents in shops, industrial and commercial buildings cause heavy toll of life and property. The fire incidents are on an increase due to lack of awareness, almost no feeling for following safety measures and practicing fire fighting drills, violation of building codes and non- compliance with the Fire fighting and Extinguishing Law 2003.

Some recent flagitious fire incidents in Dhaka city have stimulated a detailed study on high rise buildings about fire safety and awareness. This study depicts an overview on overall condition of existing fire fighting system and on awareness level among the occupants of high rise buildings in Dhaka city.

## 2. MAJOR CAUSES OF FIRE INCIDENT IN BANGLADESH

Common Causes of fire are smoking, welding or cutting operation and use of blow lamps, sparks from power unit, short circuit and over loading of electrical current, children playing with crackers, ignition by chemical action/spontaneous combustion, gross carelessness, malicious, deliberate during riot or strike, lightening, earthquake etc (see Figure 2). Fire at garments is very common in Bangladesh, major fire incidents take place due to unplanned construction of buildings being used by garment factory owners. Most of the buildings did not follow the building code and lacked arrangements for alternative staircases and emergency exits and fire fighting equipment. Keeping collapsible gates under lock and key in the name of security is the main cause of increases casualties in the incidents. According to the statistics, the major accidents occurred due to electric shot circuits. The highest 3334 accidents took place in 2006, 2787 in 2005 and 2522 in 2004,( The New Age, February 10, 2007) (see Figure 3).

High-rise buildings now being constructed in different parts of the city is in lack of the minimum safety features and endangers both adjoining structures and public thoroughfares. Many of the high-rises have been constructed without proper planning, ensuring adequate structural strength, without taking the proper safety measures and considering environmental factors.

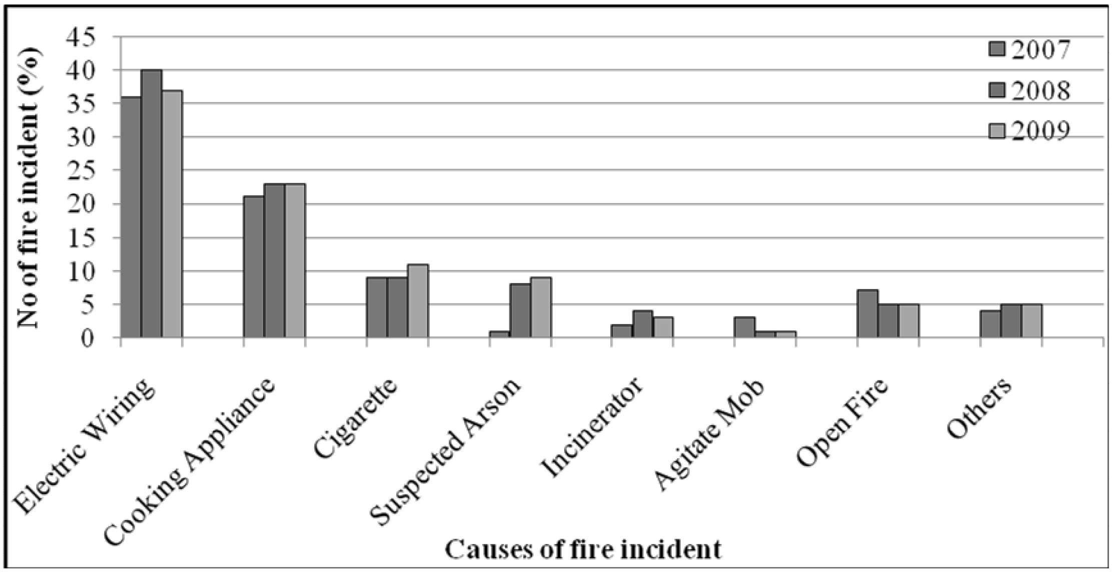



Figure 2: Causes of fire incident in Bangladesh

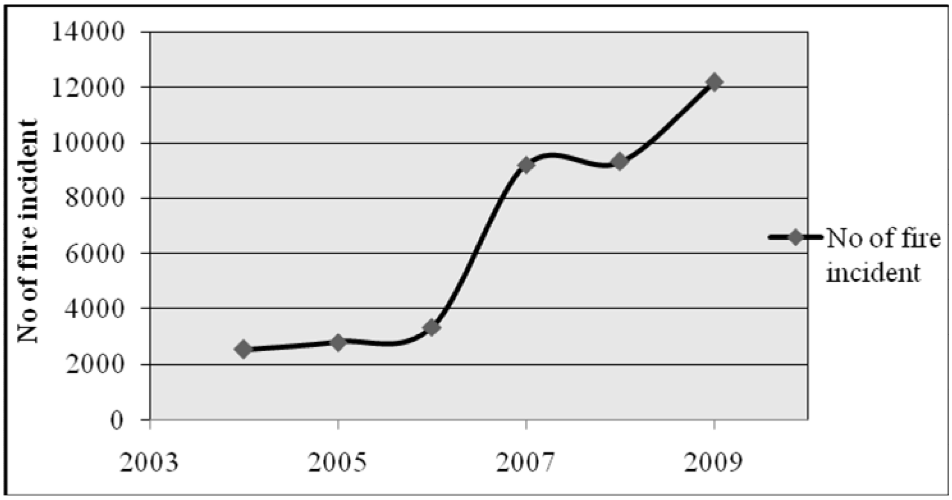



Figure 3: Trends of fire incident in Bangladesh (The New Age, 2009

## 3. RECENT SEVERE FIRE INCIDENTS IN BANGLADESH

In Bangladesh, especially in Dhaka and Chittagong city, fire is becoming an unmanageable threat particularly in high rise buildings mostly constructed violating the national building code. Various incidences of major occurrence of fires in different type buildings are given below.

## I. Fire in BSEC Bhaban

A devastating fire broke out at the Bangladesh Steel and Engineering Corporation (BSEC) Bhaban in the capital on 26 February 2007. Several witnesses said the fire originated from electric oven; while some others said it was sourced from electric short-circuit. There were fire extinguishers on almost all the floors but none dared to use them. This building's neither has any emergency exits nor a sufficient number of fire-fighting equipment and operators to use them during fire. There was also no fire lift but a switched off lift. Acute shortage of water and inadequate equipment hampered the rescue operation. Three persons were killed and more than 100 injured in this incidence. NTV, RTV offices totally burnt and went off air. (www.thedaily star.net)


Photograph 1: Smoke billows out of the BSEC building and victims trapped in the fire that caught the building come down a ladder

## II. Bashundhara Fire

On 13 march 2009, Friday at about 1-45pm, a hell fire engulfed the upper levels of 20 storey office cum shopping centre known as Bashundhara City Complex at Panthopath, Dhaka killing 7 and injured 20 people. Though the building was equipped with sufficient fire detecting, suppressing, and evacuating systems but they were useless during the fire. From the fire Brigade sources it was known that complex's water reservoir remained empty, the hydrants were useless as there was no water in the tank. Due to faulty fire fighting system, the fighters of the building didn't care about those warnings though the fire alarm on the 18th floor, where the fire broke out first, gave false alarm 18 times during the same period.

Photograph 2: Fire engulfing the Bashundhara City market

### III. Terrible fire incident in Nimtoli at Old Dhaka

An overwhelming fire broke out in the densely-populated part of Old Dhaka city at Nimtoli. Fire devoured at least 117 people and causing injury about hundreds of people at 3rd June, 2010. Most of the affected peoples were women and children. Initially it was thought that explosion of two transformers at Nimtoli started the fire but later it has been known the fire originated from an oil stove and spread to the chemical warehouses nearby and resulted high casualty figures and damages. It is common scenario in Old Dhaka that most of the buildings have small factories i.e. chemical, plastic, rubber etc., and ware house and food shops up to second floor of the residential building. In Old Dhaka no house is equipped with fire fighting equipments like extinguisher, hose pipe etc. They don't have sufficient width of staircase let alone the emergency exit. (www.thedaily star.net)

Photograph 3: Fire engulfing the Bashundhara City market

### IV. Fire in KTS textile mills

91 killed in a fire in KTS textile mill, Chittagong, February 23, 2006. At least 500 workers were inside the mill when the fire broke out. Most of the survivors had to jump from windows as the only exit from the factory was reportedly locked when the fire broke out late

on a Thursday night. Most of the victims were women, trapped by the flames or suffocated from smoke inhalation. The fire might have been caused by an electrical short circuit. The explosion of a boiler escalated the blaze. (www.thedaily star.net)

After analyzing the past incidents and accidents, some terrible facts are revealed. In most cases imperfect arrangements and training of the safety equipments such as fire alarm, smoke alarm, fire extinguishers, water supply system etc., lack of proper exit route to reach the place of safety ,routes are blocked by different materials ,lack of signage for escape route and emergency lighting, adequate doors as well as adequate staircases are not provided to aid quick exit , fire exit or emergency staircase lacks proper maintenance , lack of proper exit route to reach the place of safety and most importantly lack of awareness among the residents, workers and the owners are the main causes of heavy toll of life and property.

## 4. EXISTING CONDITION OF FIRE FIGHTING SYSTEM IN DHAKA CITY

For the evaluation of fire fighting system in Dhaka city a questionnaire survey was conducted to assess the existing condition of total fire fighting system, awareness level of the respondent and their evacuation plan during fire catch up. To have overall scenario regarding fire safety, 2.5% buildings (includes residential, commercial, garments and institutional etc.) of 2150 (according to Dhaka City Corporation, total no. of high rise building) has been surveyed from 9 zones (Department of Fire Service and Civil Defense divided Dhaka City into 12 zones) and most of them are above 8 storied (see Map1). Figure 4 and Figure 5 show number of study buildings and existing use of the buildings in percentage respectively.
Another objective of this study was to determine the awareness level of occupants of the surveyed buildings. 64% and 80% of total respondents know about earthquake and fire respectively but only a little number of respondents has any evacuation plan about fire incidents.

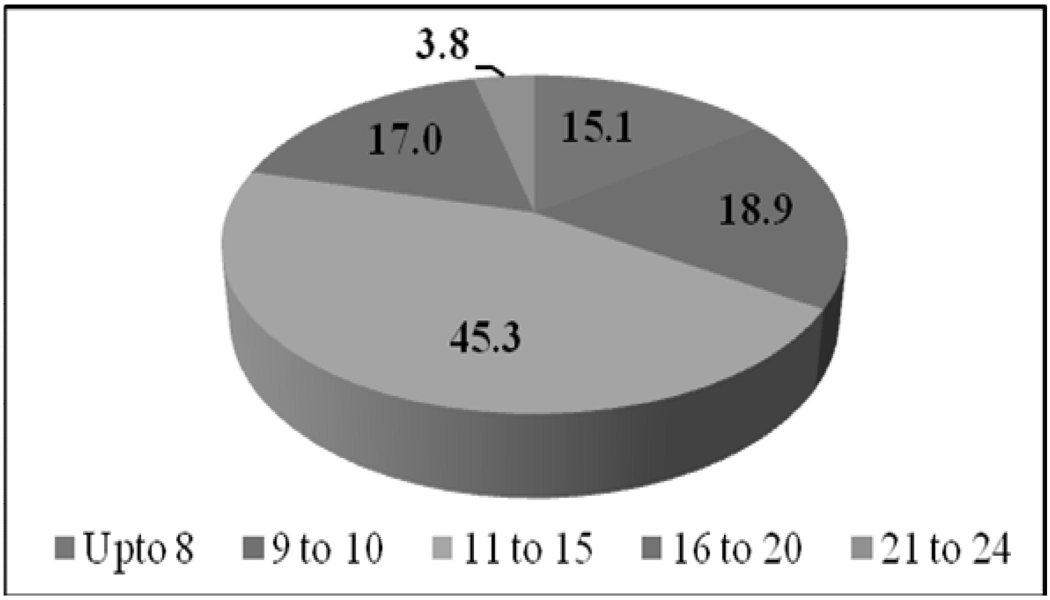



Figure 4: Number of study buildings by storey (in %)

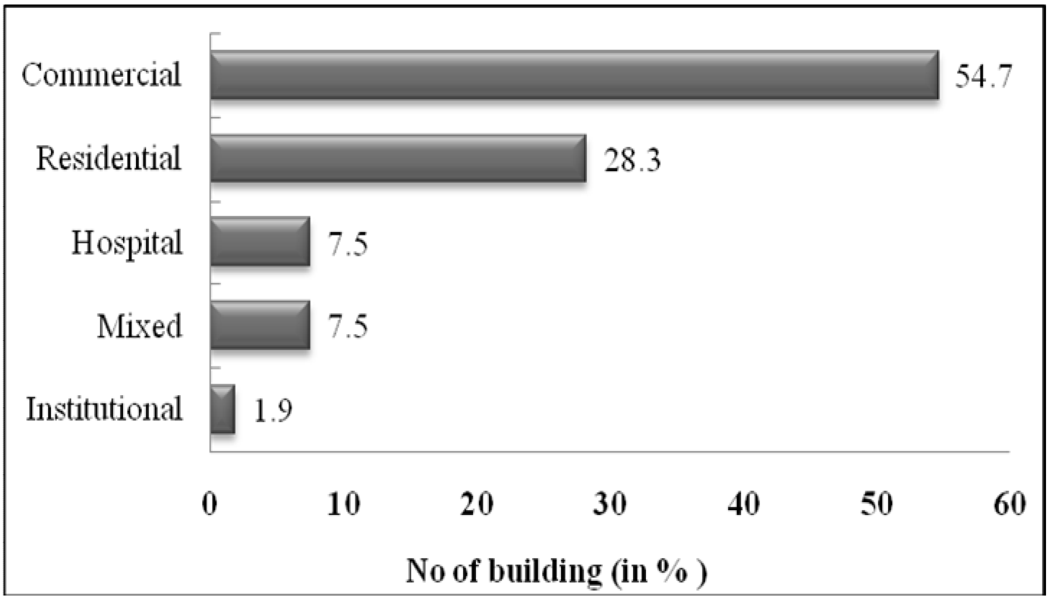
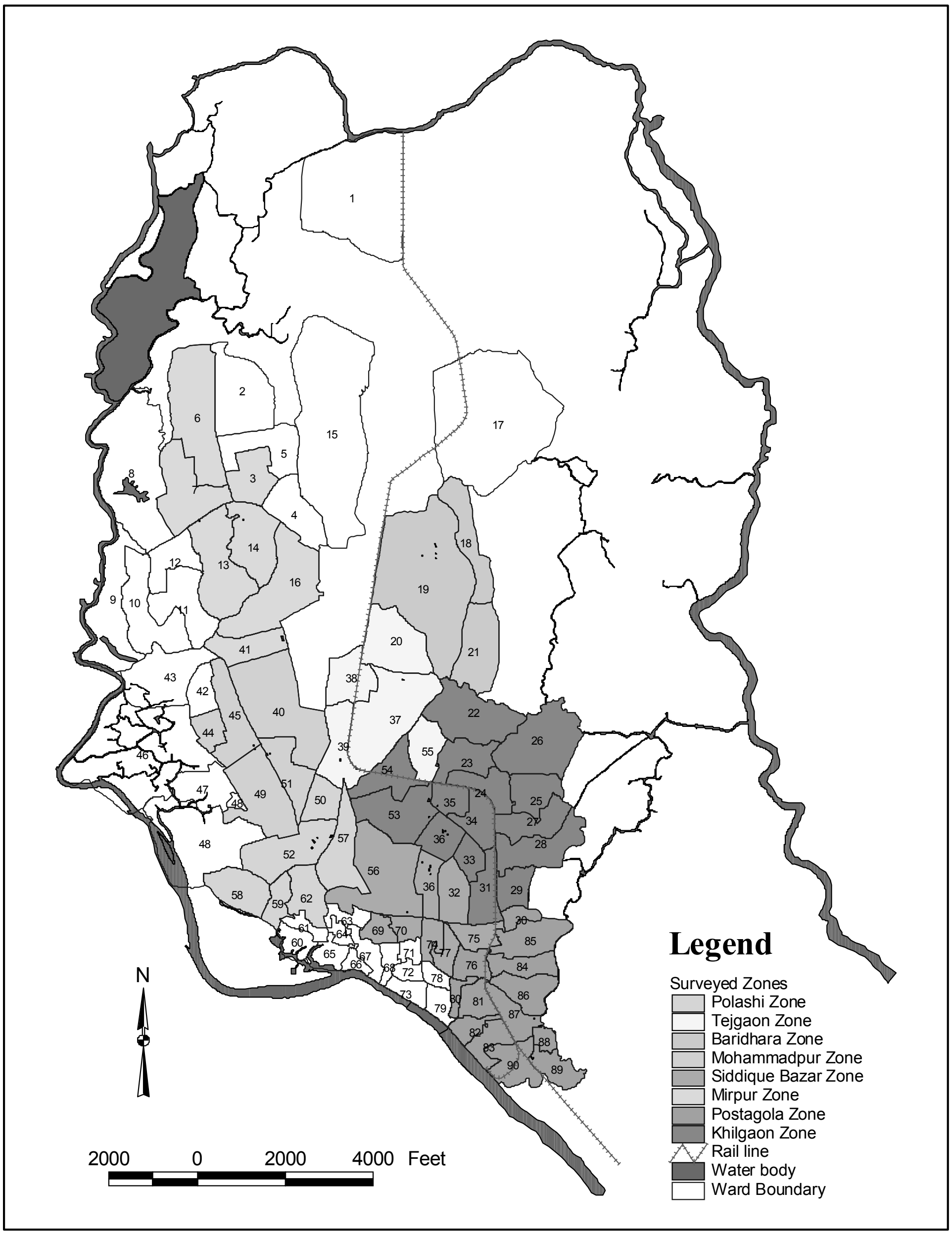



Figure 5: Use type of high rise building

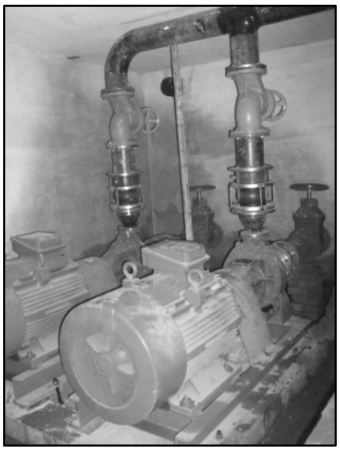



Map 1: Study Area in Dhaka city

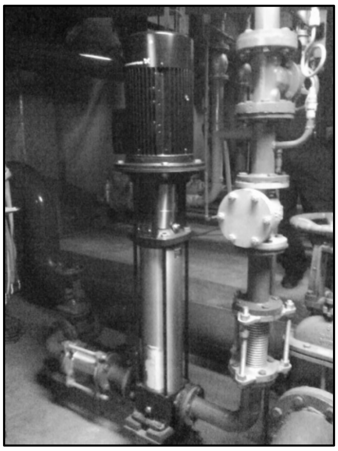
For covering the all details, fire fighting equipments are divided into four parts i.e. *fire fighting and fire protection* system which includes *water-based system* and *dry system*, *precautionary arrangement*, *detection and alarm system* , and *evacuation, rescue and salvation system*. All of these four parts comprise of several components.

### 4.1 Evaluation of fire fighting and protection system

*Fire fighting and fire protection* system consists two sub-system i.e. *water –based system* and *dry system*. *Water-based system* of fire fighting and fire protection include availability of standpipe and hose system, sprinkler system, water supply sources to standpipe, capacity of underground and roof gravity tank, details of fire pump and jockey pump, and availability of *Siamese* connection. Buildings should have underground reservoir of 50000 gallons and overhead reservoir of 25000 gallons (BNBC, 2003). But from the survey has shown that 74% and 96 % of total buildings are undersized for underground and overhead reservoir respectively. From questionnaire survey it has been found that out of 53 buildings, 24 have standpipe connection but not all of them were in work. After a detail investigation about standpipe which includes number, diameters of standpipe, class of standpipe (class I, class II, class III), only 7 buildings reflected a good condition whereas 15 buildings showed very bad condition. Among 24 buildings having standpipe, only 10 buildings have fire pumps and only 5 of these are in good condition i.e. number and pressure of pump are adequate. Only 2 commercial buildings have water sprinkler system. But in BNBC (2003), sprinklers, hose reel and hose pipe are strongly recommended to install in high-rise buildings as safety measure. Photograph 4, 5 and 6 show fire pump, jockey pump and hose reel with standpipe in a commercial building respectively.



Photograph 4: Fire pump in commercial building

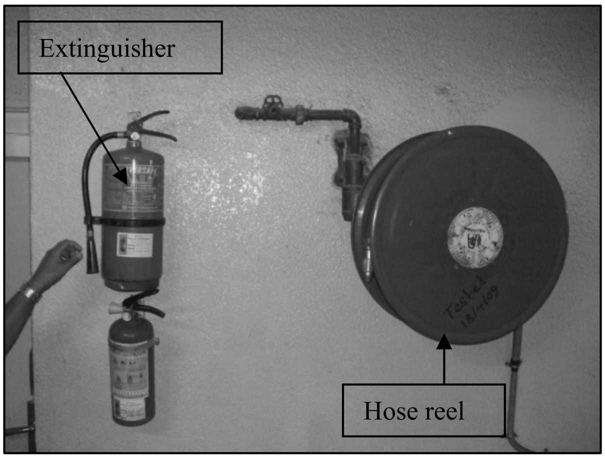


Photograph 5: Jockey pump in commercial building

Photograph 6: Hose reel with stand pipe in commercial building

*Dry system* includes fire lift and portable fire extinguisher in floor and basement. Fire extinguisher system with combination of carbon-dioxide extinguisher, dry chemical extinguisher is available in 53% buildings. However, it has been observed that most of the buildings' fire extinguishers are not in required quantity and they are out of date. As the surveyed buildings are high rise structures, it is mandatory to set up fire extinguisher system to control the fire incidents initially. Most of the buildings have no hose pipe or hose reel system.


Photograph 7: Blocked hose pipe




Photograph 8: Perfect position of hose reel with fire extinguisher

**4.2 Evaluation of precautionary arrangements**

*Precautionary arrangement* is very important for minimizing the loss of lives and properties. It comprises heat and smoke vent, four hours rated door of substation and 2 hours rated wall of substation. From the questionnaire survey it has found that only 10 buildings have 4 hours rated door and 2 hours rated wall of substation. Number of building having smoke and heat vent is only one.

**4.3 Evaluation of fire detection and alarm system**

*Detection and alarm system* includes availability of fire alarm (automatic or manual), smoke and heat detector, Public Address (P.A.) system and existence of emergency light in stair case and corridor. Among the studied buildings none of them have flame detector. On the other hand, it has been observed that 25% buildings and only 4% buildings have smoke detector and heat detector respectively. In addition, 36% buildings have alarm system and among them 30% have public address (PA) system (see Figure 6).

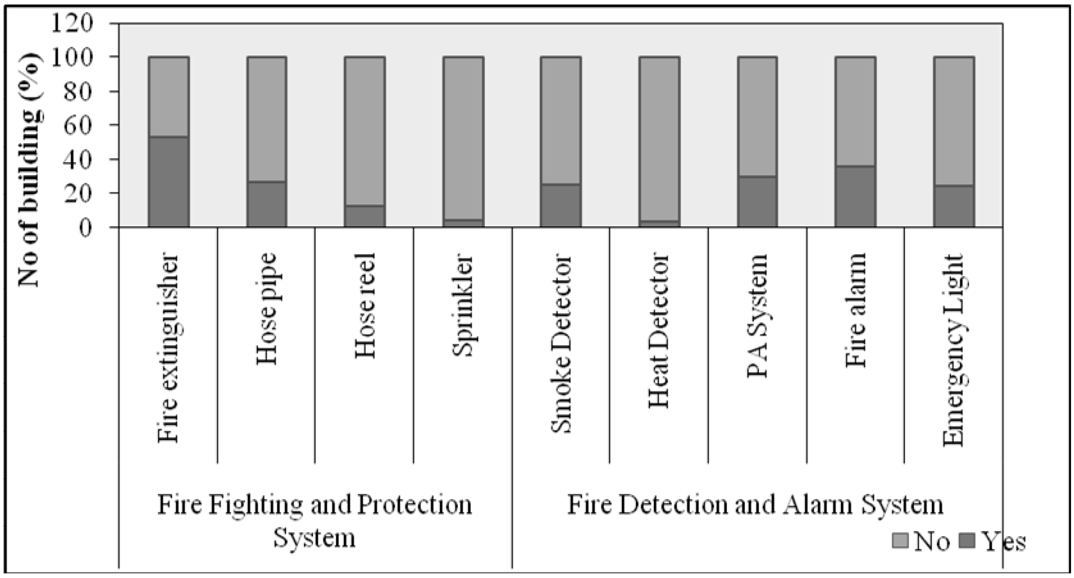
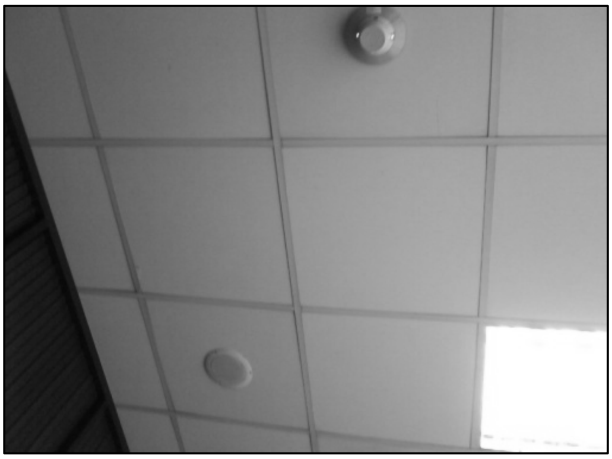



Figure 6: Overall scenario of fire fighting system in Dhaka City

From observation, it is evident that fire fighting detectors and equipments are seldom tested and checked as routine work.



Photograph 9: Fire alarm and fire bell

Photograph 10: Smoke detector

**4.4 Evaluation of evacuation, rescue and salvation system**

*Evacuation, rescue and salvation system* consists of total number of stair and emergency staircase, width of normal and emergency stair, availability of fire refuge area, trained personnel, width of front road, evacuation plan of the inmates of the buildings and practice of fire drill. According to Bangladesh Fire Service and Civil Defense (BFSCD), Minimum width of frontal road should be 30 ft for free moving of fire vehicle. Survey shows that a considerably large number of buildings i.e. 27.5% of surveyed building have inadequate width of approach road (less than 30ft) for fire engines to reach the building (see Figure 7).

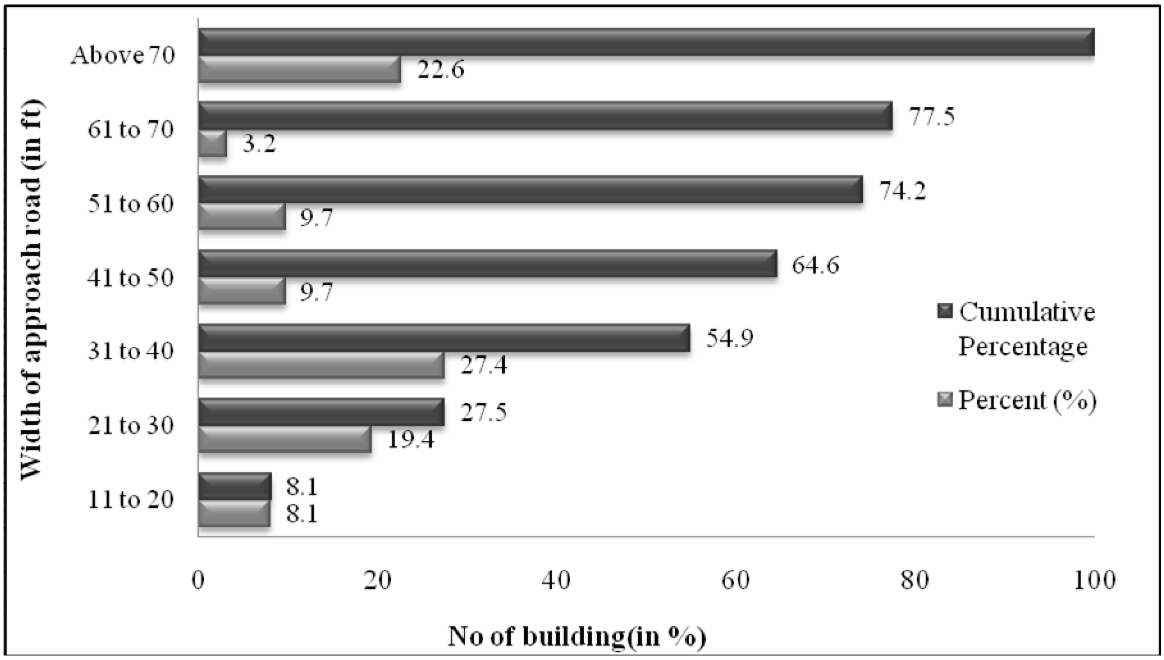



Figure 7: Width of approach road

More than 49% buildings don't have any emergency exit stair. In addition, exit signals for escape route are provided improperly and inadequately which poses a threat to the evacuation. In most of the cases escape routes remain blocked (see Photograph- 11 and 12).


Photograph 11: Narrow emergency stair case in a residential building

Photograph 12: Blocked emergency stair case in a commercial building

Among all the surveyed buildings, only 11 buildings have trained personnel and only 16 buildings which include garments and commercial building perform fire drill regularly. Most surveyed garments workers were trained by Bangladesh Garment Manufacturers and Exporters Association (BGMEA). Usually they provide lectures, taken exam and lastly done evacuation drill in the premises of garments. In the surveyed commercial buildings which have trained personnel got training related to operation of hose reel and fire extinguisher and evacuation drill from Bangladesh Fire Service and Civil Defense (BFSCD). Mainly security guard and few care takers of the building have this training. The respondents were asked about their evacuation plan during the fire incidence but only few people have their evacuation plan. Evacuation plan consists use of fire fighting equipment what they have, escape from the building through emergency exit and taking shelter in ground floor or any available open space adjacent to the building.

## 5. SCORING OF THE SURVEYED BUILDINGS

One of the main purposes of this study was to provide score to the surveyed building based on their existing fire fighting equipments. For providing score, data collected from field survey were compared to the provision of Bangladesh National Building Code (BNBC) and that of Bangladesh Fire Service and Civil Defense (BFSCD). 0-10 scale was selected to provide an initial rank to the different components of fire fighting equipments. Then from case studies and experts opinion, weights were assigned to each of the four parts of firefighting equipment. The process of obtaining the score is given below:

**Total Score (TS)** = weight for water-based system *(acquired number in scale of 0-10) + weight for dry system *(acquired number in scale of 0-10) + weight for precautionary arrangement *(acquired number in scale of 0-10) + weight for detection and alarm system *(acquired number in scale of 0-10) + weight for evacuation, rescue and salvation system *(acquired number in scale of 0-10).

Experts have assigned 12 for water-based system, 8 for dry system, 25 for precautionary arrangement, 30 for detection and alarm system and 25 for evacuation, rescue and alarm system.

For evaluating the condition of Buildings, all buildings are divided into 5 category based on their in-built fire fighting system. These categories are given below,

Table1: Building Condition Based on Total Score

| Building Condition | Total Score(TS) |
|---|---|
| Low | Below 20 |
| Moderately Low | 21-40 |
| Moderate | 41-60 |
| Moderately High | 61-75 |
| High | 75-100 |

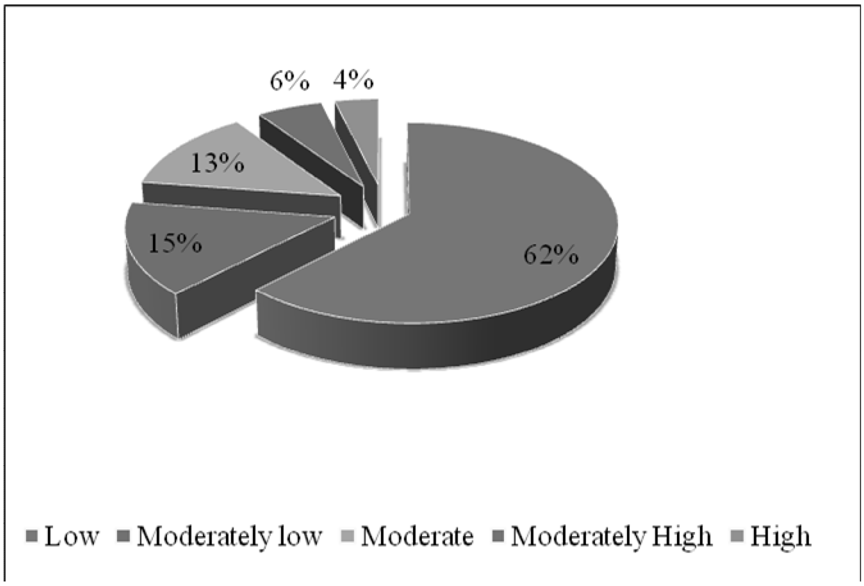



Figure 8: Quantitative diagram of present condition of building at Dhaka city

The pie chart portrays that most of the buildings (62%) are in lack of in-built fire fighting equipments whereas the number of buildings which are highly equipped with in-built fire fighting system are significantly low.

## 6. CONCLUSION

After analyzing a considerable amount of data in Dhaka city, it can be said that the overall condition of buildings very vulnerable to fire fighting. Only little number of buildings shows moderate to good condition. Though this study has not been conducted with a wide range of data, it represents the miserable condition of Dhaka city to fire hazards. For improving the condition, all buildings should follow the provision provided by Bangladesh National

Building Code and Bangladesh Fire Service and Civil Defense during construction of building. To ensure that, authority should be very strict and should take action against those violating the concerned laws. The related building codes of different countries need to be studied thoroughly and adopted according to Bangladesh's context. In addition to law enforcement, to create public awareness, different workshop can be arranged. Electronic and printing media can play an important role for increasing awareness. A pragmatic fire safety plan can be made for all the buildings with the help of the fire department.

## REFERENCES


1. Bangladesh National Building Code (BNBC), 2003
2. Bangladesh Fire Service and Civil Defense (BFSCD)
3. The Daily Star (www.thedaily star.net) accessed on June 2, 2010.
4. The New Age (2004) accessed on June 2, 2010.

# PART-III

# MICROTREMOR H/V TECHNIQUE FOR SITE RESPONSE ANALYSIS

# BANGLADESH NETWORK OFFICE FOR URBAN SAFETY (BNUS), BUET, DHAKA

**Prepared By: Saidur Rahman**

**Mehedi Ahmed Ansary**

## 1.1 INTRODUCTION

In the recent past, Bangladesh has not suffered any damaging large earthquakes, but in the past few hundred years, several large catastrophic earthquakes struck this area. So far, all the major recent earthquakes have occurred away from major cities, and have affected relatively sparsely populated areas. In 1897, an earthquake of magnitude 8.7 caused serious damages to buildings in the northeastern part of India (including Bangladesh) and 1542 people were killed. Recently, Bilham et al. [1] pointed out that there is high possibility that a huge earthquake will occur around the Himalayan region based on the difference between energy accumulation in this region and historical earthquake occurrence. The population increase around this region is at least 50 times than the population of 1897 and city like Dhaka has population exceeding several millions. It is a cause for great concern that the next great earthquake may occur in this region at any time.

The infrequent occurrence of destructive earthquakes does not permit the compilation of enough data to support the estimation of the distribution of damages in the future. To overcome this lacking, different authors proposed the use of alternative sources of excitation, such as, distant earthquakes, small near earthquakes, explosions, aftershocks and microtremors. The use of microtremor, an idea pioneered by Kanai et al. [2] turns into one of the most appealing approaches in the site effects studies, due to its relatively low economic cost, and the possibility of recordings without strict spatial or time restrictions (Rodriguez and Midorikawa [3]). The H/V spectral ratio technique of microtremors gained popularity in the early nineties, after the publication of several papers (Nakamura [4]; Field and Jacob [5]; Lermo and Chávez-García [6]) claiming the ability of this technique to estimate the site response of soft sedimentary deposits satisfactorily. This method is rather attractive in developing countries characterized by a moderate seismicity, where only very limited resources are available for seismic hazard studies. The H/V spectral ratio determined from microtremors has shown a clear peak that is well correlated with the fundamental resonance frequency at “soft” soil sites (Bard [7]; Horike et al. [8]; Field et al. [10]; Lachet and Bard [9]: Lermo and Chávez-García [11]). Comparison of microtremor and earthquake spectral ratios at strong-motion instrument sites across SW British Columbia showed similar fundamental periods and in greater Victoria remarkably similar amplitudes, validating the use of the method for linear earthquake site response Molnar et al. [12].

Ohmachi et al. [13] and Lermo and Chávez-García [6] applied the H/V ratio method to analyze microtremor measurements. Lermo and Chávez-García [11] used it to assess the empirical function of the S-wave, part of an earthquake record, obtained from three cities in

Mexico. Their results clearly indicated that the H/V ratio could provide a robust estimate of frequency and amplitude of the first resonant mode, albeit not of the higher modes. In the meantime, Field and Jacob [5] and Field et al. [10] considered the response of sedimentary layers to ambient seismic noise and claimed that the H/V ratio method was an effective and reliable tool to identify the fundamental resonance frequencies of all layered sedimentary basin. Further evidence was given by Suzuki et al. [14] who used both microtremor and strong-motion data in Hokkaido, Japan, and ascertained that the peak frequency determined by the H/V ratio seemed to correspond with the predominant frequency estimated from the thickness of an alluvial layer. Based on numerical calculations, many other researchers (Lermo and Chávez-García [11], 1994; Lachet and Bard [9]; Dravinski et al. [15] have shown that the H/V ratio method is obviously able to predict fundamental resonant frequency well. Huang et al. [16] found that the ground vulnerability index (Kg) values in the liquefied areas were higher than those in the neighboring areas without liquefaction at 42 points in central Taiwan. This study shows supporting evidence for the first time that the H/V ratios of microtremor can be a good alternative indicator for an area's potential for liquefaction. Site amplification characteristics can be evaluated by one-point two-component surface recordings of earthquake ground motion, in a similar manner as proposed by Nakamura for microtremor Ansary et al [17].

Although it is not possible to prevent such calamities, it is however, possible to mitigate the impacts of this disaster. Specific roles and responsibilities relating to earthquake hazard should be emphasized in our disaster mitigation plan. Bangladesh is a country characterized by a moderate seismicity with almost no resources is available for large scale seismic hazard studies. The objective of this study is to evaluate the site response using H/V spectral ratio of microtremors in terms of predominant frequency and corresponding amplification within Dhaka city area.

**1.2 STUDY AREA:**

Microtremor measurement has been carried out in 132 locations in the Dhaka city (See Figure 1). Figure 2 shows the Google map of the study area.

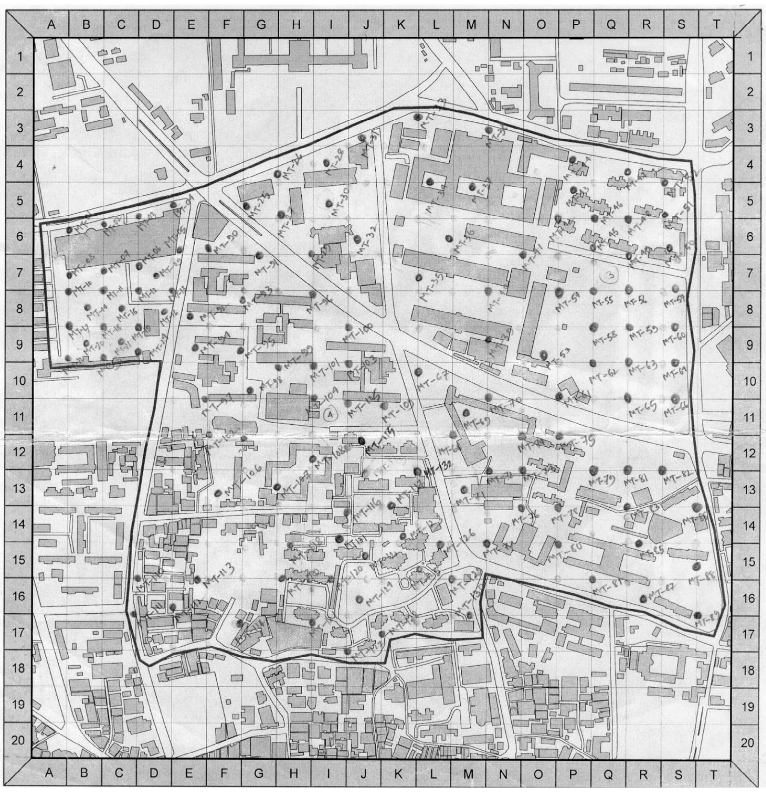


**Figure 1: GIS map of 132 Microtremor observation points of the study area**


**Figure 2: Google Map of study area**

### 1.3 MICROTREMOR OBSERVATION

There are several small amplitude vibrations that appear in a nearby surface ground. The frequency range of such vibrations is from 0.1 to 10 s. Vibrations that do not last long, less than 1 s, are currently called microtremors or Kanai's microtremors Seo [18] and those that last longer are called microseisms Taga [19]. Microtremors are probably caused by vehicular traffic, heavy machinery, household appliances and other sources that are not related to earthquakes; however, there are small waves propagated from artificial sources associated to daily life. Kanai et al. [2] originally introduced a theoretical interpretation and practical engineering application of microtremors that is especially convenient, easy and cheap for evaluating surface ground frequency properties.

|  |  |  |
|---|---|---|
| Group photo of team work | Microtremor Data Recording at Residential Hall of BUET (3:00 AM) | Microtremor Data Recording at West Polasi of BUET (4:00 PM) |

**Figure 3: Microtremor data recording for site response analysis**

This has many engineering applications, for example, soil type classification of soil layers, prediction of ground shear wave velocity and the evaluation of the predominant periods of soil layers during earthquake tremors. Microtremor measurements within the Dhaka city have been performed in the winter of 2011. After being integrated and amplified, the signal proportional to displacement have been recorded directly on a lap-top computer (See Figure 3). Microtremors have been recorded at 132 sites with a 40m x 40m dimension grid. Each observation time was 120 s and the signal was sampled every 0.01 seconds. In addition, Most of the measurements were carried out from 12:00 PM to 5:30 AM in order to minimize artificial noises due to traffic and human activities. Several windows were selected from these records, for the analysis. The criterion for selecting time histories was visual (See Figure 4). Time histories that consisted noise were excluded from calculation. As microtremors spectra could be more or less influenced by close sources, Fourier spectra have been calculated at each point for one or several parts of the vertical and the horizontal components records where there was no artificial disturbance. Consequently, special care has been taken to avoid disturbances caused by machinery, traffic or by pedestrians passing near the instrument during microtremor measurements, because such kinds of noise are transient and do not show the stationary characteristics of ground vibrations Yamanaka et al [20]. Therefore this part of the record has been removed from the analysis or in the worst cases the measurement has repeated at the same point in more favorable conditions. In order to check the stationarity of microtremor measurements, continuous measurements have been made for 24 hours at thirteen sites with different soil conditions (See Figure 6). These sites are located in the West Polasi of BUET campus.

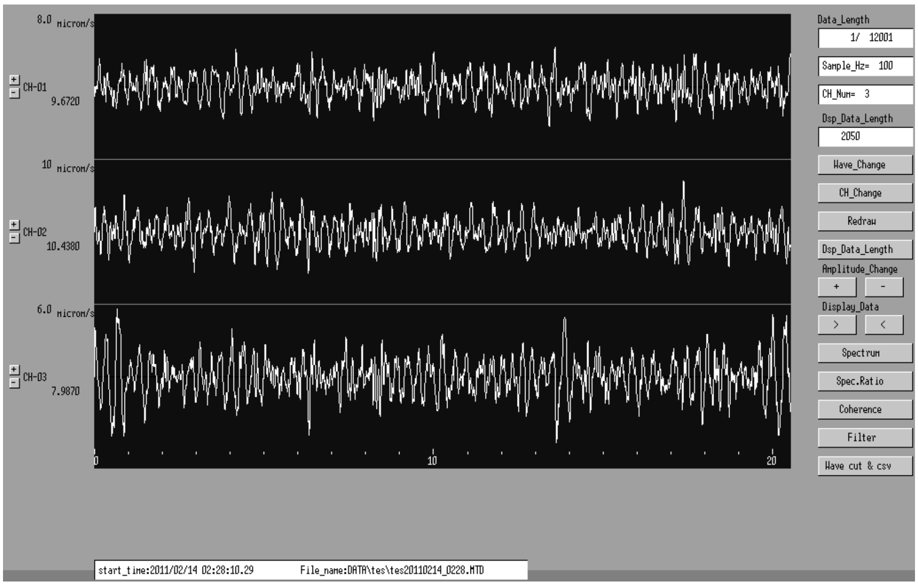



**Figure 4: Field Time History Data recording from 1 to 20.48seconds using microtremor at MT 01 observation point (During 02:28 AM on the 14th February, 2011)**

## 1.4 OUTLINE OF METHODOLOGY

The amplitude ratio (H/V) of horizontal to vertical spectra has become popular to determine predominant period and amplification of a site. It is well known that, degree of damage during earthquakes strongly depends on dynamic characteristics of buildings as well as amplification of seismic waves. Among the other time consuming and expensive approaches, microtremor is the easiest and cheapest way to understand the dynamic characteristics of soil as well as structural element. In a short period of time it provides several information including natural frequency, amplification and vibration characteristics of soil and structure at different frequencies.

Following steps have been followed in this study:

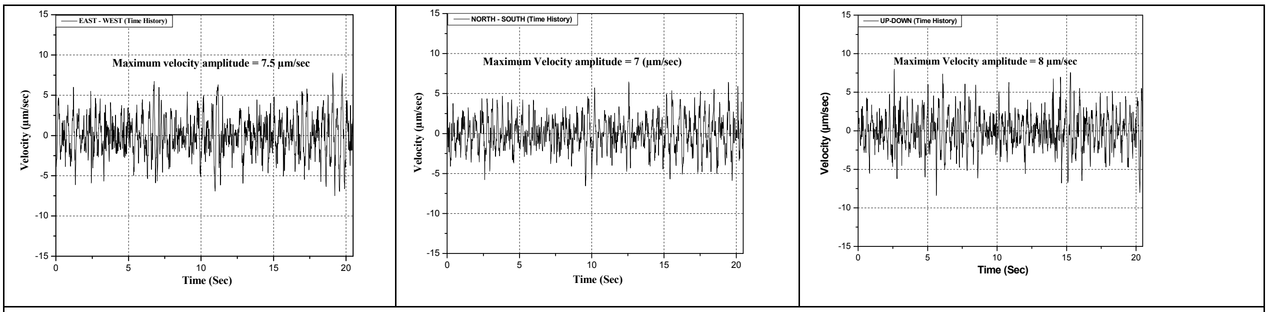
**A. Microtremor Analysis:**

Microtremors data recording have been carried out in a selected location of Dhaka city. Each record comprises of three components, viz., EW, NS and UD. For spectral analysis three noise-free portions of 20.48s of the recordings have been taken at 100 Hz instrumental sampling (See Figure 5). For the checking of stability of soil response using microtremor at each point of sensor location microtremor data recording have been executed at different time of the day (See Figure 6).

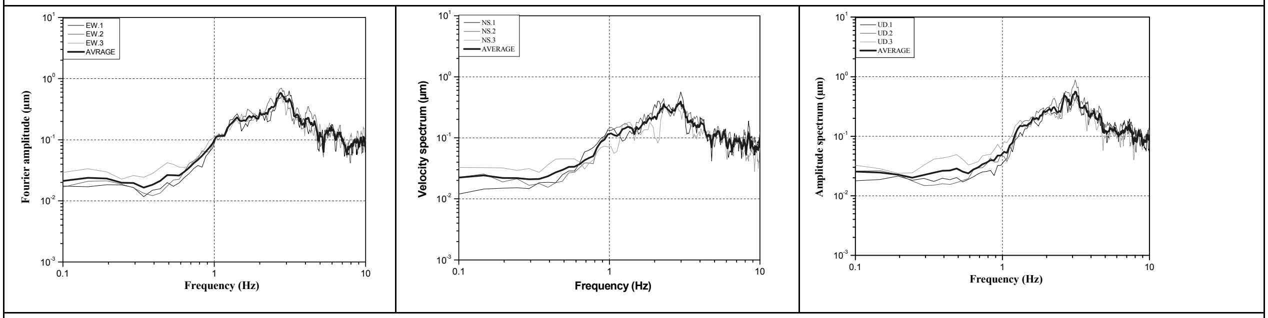
Time domain data is not suitable for the clear identification of soil response due to ambient noise. This is why First Fourier Transformation (FFT) have been applied on the time domain records. After smoothing the corresponding spectra, spectral ratio (H/V) technique have been applied to derive transfer functions. The applied sequences are given:

1. **FFT Transformation**: At first, Fourier spectra of the two horizontal directions (East-West and North-South) and the vertical component (Up-Down) have been calculated.
2. **Smoothing of the Spectra**: After Fast Fourier transformation (FFT), the combined horizontal and vertical spectra have been digitally filtered applying a logarithmic window) with a suitable bandwidth coefficient. This filtering technique has been applied to reduce the distortion of peak amplitudes.
3. **Calculation of the Soil Response functions**: The smoothed combined horizontal spectrum have been divided with the smoothed vertical component to plot Horizontal to vertical spectral ratio (H/V) which provided the desired predominant frequency and corresponding amplification factor of the investigated portions (20.48 s) of records.
4. **Estimation of Predominant period and Amplification**: After calculating three sets of the H/V ratios at selected grid, they have been normalized to obtain a relatively non-biased site specific H/V ratio. Then, Normalized H/V ratios at different time of the day have been plotted in Logarithmic window. From this normalized H/V ratio the predominant frequency and corresponding amplification factor of this site have been taken.

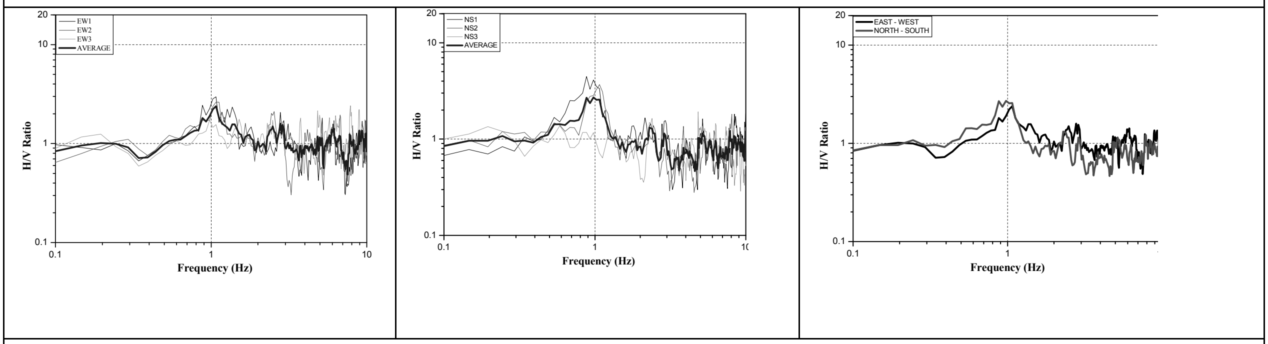
The analysis result of predominant frequency and Horizontal to Vertical spectral ratio (H/V) along East-West and North – South direction has been shown in Table 1.




**Velocity Time History along three directions (MT_113)**

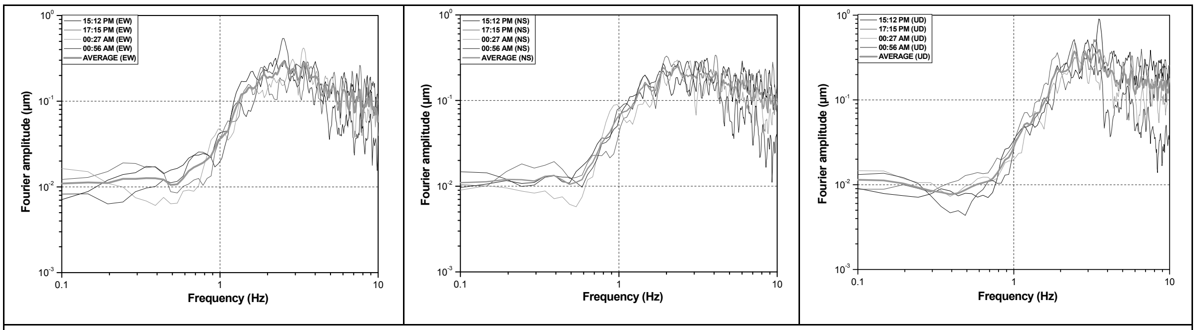



**Three segments of Fourier amplitude and their average value along three directions (East-West, North - South and Up - Down) (MT_113)**




**H/V Spectral Ratio (MT_113)**

**Figure 5: Processed graphs of MT 113 observation point**




**Fourier amplitude at four different times along three directions (East-West, North - South and Up - Down) (MT_16)**

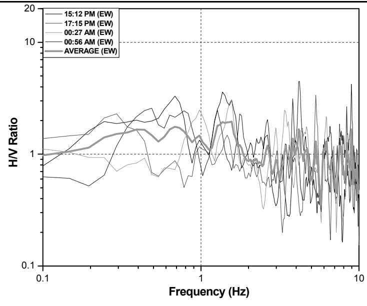
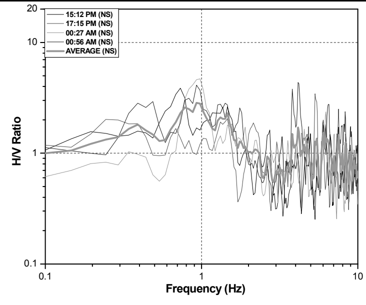
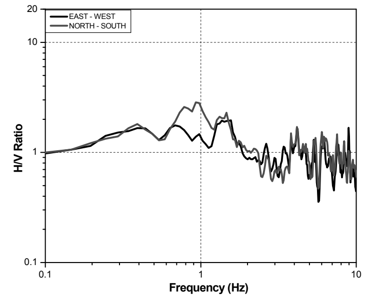
| | | |
|---|---|---|
|  |  |  |
| **H/V Ratio at different time along East-West direction (MT_16)** | **H/V Ratio at different time along North – South direction (MT_16)** | **H/V Ratio along East-West and North – South (MT_16)** |

**Figure 6: Stability check of soil response at different time at MT 16 observation point**

**Table 1: Microtremor Data Analysis**

| ID | Predominant Frequency (FF) | | H/V Ratio | | ID | Predominant Frequency (FF) | | H/V Ratio | |
|---|---|---|---|---|---|---|---|---|---|
| | EW | NS | EW | NS | | EW | NS | EW | NS |
| 1 | 1.50 | 1.6 | 2.30 | 2.25 | 2 | 1.00 | 0.80 | 2.25 | 2.50 |
| 3 | 0.98 | 0.97 | 3.00 | 2.70 | 4 | 0.70 | 0.65 | 2.70 | 2.30 |
| 5 | 0.75 | 0.80 | 6.50 | 2.00 | 6 | 0.90 | 0.90 | 3.00 | 2.00 |
| 7 | 1.35 | 1.35 | 2.00 | 2.00 | 8 | 1.30 | 1.25 | 3.50 | 2.50 |
| 9 | 1.30 | 1.20 | 1.90 | 1.80 | 10 | 0.55 | 0.50 | 1.70 | 1.40 |
| 11 | 0.70 | 0.85 | 2.50 | 1.90 | 12 | 0.80 | 0.90 | 2.45 | 2.40 |
| 13 | 0.70 | 0.50 | 2.20 | 1.85 | 14 | 0.45 | 0.43 | 5.00 | 2.10 |
| 15 | 1.02 | 1.15 | 3.00 | 2.05 | 16 | 0.98 | 1.45 | 2.50 | 1.80 |
| 17 | 0.35 | 0.40 | 1.80 | 1.70 | 18 | 0.90 | 0.95 | 3.00 | 2.75 |
| 19 | 0.98 | 0.85 | 2.20 | 1.95 | 20 | 0.65 | 0.60 | 2.00 | 1.75 |
| 21 | 0.70 | 1.35 | 4.00 | 3.00 | 22 | 0.70 | 1.00 | 2.50 | 2.00 |
| 23 | 1.01 | 0.98 | 2.00 | 2.30 | 24 | 0.80 | 0.90 | 3.00 | 2.00 |
| 25 | 1.35 | 0.90 | 3.50 | 2.50 | 26 | 1.45 | 1.40 | 3.50 | 3.00 |
| 27 | 2.30 | 2.40 | 1.90 | 1.90 | 28 | 2.50 | 2.50 | 2.00 | 1.90 |
| 29 | 1.40 | 0.80 | 4.00 | 2.50 | 30 | 1.50 | 1.50 | 2.50 | 2.40 |
| 31 | 0.30 | 0.30 | 1.00 | 1.20 | 32 | 4.00 | 5.00 | 1.90 | 2.50 |
| 33 | 1.80 | 1.80 | 2.30 | 1.90 | 34 | 1.30 | 1.25 | 3.00 | 1.25 |
| 35 | 0.50 | 0.40 | 2.00 | 4.50 | 36 | 0.35 | 0.36 | 4.50 | 3.20 |

| ID | Predominant Frequency (FF) | | H/V Ratio | | ID | Predominant Frequency (FF) | | H/V Ratio | |
|---|---|---|---|---|---|---|---|---|---|
| | EW | NS | EW | NS | | EW | NS | EW | NS |
| 37 | 0.35 | 0.70 | 3.00 | 2.00 | 38 | 1.35 | 1.35 | 2.20 | 2.20 |
| 39 | 1.35 | 1.32 | 6.00 | 3.00 | 40 | 1.25 | 0.98 | 3.00 | 1.50 |
| 41 | 0.65 | 0.70 | 1.65 | 2.20 | 42 | 0.35 | 0.35 | 2.05 | 2.50 |
| 43 | 1.35 | 1.55 | 2.90 | 2.80 | 44 | 1.40 | 1.45 | 2.50 | 2.03 |
| 45 | 0.98 | 1.35 | 2.30 | 2.25 | 46 | 1.30 | 1.35 | 2.20 | 1.95 |
| 47 | 0.75 | 0.70 | 1.70 | 1.12 | 48 | 1.30 | 0.80 | 3.00 | 2.80 |
| 49 | 1.30 | 1.50 | 2.25 | 3.00 | 50 | 1.40 | 1.36 | 1.90 | 1.85 |
| 51 | 1.35 | 0.70 | 2.24 | 2.20 | 52 | 1.20 | 0.50 | 2.00 | 2.50 |
| 53 | 1.30 | 0.90 | 3.50 | 3.00 | 54 | 0.80 | 1.50 | 2.20 | 2.10 |
| 55 | 3.00 | 3.00 | 2.00 | 2.05 | 56 | 0.50 | 0.40 | 2.50 | 2.20 |
| 57 | 0.50 | 0.50 | 1.25 | 0.90 | 58 | 1.70 | 1.70 | 1.80 | 2.00 |
| 59 | 1.35 | 1.50 | 3.50 | 1.50 | 60 | 1.35 | 1.38 | 4.0 | 2.5 |
| 61 | 0.98 | 0.90 | 1.70 | 1.60 | 62 | 0.45 | 0.40 | 8.00 | 4.50 |
| 63 | 1.35 | 1.32 | 4.20 | 2.00 | 64 | 1.40 | 1.45 | 2.40 | 2.38 |
| 65 | 1.30 | 1.35 | 1.80 | 1.75 | 66 | 1.55 | 1.50 | 2.05 | 1.90 |
| 67 | 2.50 | 2.45 | 1.50 | 2.00 | 68 | 2.05 | 2.08 | 1.30 | 1.25 |
| 69 | 2.00 | 3.00 | 1.50 | 1.30 | 70 | 5.00 | 5.10 | 1.85 | 1.95 |
| 71 | 1.50 | 0.75 | 1.95 | 2.70 | 72 | 1.35 | 1.35 | 2.50 | 2.45 |
| 73 | 2.90 | 3.00 | 1.80 | 1.75 | 74 | 1.35 | 1.40 | 1.50 | 2.00 |
| 75 | 5.00 | 5.00 | 1.70 | 1.60 | 76 | 4.50 | 4.00 | 1.70 | 1.50 |
| 77 | 2.40 | 2.60 | 1.50 | 1.60 | 78 | 0.45 | 0.40 | 1.65 | 1.60 |
| 79 | 0.90 | 0.75 | 2.20 | 2.50 | 80 | 0.40 | 0.40 | 1.50 | 1.45 |
| 81 | 1.03 | 1.02 | 2.20 | 1.75 | 82 | 1.30 | 3.00 | 1.50 | 1.10 |
| 83 | 0.50 | 0.40 | 3.05 | 2.10 | 84 | 0.35 | 0.40 | 5.00 | 3.50 |
| 85 | 0.90 | 1.10 | 2.40 | 2.05 | 86 | 0.35 | 0.37 | 1.85 | 1.15 |
| 87 | 0.80 | 0.77 | 2.30 | 2.25 | 88 | 0.70 | 0.90 | 3.50 | 3.05 |
| 89 | 1.40 | 1.30 | 2.50 | 2.00 | 90 | 1.35 | 0.50 | 1.70 | 1.90 |
| 91 | 1.80 | 1.90 | 1.60 | 1.55 | 92 | 0.70 | 0.85 | 2.30 | 3.05 |
| 93 | 0.70 | 0.80 | 2.70 | 2.10 | 94 | 2.50 | 4.50 | 1.40 | 2.00 |

| ID | Predominant Frequency (FF) | | H/V Ratio | | ID | Predominant Frequency (FF) | | H/V Ratio | |
|---|---|---|---|---|---|---|---|---|---|
| | EW | NS | EW | NS | | EW | NS | EW | NS |
| 95 | 1.75 | 1.80 | 2.00 | 2.50 | 96 | 4.50 | 4.00 | 2.05 | 2.40 |
| 97 | 4.10 | 4.05 | 1.70 | 2.50 | 98 | 1.40 | 1.25 | 2.70 | 2.05 |
| 99 | 0.70 | 0.70 | 2.00 | 2.10 | 100 | 7.00 | 7.10 | 1.50 | 1.70 |
| 101 | 0.85 | 0.90 | 3.50 | 3.40 | 102 | 1.40 | 1.15 | 2.50 | 2.45 |
| 103 | 0.50 | 0.50 | 5.50 | 4.50 | 104 | 2.50 | 2.70 | 1.50 | 1.70 |
| 105 | 0.50 | 0.30 | 2.10 | 1.03 | 106 | 1.40 | 1.45 | 2.20 | 2.30 |
| 107 | 1.35 | 1.40 | 2.25 | 2.30 | 108 | 2.50 | 2.40 | 1.00 | 1.05 |
| 109 | 0.40 | 0.50 | 6.00 | 3.50 | 110 | 1.40 | 1.50 | 2.50 | 2.45 |
| 111 | 1.30 | 0.85 | 4.50 | 2.75 | 112 | 1.35 | 1.00 | 3.50 | 2.50 |
| 113 | 1.10 | 1.00 | 2.05 | 2.15 | 114 | 1.25 | 1.10 | 2.50 | 2.00 |
| 115 | 1.40 | 0.85 | 3.10 | 2.40 | 116 | 1.20 | 1.10 | 2.10 | 1.50 |
| 117 | 5.50 | 5.50 | 1.90 | 1.70 | 118 | 1.40 | 1.30 | 2.95 | 2.10 |
| 119 | 1.30 | 0.95 | 2.85 | 2.10 | 120 | 1.50 | 0.50 | 3.50 | 2.50 |
| 121 | 1.25 | 1.35 | 4.00 | 2.05 | 122 | 1.30 | 1.15 | 2.50 | 2.00 |
| 123 | 2.50 | 3.00 | 2.15 | 1.55 | 124 | 4.00 | 4.20 | 1.40 | 1.50 |
| 125 | 4.50 | 4.45 | 2.20 | 3.00 | 126 | 2.50 | 2.45 | 1.50 | 1.45 |
| 127 | 6.00 | 6.50 | 2.10 | 2.05 | 128 | 1.05 | 2.50 | 1.60 | 1.50 |
| 129 | 1.10 | 3.15 | 1.50 | 1.95 | 130 | 1.40 | 1.10 | 2.05 | 1.75 |
| 131 | 3.00 | 3.05 | 1.75 | 2.00 | 132 | 1.25 | 1.10 | 2.60 | 2.15 |

**CONCLUSIONS:**

The results show that the ranges of predominant frequency ($f_o$) in Bangladesh University of Engineering and Technology (BUET) area are between 0.30 and 6.5 Hz. The maximum and the minimum Predominant frequency have been found in MT 31 (East – West) and MT 127 (North - South). In addition to this, Horizontal to Vertical spectral Ratio (H/V) ranges between 1.0 and 6.5. The Maximum and the minimum H/V Ratio have been found in MT MT 05 (East - West) and MT 108 (East - West). In some locations of the observation point the H/V ratio obtained was very flat. In other locations the result was very clear predominant peaks. For the stability analysis of microtremor thirteen selected points show that H/V ratios are very stable. In general, the long period or low frequency zone corresponds to the soft soil zone, with shorter period or high frequency in the hard and middle soil zones. In some places, long periods or low frequency have been detected in the hard soil zone, this being due to local artificial deposits caused by compacting the soil. For details investigation SPT borelogs and soil model are required to compare microtremor result.

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BANGLADESH NETWORK
OFFICE FOR URBAN SAFETY

# PART-IV

# VULNERABILITY ASSESSMENT OF PUBLIC BUILDINGS IN OLD TOWN

**BANGLADESH NETWORK OFFICE FOR URBAN SAFETY (BNUS), BUET, DHAKA**

**Prepared By: Israt Jahan Sheuly, Sharmin Ara**
**Mehedi Ahmed Ansary**

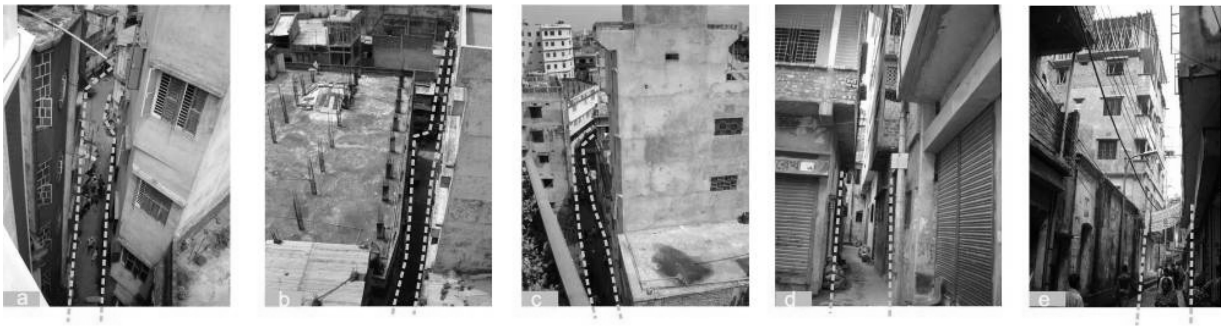
## 1. Introduction

Dhaka City Corporation (DCC) has 90 Wards in its jurisdiction. Old Dhaka is especially characterized by high population density, poor structures and close proximity of buildings, narrow road strips and earthquake vulnerability. To assess the earthquake vulnerability of buildings, Ward no. 68 of Old Dhaka is selected as the study area. It is very difficult and time consuming task to assess the earthquake vulnerability of the existing buildings in any study area. In this study the Rapid Visual Screening (RVS) method (FEMA-154, 2002) was used to assess 1,383 buildings which covered 77 percent of the existing buildings in the study area. Turkish Level-I and Level-II (Sucuoglu and Yazgan, 2003) a more detail analysis of the building was used to assess the structures proposed to be used as evacuation place. The religious place like mosques, community center, educational institutes like schools, colleges and other public places along with the open spaces like park, playground are considered as evacuation sites in this study. Four mosques, two schools and one community center were analyzed in detail using Ferro-scanner which is a reinforcement detection instrument with the help of Department of Civil Engineering, BUET.

## 2. Existing Condition of the Building

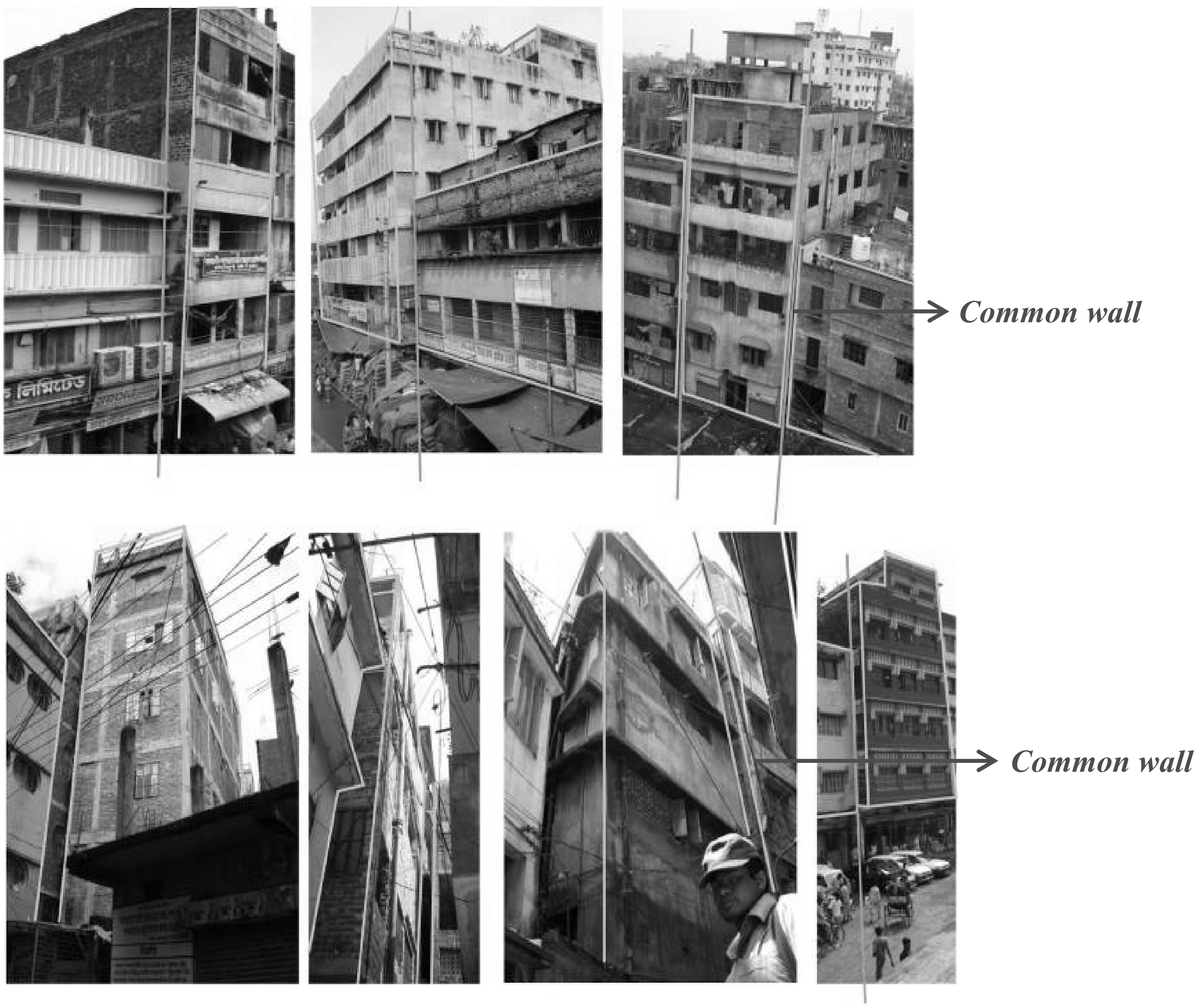
The study area is highly vulnerable to earthquake due to its high density of population and poor structural build up. Photograph 1 to 3 shows the existing condition of the study area.

**Photograph 1:** Unplanned urbanization- contiguous building character




**Photograph 2:**

Poor infrastructure - narrow road width in terms of building height, building density and also population density.




**Photograph 3:**

The adjacency of building without any set back, serious pounding may occur during earthquake

### a) Type of Building Structure

At the first stage of urbanization and city development in our country, the capital city Dhaka flourished from the older part. In the study area 39% buildings were found URM structure which was very significant. 60% of the buildings were $C_3$ structures. The number of $C_2$ structure was very few (only eight) in this area because there were some recently constructed 7-8 storied structures with lift facility and shear wall. These three categories of buildings were found in the site (see Figure 1).

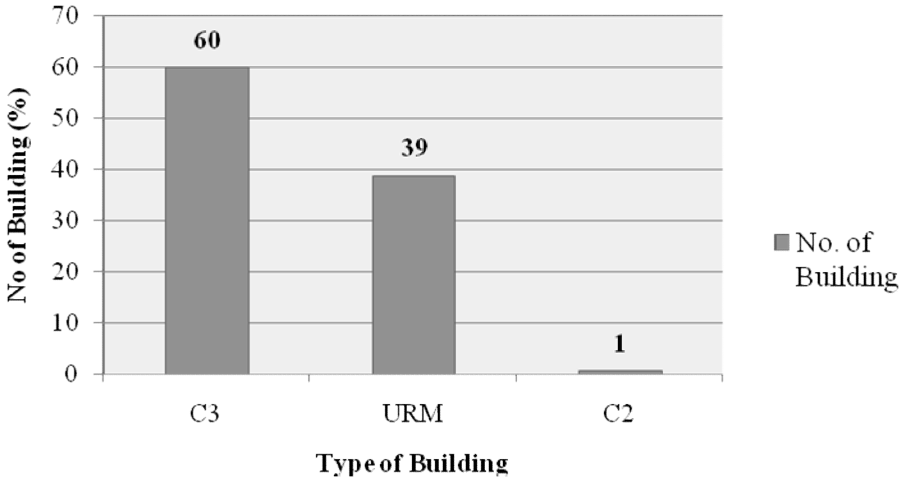



**Figure 1:** Type of building structure in study area

*Source: Field survey, 2009*

**Table 1:** Type of building structures found in the study area

| **Building identifier** | **Photograph** | **Characteristics and performance** |
|---|---|---|
| **$C_3$** (Moment resisting frame) |  | • Usually masonry exposed in exterior.<br>• Concrete columns and beams may be full wall thickness |

| | | |
|---|---|---|
| **$C_2$**<br>(Concrete shear wall buildings) |  | • Concrete shear wall buildings are usually cast in place.<br>• Shear wall thickness ranges from 6-10 inch.<br>• These buildings generally perform better than concrete frame buildings.<br>• Damage commonly observed in taller buildings is caused by vertical discontinuities and irregular configurations. |
| **URM**<br>(Unreinforced masonry buildings) |  | • These buildings often use weak lime mortar to bond the masonry unit together.<br>• Unreinforced masonry usually shows header bricks in the wall surface.<br>• The performance of this type of construction is poor due to lack of anchorage of walls to floors and roof, soft mortar and narrow piers between window openings. |

**b) Comparison of Buildings With Respect to Shape**

The configuration of building is very important for its performance during earthquake. Buildings with irregular plans and elevation suffer much more damage compared to buildings with regular shapes. Figure 2 shows that 72% buildings of the study area have rectangular plan i.e. the shape of the plan are rectangular and 28% buildings have irregularity in their plan. It has also found from field survey that 25 % buildings are vertically irregular and 75% buildings are regular in their elevation shape (see Figure 3). Buildings with irregular shape with respect to both plan and elevation shape tend to be more vulnerable to earthquake (see Map 1 and Map 2).

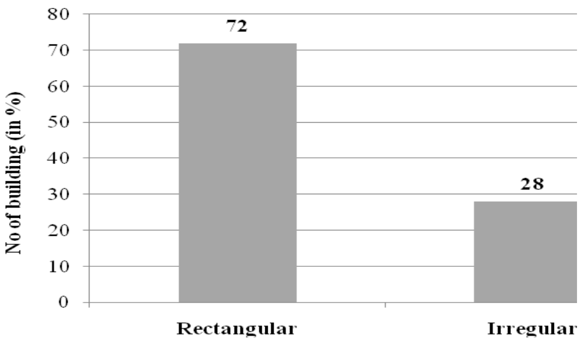



**Figure 2:** Plan irregularities in buildings

*Source: Field survey, 2009*

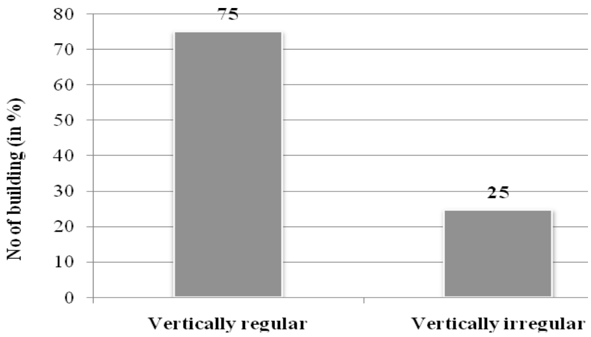
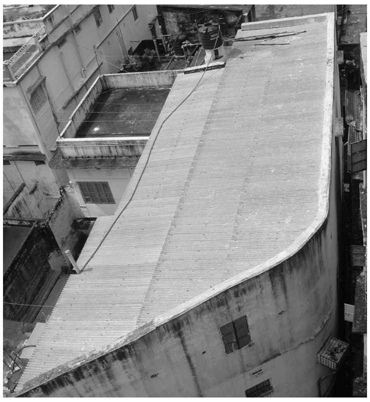


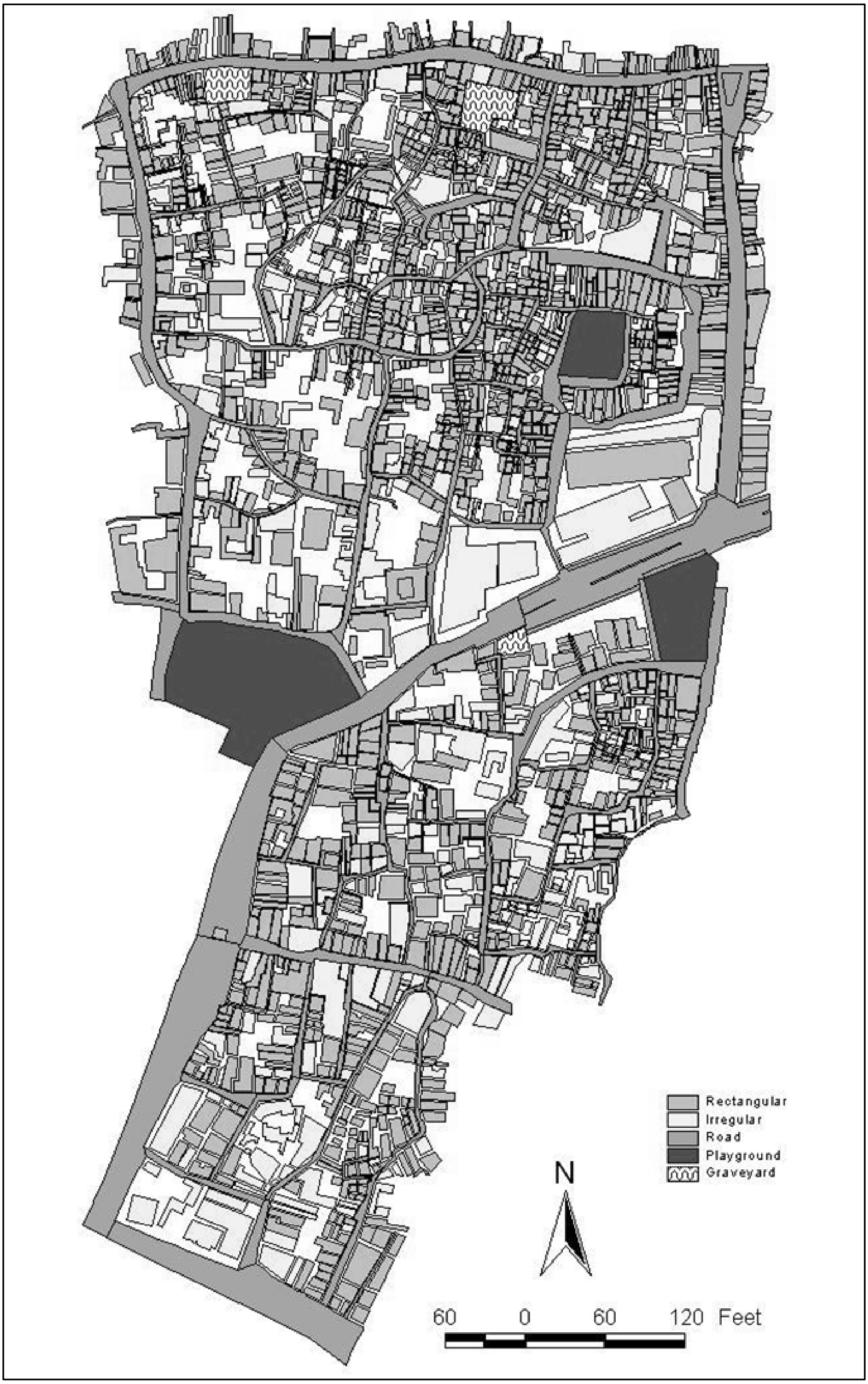

**Figure 3:** Vertical irregularities in buildings

*Source: Field survey, 2009*

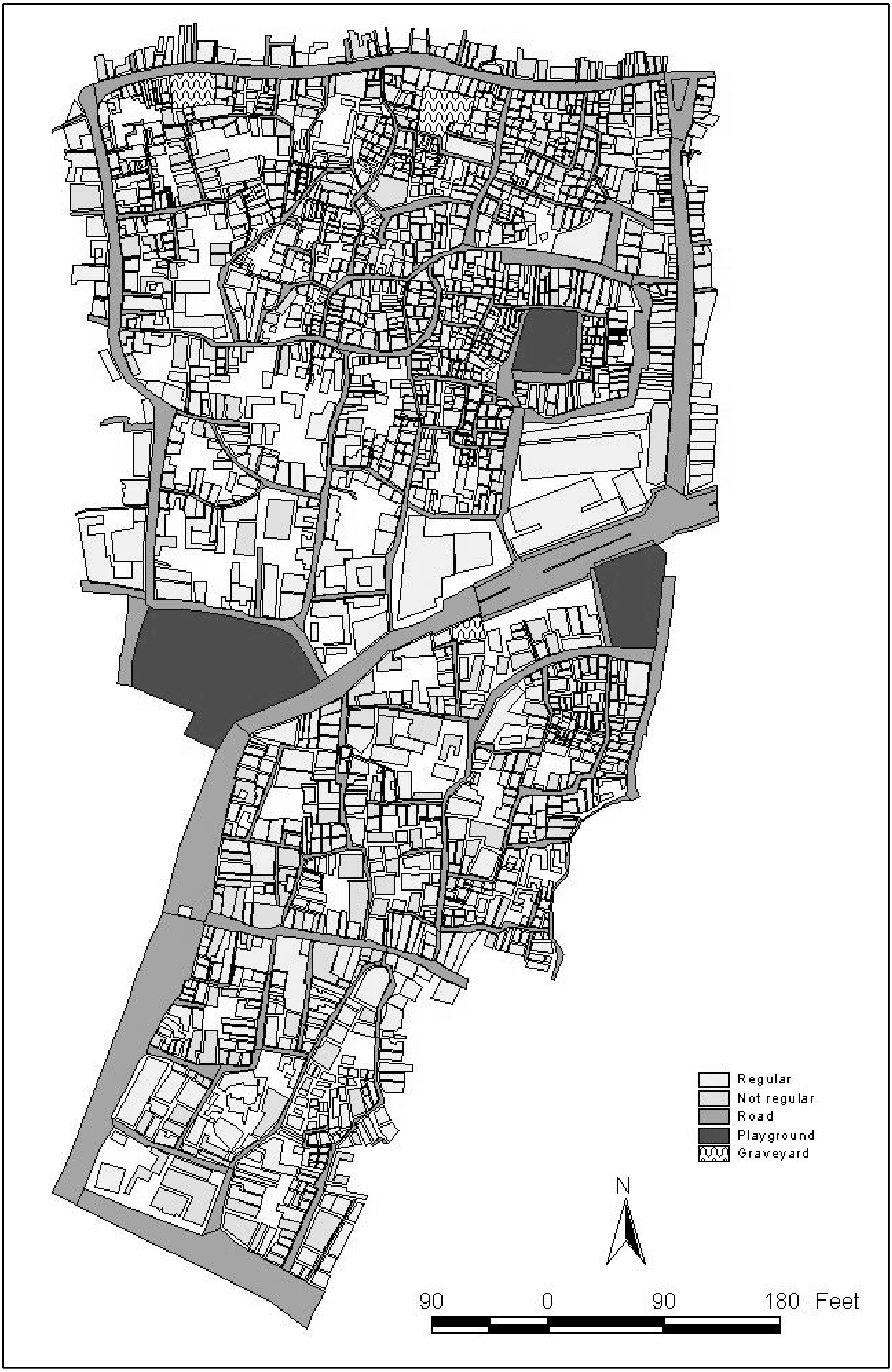


**Photograph 4:** Plan irregularity

**Photograph 5:** Vertical irregularity




**Map 1:** Plan irregularities in building structure
*Source: Field survey, 2009*




**Map 2:** Vertical irregularities in building structure
*Source: Field survey, 2009*

### c) Staircase Condition of the Residing Building

From household survey most of the respondents were found to consider the staircase condition of their residing building to be ‘good’ but other part of the questionnaire shows most of the buildings have very narrow width even less than or equal to 3 feet that is not favorable in terms of evacuation from the building. Table 2 shows the existing width of staircase in the surveyed buildings.

**Table 2:** Staircase width of the surveyed buildings

| **Staircase Width (in feet)** | **Number of buildings** |
|---|---|
| Less than or equal to 3 | 116 |
| 3 – 5 | 46 |
| 5 – 7 | 20 |
| 7 – 9 | 10 |
| 9 – 11 | 3 |
| 11 – 13 | 3 |
| No stair case (Semi-Pucca Building) | 12 |
| **Total** | **210** |

*Source- Field survey, 2009*

Figure 4 shows a comparative study of the perception of the respondents about the condition of the staircase in the building. It is seen from the figure that significant number of people thinks the stair case of their buildings is ‘bad’ due to narrow width.

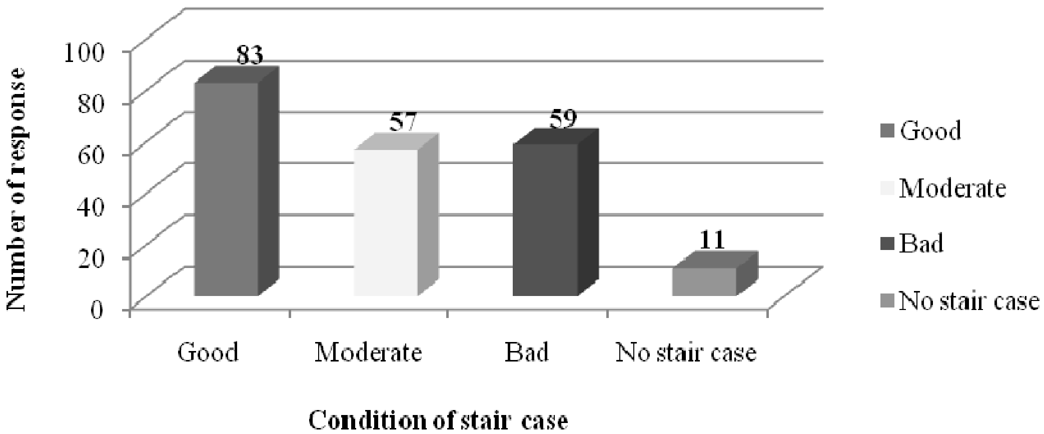



**Figure 4:** Staircase condition of residing building
*Source: Field survey, 2009*

# 3. Vulnerability Assessment of Buildings

To propose an effective earthquake evacuation plan it is needed to assess the vulnerability of existing buildings. For the assessment of existing buildings vulnerability, two different visual screening methods i.e. FEMA-RVS and Turkish Simple Survey (Level-I and Level-II) procedure were applied. For the field survey of 77% of existing buildings the RVS method was used while for detail evaluation of proposed evacuation shelter buildings Turkish Level I and Level II Simple Survey method was used. Besides the building age, height, occupancy and other relevant parameters were also analyzed to have a clear view of the locality. It is already mentioned in Chapter 3 that the two storied buildings are more in number (22%) followed by three storied buildings (19%) in the study area. As Old Dhaka is the ancient part of the Dhaka city, the number of URM structure (39%) is significant here. The construction year of the buildings were also studied to get an overview about the existing condition of buildings in the study area. It helped in vulnerability assessment through focusing on the deteriorated condition of the structures. In the study area 67% buildings age varied from 10 to 30 years and 11% buildings were more than 30 years old which made the area more susceptible to earthquake damage. In the following sections the field survey data findings on earthquake vulnerability of the buildings are analyzed.

### a) Buildings vulnerability assessment by RVS method

The earthquake vulnerability of the buildings is assessed using the Rapid Visual Screening (RVS) Method. Among 1,383 surveyed buildings, 1,375 buildings have been analyzed using Rapid Visual Screening (RVS) method and rest structures are *tin shed* and *semi pucca*. The score below which a structure is assumed to require further investigation is termed as "cut-off" score. It is suggested that buildings having a score less than the "cut-off" score should be investigated by an experienced seismic design professional. If the obtained "final score" is greater than the "cut-off" score the building should perform well in a seismic event. A score of 1.5 and 2 are used in this study as two "cut-off" scores. RVS score '0' is given to the buildings that showed negative results, that means the buildings are in emergency need of detail evaluation by any structural engineer and take further actions like retrofitting, etc. based on the result found.

The Figure 5 shows that 54% buildings fall below the cut off value 2 according to FEMA method and all of them require further detailed analysis on vulnerability to determine the level of actual risk (see Map 5).

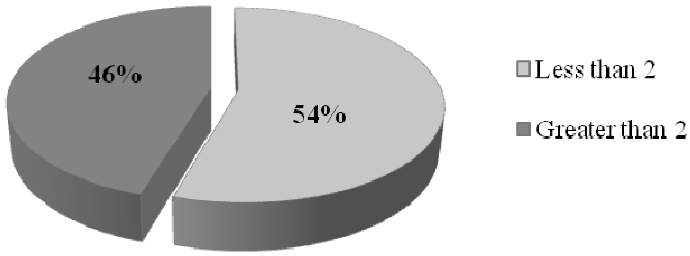



**Figure 5:** Buildings according to RVS cut-off score 2

*Source: Field Survey, 2009*

Considering the economic condition of Bangladesh, 1.5 may be set as the cut-off score. In this case 61% building fall in the safe region (see Figure 6 and Map 6) and they do not require detail structural analysis.

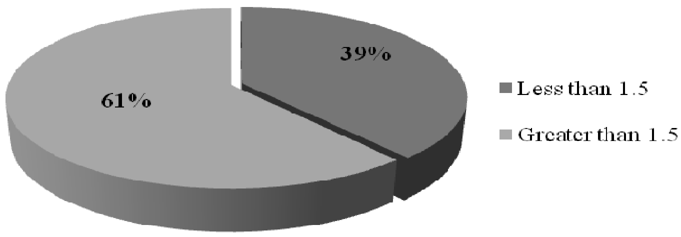



**Figure 6:** Buildings according to RVS cut-off score 1.5

*Source: Field Survey, 2009*

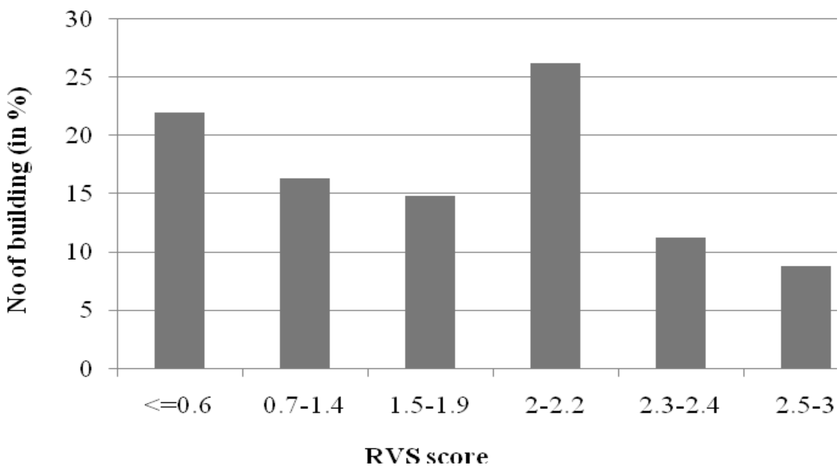
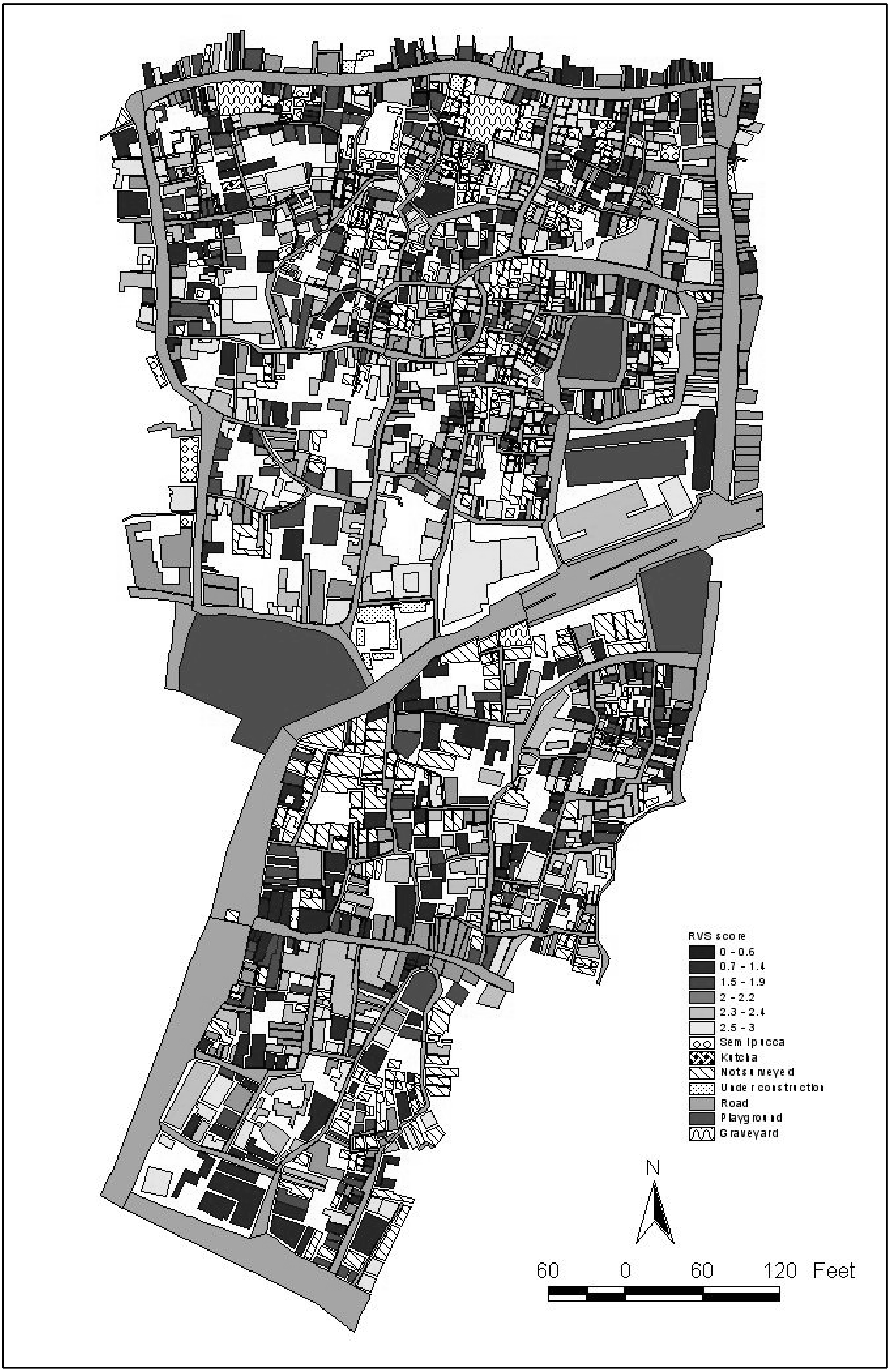


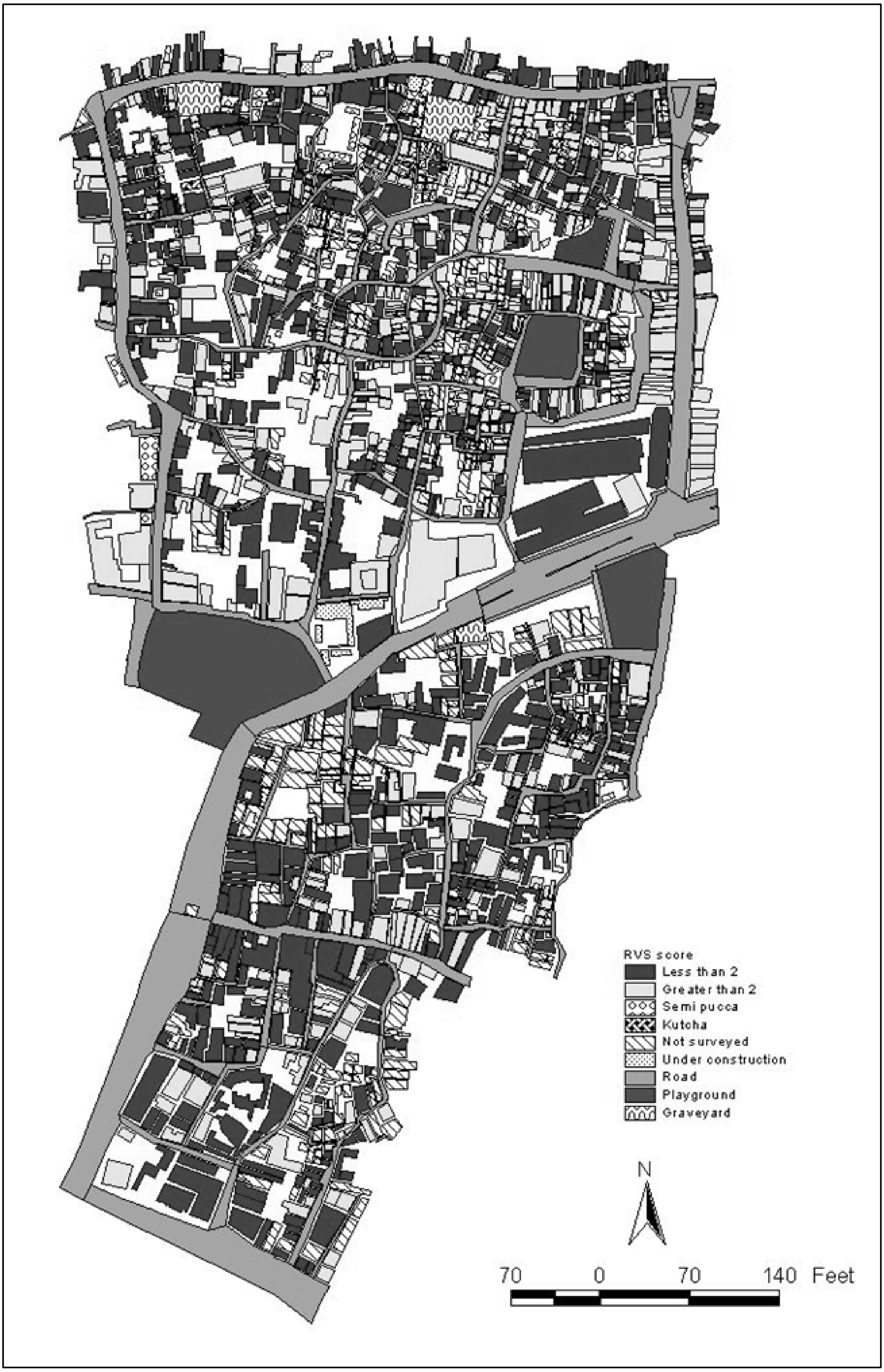

**Figure 7:** Buildings classified on RVS score

*Source: Field Survey, 2009*



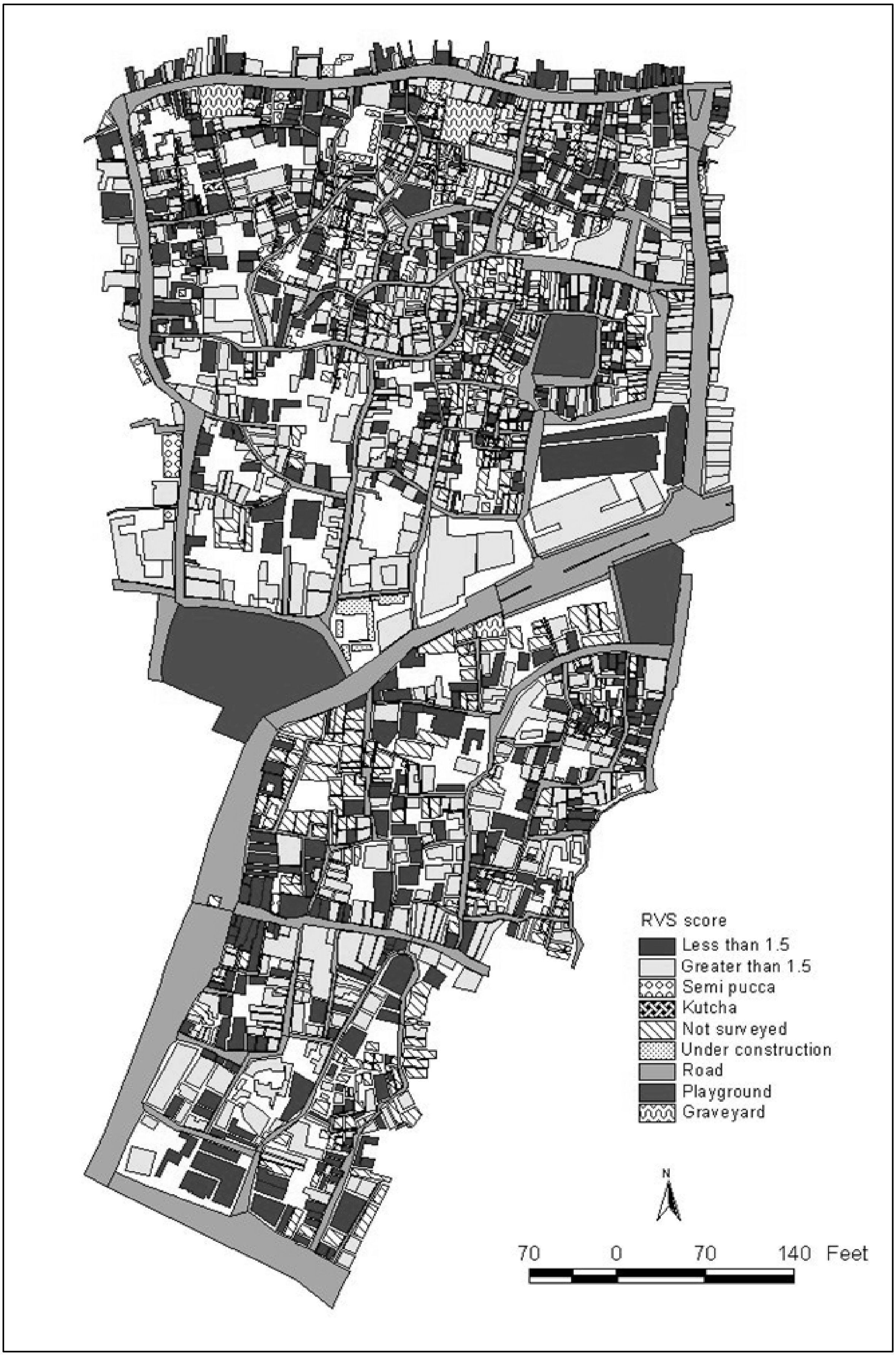

**Map 3:** Building vulnerability assessment through RVS score in the study area

*Source: Field survey, 2009*




**Map 4:** Building vulnerability assessment through RVS cut off score 2

*Source: Field survey, 2009*




**Map 5:** Building vulnerability assessment through RVS cut off score 1.5

*Source: Field survey, 2009*

### b) Assessment of public building to be proposed as evacuation shelter

Many features are considered in selecting evacuation place for the dwellers of this area. Basically the Public buildings are selected on the basis of land use like mosque, school, college, community center, meeting place etc. to be proposed as earthquake evacuation shelters. Because the public places are accessible for all residents and usually it is located in the central places within a targeted community group. The targeted area is highly dense and there is a little number of open spaces. It is hard to reallocate and redevelop land and propose for more open spaces due to high land prices and many other constraints. That's why along with the available open fields the public buildings are considered as shelter place with necessary precautions to keep the building fit during earthquake.

In this study area 25 public buildings were selected as evacuation centers for the residents. A more detail analysis using Turkish Level-I and Level-II method was done for the RCC ($C_3$ and $C_2$) type buildings (21 in numbers in comparison with the RVS method). Turkish method is not applicable for URM buildings (4 public buildings in the area). It has been found from other studies that the Turkish method is more compatible in the circumstances of our country. Besides the existing open spaces the following public buildings were selected to be used as shelter and their vulnerability was assessed.

1. Islampur Jame Mosque
2. ShahjadaMia Jame Mosque
3. Jhubbu Khanam Jame Mosque
4. Jindabahar Jame Mosque
5. Kamranga Jame Mosque
6. Maulana Mosque
7. Mahuttuli Jame Mosque
8. Shahjadi Begum Jame Mosque
9. Malibag (Bangshal) Peyala Mosque
10. Samsabad Boro Mosque
11. Kosaituli Old Jame Mosque
12. Kosaituli Panchayet Committee and School
13. Bangshal RokonUddin Jame Mosque
14. Babubazar Ghat Jame Mosque
15. Anondomoyee Girls' High School
16. Ahmed Bawani School and College
17. Haybotnagar Primary School
18. Samsabad Primary School
19. Jummon Community Center
20. Kona Party Center
21. Mokimbazar school
22. Ahmedabad School/ Hammadia School
23. Mahuttuli Primary School
24. Mosjid-e-Baitul-Mamur
25. Nobab Yousuf Market Mosque

Table 3 shows a comparative view of these two methods. It is clear that most of the structures fall below the cut-off score in the RVS method but in the Turkish Method, most of them fall above the cut-off score that means they don't need any further detail analysis.

**Table 3:** Vulnerability assessment of Public Buildings using RVS and Turkish Method

| Sl no. | Building name | Building Height | RVS Score | Turkish Score | | Building Type | Building Occupancy |
|---|---|---|---|---|---|---|---|
| | | | | Level 1 | Level 2 | | |
| 1 | Islampur Jame Mosque | 7 | **0** | **60** | **52** | C3 | Religious |
| 2 | Shahjada Mia Jame Mosque | 3 | 1.7 | 115 | 118 | C3 | Religious |
| 3 | Jabbu Khanam Jame Mosque | 4 | 1.9 | 90 | 100 | C3 | Religious and Commercial |
| 4 | Jindabahar Jame Mosque | 7 | **1.4** | **50** | **47** | C3 | Religious |
| 5 | Kamranga Jame Mosque | 3 | **0.0** | 110 | 106 | C3 | Religious |
| 6 | Maulana Mosque | 2 | 2.1 | 125 | 130 | C3 | Religious |
| 7 | Mahuttuli Jame Mosque | 2 | 2.2 | 125 | 130 | C3 | Religious |
| 8 | Shahajadi Begum Jame mosque | 2 | 2.2 | 125 | 121 | C3 | Religious |
| 9 | Malibagh (Bangshal) Peyala Mosque | 6 | 2.4 | **65** | **42** | C3 | Religious |
| 10 | Samsabad Boro Mosque | 2 | 2.2 | 120 | 125 | C3 | Religious |
| 11 | Kashaituli old jame mosque | 2 | 2.6 | - | - | URM | Religious |
| 12 | Kashaituli Panchayet Committee and School | 6 | 2.4 | 80 | 77 | C3 | Public use (Assembly) and Educational |
| 13 | Bongshal Rokonuddin Jame Mosque | 4 | 1.9 | 90 | 100 | C3 | Religious |
| 14 | Babubajar Ghat Mosque | 1 | 2.6 | - | - | URM | Religious |
| 15 | Anandomoyee Girls High School | | | | | | |
| | Structure-1 | 3 | 2.2 | 125 | 125 | C3 | Educational |
| | Structure-2 | 3 | 2.2 | 125 | 123 | C3 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Structure-3 | 2 | 2.2 | 115 | 120 | C3 | |
| 16 | Ahmaed Baowani College | 4 | 1.9 | - | - | URM | Educational |
| | Ahmaed Baowani School | 4 | 1.9 | 75 | 85 | C3 | |
| 17 | Haibat Nogor Primary School | 3 | 1.7 | 115 | 113 | C3 | Educational |
| 18 | Samsabad Primary School | 5 | 1.9 | 75 | 72 | C3 | Educational |
| 19 | Jummon Community Center | 3 | 1.7 | 125 | 125 | C3 | Public use (Assembly) |
| 20 | Kona Party Center | 4 | **0.4** | 80 | 85 | C3 | Public use (Assembly) |
| 21 | Mokimbazar school | 5 | 2.4 | Not surveyed | | C3 | Educational |
| 22 | Hammadia School | 3 | 2.2 | Not surveyed | | C3 | Educational |
| 23 | Mahuttuli Primary School | 3 | 2.2 | - | - | URM | Educational |
| 24 | Mosjid-e-Baitul-Mamur | 2 | 2.2 | 120 | 125 | C3 | Religious |
| 25 | Nobab Yousuf Market Mosque | 3 | **0** | Not surveyed | | C3 | Commercial and Religious |

Table 3 shows that the Islampur Jame Mosque, Jindabahar Jame Mosque, Kamranga Jame Mosque, Malibagh (Bangshal) Peyala Mosque, Kona Party Center, Nobab Yousuf Market Mosque requires more detail structural analysis based on the vulnerability assessment in both methods. The proposed shelter buildings especially these six structures should be considered for certain preventive measures like retrofitting to be fit during earthquake and give service as a post earthquake shelter.

## Considerations in assessing the earthquake vulnerability of a building

According to Ansary and Noor, 2006 the general considerations in determining the vulnerability of a building are as follows:

- **Shape of the building:** The vulnerability of building depends on the shape of the building. The shape of the buildings is generally L, T, Y, C, Circular, etc. The irregular shape of the building is not susceptible to earthquake vulnerability. Square, rectangular and circular shape building is effective for earthquake. C, L, T and Y shaped buildings are not effective for earthquake protection.

- **Length-Breadth Ratio:** The length and breadth ratio of a building should not be more than three (3).
- **Extension of the building:** The extension of a building should not be more than 1/6th of the breadth.
- **Complex shape:** The aperture *(space)* between the complex structures is mandatory for earthquake protection.
- **Height of the building:** The height to breadth ratio of the building should not be more than three.
- **Reinforcement Distribution:** Reinforcement distribution at column is very important for earthquake. The intersection point between column and beam should be designed properly. The tie rods distribution from the intersection to 18" should be 4" c/c and 8" c/c from the 18" to remain-end.
- **Column Spacing:** The distance between two columns should not be more than 15 ft.
- **Number of columns:** Number of columns should not be more than eight in one direction.
- **Column size:** Minimum nominal dimension should be 250 mm (10")

## Detail Evaluation of the Public Buildings

Based on the data found from Turkish Level I and Level II survey a more detail analysis of the RCC types public buildings are done to make more effective evacuation proposals. The detail Auto CAD drawing of the public buildings were assessed on vulnerability criterion. Some of the RCC public buildings were assessed using Ferro scanner with the help of the Department of Civil Engineering, BUET to justify the building condition with respect to its coping capacity in future disaster. Dr. Mehedi Ahmed Ansary, Professor, Department of Civil Engineering, BUET has performed the survey by himself with the assistance of BNUS Staff. The findings from these surveys are discussed in the following sections.

### a) Types of Building Structure

Mainly three types of structures- $C_3$, $C_2$ and URM were found in the study ward. But among the public buildings 85% were $C_3$ structures and only 15% was URM structure (see Figure 8) i.e. only four buildings were unreinforced masonry building (URM) in the study area.

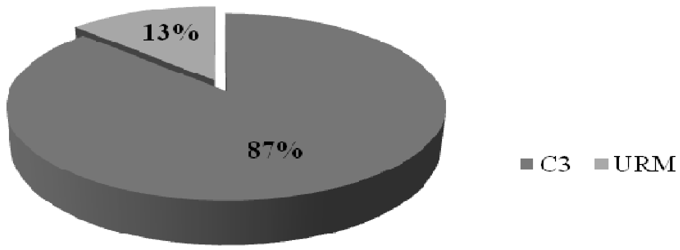



**Figure 8:** Structure type of public building

*Source: Field survey, 2009*

**b) RVS Score for Public building**

The Figure 9 shows that 54% public buildings RVS score is greater than cut off score 2 and 46% buildings have RVS score less than two. These buildings require further detail analysis on vulnerability to determine the level of actual risk. If the cut off score 1.5 most of the public buildings in the study area fall in safe side.

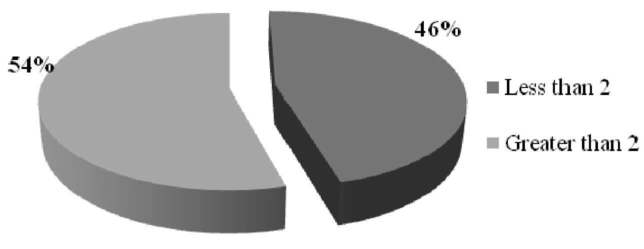



**Figure 9:**

RVS score of the public building (cut off score 2)

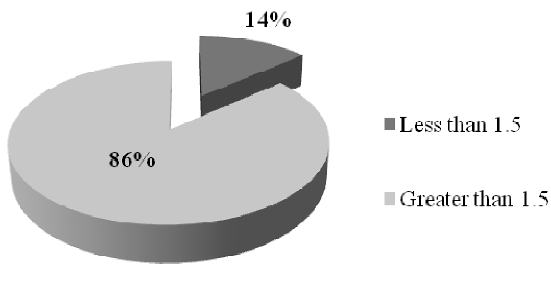



**Figure 10:**

RVS score of the public building (cut off score 1.5)

**c) Vertical Irregularity**

It has found from field survey that 83% public buildings in the study area have regularity in their elevation shape i.e. they are vertically regular and 17% buildings have irregular shape (see Figure 11)

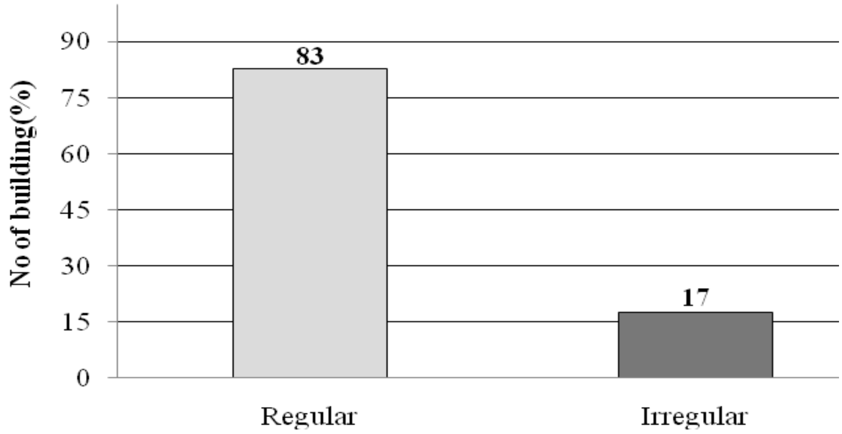



**Figure 11:** Vertical irregularity of public building

*Source: Field survey, 2009*

#### d) Plan Irregularity

Irregularity in building plan is a deviation from a rectangular plan. Such deviation from plan irregularity leads to irregularities in stiffness and strength distributions, which in turn increase the risk of damage localization under strong ground excitations. In earthquake resistant design, regularity in plan is encouraged. In the study area a number of public buildings have irregularity in plan. Figure 12 shows that about fourteen buildings have rectangular shape and nine buildings have irregular plan.

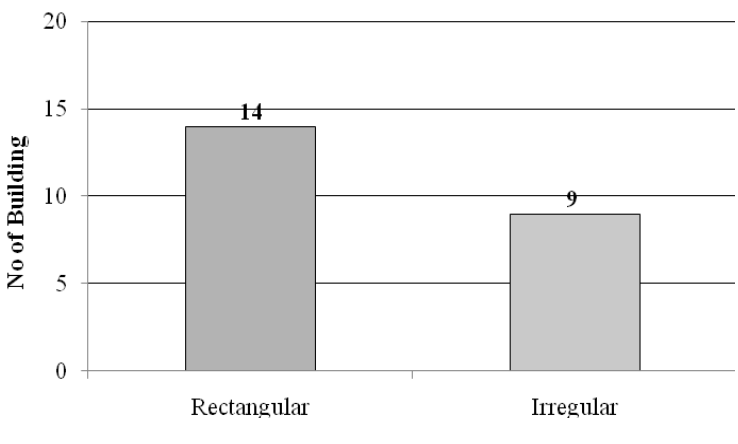



**Figure 12:** Plan irregularity of public building

*Source: Field survey, 2009*

### e) Height of the Public Building

It has observed that among all public buildings in the study area 70% are one to three storied and only 9% buildings are more than six storied (see Figure 13). It has also found that only two public buildings (Islampur Jame Mosque and Zindabahar Jame Mosque) are seven storied.

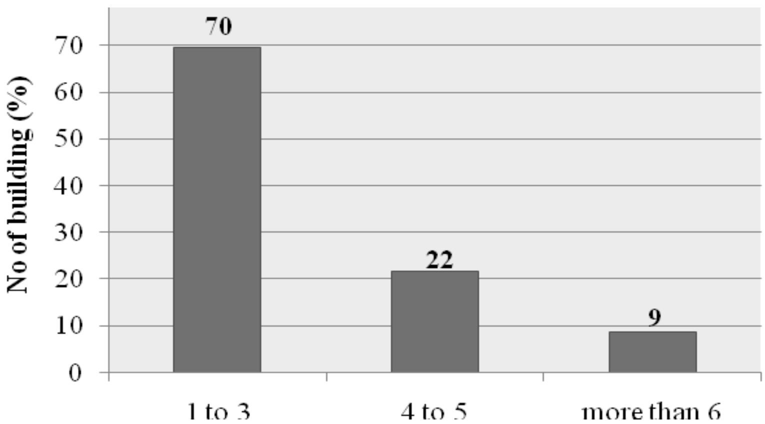



**Figure 13:** Height according to storey of public building

*Source: Field survey, 2009*

### f) Soft Storey of the public building

Soft storey buildings are open ground storey buildings, consistently shown poor performance during earthquakes. A significant number of them have collapsed. In the study area it has found that 95% buildings have no open ground and only 5% public buildings have open ground i.e. presence of walls at upper storey (See figure 14).

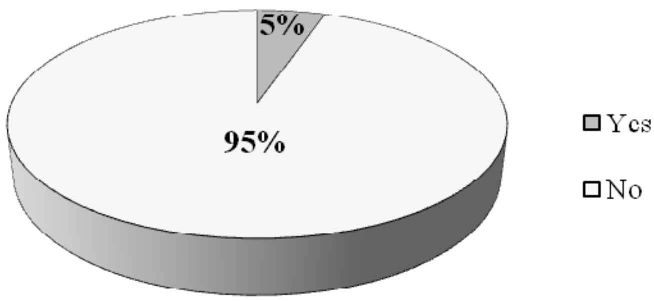



**Figure 14:** Soft storey of public building

*Source: Field survey, 2009*

The existence of walls in upper storey makes them much stiffer than the open ground storey. The existing open ground storey buildings need to be strengthened suitably to prevent them from collapsing during strong earthquake. The owners should seek the services of qualified structural engineers who are able to suggest appropriate solutions to increase seismic safety of these buildings.

### g) Overhang of the public building

From field survey it has observed that most of the public buildings (84%) have no overhang in their structures. These buildings expanded without any desecration of plan. Only three buildings (16%) do not follow the plan and design accurately (see Figure 15).

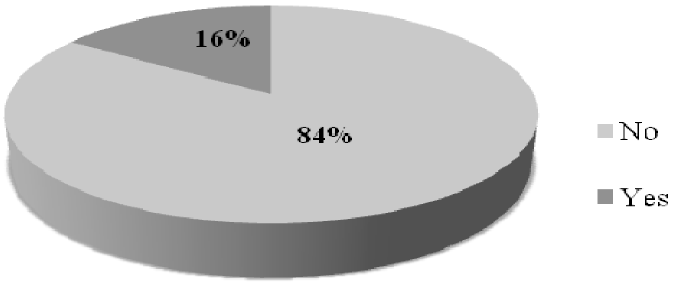



**Figure 15:** Overhang of public building

*Source: Field survey, 2009*

### h) Pounding effect of public building

Seismic pounding between two adjacent buildings occur during an earthquake. It is one of the main causes of severe building damages in earthquake. The non-structural damage involves pounding or movement across separation joints between adjacent structures. In Old Dhaka it is conspicuous that most of the buildings are constructed in congested way. So it is evident that 84% buildings in the study area might face pounding effect and only 16% buildings are free from this (see Figure 16).

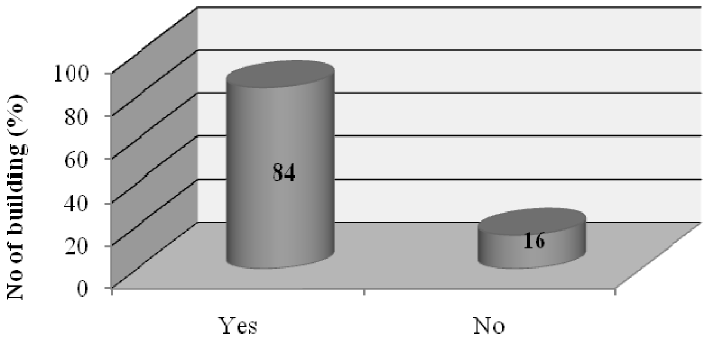



**Figure 16:** Pounding effect of public building

*Source: Field survey, 2009*

**i) Short Column of public building**

During past earthquakes, reinforced concrete (RC) buildings that have columns of different heights within a storey, suffered more damage in the shorter columns as compared to taller columns in the same storey. The short column is stiffer as compared to the tall column and it attracts larger earthquake force. If a short column is not adequately designed for such a large force, it can suffer significant damage during an earthquake. Figure 17 shows short column is identified in 16% buildings. In existing buildings with short columns, different retrofit solutions can be applied to avoid damage in future earthquakes.

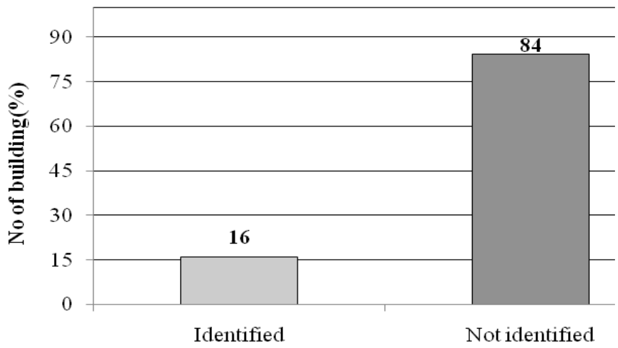



**Figure 17:** Short column of public building

*Source: Field survey, 2009*

**j) Detail Analysis of the public building**

Building wise detail analysis is discussed in the following sections.

**I. Islampur Jame Mosque**

From the plan of structure it is found that the building shape is regular. The length and breadth ratio of the building is more than three and column spacing is more than 15 ft that increases the risk of the building to be vulnerable to earthquake hazard (see Figure 18).

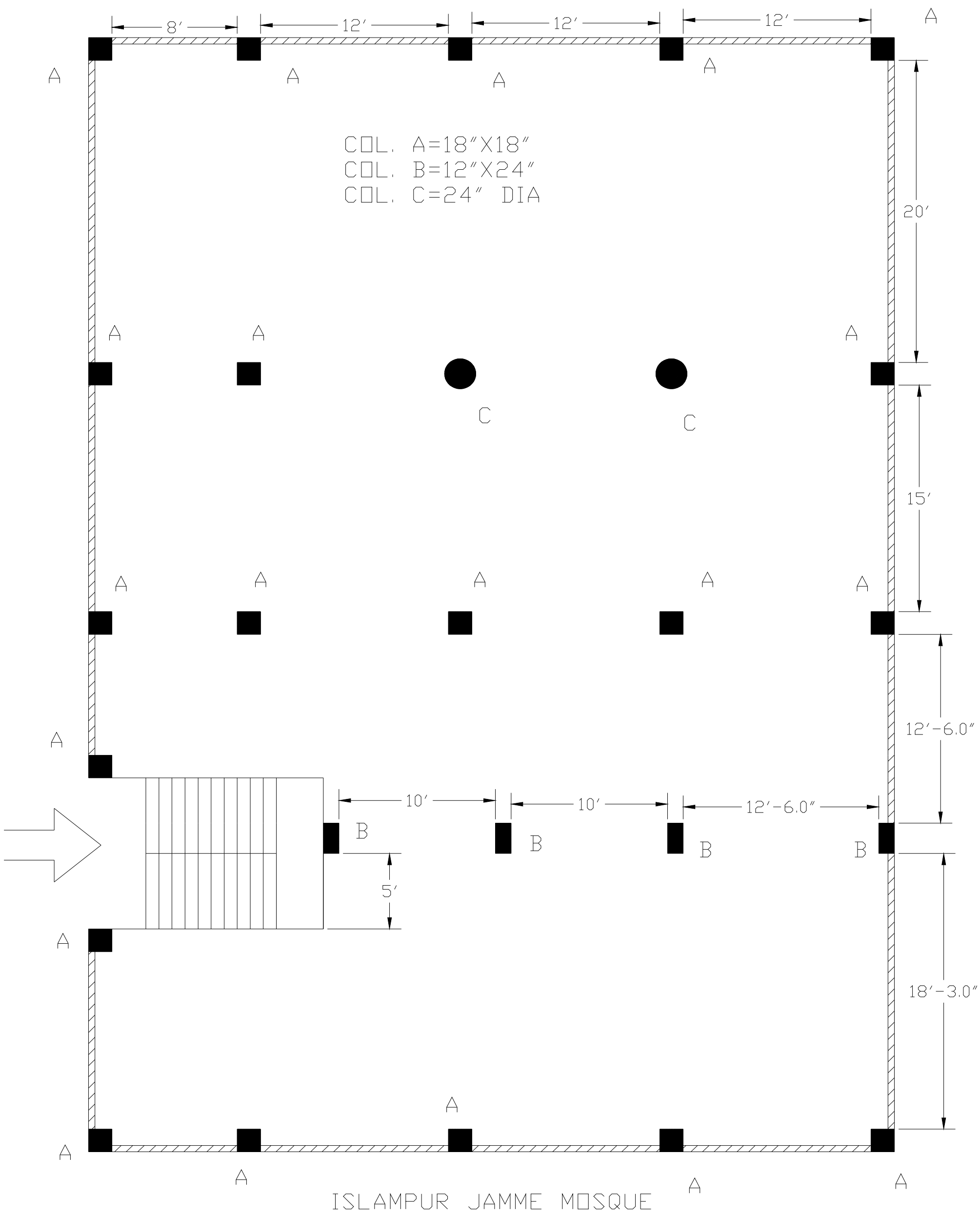



**Figure 18:** Building plan of Islampur Jame Mosque

*Source: Field survey, 2009*

From ferro scan of the building it has found that the beam and column dimensions are appropriate but the reinforcement distribution at beam and column are not sufficient. Mezzanine floor was found in the ground floor of the building that made it more vulnerable to earthquake. It can be concluded from the analysis that the building needs detail structural analysis and earthquake resistant design can be applied as appropriate according to the building condition like retrofitting to be used as a shelter (see Figure 19).

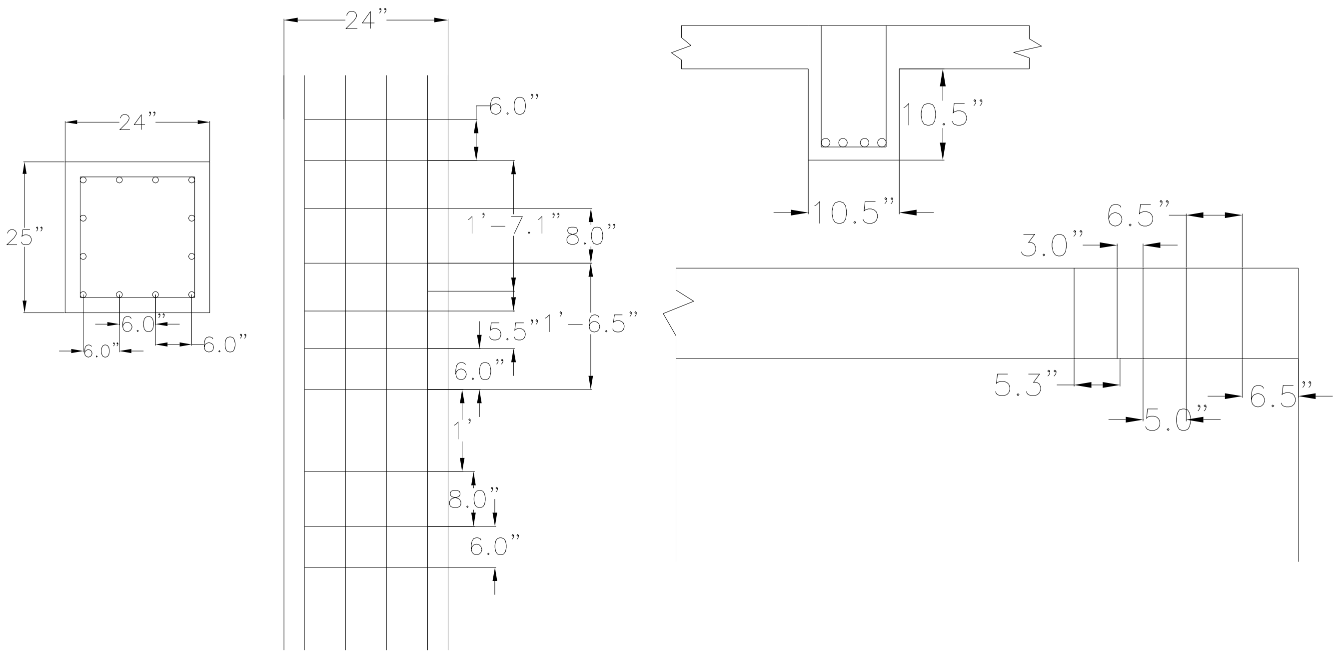



**Figure 19:** Findings from Ferro Scan of Islampur Jame Mosque

*Source: Field survey, 2009*

**Photograph 6:** Islampur Jame Mosque

## II. ShahjadaMia Jame Mosque

The building is L-shaped that is not suitable in consideration with earthquake. The length and breadth ratio of the building is satisfactory (see figure 20).

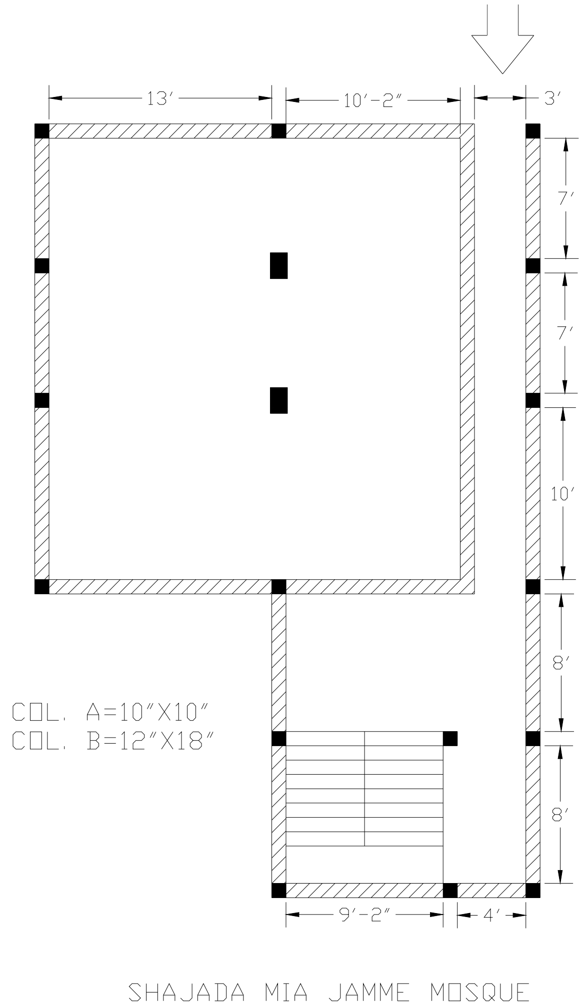



**Figure 20:** Building Plan of ShahjadaMia Jame Mosque

*Source: Field survey, 2009*

Beam and column dimension is appropriate. Reinforce distribution at column is not accurate (see Figure 21).

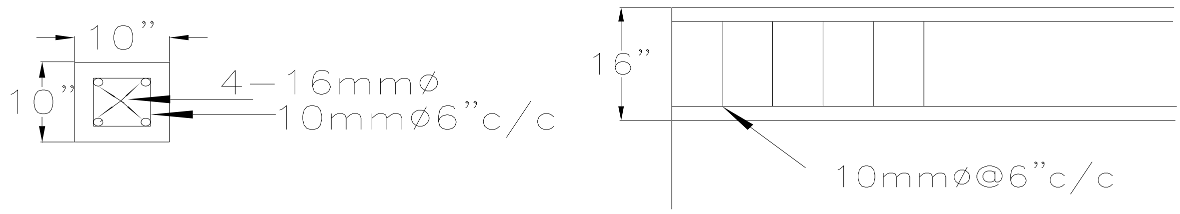



**Figure 21:** Findings from Ferro Scan of ShahjadaMia Jame Mosque

*Source: Field survey, 2009*

**Photograph 7:** ShahjadaMia Jame Mosque

### III. Jhubbu Khanam Jame Mosque

From plan of the structure it is found that the structure is nearly regular in shape that is all right considering reaction in earthquake. The length and breadth ratio of the building is also adequate (see Figure 21).

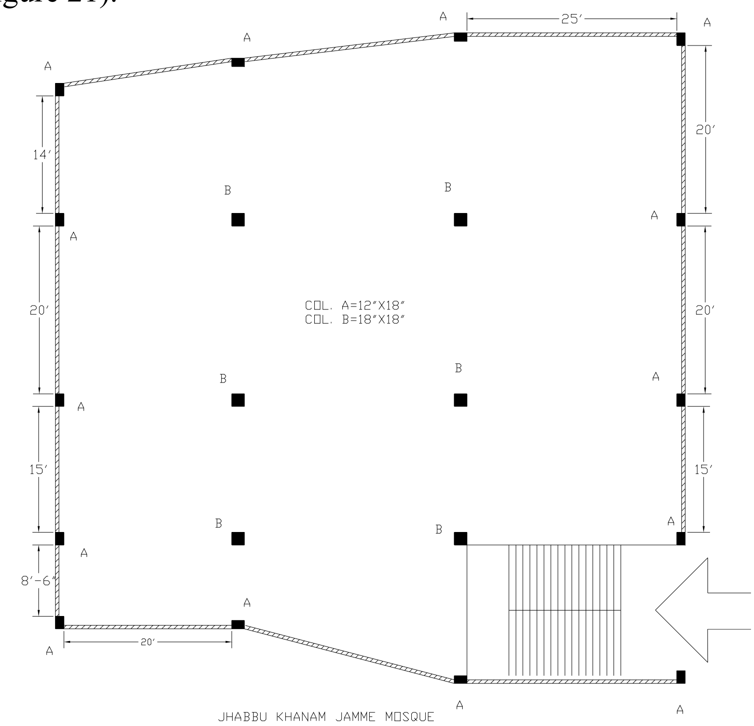



**Figure 22:** Building Plan of Jhubbu Khanam Jame Mosque

*Source: Field survey, 2009*

From Ferro Scan and visual observation it has found that the building's roof is flat plate. It is not suitable considering earthquake resistant building design. The reinforcement distribution in beam and column is not sufficient. The spacing within column is not appropriate (see Figure 23). Thus the building needs preventive measures like retrofitting to sustain during time of earthquake.

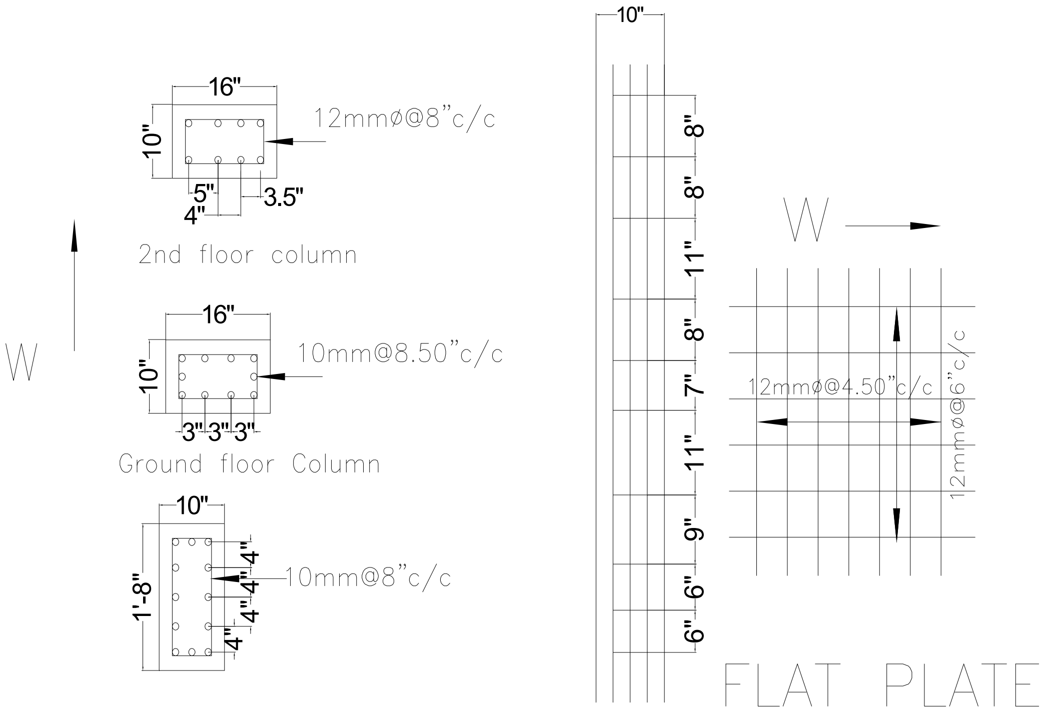



**Figure 23:** Findings from Ferro Scan of Jhubbu Khanam Jame Mosque

*Source: Field survey, 2009*

**Photograph 8:** Jhubbu Khanam Jame Mosque

## IV. Zindabahar Jame Mosque

From the plan of Structure it is found that the structure is regular in shape that is acceptable considering earthquake. But the building has little overhang that is not correct for earthquake resistance design (see Figure 24).

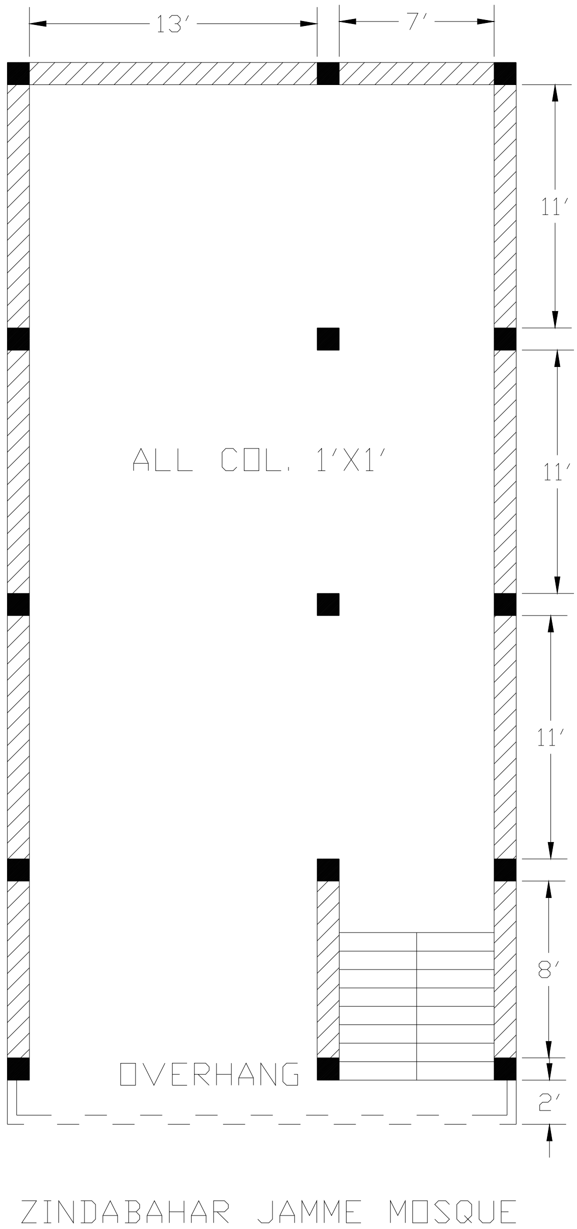



**Figure 24:** Building Plan of Zindabahar Jame Mosque

*Source: Field survey, 2009*

From Ferro Scan and visual observation it was found that the building's roof is flat plate that is not suitable for proper functioning at time of earthquake (see Figure 5.25). So the building needs preventive measures like retrofitting to sustain during time of earthquake.

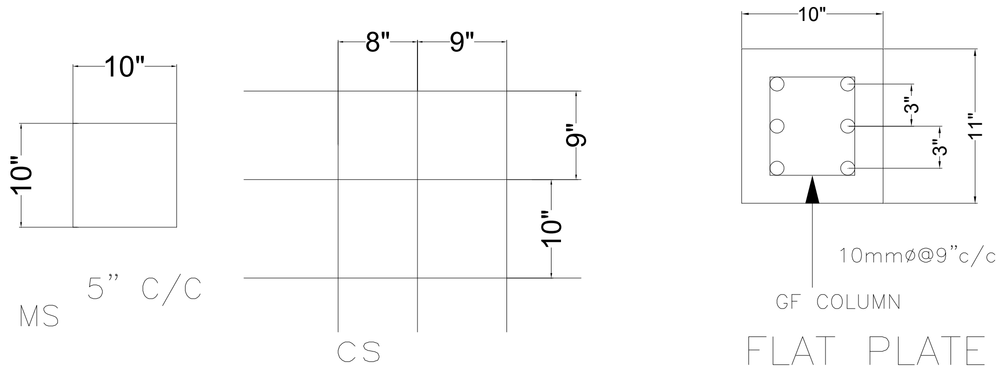



**Figure 25:** Findings from Ferro Scan of Zindabahar Jame Mosque

*Source: Field survey, 2009*

**Photograph 9:** Zindabahar Jame Mosque

**V. Kamranga Jame Mosque**

It is clear from the plan of the structure that it is almost regular in shape that is acceptable in earthquake consideration (see Figure 26).

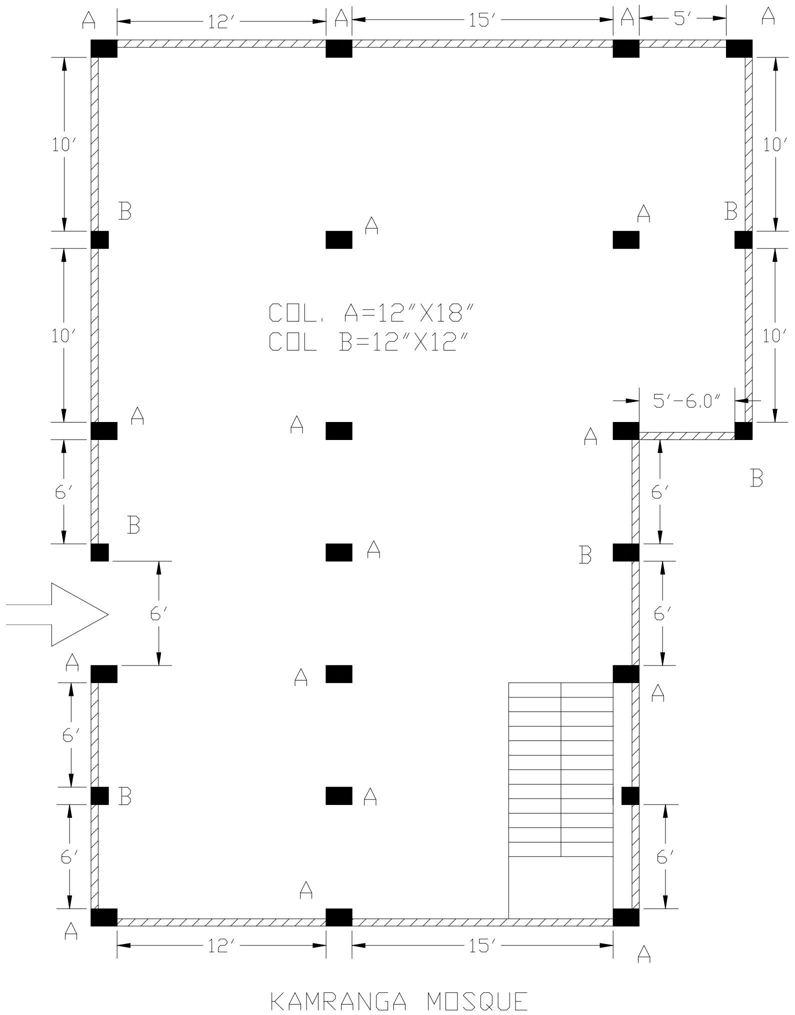
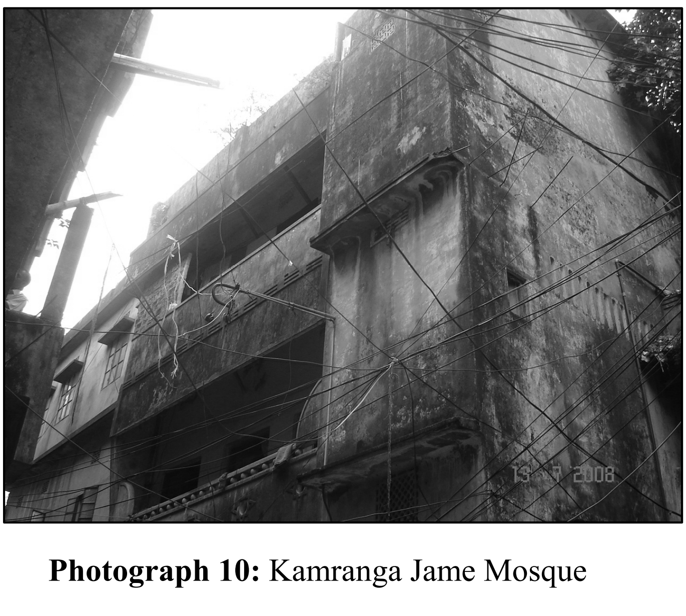



**Figure 26:** Building Plan of Kamranga Jame Mosque

*Source: Field survey, 2009*



**Photograph 10:** Kamranga Jame Mosque

**VI. Maulana Mosque**

The building plan is almost regular in shape that is all right considering earthquake resistant design (see Figure 27).

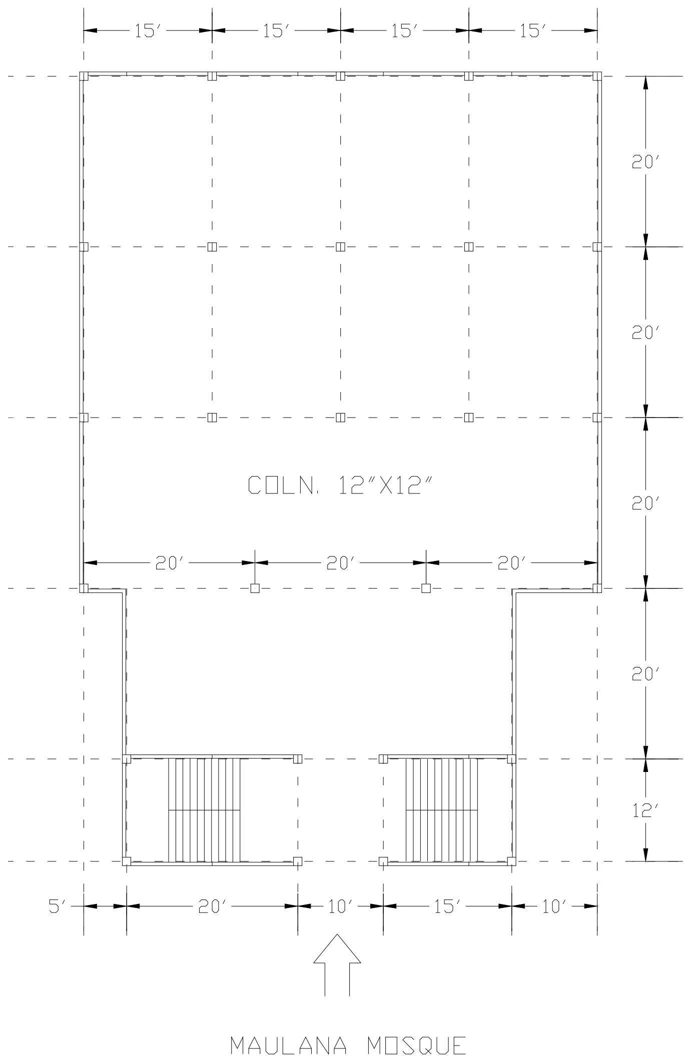



**Figure 27:** Building Plan of Maulana Mosque

*Source: Field survey, 2009*

**VII. Mahuttuli Jame Mosque**

From figure it is seen that the building plan is regular. The length breadth ratio is ok (see Figure 28).

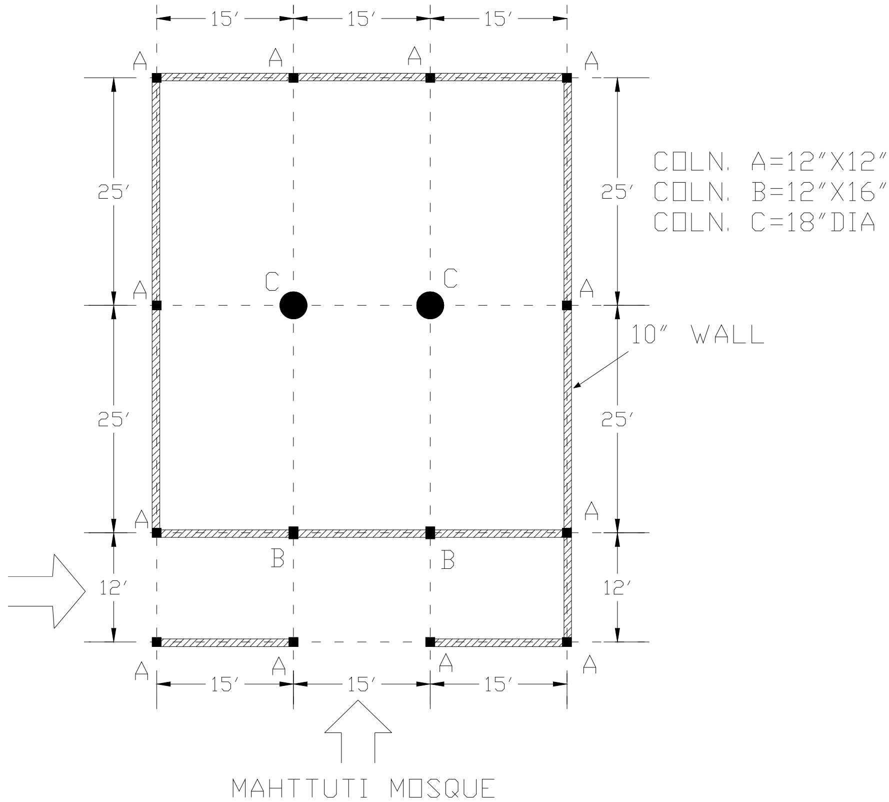



**Figure 28:** Building Plan of Mahuttuli Jame Mosque

*Source: Field survey, 2009*

**Photograph 11:** Mahuttuli Jame Mosque

**VIII. Shahjadi Begum Jame Mosque**

The building plan is not perfect as the shape is irregular and the length breadth ratio of the building is more than three and it is not accurate according to earthquake resistant building design (see Figure 29).

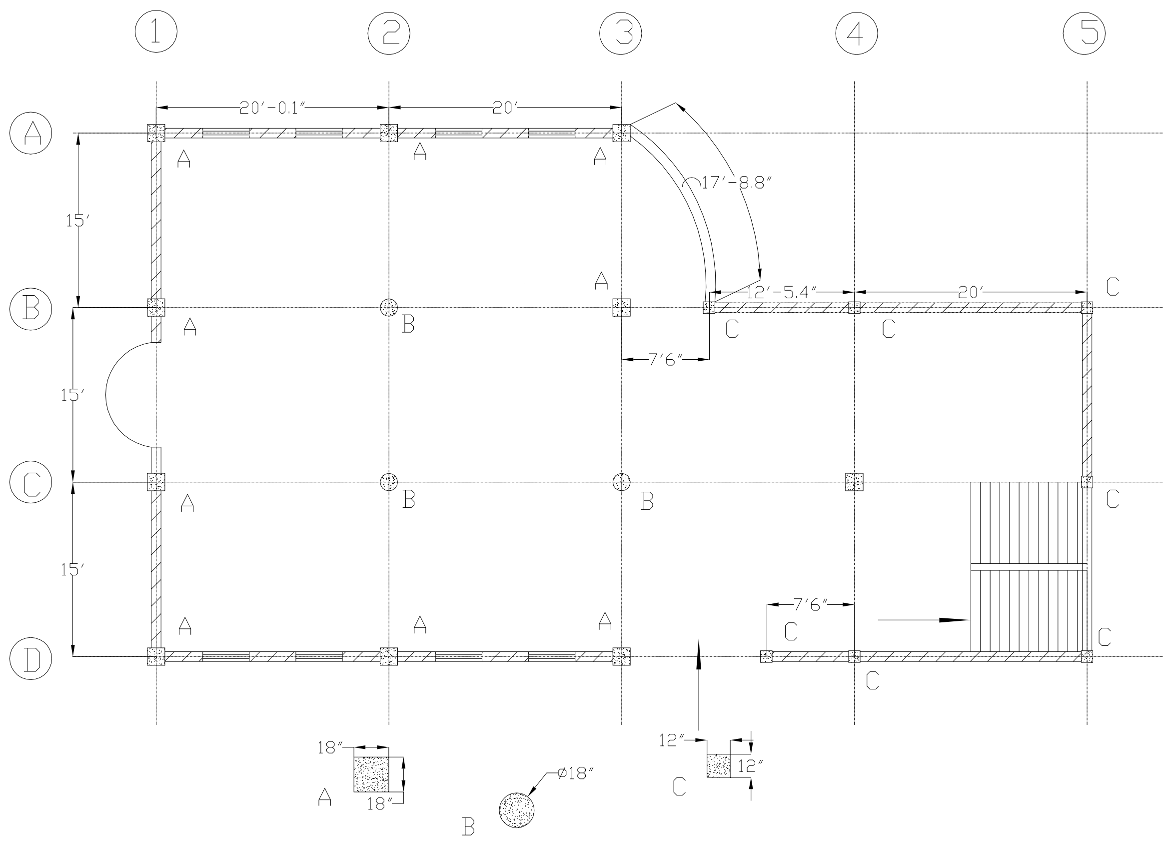
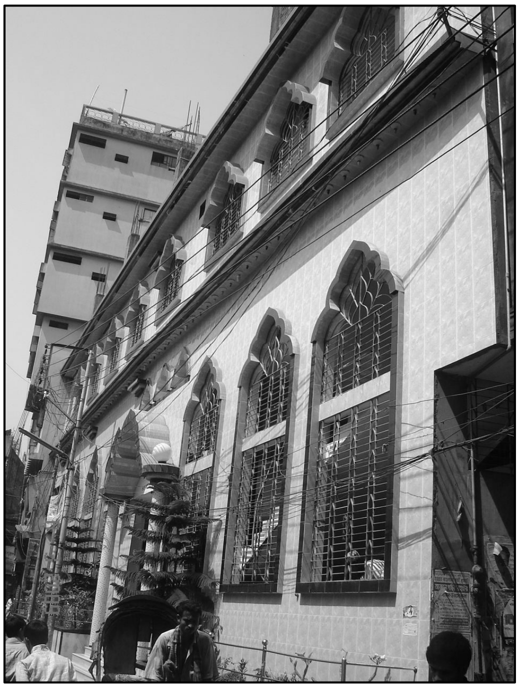



**Figure 29:** Building Plan of Shahjadi Begum Jame Mosque

*Source: Field survey, 2009*



**Photograph 12:** Shahjadi Begum Jame Mosque

**IX. Malibag (Bangshal) Peyala Mosque**

The building plan according to its shape and length-breadth ratio is accurate. The building is less vulnerable to earthquake hazard (see Figure 30).

.

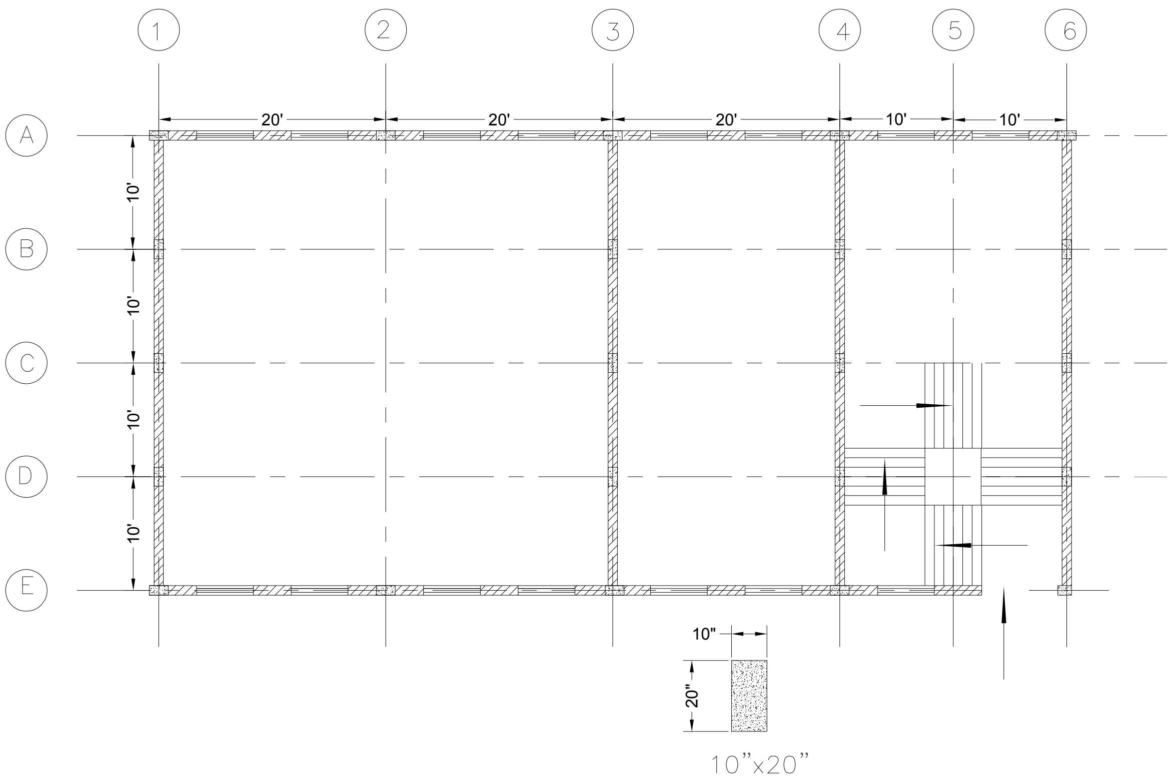



**Figure 30:** Building Plan of Malibag (Bangshal) Peyala Mosque

*Source: Field survey, 2009*

**Photograph 13:** Malibag (Bangshal) Peyala Mosque

**X. Samsabad Boro Mosque**

The building plan is square in shape. The building is comparatively less vulnerable to earthquake (see Figure 31).

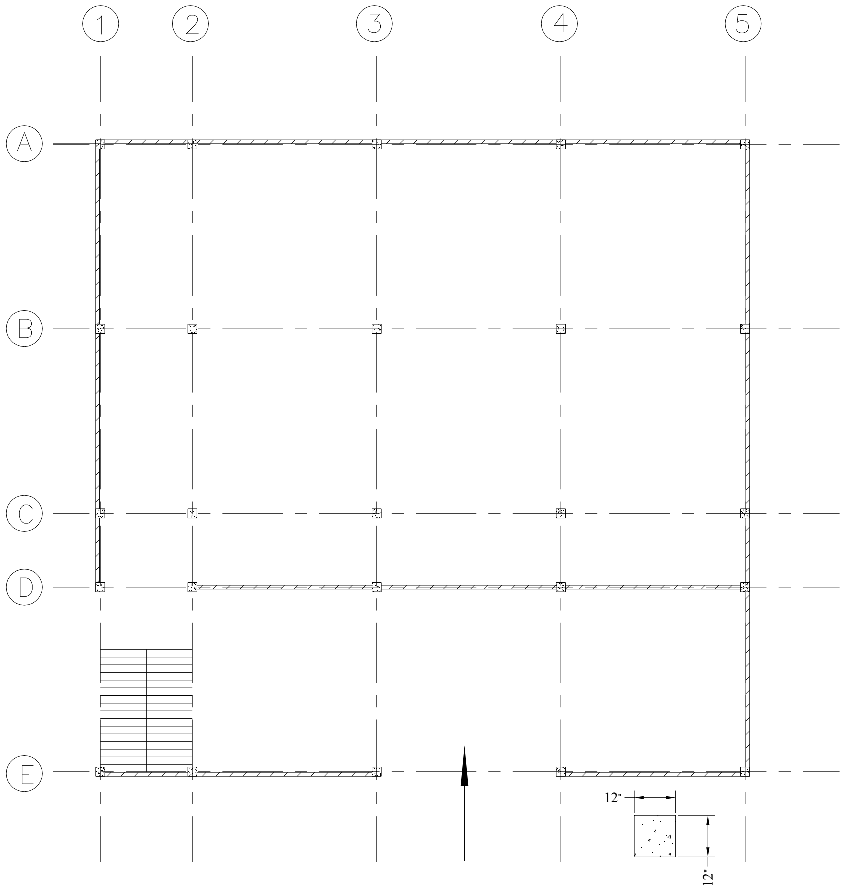



**Figure 31:** Building Plan of Samsabad Boro Mosque

*Source: Field survey, 2009*


**Photograph 14:** Samsabad Boro Mosque

**XI. Kosaituli Old Jame Mosque**

From field survey and analyzing design, the building was found highly vulnerable to earthquake. The building plan is irregular in shape. There was existence of mezzanine floor. Also RCC structures were built with the old aged URM building for extension of the structure making it more vulnerable to earthquake (see Figure 32). The building also represents a significant historical site in the area. Therefore the structure needs more analysis by structural engineers to be proposed as earthquake evacuation shelter.

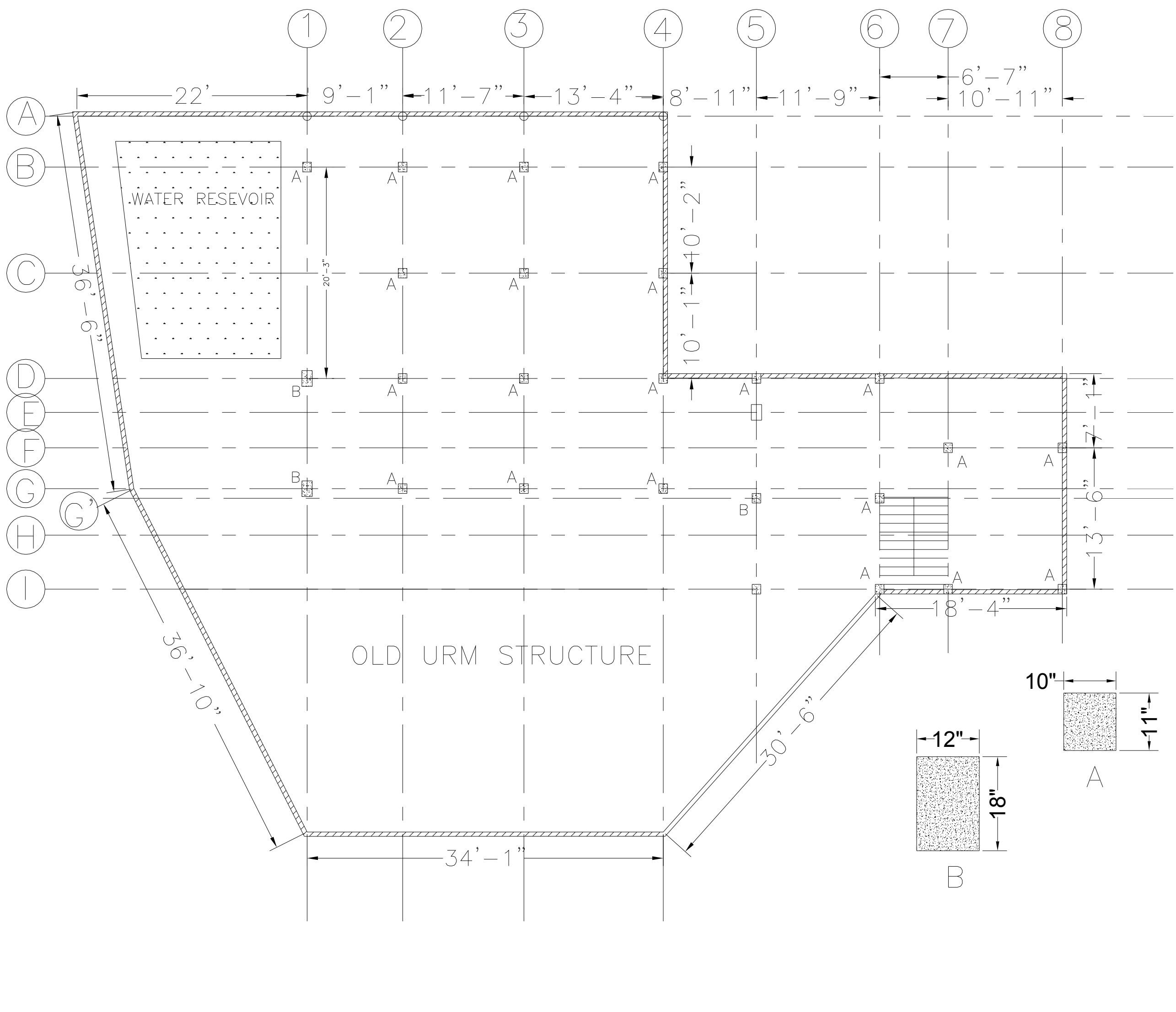
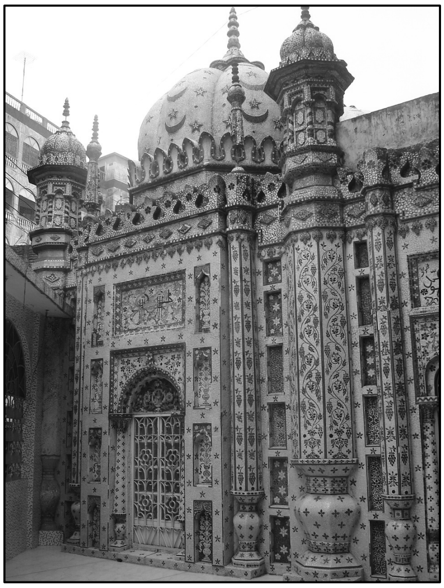



**Figure 32:** Building Plan of Kosaituli Old Jame Mosque

*Source: Field survey, 2009*



**Photograph 15:** Kashaituli Old Jame Mosque

**XII. Kosaituli Panchayet Committee and School**

The building shape is regular but the length breadth ratio is not adequate (see Figure 5.33). Building extension was not made accurately.

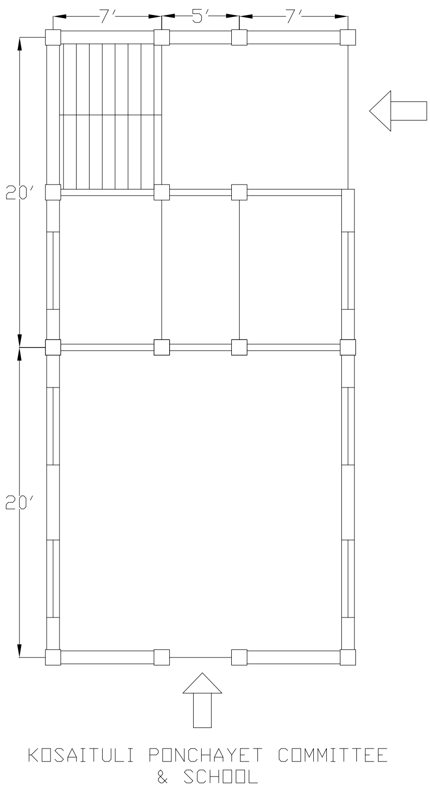



**Figure 33:** Building Plan of Kosaituli Panchayet Committee and School

*Source: Field survey, 2009*

From Ferro scan it was found that the reinforcement distribution in the column was not correct (see Figure 34). Over all the building needs special consideration to be used as evacuation shelter during emergency time.

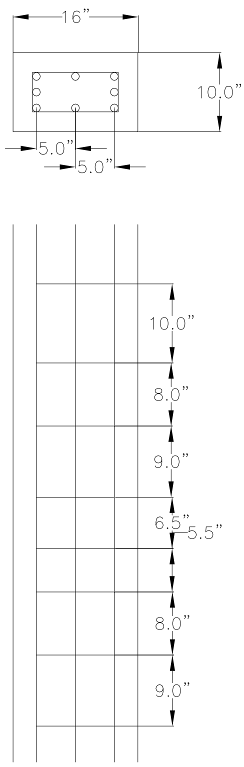



**Figure 34:** Findings from Ferro Scan of Kosaituli Panchayet Committee and School

*Source: Field survey, 2009*

**Photograph 16:** Kosaituli Panchayet Committee and School

## XIII. Bangshal RokonUddin Jame Mosque

This building is almost regular in shape. The length and breadth ratio is acceptaple but the column spacing is not correct (see Figure 35).

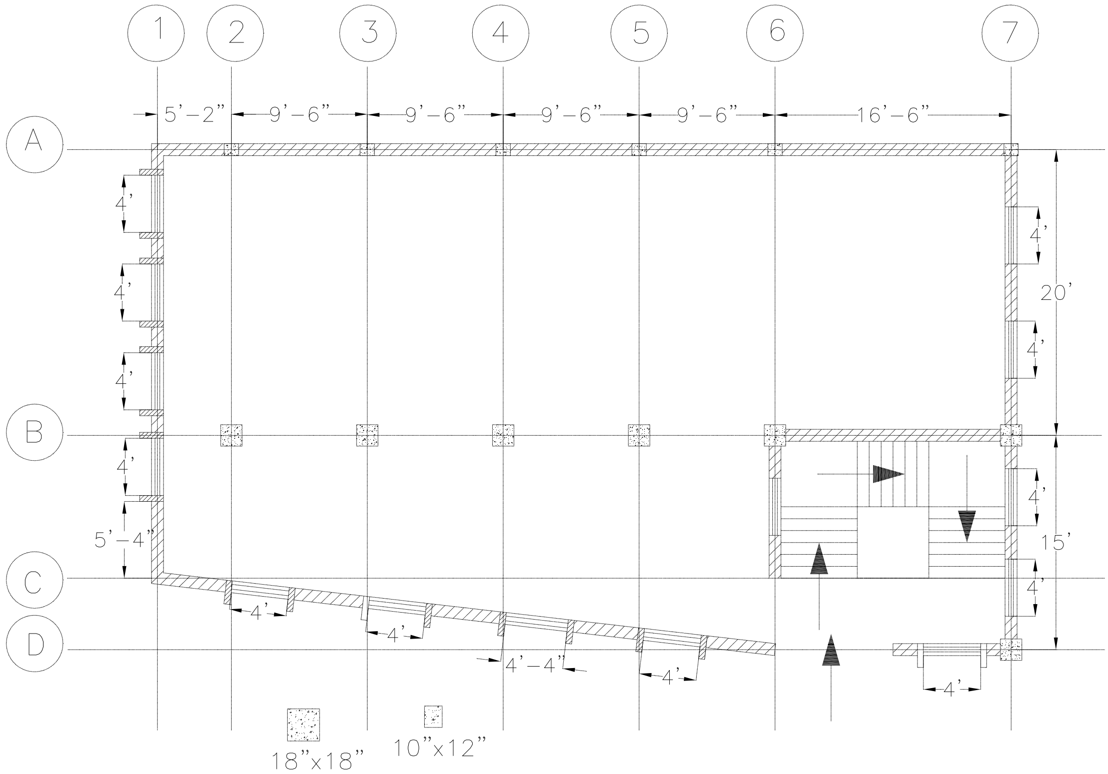



**Figure 35:** Building Plan of Bangshal RokonUddin Jame Mosque

*Source: Field survey, 2009*

**Photograph 17:** Bangshal RokonUddin Jame Mosque

**XIV. Babubazar Ghat Jame Mosque**

This is an old URM building situated on the bank of river Buriganga and standing as a land mark of historical site. The building shape is regular along with column spacing (see Figure 36). The existing heavy load bearing walls in the building will carry the extra load from ground shaking during earthquake. The building has a handsome amount of open space circling the main building. It can serve as a proper shelter place for the local residents.

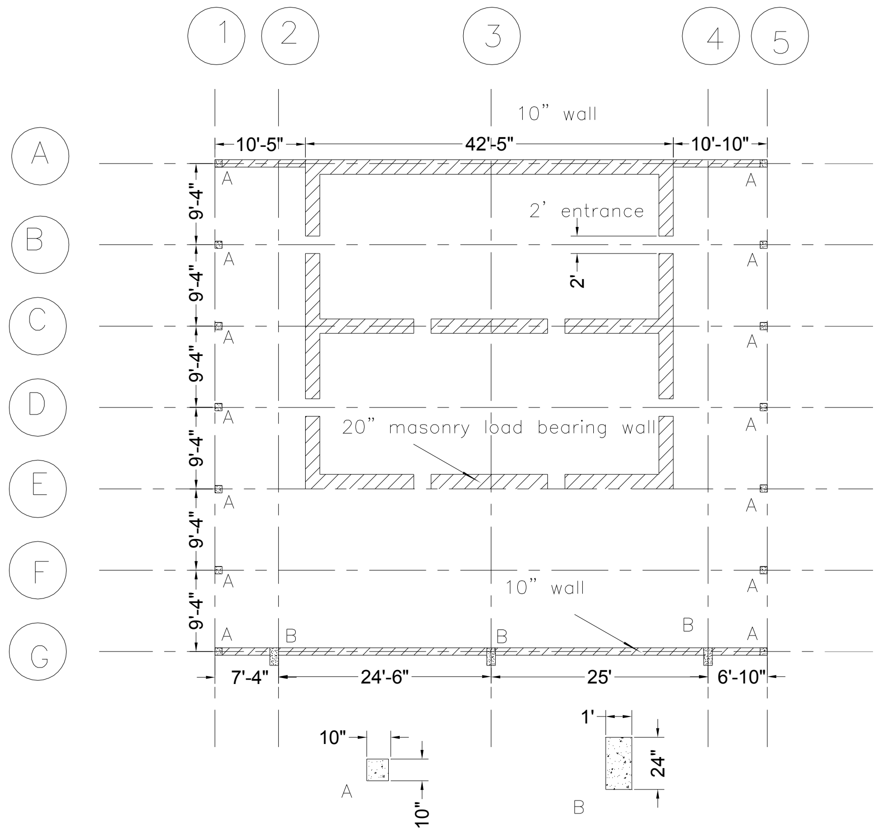
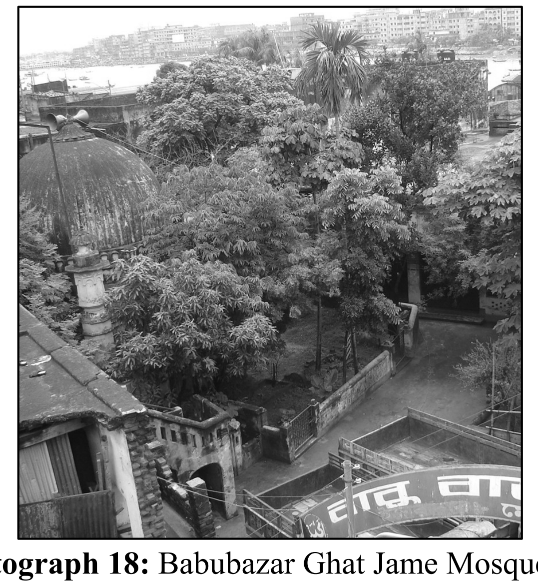



**Figure 36:** Building Plan of Babubazar Ghat Jame Mosque

*Source: Field survey, 2009*



**Photograph 18:** Babubazar Ghat Jame Mosque

**XV. Anondomoyee Girls' High School**

From the plan of 1st structure it can be said that the building shape is irregular, its extension is not 1/6 th of width, the length and breadth ratio of the building is not perfect as it is more than three and column spacing is more than 15 ft that increases the risk of the building to be vulnerable to earthquake hazard (see Figure 37). In terms of structure 2 and 3 the shape is regular, their length and breadth ratio is considerable but their column spacing has not maintained the standard of being within 15 ft.

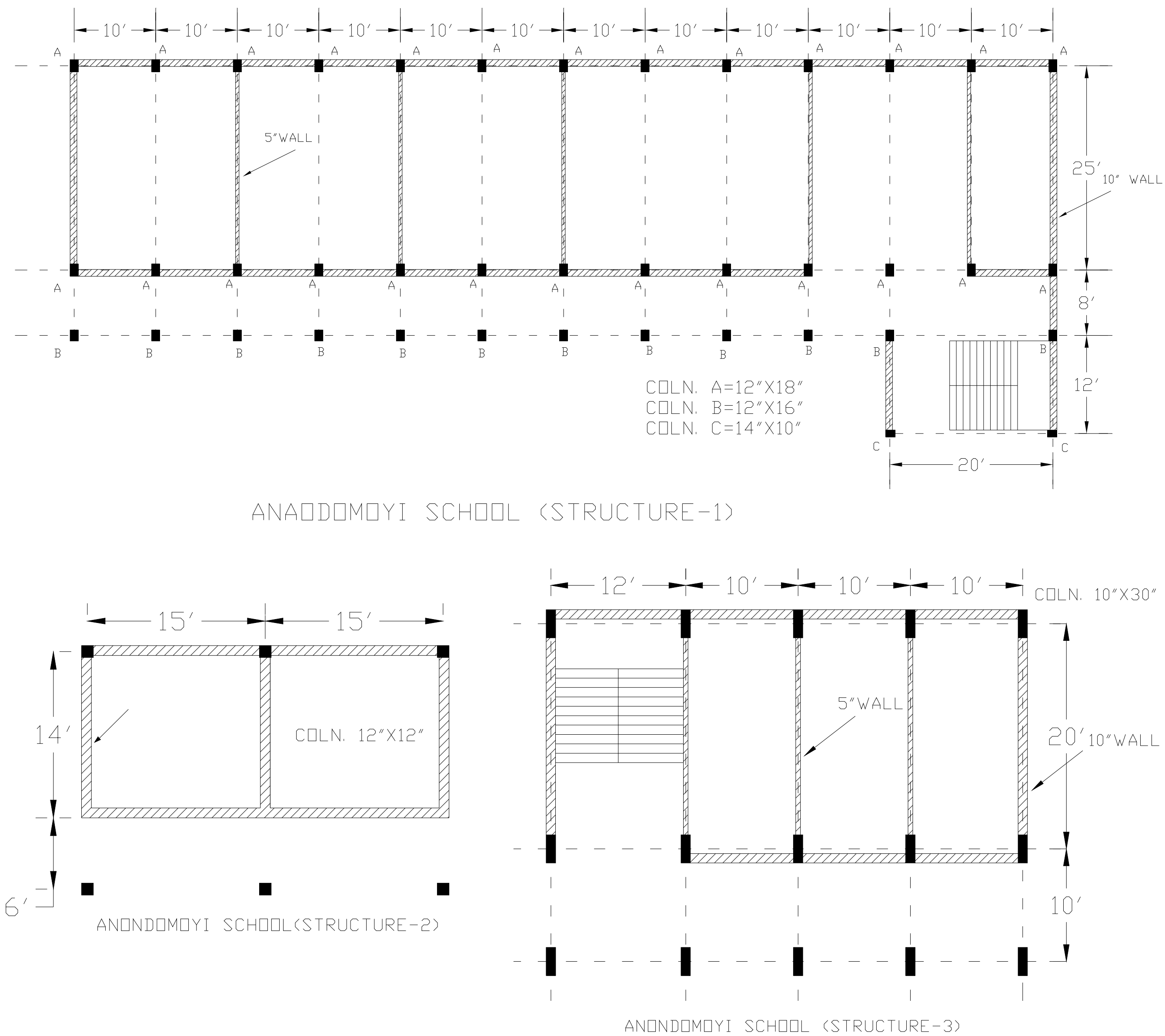



**Figure 37:** Building Plans of Anondomoyee Girls' High School

*Source: Field survey, 2009*

From the column section in the figures of three structures it can be said that the reinforcement distribution also not followed the standard to be judged as earthquake resistant building. But the RVS Score and Score from Turkish Level II survey has declared the building structures could be safe as it showed values above the cutoff score (see Figure 38).

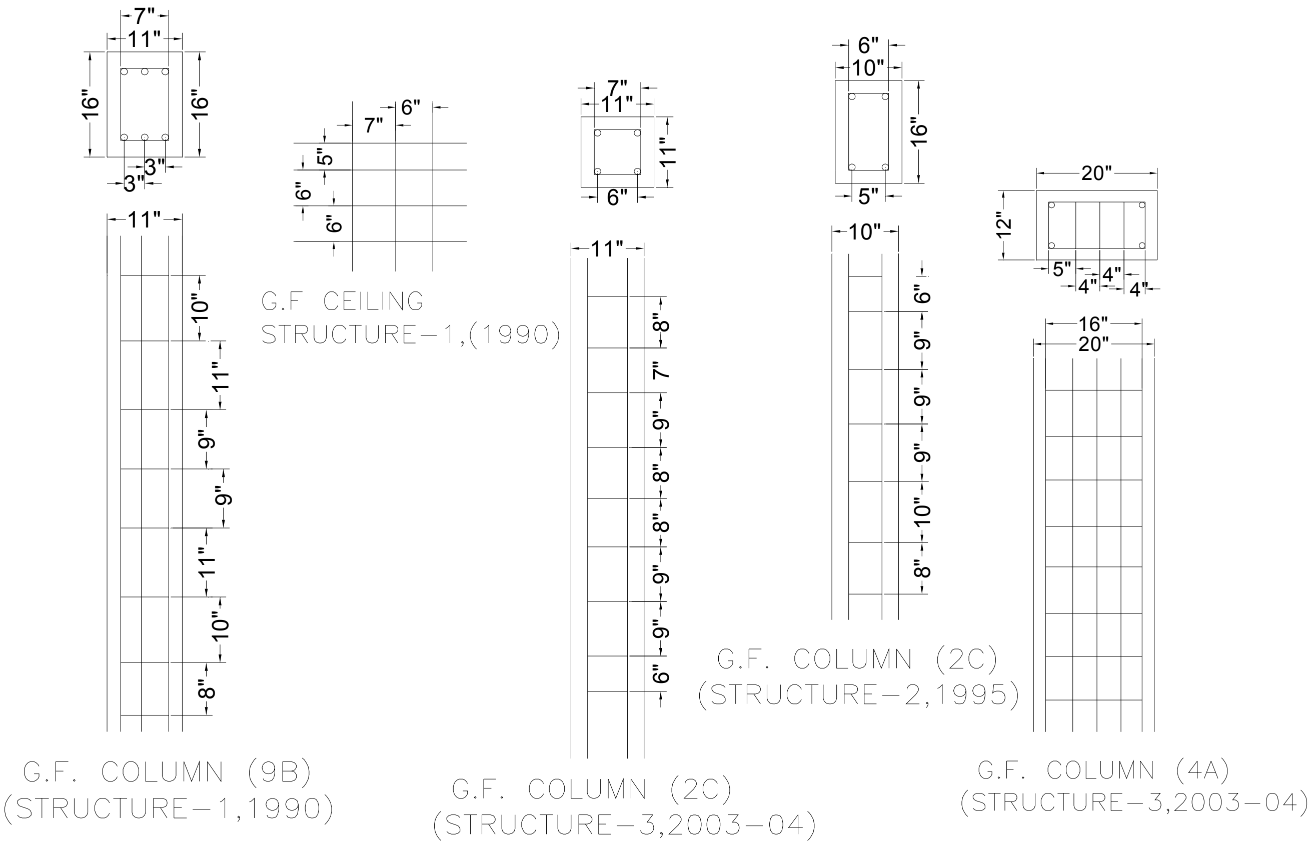
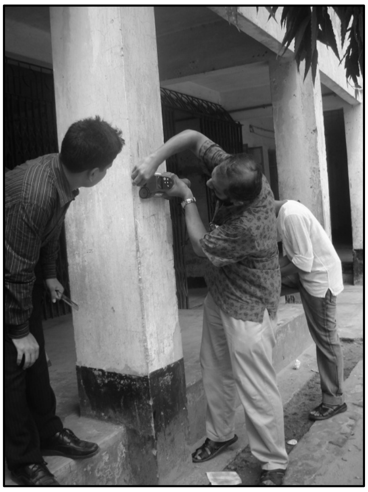



**Figure 38:** Ferro scan result of Anondomoyee Girls' High School

*Source: Field survey, 2009*

**Photograph 19:** Anondomoyee Girls' High School

After analyzing the above situations the building structures can be suggested for further investigation by the structural engineers and retrofitting or other measures of strengthening the existing structures to withstand earthquake calamity are suggested here.



**Photograph 20:** Prof. Ansary and BNUS Staff performing Fero-Scan of the School Building

## XVI. Ahmed Bawani School and College

The building plan is not regular in shape. The length and breadth ratio of the building is also not accurate according to earthquake resistant building design (see Figure 39). The left portion of the drawing is the college section with RCC building structure and the right portion is school section with an URM type structure. Two structures are positioned in such a way that it looks like a same building and as the two structures are connected with each other with different floor heights it behave like a mezzanine floor which is very bad feature for a building to behave well during earthquake. It needs certain preventive measures to act as an evacuation shelter.

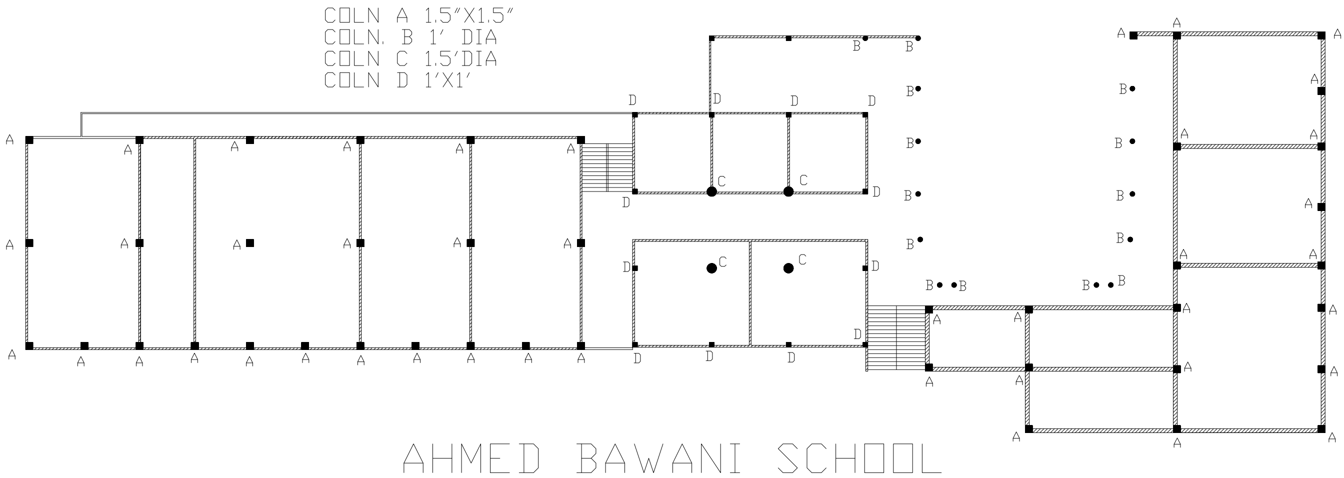



**Figure 39:** Building Plan of Ahmed Bawani School and College

*Source: Field survey, 2009*


**Photograph 21:** Ahmed Bawani School and College

**XVII. Haybotnagar Primary School**

The shape of the building is irregular. The extension is not 1/6 th of its width but the column spacing is ok (see Figure 40). Above all the building needs further analysis and measures to be sustain in times of earthquake and work perfectly as a shelter.

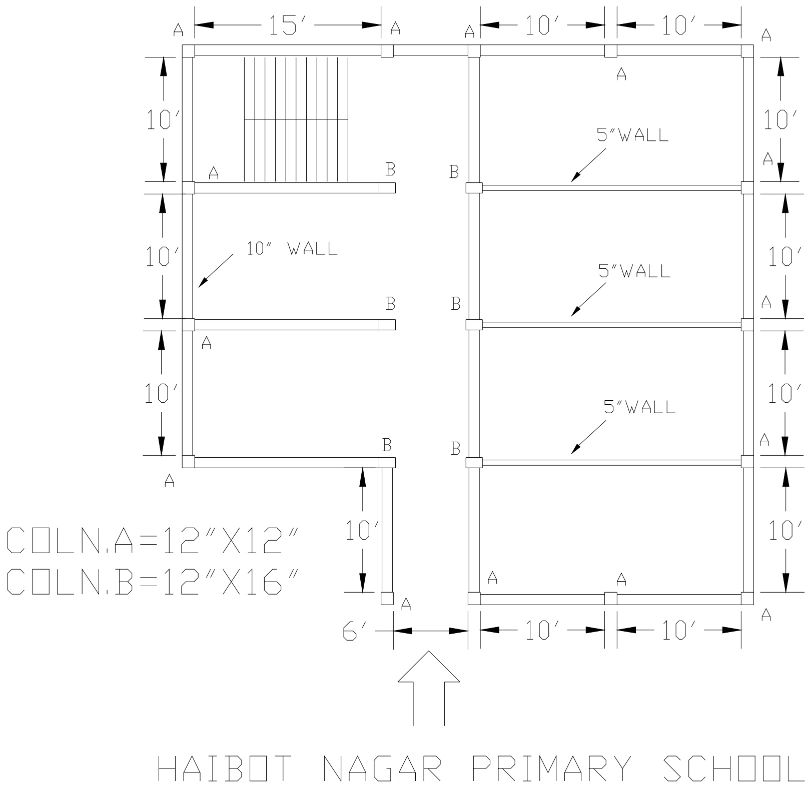



**Figure 40:** Building Plan of Haybotnagar Primary School

*Source: Field survey, 2009*

**Photograph 22:** Haybotnagar Primary School

### XVIII. Samsabad Primary School

The shape of the building along with its length breadth ratio is ok (see Figure 41). But the column spacing is not accurate. It needs more study and specific treatments to be used as a shelter place.

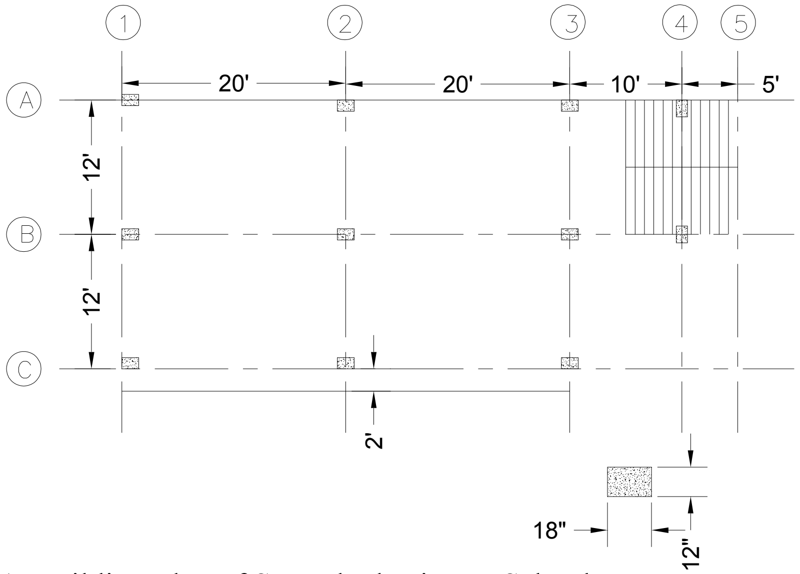



**Figure 41:** Building Plan of Samsabad Primary School

*Source: Field survey, 2009*

**Photograph 23:** Samsabad Primary School

## XIX. Jummon Community Center

The building shape is irregular. Extension is more than one sixth of its width (see Figure 42).

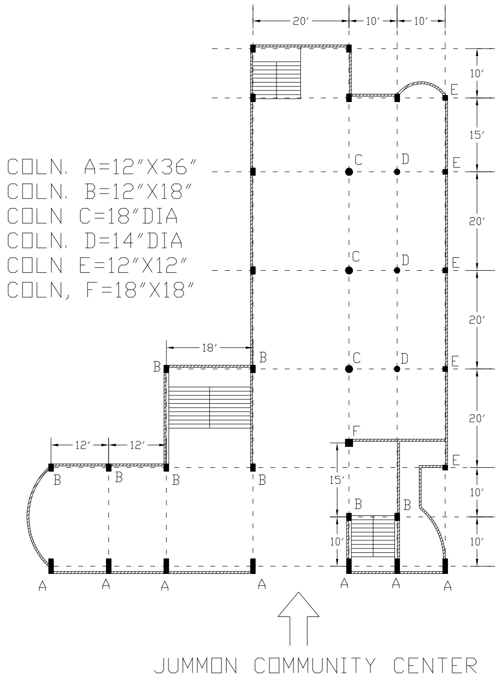



**Figure 42:** Building Plan of Jummon Community Center

*Source: Field survey, 2009*

Reinforcement distribution at column is incorrect. The building needs more detail evaluation and based on those results building specific preventive measures like retrofitting and others should be taken to be performed as an earthquake evacuation shelter (see Figure 43).

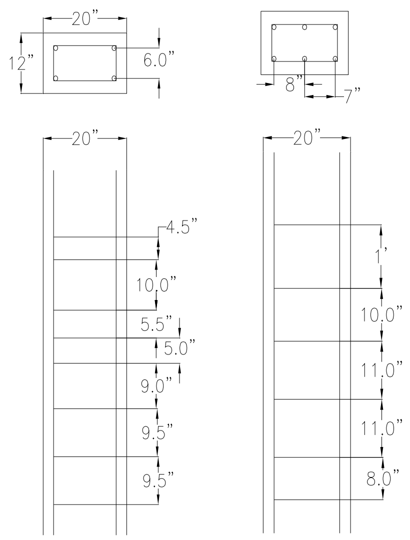


**Figure 43:** Ferro scan result of Jummon Community Center

*Source: Field survey, 2009*

**Photograph 24:** Jummon Community Center

**XX. Kona Party Center**

The building shape is regular. The length breadth ratio with its column spacing is correct (see Figure 44)

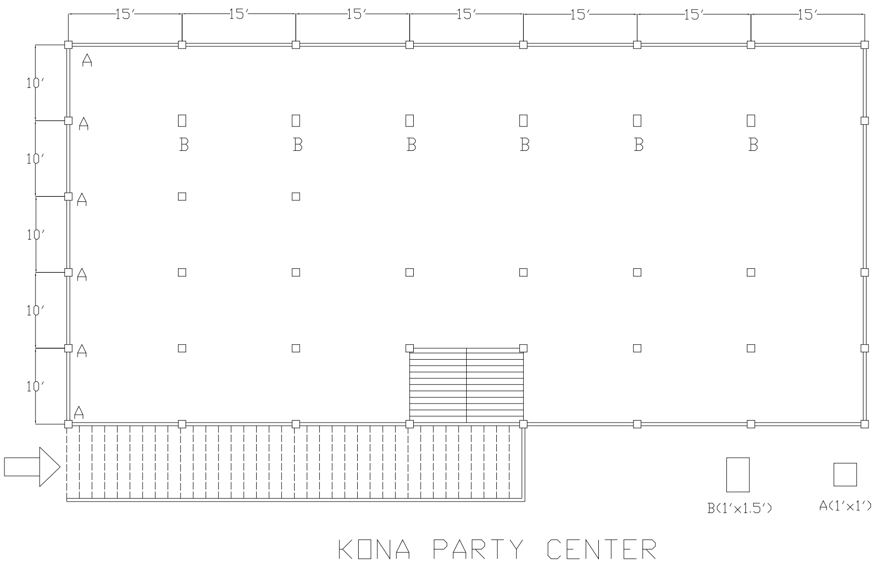



**Figure 44:** Building Plan of Kona Party Center (Ground Floor)

*Source: Field survey, 200*


**Photograph 25:** Kona Party Center

## Summary

This chapter analyzes the vulnerability of 77% surveyed building in the study area using FEMA-RVS method. Only the proposed evacuation shelters were assessed in detail using Turkish Level-I and Level-II methods. It was found from field survey using RVS method that 54% of the building falls below the FEMA declared cut-off score i.e. '2'. Considering cut-off score of '1.5', only 39% of surveyed buildings were found for further detail analysis by structural engineers. In the study area huge amount of buildings with plan irregularity and vertical irregularity were found that made the scenario worst considering earthquake vulnerability. The existence of old dilapidated building is also a reason for the area to be earthquake vulnerable. Finally the findings for proposed evacuation shelters were analyzed in detail to have a clear idea on the shelter buildings and to have specific recommendations in retrofitting the structure based on existing condition.

# PART-V

# INSTALLATION OF A DIGITAL EARTHQUAKE MONITORING SYSTEM FOR BANGLADESH


**BANGLADESH NETWORK OFFICE FOR URBAN SAFETY (BNUS), BUET, DHAKA**

**Prepared By: Md. Shamsur Rahman**

**Mehedi Ahmed Ansary**

## 1. Introduction

Five large earthquakes occurred in Bangladesh and neighboring region between 1869 and 1930. Recently, no large earthquakes occurred in Bangladesh. A large earthquake may occur any time in the future. For seismic hazard analysis earthquake monitoring is important. Recently twenty five accelerometers (Model-ETNA) were deployed in Bangladesh. Another seven accelerometers were deployed within a 60 Km radius of Jamuna bridge in 2003 and thirty four Strong Motion Accelerograph (SMAs) were also deployed in PWD offices all over Bangladesh in 2005. Under the guidance of Professor Dr. Mehedi Ahmed Ansary, Department of Civil Engineering, Bangladesh University of Engineering and Technology (BUET), the accelerometers are being maintained. To assist in the various works during the installation and monitoring phases Md. Samsur Rahman, was appointed as a Research Assistant from January 01, 2010.

An earthquake is a sudden and violent motion of the earth usually caused by volcanic eruption, plate tectonics, or man-made explosions which lasts for a short time, and within a very limited region. Most earthquakes last for less than a minute. The larger earthquakes are followed by a series of after-shocks which also may be dangerous. Volcanic eruption or plate tectonics is responsible for causing earthquakes. Also small earthquakes can be caused by blasting, quarrying and mining. Man made earthquakes are like underground nuclear explosions. But plate tectonics cause large number of big earthquakes. Bangladesh did not have any modern recording station for monitoring strong ground motion. The relationship between magnitude, epicentral distance and peak ground acceleration of those earthquakes constitute the basic parameter needed for assessing seismic hazard at a given site. The purpose of acclerometer installation is to present a predicting model for acceleration-attenuation for earthquakes in Bangladesh and its neighboring region.

## 2. Objectives

During the last two centuries, Bangladesh and its neighboring region have experienced several large earthquakes. The peak ground acceleration of these earthquakes has been estimated using different existing attenuation laws. For earthquake hazard analysis, unified acceleration attenuation relationship for Bangladesh is required.

The major objective of the study is to compile digital earthquake records for Bangladesh.

## 3. Seismic Measurement Device Installation Works

### 3.1 Base casting /Foundation for model ETNA Instrument

At first, the location of the ETNA instruments is selected. The Strong Motion Instrument must be situated on the ground surface. The soil condition must be dense sand/stiff clay. The trench size is 1050mm x 1050mm x 450mm. In the sand filling and brick flat soling (B.F.S) is 450mm and finally Concrete Base-1 Foundation Casting size is 900mm x 900mm x 150mm and RCC casting ratio is 1: 2: 4 and in another base casting size is 400mm x 400mm x 100mm. **Figure 1** shows the concrete base for the ETNA. BUET team started working from February 02, 2010 for installing the seismic instruments. Work plan and schedule was formulated to finish the installation work within two month. The Seismic Measuring Device Installation photographs are shown in **Appendix-B**. Public Works Department (PWD), Local Government, Bangladesh Atomic Energy Commission (BAEC), Geological Survey of Bangladesh (GSB), Jamuna Multipurpose Bridge Authority (JMBA) provided necessary space, support and assistance. **Figure 2** and **Table 1** present the locations of digital accelerometers.

### 3.2 Protections of ETNA-Station and Electrical Connections

Iron grill and galvanized steel sheet fencing is put around the ETNA-Instrument for protection. Each of the free field stations is setup individually. The systems are powered by batteries that are charged by AC power supply. At this moment the data is collected manually by downloading the data into a laptop computer. All the sensors are placed in their designated positions and each of them is connected to one particular channel of a recorder.

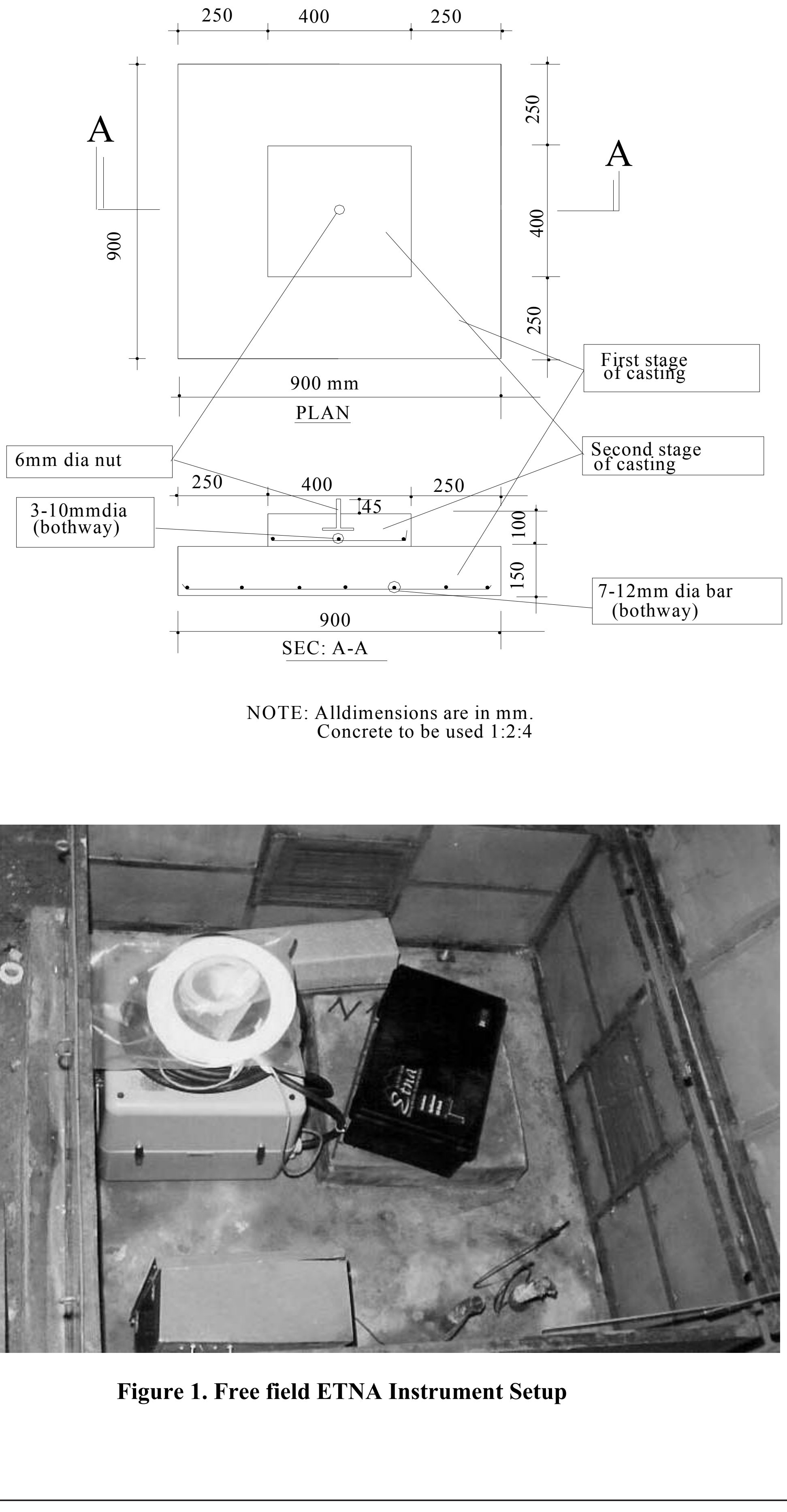



**Figure 1. Free field ETNA Instrument Setup**

**Table 1. Digital Free-field Instruments (ETNA)**

| SL.No | Model | Location | Latitude | Longitude |
|---|---|---|---|---|
| **1** | ETNA | PWD, Ashkona-Hazi camp | $23.71^0$N | $90.38^0$E |
| **2** | ETNA | Pollice Staff College | $23.72^0$N | $90.25^0$E |
| **3** | ETNA | GSB-Dhaka | $23.75^0$N | $90.35^0$E |
| **4** | ETNA | GSB-Chittagong | $22.15^0$N | $91.80^0$E |
| **5** | ETNA | PWD, Cox's-bazar | $21.42^0$N | $91.89^0$E |
| **6** | ETNA | PWD, Bandarban | $22.25^0$N | $92.32^0$E |
| **7** | ETNA | PWD, Rangamati | $22.72^0$N | $92.38^0$E |
| **8** | ETNA | PWD, Khagrachari | $22.45^0$N | $92.18^0$E |
| **9** | ETNA | PWD, Sunamganj | $25.07^0$N | $91.32^0$E |
| **10** | ETNA | PWD, Sylhet | $25.15^0$N | $91.25^0$E |
| **11** | ETNA | PWD, B.Baria | $23.92^0$N | $91.25^0$E |
| **12** | ETNA | PWD, Moulvibazar | $24.35^0$N | $91.72^0$E |
| **13** | ETNA | Koroytoli Deepo, Haluaghat | $22.45^0$N | $92.18^0$E |
| **14** | ETNA | PWD, Sherpur | $25.15^0$N | $90.12^0$E |
| **15** | ETNA | PWD, Netokona | $24.72^0$N | $90.65^0$E |
| **15** | ETNA | PWD, Kishoreganj | $24.35^0$N | $90.92^0$E |
| **16** | ETNA | PWD, Satkhira | $25.35^0$N | $88.12^0$E |
| **17** | ETNA | PWD, Meherpur | $23.75^0$N | $88.62^0$E |
| **18** | ETNA | Atomic E. C. Rooppur-Pabna | $23.42^0$N | $88.75^0$E |
| **19** | ETNA | PWD, Rangpur | $25.80^0$N | $89.20^0$E |
| **20** | ETNA | PWD, Lalmonirhat | $25.90^0$N | $89.35^0$E |
| **21** | ETNA | PWD, Kurigram | $25.60^0$N | $89.80^0$E |
| **22** | ETNA | PWD, Panchagarh | $26.15^0$N | $88.25^0$E |
| **23** | ETNA | PWD, Meherpur | $23.25^0$N | $88.62^0$E |
| **24** | ETNA | LGED-Gazipur | $23.75^0$N | $90.85^0$E |

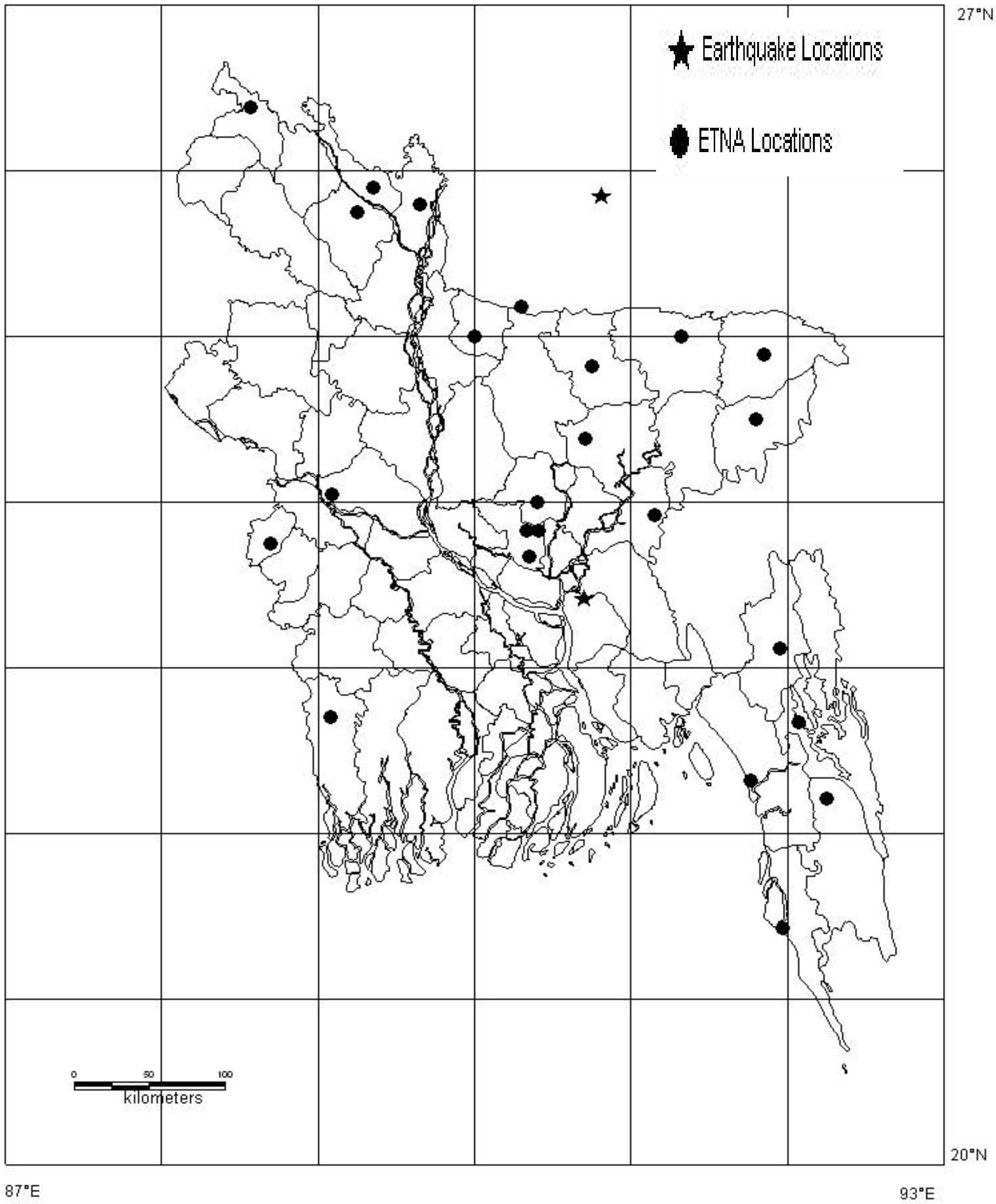



**Figure 2. Location of ETNAs**

### 3.3 System Testing

After the sensors are connected, they have to go through the Functionality Test done with the operating software. Then they have to be corrected for any offsets in the readings. Once all of these are done for each of the sensors, the system is ready. It has been tested to see if data from all the channels are reaching the recorders and whether they are set at real time through GPS. The GPS are set at UTC time as stated in the original documents. The system is such that each of the sensors can be configured separately, but they are kept the same at the beginning. Each sensor can be set to trigger the whole system. The trigger value for the twenty four free-field ground accelerometers was set at 0.25% of 2g (5 cm/sec$^2$). Whenever the acceleration exceeds the trigger value, automatic data recording will take place.

### 3.4 Software Installation

There are some custom-made softwares that came with the instruments to operate and monitor the whole system. One can also interact with the instruments (i.e., K2s) using the software called Quick Talk and changes the settings. Quick Talk and Quick Look may also be used for downloading or viewing the incoming data without any processing.

To process, analyze and interpret the data, the software called Strong Motion Analyzer (SMA) is used. One can perform necessary filtering, corrections and plotting of the signals received from the sensor.

All the softwares are installed at the server at the Data Control Center and they are used during the initial checks of the system. For analysis and processing of data, the software SMA has been later installed in the data analysis computer.

## 4. Recorded Accelerometer Data

After installation has been completed in May 2010, acceleration data of two earthquakes have been recorded by the installed accelerometers. All the data recorded during these two earthquakes are presented in **Appendix-A**.

### 4.1 September 10, 2010: Chandpur Earthquake

On September 10, 2010 Chandpur Earthquake has been recorded by the free-field stations Brahmanbaria, Hazicamp and GSB-Segunbagicha at 22:25:50 hrs BST (16:25:50 hrs GMT, September 10, 2010). Magnitude of this earthquake has been 4.6 and depth 25 Km. Maximum acceleration of this earthquake is at Hazicamp. The PGA value is 10.83 cm/sec$^2$ in East-West direction.

### 4.2 September 11, 2010: Assam Earthquake (Meghaloy)

On September 11, 2008 Assam Earthquake has been recorded by the free-field stations Kurigram, Panchagarh, Bogra, Natore and Sherpur at 10:42:55 hrs BST (04:42:55 hrs GMT, September 10, 2010). Magnitude of this earthquake has been 4.7 and depth 33 Km. Maximum acceleration of this earthquake is at Kurigram. The PGA value is 18.08 cm/sec$^2$ in North-South direction.

## 5. Conclusions and Recommendations

The Seismic Instrumentation Project has entered a very significant stage with the setup and operation of the digital seismic instruments. It is hoped that with the necessary adjustments done in time, the system will yield valuable data to the local researchers to have better ideas on the performance of the bridges and free-field stations as well as seismic activities of the whole region. For the next few years we need to record such earthquake data to develop the attenuation law for Bangladesh. This attenuation law will help us to develop the seismic zonation map for Bangladesh.

**Acknowledgement**
The fund obtained for undertaking the work from CASR, BUET is gratefully acknowledged.

# APPENDIX-A

# TIME HISTORY RECORDED BY THE FREE-FIELD STATIONS DURING CHANDPUR AND MEGHALOY EARTHQUAKES

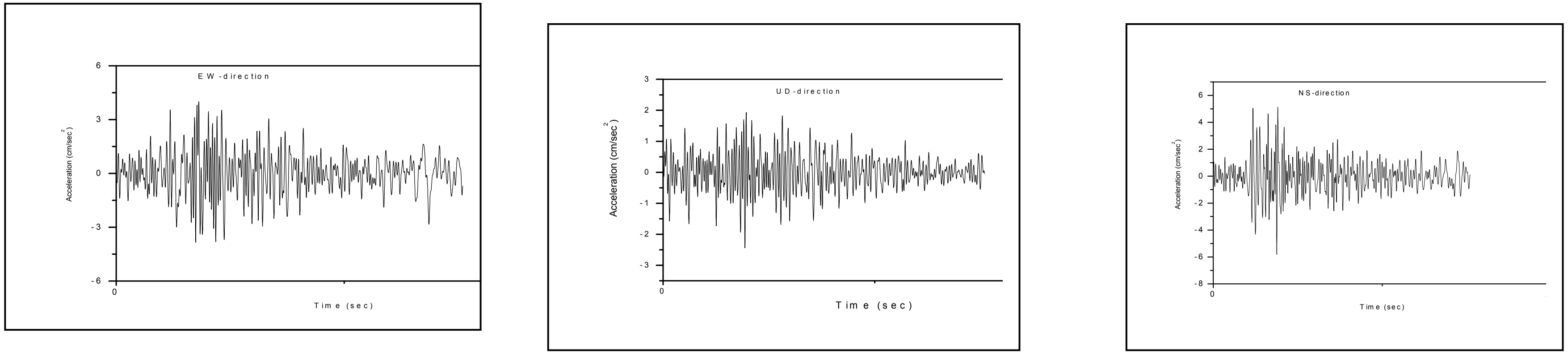



**Figure A1. Time history of Brahmanbaria free-field station during the Chandpur Earthquake of September 10, 2010**

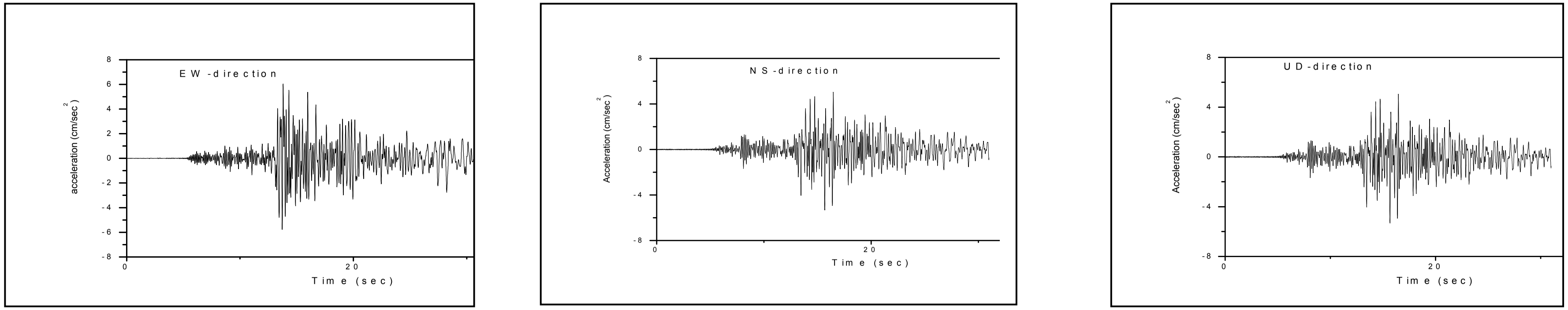



**Figure A2. Time history of GSB-Dhaka free-field station during the Chandpur Earthquake of September 10, 2010**

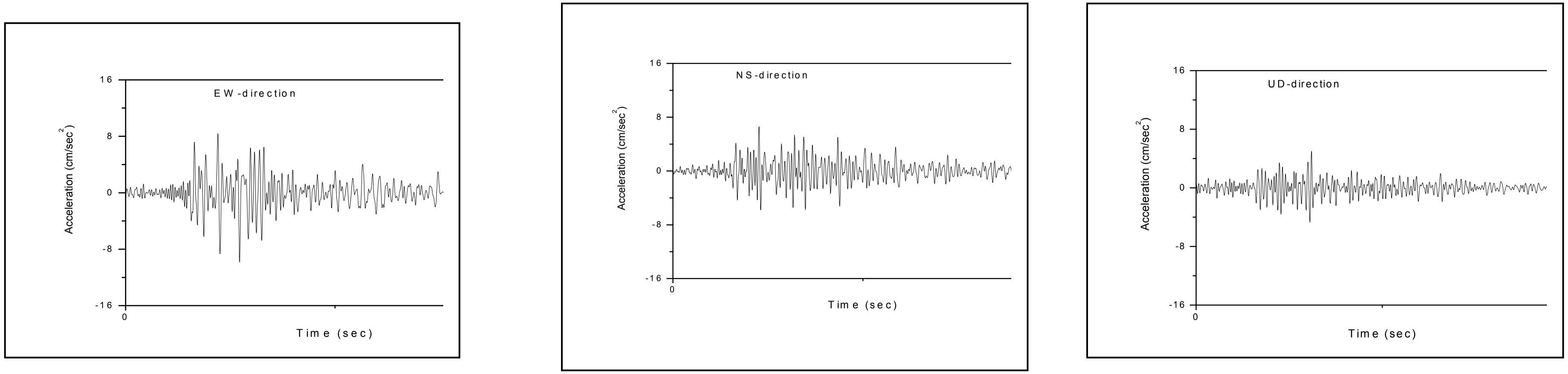



Figure A3. Time history of Hazicamp free-field station during the Chandpur Earthquake of September 10, 2010

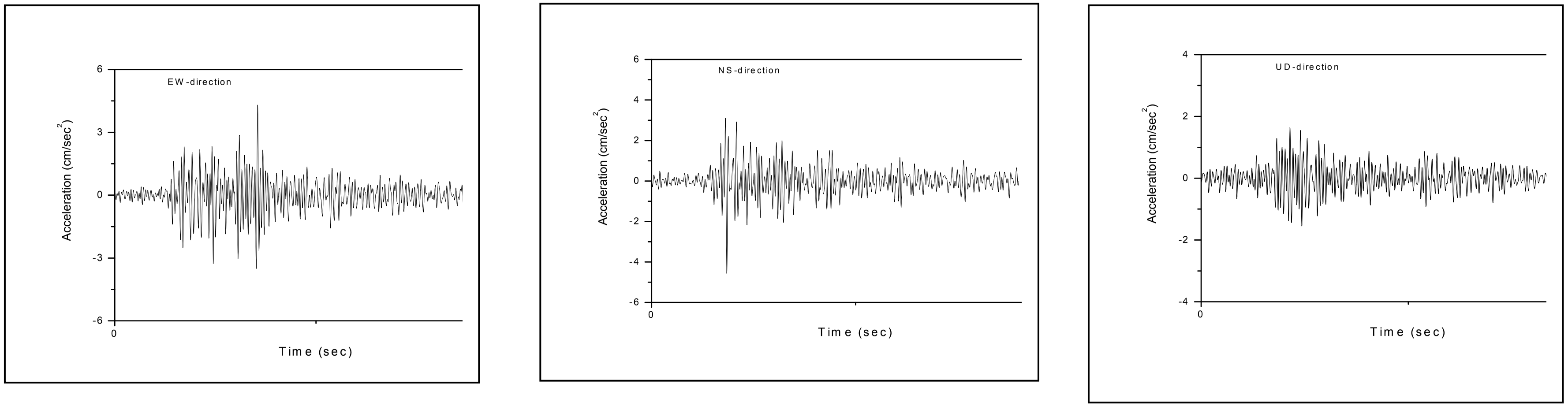



Figure A4. Time history of Sherpur free-field station during the Meghaloy Earthquake of September 11, 2010

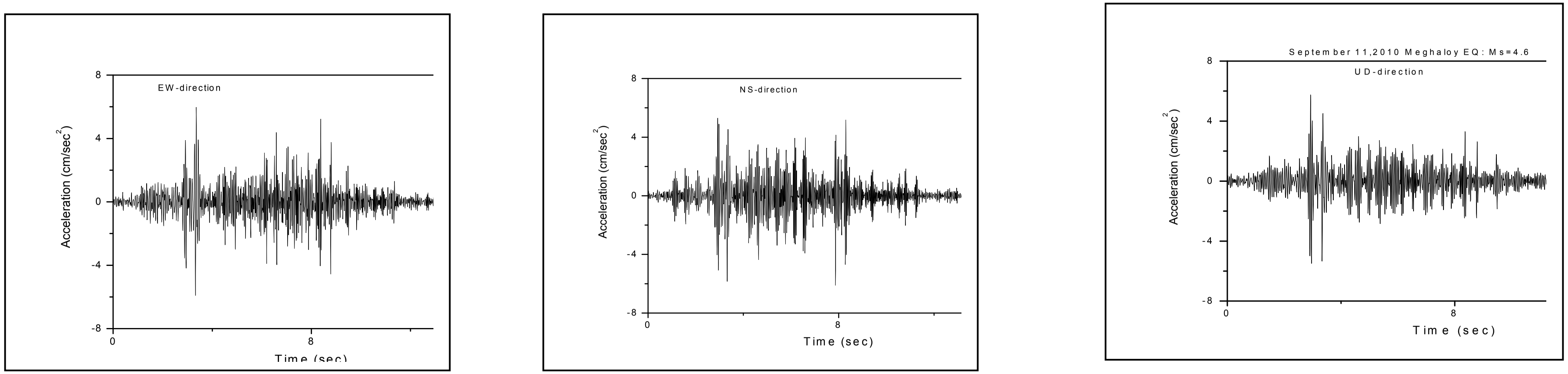



**Figure A5. Time history of Panchagarh free-field station during the Meghaloy Earthquake of September 11, 2010**

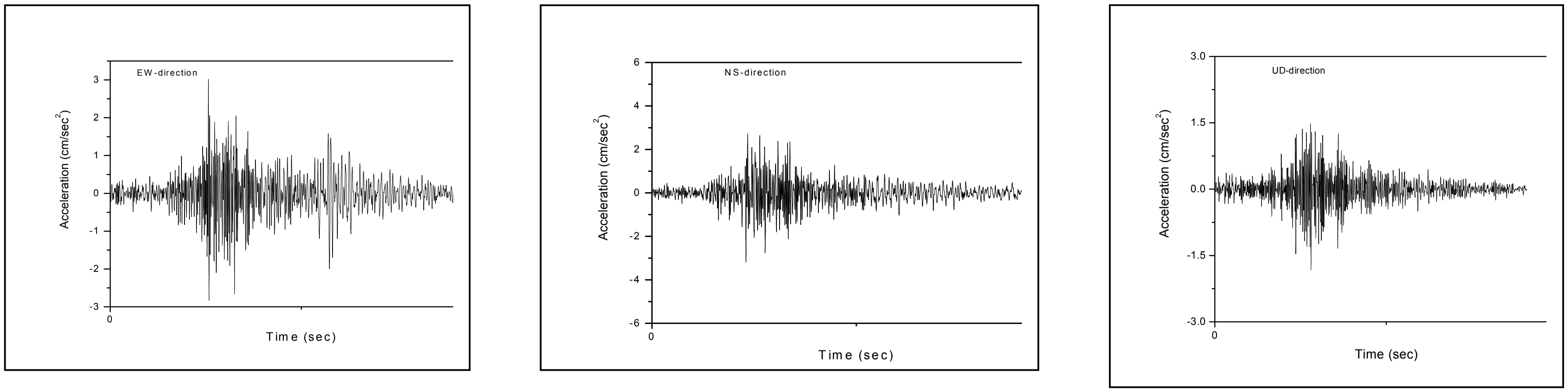



**Figure A6. Time history of Natore free-field station during the Meghaloy Earthquake of September 11, 2010**

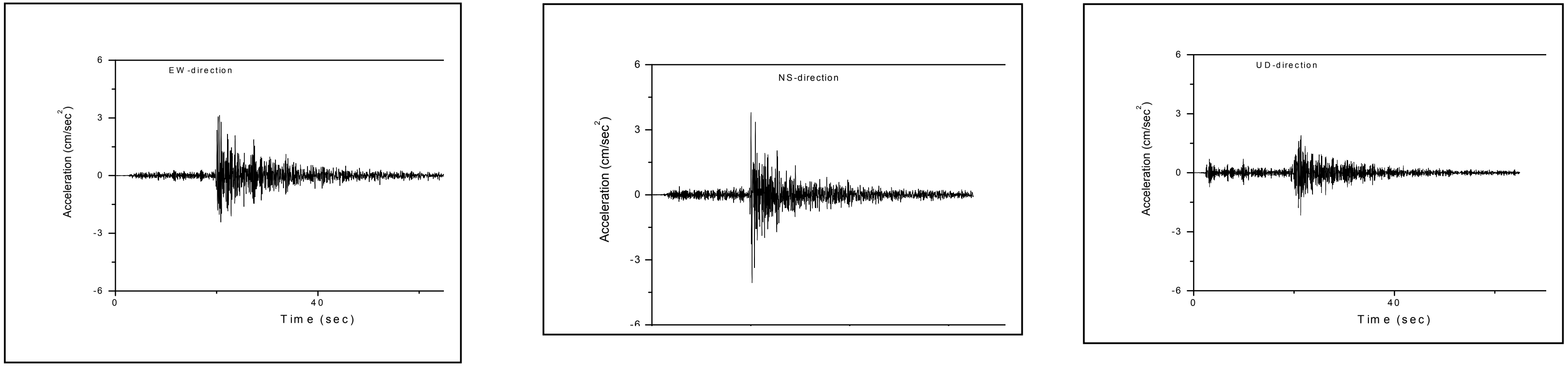



Figure A7. Time history of Bogra free-field station during the Meghaloy Earthquake of September 11, 2010

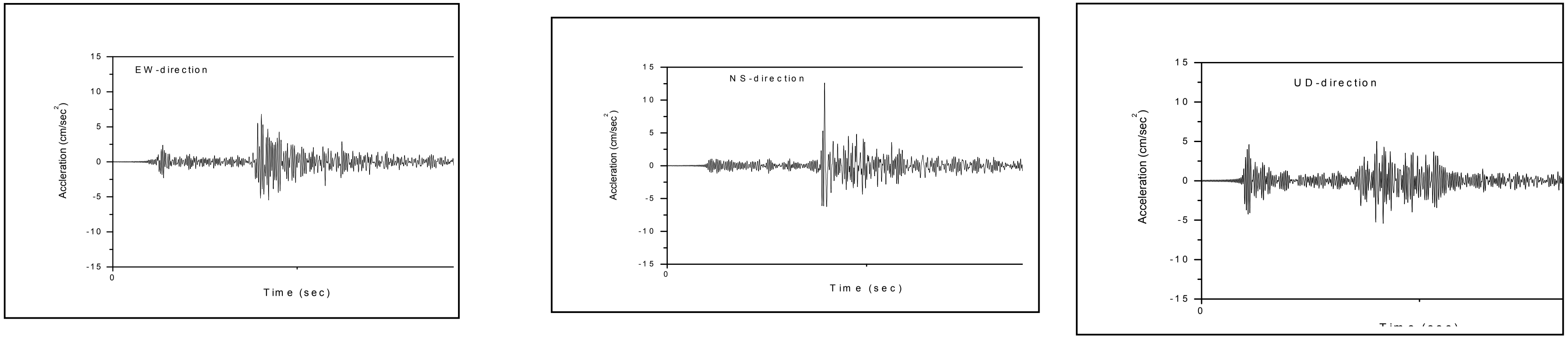



Figure A8. Time history of Kurigram free-field station during the Meghaloy Earthquake of September 11, 2010

# PART-VI

# CHARACTERISTICS OF MICROTREMOR FOR A 110 MW POWER PLANT IN SOUTH WESTERN REGION OF BANGLADESH

**BANGLADESH NETWORK OFFICE FOR URBAN SAFETY (BNUS), BUET, DHAKA**

**Prepared By: Ram Krishna Mazumder**

**Mehedi Ahmed Ansary**

## 1. INTRODUCTION

In areas of low or moderate seismic activity, the effects of possible large earthquakes are usually explored through earthquake scenarios. One of the main parameters controlling the possible consequences of strong events is the ability of the structure to resist to the ground motion. Aim of this study is to obtain the characteristics of microtremor for the power plant at different conditions.

Microtremor is used to record the fundamental frequency and period of the structure and soil. The dynamic properties are the important factor for seismic design. Response of structure mainly depends on the characteristics of both excitation forces and dynamic properties of structures. This is why the natural frequency and period is taken on the basement, cement concrete floor to identify the dynamic properties of structures. The vibration characteristics in soil are different to structure. Hard soil gives high frequency and soft soil gives low frequency [4]. A structure may experience a vibration period at which it oscillates in the earthquake vibration motion and will tend to response to that. Natural frequency of structure is obtained based on the spectral characteristics of horizontal component of the structure to that of ground.

First Fourier Transform (FFT) of foundation, concrete floor and free-field are similar during the full vibration of the machine load and zero vibration consideration for the power plant.

## 2. STUDY AREA

The studied power plant has the capacity of 110 MW is situated near the bank of Padma River, south western part of Bangladesh. The plant was established in 2010. There have total 14 machines to generate the power. The study was considered during the full vibration (four machines running at a time) to compare the results with the machines at rest. Fig 1 shows the study area.


Fig 1: Study area of the microtremor.

3. MICROTREMOR OBSERVATION

Soil characteristics can be assessed by Microtremor measurement. Hard soil gives high frequency and soft soil gives low frequency. A structure may experience a vibration period at which it oscillates in the earthquake vibration motion and will tend to response to that. Natural frequency of structure is obtained based on the spectral ration of horizontal component of the structure to that of ground. Wave propagation mechanism of Microtremor and its relation with ground vibration characteristics were studied from the beginning of Microtremor studies [4], [6].

Basically there are two types of Microtremor observations to the number of observation points. These are point and array observations of microtremors [5]. From the array observation of Microtremor of period greater than 1 sec, Rayleigh-wave and Love-wave originating from natural sources, such as sea wave, variation of air and wind pressure can be recognized. On the other hand, short-period Microtremor of period less than 1 sec is thought to be generated by artificial noises such as traffic vehicles, industrial plants, household appliances, etc. Some researches [3], [2] have showed that microtremors are mainly composed of Rayleigh-wave and some researchers [7] have showed that short-period Microtremor bears resemblance to shear-wave characteristics. On the other hand, Microtremor can also be dominated by Love–wave [1]. Recently, Suzuki et al. (1995) have applied Microtremor measurements to the estimation of earthquake ground motions based on a hypothesis that the amplitude ratio defined by Nakamura can be regarded identical with half of the amplification factor from bedrock to the ground surface. However, the real generation and nature of microtremors have not yet been established.

In general, the approaches to the identification the dynamic properties of structure can be categorized into three main approaches: (1) empirical, (2) numerical analysis, and (3) direct measurement approaches. The empirical approach provides simplified formulas for estimating the fundamental periods of structures in terms of geometric dimensions of the structures. The second approach, the numerical analysis, is normally used during the design process. A finite model of the structure is first formulated. Dynamic properties such as natural frequencies and vibration mode shapes are obtained by the Eigen analysis. The third approach is the direct measurement approach, which first measures dynamic responses of existing structures, and then identifies their dynamic properties from the measured responses.

4. SOIL DATA

For this site, Standard Penetration Test was performed for 18 bore holes. These are obtained from subsoil investigation. Typical boreholes are shown in Fig 2. This 110 MW power plant is constructed on pile foundation.

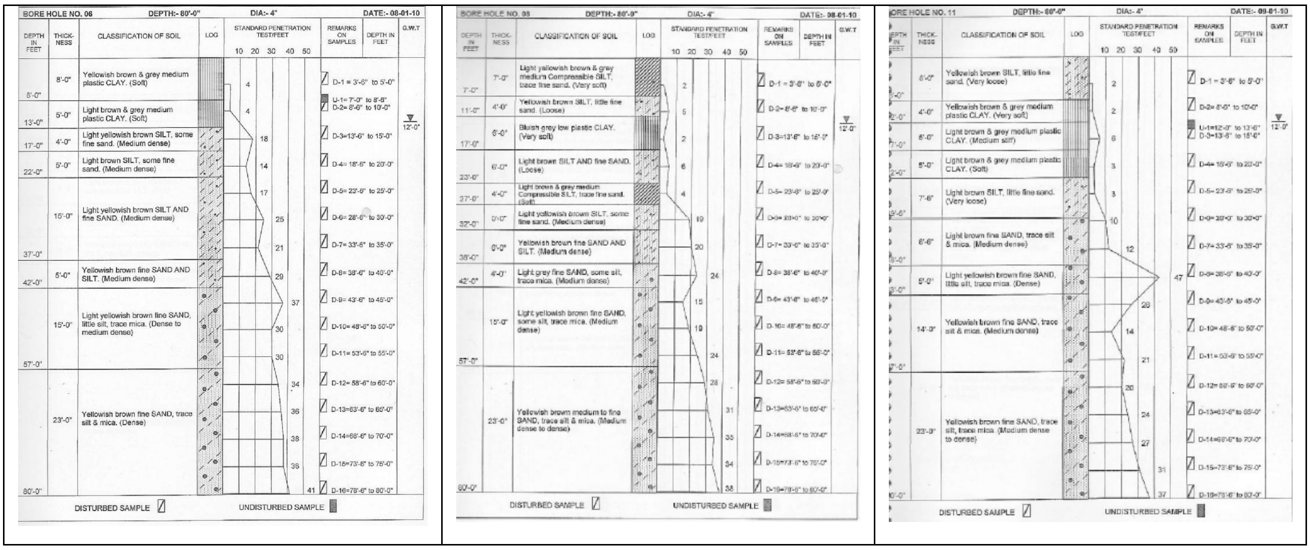


Fig 2: Measured subsoil SPT values for three bore holes.

In general, the top several feet of soil consists of yellowish brown silt with fine sand, the next layer contains medium plastic clay and the bottom layer consists of thick medium dense to dense yellowish brown fine sand.

5. DATA COLLECTION AND PROCESSING

For Microtremor observation at the power plant, initially the sensors are deployed. One sensor is fixed on the machine basement, one on the free field near the structure and another on concrete floor as shown in Fig 3. At first data was recorded during the machines running at full load, then data was recorded when all machines were in rest. After taking the observation with the help of microtremor program the time domain velocity data is converted to frequency domain data and find out the natural period of the structures were found. Microtremor measurement is shown below in Fig 4. Around the investigated structure three 3-dimensional accelerometers are assembled to measure the ground response of the ambient excitation.

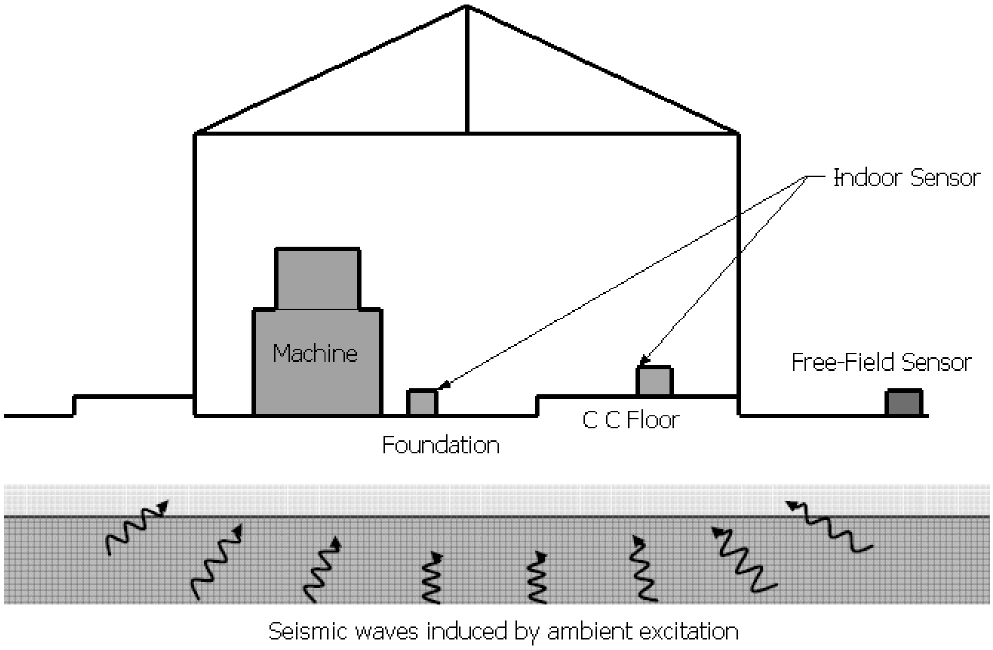



Fig 3: Instrument for ambient vibration measurement

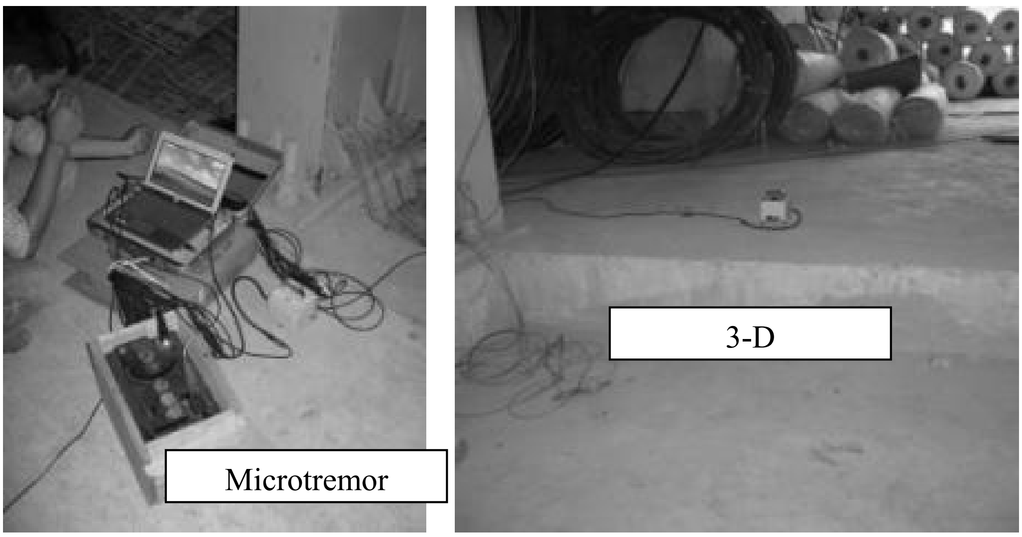



Fig 4: Microtremor data observation

The computation steps of the spectrum analysis is shown in Fig 5 and described as follows:

- Pre-Processing:

- 3-dimensional input (the accelerometer in northward direction to get North-South, East-West and vertical components)
- Windowing of the signal (in our case only the ambient parts are of interest, observe, in case of transient excitation only the transient parts of the time response are of interest)

- Main Data-Processing:

Hence the three different components of the signal were considered separately. The main data processing is repeated for every input-signal (n-Steps according to the numbers of preliminary separated windows).
- FFT is applied to obtain the several spectral amplitudes of the three components
- Smoothing of the three spectral amplitudes with a bandwidth factor of 15
- Afterwards the resulting horizontal component and vertical component are plotted to obtain the amplitude in frequency domain

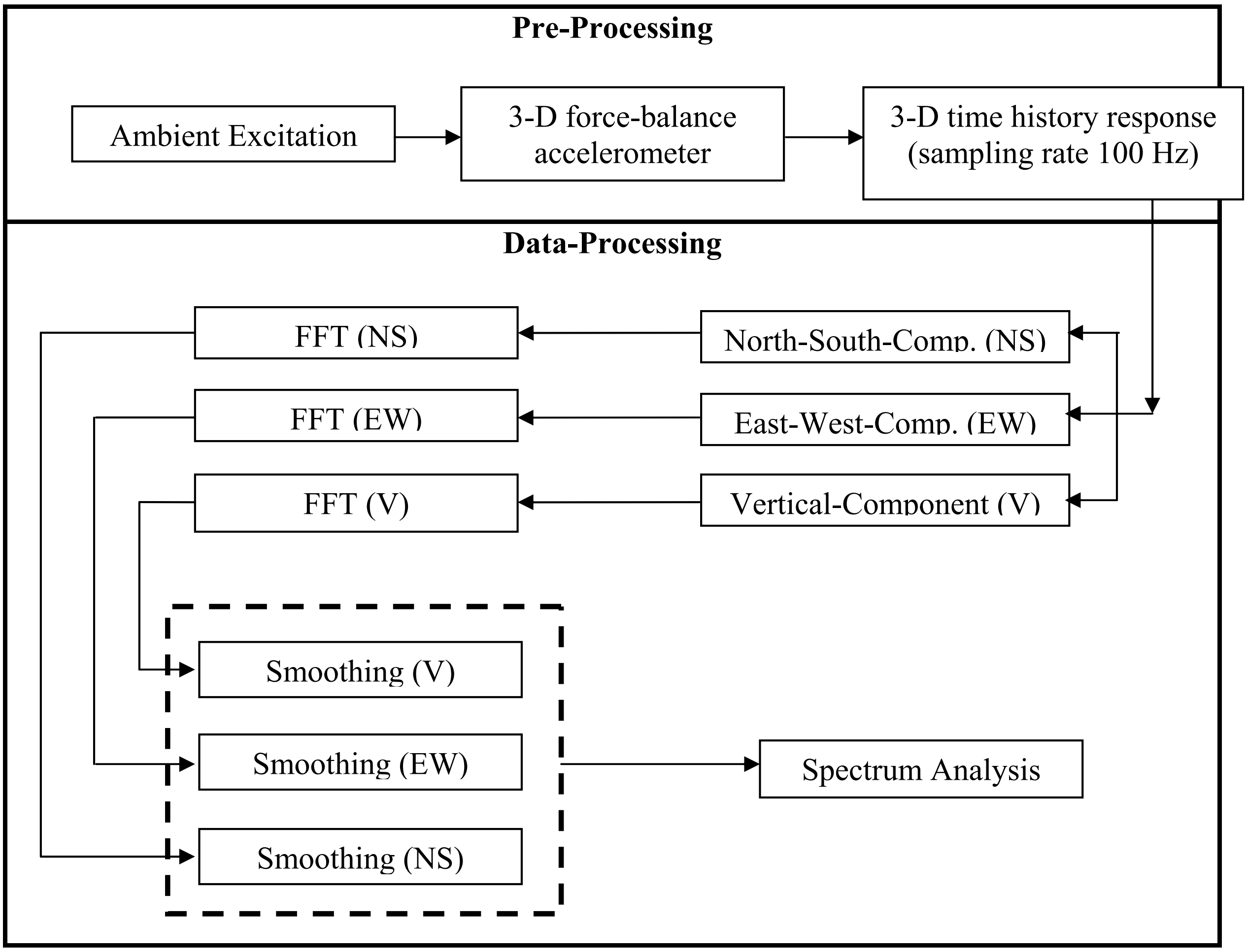
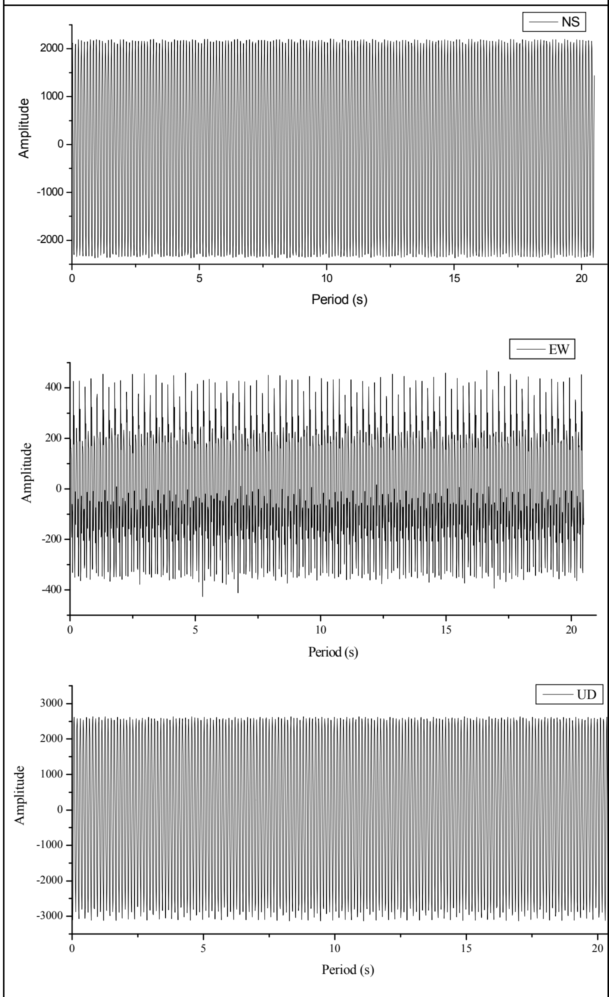
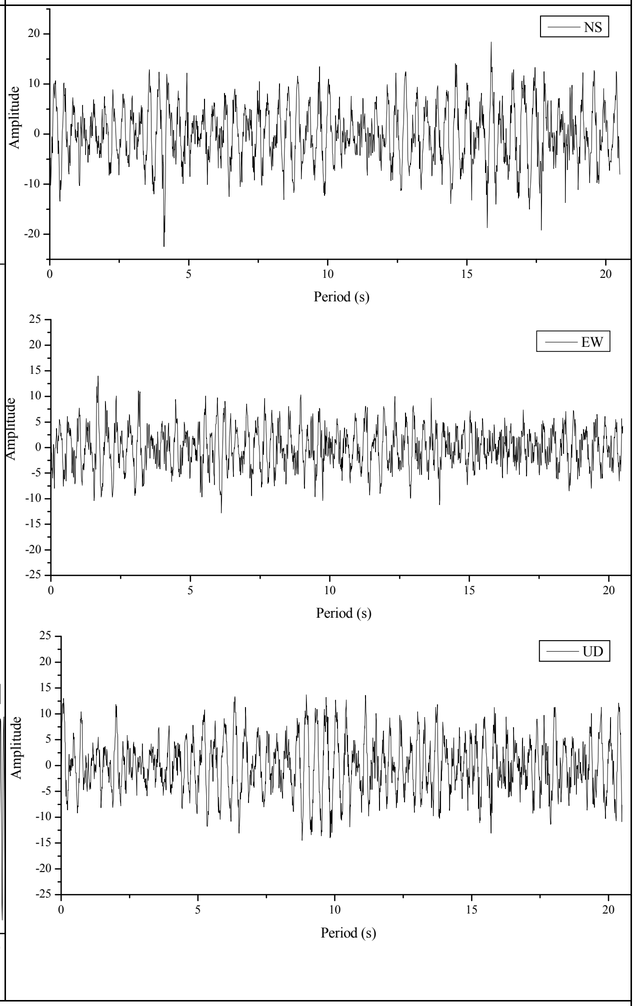
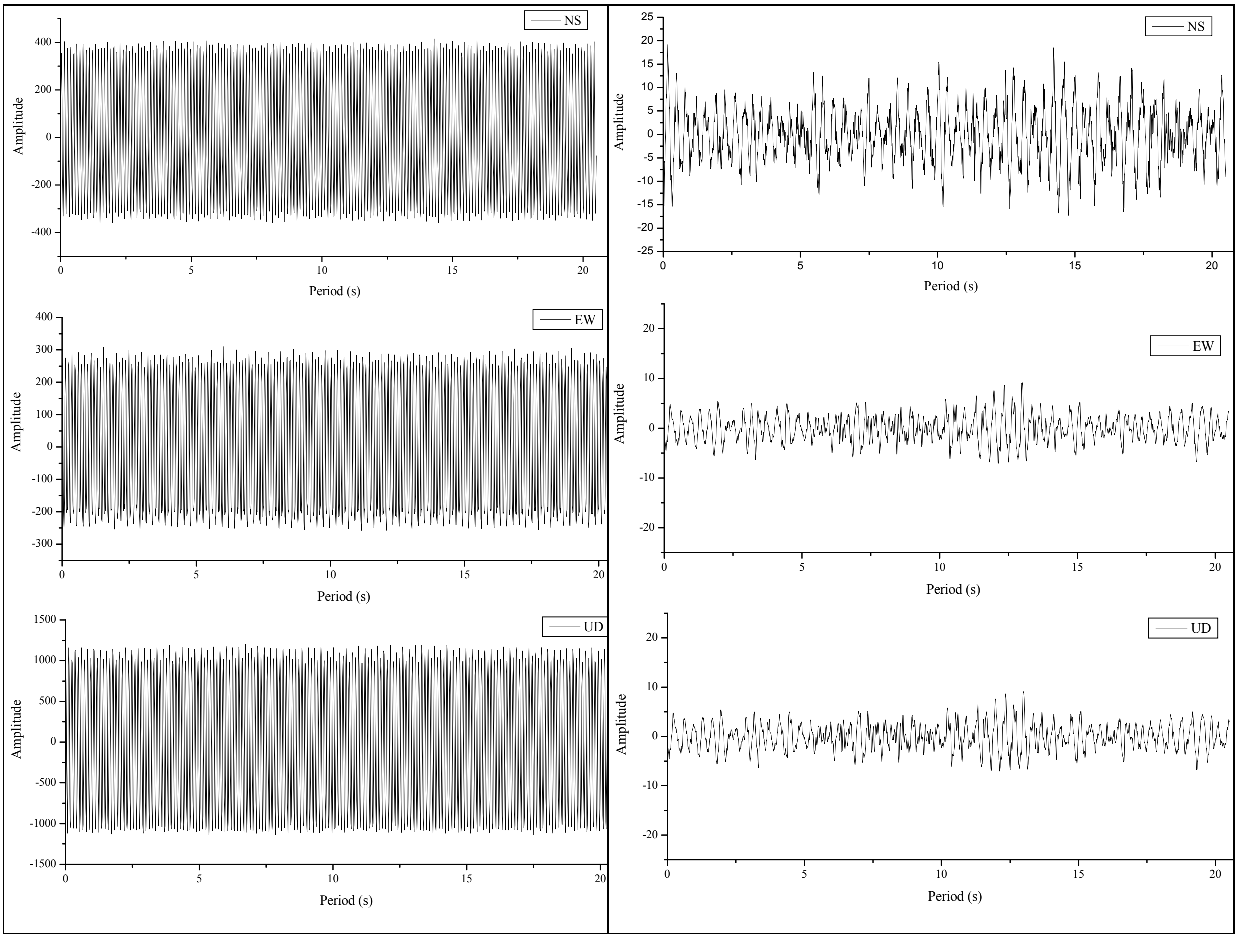


Fig 5: Flowchart of data processing

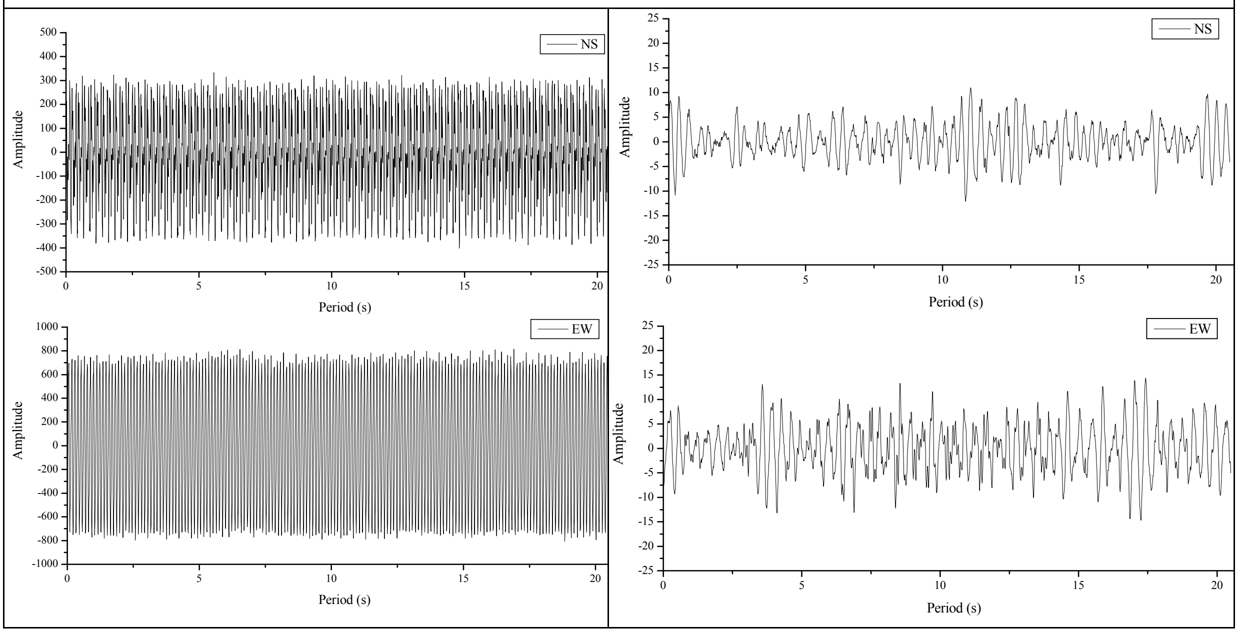
## 6. RESULTS

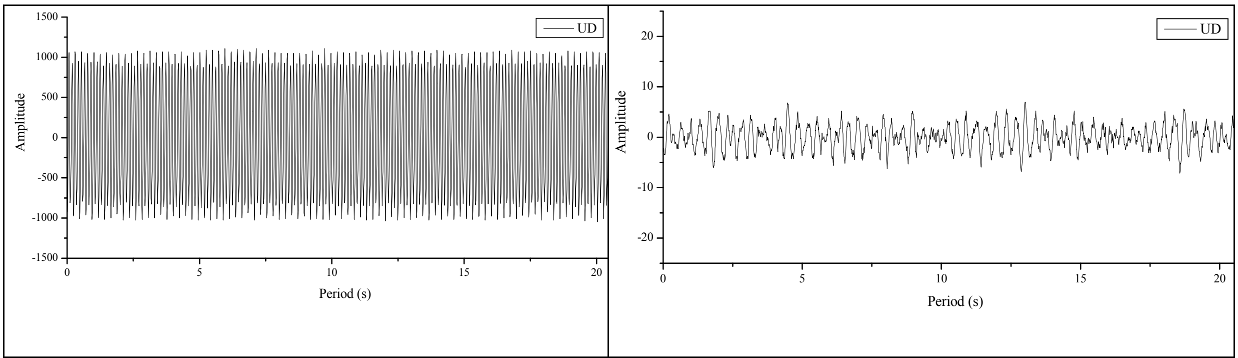
Fig 6 shows individual time histories for North-South, East-West and Up-Down components for free-field, concrete floor and machine foundation. Fig 7 shows FFT of those time histories. In this site, separation between machine foundation and surrounding soil is essential but no separation has been kept. This can be seen from Fig 7. As for fully loaded condition, predominant frequency is 8 Hz at all locations; Machine base has high amplitude, but on concrete floor and ground level amplitude decreased. With zero load, frequency is 3 Hz; but amplitude was 100 times lower than fully loaded condition. All amplitude is presented in micrometer.

| Machine running with full load | Machine at rest |
|---|---|
|  |  |
| 3-D accelerometer on machine basement | |



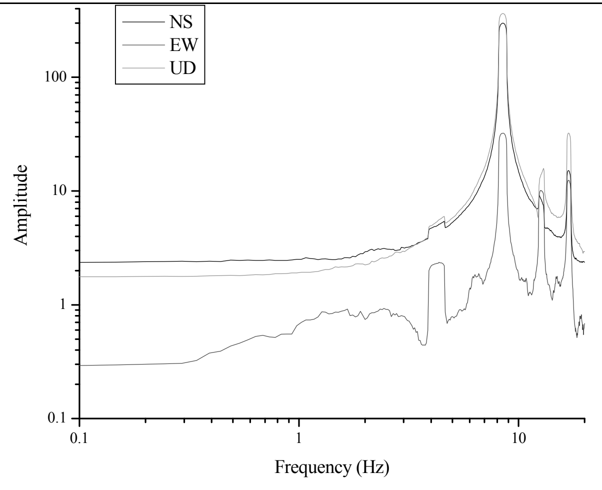
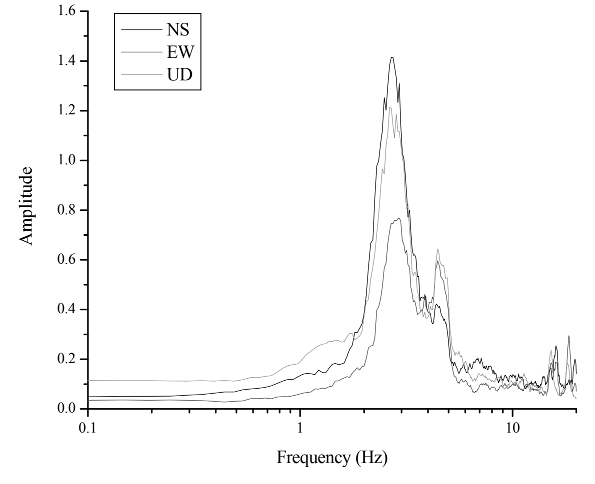

3-D accelerometer on concrete floor






3-D accelerometer on free-field

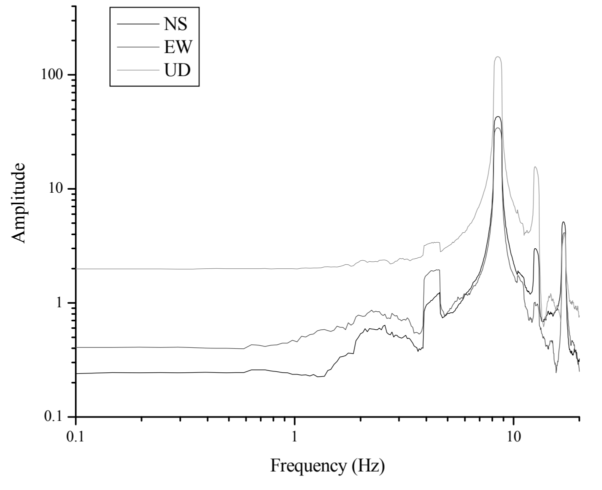
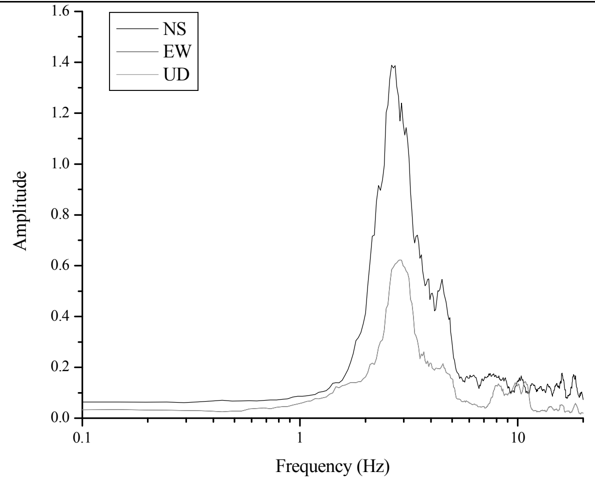
Fig 6: Time history data at different conditions and at different locations.

| Machine running with full load | Machine at rest |
|---|---|
|  |  |





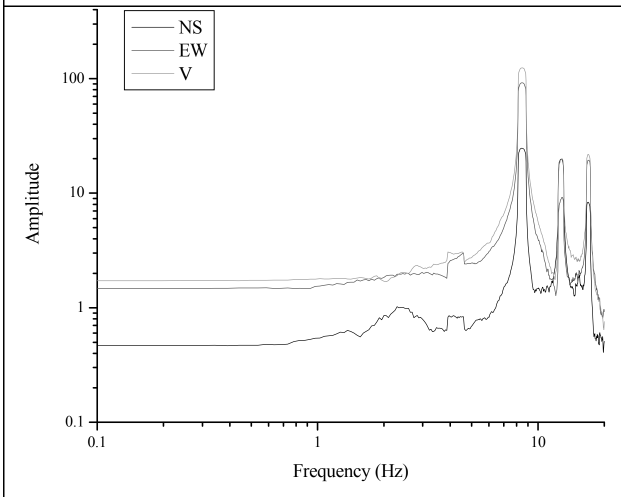
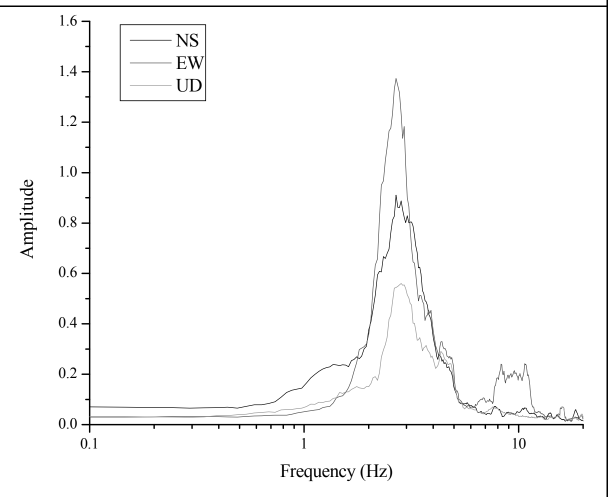
3-D accelerometer on machine basement

| | |
|---|---|
|  |  |





3-D accelerometer on concrete floor

| | |
|---|---|
|  |  |





3-D accelerometer on soil

Fig 7: Smoothed data of horizontal and vertical Fourier spectra of microtremors.

7. CONCLUSION

This paper summarizes the microtremor observations at different locations of the power station. Microtremor observations have been made on machine foundation, concrete floor and free-field for 10 minute. The reading has been repeated for two times to check the stability of the acquired data. From observation, no separation has been found between machine foundation and surrounding soil. For fully loaded condition, predominant frequency is 8 Hz at all locations; Machine base has high amplitude, but on concrete floor and ground level amplitude decreased. For machine at rest, amplitude was 100 times lower than fully loaded condition with frequency 3 Hz.

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BANGLADESH NETWORK
OFFICE FOR URBAN SAFETY

# PART-VII

# SEISMIC VULNERABILITY ASSESSMENT OF EDUCATIONAL BUILDINGS IN OLD DHAKA

## BANGLADESH NETWORK OFFICE FOR URBAN SAFETY (BNUS), BUET, DHAKA

**Prepared By: Ram Krishna Mazumder**

**Mehedi Ahmed Ansary**

## Introduction

This report is prepared by Bangladesh Network Office for Urban Safety (BNUS) as part of the qualitative earthquake vulnerability assessment of educational buildings in Wari, located at ward no. 74. The report describes the method and findings of the assessment, which was done in October 2010. Recommendations are provided for improving seismic performance of the assessed buildings.

This report is based on the methodology described in Section 2 and best engineering judgment arrived at from the site visit, review of available architectural drawings, and non-destructive test carried out at site. All possible efforts have been made to provide accurate and authoritative seismic vulnerability assessment of the building in the given circumstances of information provided by the client and limited number of field-tests. Therefore, neither BNUS nor any of its employees make any warranty, expressed or implied, nor assumes any responsibility for the accuracy, completeness, or usefulness of the statement made in this report in case the starting information does not stand correct.

The seismic evaluation process generally consists of two phases. The first phase is qualitative method to identify the seismic deficiency of the building. The evaluation involves a set of checklist and identifies areas of potential weakness in the building. If seismic deficiency of the building is not up to the acceptable level either second phases or demolition is recommended. The second phase involves the details seismic evaluation followed by design for seismic strengthening measures as modifications to correct or reduce seismic deficiency identified during the evaluation procedure in first phase, this is known as retrofitting of the building. This report is divided into three chapters.

Chapter one begins with introductions, objective, scope, methodology and limitations; Chapter two outlines the data collection, assessment methodology, and survey findings. Chapter three presents the summary and recommendations.

In addition, this report also includes ten annexes that provide supporting information on issues discussed in the main report. These include details of intensity scale, damage grade of the building, rapid visual screening, Turkish vulnerability score, building drawings, Non-destructive testing and photographs.

**Objective**

The main objective of the task is to evaluate the seismic safety of the proposed school building with recommendations for increasing the seismic safety of the building.

**Scope of Work**

The scope of the work for assessment is as follows:

i. Prepare as-built drawings of the building
ii. Conduct a survey to determine the structural characteristics of the building
iii. Assess the structural and non-structural earthquake vulnerability of the building by qualitative method
iv. Prepare the report explaining procedures and presenting findings and recommendation

**Overall Methodology**

The overall methodology adopted for this study is as follows:

i. Reconnaissance of building structure
ii. Identification of building typology based on construction materials and structural systems
iii. Detailed visual survey of building which includes:
    - Identification of strengths and deficiencies
    - Identification of structural vulnerability factors: Plan and vertical irregularities, vertical load path, configuration problems, lateral force resisting system, material deterioration etc
iv. Evaluation of general earthquake performance of the building. The building performance is evaluated based on the available fragility.
v. Summarization of findings and recommendation

The detailed description of each methodology for seismic vulnerability assessment is given in the respective chapter.

**Limitations**

No specific details could be collected from the people involved in the design and construction of the building. Hence, review of available drawings, visual inspection and nondestructive tests were carried out to determine the building details and educated guess was done to determine the expected performance of the building.

Effects of secondary or collateral hazards such as liquefaction, soil spreading, fire is not considered during the study.

## Assessment of the Buildings

Qualitative and some quantitative structural assessment of the building are done based on visual observation and review of drawings, design details observed at site during field visit. Different seismic vulnerability factors are checked and expected performance of the building is estimated for different intensities earthquakes. Different steps of the assessment process and their outcomes are described in this section.

**Descriptions of the schools**

**A.** Siverdale Preparatory and Girls High School is located in ward no. 74 of Dhaka City Corporation area. The street is named Rankin Street in Wari. It was established in 1985. It has around 1500 students.

**B.** Wari Girls Govt. Primary School is located in ward no. 77 of Dhaka City Corporation area. It was established on 2002. It has around 200 students. The school has a single main block

**C.** Salim Ullah Degree College is located at Rankin Street in Wari, Dhaka. Age of the buildings is less than 30 years. It has around 1500 students. The school has two blocks. One is administration office and another is academic building. Academic building was investigated.

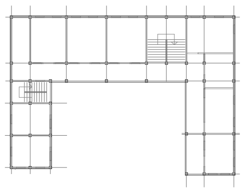
**D.** Graduate High School is located in ward no. 77 of Dhaka City Corporation area. It was established on 1985. It has around 400 students. The school has a single main block.

| | | |
|---|---|---|
|  |  |  |
| **A** | **B** | **C** and **D**(left) |

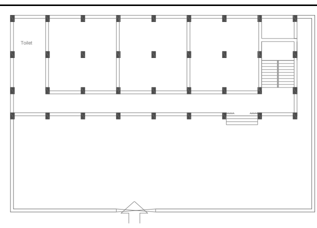
Figure1: Location of School Building.

**Descriptions of the buildings**

**A.** Following are the descriptions of the buildings based on prepared architectural drawing and site observations. Site visit to the building was made on 30 October, 2010.

| | | |
|---|---|---|
| Owner | - |  |
| Location | Wari, Dhaka | |
| G.P.S | - | |
| Terrain Type | Flat | |
| Age of Building | About 25 years | |
| No of Stories | 5 storey | |
| Plan configuration | Irregular | |
| Vertical Configuration | Regular | Perspective view |
| Position of the building block | Free Standing |  |
| Building Typology | RC | |
| Mortar Type | Cement mortar. | |
| Total Plinth Area | 2600 Sq. ft | |
| Exterior Wall Thickness | 5 inch. | |
| Interior Wall Thickness | 5 inch. | |
| Foundation | Not Known | |
| Roof structure | RCC | |
| Roof Shape | Flat | Building Plan |
| Designed and Supervised of the Building | Not Known | |
| Earthquake-Resistant Element | No | |
| Local hazard | Earthquake, Fire. | |
| Building Condition | Average | |

**B.** Following are the descriptions of the buildings based on prepared architectural drawing and site observations. Site visit to the building was made on 31 October, 2010.

| | | |
|---|---|---|
| Owner | - |  |
| Location | Wari, Dhaka | |
| G.P.S | - | |
| Terrain Type | Flat | |
| Age of Building | 8 years | |
| No of Stories | 2storey | |
| Plan configuration | Regular | |
| Vertical Configuration | Regular | Perspective view |
| Position of the building block | Free Standing |  |
| Building Typology | RC | |
| Mortar Type | Cement mortar. | |
| Exterior Wall Thickness | 5 inch. | |
| Interior Wall Thickness | 5 inch. | |
| Foundation | Not Known | |

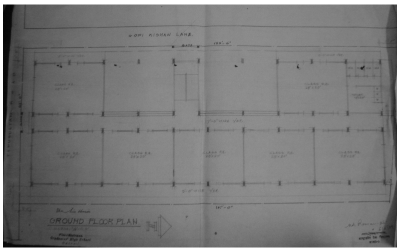
| | | |
|---|---|---|
| Roof structure | RCC | |
| Roof Shape | Flat | Building Plan |
| Designed and Supervised of the Building | Not Known | |
| Earthquake-Resistant Element | No | |
| Local hazard | Earthquake, Fire. | |
| Building Condition | Average | |

**C.** Following are the descriptions of the buildings based on prepared architectural drawing and site observations. Site visit to the building was made on 31 October, 2010.

| | | |
|---|---|---|
| Owner | - |  |
| Location | Wari, Dhaka | |
| G.P.S | - | |
| Terrain Type | Flat | |
| Age of Building | Less than 30 years | |
| No of Stories | 3storey | |
| Plan configuration | Regular | |
| Vertical Configuration | Regular | Perspective view |
| Position of the building block | Free Standing | |
| Building Typology | Mixed (RC and URM) | |
| Mortar Type | Cement mortar. | |
| Exterior Wall Thickness | 5 inch. | |
| Interior Wall Thickness | 5 inch. | |
| Foundation | Not Known | |
| Roof structure | RCC | |
| Roof Shape | Flat | Building Plan |
| Designed and Supervised of the Building | Not Known | |
| Earthquake-Resistant Element | No | |
| Local hazard | Earthquake, Fire. | |
| Building Condition | Good | |

**D.** Following are the descriptions of the buildings based on prepared architectural drawing and site observations. Site visit to the building was made on 31 October, 2010.

| | | |
|---|---|---|
| Owner | - |  |
| Location | Wari, Dhaka | |
| G.P.S | - | |
| Terrain Type | Flat | |
| Age of Building | 25 years | |
| No of Stories | 3storey | |
| Plan configuration | Irregular | |
| Vertical Configuration | Regular | Perspective view |

| | | |
|---|---|---|
| Position of the building block | Free Standing |  |
| Building Typology | RC | |
| Mortar Type | Cement mortar. | |
| Exterior Wall Thickness | 5 inch. | |
| Interior Wall Thickness | 5 inch. | |
| Foundation | Not Known | |
| Roof structure | RCC | |
| Roof Shape | Flat | Building Plan |
| Designed and Supervised of the Building | Not Known | |
| Earthquake-Resistant Element | No | |
| Local hazard | Earthquake, Fire. | |
| Building Condition | Average | |

**Building Typology Identification**

Identification of building typology was determined on the classification of building types in the region as given in the following table 1. From the visual observation and study of the prepared drawings, the buildings were identified as followings:
**Building-A:** Reinforced Concrete Ordinary Moment Resisting Frame (Type 3)
**Building-B:** Reinforced Concrete Ordinary Moment Resisting Frame (Type 3)
**Building-C:** Reinforced Concrete Ordinary Moment Resisting Frame (Type 3) with a portion of Type 2.
**Building-D:** Reinforced Concrete Ordinary Moment Resisting Frame (Type 3)

**Table 1: Buildings Types in the Region**

| **No.** | **Building Types in Region** | **Description** |
|---|---|---|
| 1 | Adobe, stone in mud, brick-in-mud (Low Strength Masonry). | <u>Adobe Buildings:</u> These are buildings constructed in sun-dried bricks (earthen) with mud mortar for the construction of structural walls.<br><u>Stone in Mud:</u> These are stone-masonry buildings constructed using dressed or undressed stones with mud mortar. These types of buildings have generally flexible floors and roof.<br><u>Brick in Mud:</u> These are brick masonry buildings with fired bricks in mud mortar. |
| 2 | Brick in Cement, Stone in Cement | These are brick masonry buildings with fired bricks in cement or lime mortar and stone-masonry buildings using dressed or undressed stones with cement mortar. |
| 3 | Reinforced Concrete Ordinary- | These are buildings with reinforced concrete frames and unreinforced brick masonry infill in cement mortar. The thickness of infill walls is full brick thick or even half brick. |

| | | |
|---|---|---|
| | Moment-Resisting-Frame Buildings | |
| 4 | Reinforced Concrete Intermediate-Moment-Resisting-Frame Buildings | These buildings consist of a frame assembly of cast-in-place concrete beams and columns. Floor and roof framing consists of cast-in-place concrete slabs. Lateral forces are resisted by concrete moment frames that develop their stiffness through monolithic beam-column connections. These are engineered buildings designed without earthquake load or with old codes or designed for small earthquake forces. |
| 5 | Reinforced concrete special-moment-resistant-frames (SMRF) | These buildings consist of a frame assembly of cast-in-place concrete beams and columns. Floor and roof framing consists of cast-in-place concrete slabs. Lateral forces are resisted by concrete moment frames that develop their stiffness through monolithic beam-column connections. These buildings have joint reinforcing, closely spaced ties, and special detailing to provide ductile performance. |
| 6 | Others | Mixed buildings like Stone and Adobe, Stone and Brick in Mud, Brick in Mud and Brick in cement etc. are other building. |

**Fragility of the Identified Building Typology**

The fragility or the seismic vulnerability of a building is the possible consequences to the building due to the probable earthquake shaking. The fragility is expressed as the degree of severity of damage (Damage Grade) in a building during different earthquake intensities. Normally, the buildings with similar structural systems and properties behave in similar pattern during the earthquakes. Hence, generalized fragility functions (or curves) are available for different types of building. In Bangladesh case, fragility functions from Nepal, India and Pakistan are utilized and verified with "European Macro-seismic Scale (EMS 98)" *http://www.gfz-potsdam.de/pb5/pb53/projekt/ems/core/ emsacor.htm.* Damage grades of different building typologies in different intensities of earthquakes are extracted from such fragility functions. Such damage grades for the identified Masonry Building, Reinforced Concrete Ordinary Moment Resisting Frame Building and Reinforced Concrete Intermediate Moment Resisting Frame building are given below in Tables 2 and 3 respectively.

The EMS is a unit to measure the intensity of earthquake in a particular area. The EMS is a qualitative measure of the actual shaking at a location during earthquake, and is assigned as Roman Capital Numerals. It ranges from I (least perceptive) to XII (most severe). The intensity scales are based on three features of shaking- perception by people and animals, performance of buildings, and changes to natural surroundings. The detailed description of Intensity Scale is given on ***Annex 1***.

**Table 2: Fragility of the Masonry Building on Brick in Cement Mortar**

| Shaking Intensity (EMS) | | VII | VIII | IX |
|---|---|---|---|---|
| Damage Grades for Different Classes of Buildings | Weak | DG3 | DG4 | DG5 |
| | Average | DG2 | DG3 | DG4 |
| | Good | DG1 | DG2 | DG3 |

Table 2 shows that the weaker buildings of this category get damage degree of four (DG5) at intensity IX where as good buildings of this category will suffer damage degree of two (DG3) at the same intensity. For the detail description of different damage grade of building refer ***Annex 2***.

**Table 3: Fragility of the Reinforced Concrete Ordinary Concrete Moment Resisting Frame**

| Shaking Intensity (EMS) | | VII | VIII | IX |
|---|---|---|---|---|
| Damage Grades for Different Classes of Buildings | Weak | DG2 | DG3 | DG4 |
| | Average | DG1 | DG2 | DG3 |
| | Good | - | DG1 | DG2 |

The Table 3 shows that the weaker buildings of this category get damage degree of four (DG4) at intensity IX where as good buildings of this category will suffer damage degree of two (DG2) at the same intensity. For the detail description of different damage grade of building refer ***Annex 2***.

**Identification of Vulnerability Factors**

The general vulnerability of the building as identified by the use of generalized fragility function needs to be modified based on the influence of different vulnerability factor existing in the building. The different vulnerability factors associated with particular type of building are checked with a set of appropriate checklist from FEMA 310, "Handbook for the Seismic Evaluation of Buildings" and Indian Standard Guidelines for Seismic Evaluation and Strengthening of Existing Buildings. The basic vulnerability factors are building system, plan irregularities, vertical irregularities, lateral force resisting system, connections diaphragms etc. Influence of Different Vulnerability Factors to the Seismic Performance of the Building

Based on the existence of different vulnerability factors as appearing in the surveyed checklist following table (Table 4: Influence of Different Vulnerability Factors to the Building) is completed to evaluate the final influence of different vulnerability factors on the fragility of the building.

**Table 4 : Influence of Different Vulnerability Factors to the Building**

| **Vulnerability Factors** | | Increasing Vulnerability of the Building by different vulnerability factors | | | | |
|---|---|---|---|---|---|---|
| | | **High** | **Medium** | **Low** | **N/A** | **Not known** |
| **Building System** | Number of storey | | | | | |
| | Shape | | | | | |
| | Proportion in plan | | | | | |
| | Opening in wall | | | | | |
| | Position of opening | | | | | |
| | Load Path | | | | | |
| | Adjacent buildings | | | | | |
| | Mezzanines floors | | | | | |
| | Deterioration of concrete | | | | | |
| | Masonry units | | | | | |
| | Masonry joints | | | | | |
| | Cracks in infill walls | | | | | |
| | Unsupported wall length | | | | | |
| **Plan irregularities** | Torsion | | | | | |
| | Diaphragm continuity | | | | | |
| **Vertical irregularities** | Weak storey | | | | | |
| | Soft storey | | | | | |
| | Mass irregularity | | | | | |
| | Vertical geometric | | | | | |
| | Vertical discontinuities | | | | | |
| **Lateral load resisting system** | Redundancy | | | | | |
| | Height to thickness ratio | | | | | |
| | Masonry lay up | | | | | |
| | Vertical reinforcement | | | | | |
| | Horizontal bands | | | | | |
| | Corner stitch | | | | | |
| | Gable band | | | | | |
| | Diagonal bracing | | | | | |
| **Diaphragm** | Diaphragm opening at walls | | | | | |
| | Plan irregularities | | | | | |
| | Diaphragm reinforcement at opening | | | | | |
| **Connections** | Wall anchorage | | | | | |
| | Transfer to walls | | | | | |
| | Lateral restrainers | | | | | |
| **Geologic Site** | Area History | | | | | |
| | Liquefaction | | | | | |
| | Slope Failure | | | | | |
| **Others** | Non Structural Components | | | | | |

**Reinterpretation of the Building Fragility Based on Observed Vulnerability Factors**

The above completed table 4 shows that the influence of different vulnerability factors is critical which makes the building to fall under "Average" category of the building typology. Hence, the assessed building is an ***Average type of Reinforced Concrete Ordinary Concrete Moment Resisting Frame***

**Table 5: Reinterpreted Fragility of the Building**

| ID | Building | | Building Performance (EMS) | | |
|---|---|---|---|---|---|
| | | | VII | VIII | IX |
| A | Main Block | Average | DG1 | DG2 | DG3 |
| B | Main Block | Good | - | DG1 | DG2 |
| C | Main Block | Average | DG1 | DG2 | DG3 |
| D | Main Block | Weak | DG2 | DG3 | DG4 |

***The minimum requirement of the building is to provide life safety for its occupants. It may not provide when the performance of building will be DG4 or DG5 during an earthquake.***

**Probable Performance of the Buildings at Different Intensities**

The performance of the building in terms of vulnerability is given in Table 9 as per the qualitative assessment done above.

**Table 6: Probable performance of the building**

| ID | Building | **Item** | **Performance of the Building** | | |
|---|---|---|---|---|---|
| | | | **EMS = VII** | **EMS =VIII** | **EMS = IX** |
| A | Main Block | Structural Damage | - | Slight | Moderate |
| B | Main Block | Structural Damage | - | Very Low | Slight |
| C | Main Block | Structural Damage | - | Slight | Moderate |
| D | Main Block | Structural Damage | Slight | Moderate | High |

**Rapid Visual Screening**

Rapid visual screening of buildings for potential seismic hazards, as described herein, originated in 1988 with the publication of the FEMA 154 provided a "sidewalk survey" approach that enabled users to classify surveyed buildings into two categories: those acceptable as to risk to life safety or those that may be seismically hazardous and should be evaluated in more detail by a design professional experienced in seismic design.

Fundamentally, the final S score is an estimate of the probability (or chance) that the building will collapse if ground motions occur that equal or exceed the maximum considered earthquake (MCE) ground motions (the current FEMA 310 ground motion specification for detailed seismic evaluation of buildings). These estimates of the score are based on limited observed and analytical data, and the probability of collapse is therefore approximate. For example, a final score of S = 0.2 implies there is a chance of 1 in $10^{0.2}$, or 63% chance that the building will collapse if such ground motions occur. RVS calculation sheet are attached in ***Annex 3***.

**Turkish Vulnerability Score**

Current approaches in seismic vulnerability evaluation methods can be classified in three main groups depending on their level of complexity. The first, most simple level is known as "Walkdown Evaluation." Evaluation in this first level does not require any analysis and its goal is to determine the priority levels of buildings that require immediate intervention. Preliminary assessment methodologies (PAM) are applied when more in-depth evaluation of building stocks is required. In this stage, simplified analysis of the building under investigation is performed based on a variety of methods. These analyses require data on the dimensions of the structural and nonstructural elements in the most critical story. The procedures by FEMA 310 (1998) Tier 2 and Ozcebe et al. (2003), later complemented by Yakut et al. (2003) can be listed as the examples of preliminary survey procedures.

The procedures in third tier employ linear or nonlinear analyses of the building under consideration and require the as-built dimensions and the reinforcement details of all structural elements. The procedures proposed in FEMA 356 (2000), ATC 40 (1996), EUROCODE 8 (2004) and those by Sucuoglu et al. (2004) and Park and Ang (1985) are examples of third level assessment procedures. This report only presents the first two phase seismic vulnerability assessment. Calculation of first two level are attached in ***Annex 4.***

**Table7: Observed Performance Score Assignment**

| Observed Performance | Observed Performance Score |
|---|---|
| None | 100 |
| Light | 80 |
| Moderate | 50 |
| Severe | 0 |

**Non Destructive Testing**

Non destructive testing is a wide group of analysis techniques used to evaluate the material properties, position of materials without causing damage. To identify the steel rebar position in structural component, Hilti PS 200 Ferro scan device is used. Ferro scan Screening results is shown in ***Annex 5.***

## Summary

**To evaluate seismic safety of Silverdale Preparatory and Girls High School at Wari, Dhaka, the study had to base upon various assumptions because of the unavailability of the people involved in design and construction of this building. Tables 8, 9 and 10 present results of the studied building.**

**Table 8: Summary of Seismic Vulnerability Assessment of Building.**

| | | |
|---|---|---|
| Building - A | Building typology | Average type of reinforced concrete ordinary moment resisting frame building. |

| | | | | |
|---|---|---|---|---|
| | Vulnerability Factors to the Building | Discontinuity of beams, strong beam- weak column, Non structural components. | | |
| | Probable structural performance of the building | EMS VII | EMS VIII | EMS IX |
| | | -- | Slight | Moderate |
| Building - B | Building typology | Average type of reinforced concrete ordinary moment resisting frame building. | | |
| | Vulnerability Factors to the Building | Discontinuity of beams, strong beam- weak column, Non structural components. | | |
| | Probable structural performance of the building | EMS VII | EMS VIII | EMS IX |
| | | -- | No | Slight |
| Building - C | Building typology | Average type of reinforced concrete ordinary moment resisting frame building. | | |
| | Vulnerability Factors to the Building | Discontinuity of beams, strong beam- weak column, Non structural components. | | |
| | Probable structural performance of the building | EMS VII | EMS VIII | EMS IX |
| | | - | Slight | Moderate |
| Building - D | Building typology | Average type of reinforced concrete ordinary moment resisting frame building. | | |
| | Vulnerability Factors to the Building | Discontinuity of beams, strong beam- weak column, Non structural components. | | |
| | Probable structural performance of the building | EMS VII | EMS VIII | EMS IX |
| | | Slight | Moderate | High |

**Table 9: Summary of Results.**

| **Check** | Building - A | Building - B | Building - C | Building - D | **Reference** |
|---|---|---|---|---|---|
| Rapid Visual Screening | High | Low | Low | Low | Annex3 |
| Turkish Level 1 | Moderate | None | None | None | Annex4 |
| Turkish Level 2 | Severe | Low | Moderate | Sever | Annex4 |
| Column Bar Spacing & Cover | Not Satisfied | Not Satisfied | - | Not Satisfied | Annex5 |
| Beam Bar Spacing & Cover | Satisfied | Not Satisfied | Satisfied | Not Satisfied | Annex5 |
| Slab Bar Orientation | Satisfied | Not Satisfied | Not Satisfied | Not Satisfied | Annex5 |

**Table 10: General Importance Factor**

| **Item** | Building - A | Building - B | Building - C | Building - D |
|---|---|---|---|---|
| Building Use | Educational | Educational | Educational | Educational |
| Building Age | 25 yrs | 8 yrs | Less than 30 yrs | 25 yrs |

| | | | | |
|---|---|---|---|---|
| Visible Physical Condition | Average | Good | Good | Poor |
| Occupancy | High | Low | High | High |

## Conclusions

**Based on the assessment done above on the basis of the available information about the building, the architectural and structural information from field visit, and implementation of limited number of non-destructive field tests, it be expected that the assessed building is likely to suffer moderate structural damage at large earthquakes of intensity IX.**

**According to Specialist's judgment,** Building A **falls under moderate risk group,** Building B **falls under Low risk group,** Building C **&** Building D **fall under High risk group. For last two buildings, a non-compliance situation observed with respect to the Bangladesh National Building Code that requires; "Structures should be able to resist moderate earthquakes without significant damage"; and "Structures should be able to resist major earthquakes without collapse".**

# Annex 1: Definitions of intensity degrees

## Arrangement of the scale:

a) Effects on humans
b) Effects on objects and on nature (effects on ground and ground failure are dealt with especially in Section 7)
c) Damage to buildings

## Introductory remark:

The single intensity degrees can include the effects of shaking of the respective lower intensity degree(s) also, when these effects are not mentioned explicitly.

**I. Not felt**
a) Not felt, even under the most favourable circumstances.
b) No effect.
c) No damage.

**II. Scarcely felt**
a) The tremor is felt only at isolated instances (<1%) of individuals at rest and in a specially receptive position indoors.
b) No effect.
c) No damage.

**III. Weak**
a) The earthquake is felt indoors by a few. People at rest feel a swaying or light trembling.
b) Hanging objects swing slightly.
c) No damage.

**IV. Largely observed**
a) The earthquake is felt indoors by many and felt outdoors only by very few. A few people are awakened. The level of vibration is not frightening. The vibration is moderate. Observers feel a slight trembling or swaying of the building, room or bed, chair etc.
b) China, glasses, windows and doors rattle. Hanging objects swing. Light furniture shakes visibly in a few cases. Woodwork creaks in a few cases.
c) No damage.

**V. Strong**
a) The earthquake is felt indoors by most, outdoors by few. A few people are frightened and run outdoors. Many sleeping people awake. Observers feel a strong shaking or rocking of the whole building, room or furniture.
b) Hanging objects swing considerably. China and glasses clatter together. Small, top-heavy and/or precariously supported objects may be shifted or fall down. Doors and windows swing open or shut. In a few cases window panes break. Liquids oscillate and may spill from well-filled containers. Animals indoors may become uneasy.
c) Damage of grade 1 to a few buildings of vulnerability class A and B.

**VI. Slightly damaging**
a) Felt by most indoors and by many outdoors. A few persons lose their balance. Many people are frightened and run outdoors.
b) Small objects of ordinary stability may fall and furniture may be shifted. In few instances dishes and glassware may break. Farm animals (even outdoors) may be frightened.
c) Damage of grade 1 is sustained by many buildings of vulnerability class A and B; a few of class A and B suffer damage of grade 2; a few of class C suffer damage of grade 1.

**VII. Damaging**
a) Most people are frightened and try to run outdoors. Many find it difficult to stand, especially on upper floors.
b) Furniture is shifted and top-heavy furniture may be overturned. Objects fall from shelves in large numbers. Water splashes from containers, tanks and pools.
c) Many buildings of vulnerability class A suffer damage of grade 3; a few of grade 4.
Many buildings of vulnerability class B suffer damage of grade 2; a few of grade 3.
A few buildings of vulnerability class C sustain damage of grade 2.
A few buildings of vulnerability class D sustain damage of grade 1.

**VIII. Heavily damaging**
a) Many people find it difficult to stand, even outdoors.
b) Furniture may be overturned. Objects like TV sets, typewriters etc. fall to the ground. Tombstones may occasionally be displaced, twisted or overturned. Waves may be seen on very soft ground.
c) Many buildings of vulnerability class A suffer damage of grade 4; a few of grade 5.
Many buildings of vulnerability class B suffer damage of grade 3; a few of grade 4.
Many buildings of vulnerability class C suffer damage of grade 2; a few of grade 3.
A few buildings of vulnerability class D sustain damage of grade 2.

**IX. Destructive**
a) General panic. People may be forcibly thrown to the ground.
b) Many monuments and columns fall or are twisted. Waves are seen on soft ground.
c) Many buildings of vulnerability class A sustain damage of grade 5.
Many buildings of vulnerability class B suffer damage of grade 4; a few of grade 5.
Many buildings of vulnerability class C suffer damage of grade 3; a few of grade 4.
Many buildings of vulnerability class D suffer damage of grade 2; a few of grade 3.
A few buildings of vulnerability class E sustain damage of grade 2.

**X. Very destructive**
c) Most buildings of vulnerability class A sustain damage of grade 5.
Many buildings of vulnerability class B sustain damage of grade 5.
Many buildings of vulnerability class C suffer damage of grade 4; a few of grade 5.
Many buildings of vulnerability class D suffer damage of grade 3; a few of grade 4.
Many buildings of vulnerability class E suffer damage of grade 2; a few of grade 3.
A few buildings of vulnerability class F sustain damage of grade 2.

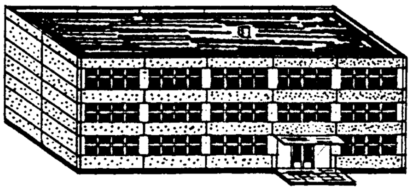
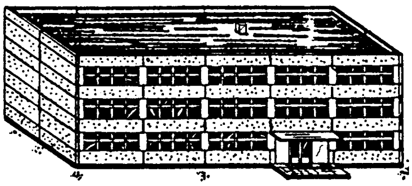
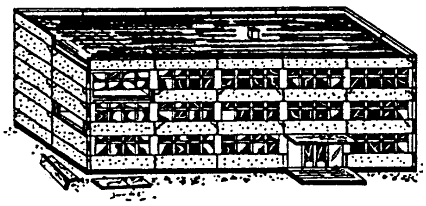
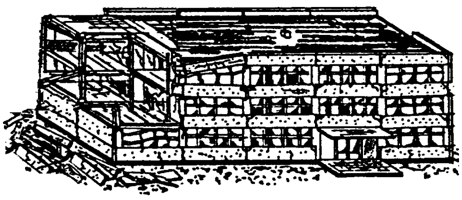
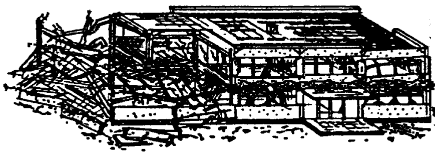
**XI. Devastating**
c) Most buildings of vulnerability class B sustain damage of grade 5.
Most buildings of vulnerability class C suffer damage of grade 4; many of grade 5.
Many buildings of vulnerability class D suffer damage of grade 4; a few of grade 5.

Many buildings of vulnerability class E suffer damage of grade 3; a few of grade 4.
Many buildings of vulnerability class F suffer damage of grade 2; a few of grade 3.

**XII. Completely devastating**
c) All buildings of vulnerability class A, B and practically all of vulnerability class C are destroyed.
Most buildings of vulnerability class D, E and F are destroyed. The earthquake effects have reached the maximum conceivable effects.

## *Annex 2: Damage Grades of the Buildings (For Reinforced Concrete Buildings)*

(Classification from European Macro-seismic Scale (EMS 98))

| Classification of damage to buildings of reinforced concrete | |
|---|---|
| <br>**Grade 1: Negligible to slight damage** | **Structural damage : No**<br>**Non-structural damage: Slight**<br>• Fine cracks in plaster over frame members or in walls at the base.<br>• Fine cracks in partitions and infills. |
| <br>**Grade 2: Moderate damage** | **Structural damage : Slight**<br>**Non-structural damage: Moderate**<br>• Cracks in columns and beams of frames and in structural walls.<br>• Cracks in partition and infill walls; fall of brittle cladding and plaster.<br>• Falling of mortar from the joints of wall panels. |
| <br>**Grade 3: Substantial to heavy damage** | **Structural damage: Moderate**<br>**Non-structural damage: Heavy**<br>• Cracks in columns and beam column joints of frames at the base and at joints of coupled walls.<br>• Spalling of concrete cover, buckling of reinforced bars.<br>• Large cracks in partition and infill walls, failure of individual infill panels. |
| <br>**Grade 4: Very heavy damage** | **Structural damage: Heavy**<br>**Non-structural damage: Very heavy**<br>• Large cracks in structural elements with compression failure of concrete and fracture of rebars; bond failure of beam reinforced bars; tilting of columns.<br>• Collapse of a few columns or of a single upper floor. |
| <br>**Grade 5: Destruction** | **Structural damage: very heavy**<br>• Collapse of ground floor or parts (e.g. wings) of buildings. |

# Annex 3: Rapid Visual Screening

| RVS SCORE-Building A | | | |
|---|---|---|---|
| Seismic zone | Moderate | | |
| Building Type | C3 | | |
| Vulnerability Factors | Presence of Vulnerability Factors | Basic Score & Score Modifiers | Total Score |
| Basic Score | | 3.2 | 3.2 |
| Mid Rise (4 to 7 stories) | 1 | 0.2 | 0.2 |
| High Rise (> 7 stories) | 0 | 0.4 | 0 |
| Vertical Irregularity | 1 | -2 | -2 |
| Plan Irregularity | 1 | -0.5 | -0.5 |
| Pre-Code | 0 | -1 | 0 |
| Post-Benchmark | 0 | N/A | 0 |
| Soil Type C | 0 | -0.6 | 0 |
| Soil Type D | 1 | -1 | -1 |
| Soil Type E | 0 | -1.6 | 0 |
| | | Total Score 'S'= | -0.1 |
| | | Probability of collapse at Maximum Considered Earthquake | 100% |

| RVS SCORE-Building B | | | |
|---|---|---|---|
| Seismic zone | Moderate | | |
| Building Type | C3 | | |
| Vulnerability Factors | Presence of Vulnerability Factors | Basic Score & Score Modifiers | Total Score |
| Basic Score | | 3.2 | 3.2 |
| Mid Rise (4 to 7 stories) | 0 | 0.2 | 0 |
| High Rise (> 7 stories) | 0 | 0.4 | 0 |
| Vertical Irregularity | 0 | -2 | 0 |
| Plan Irregularity | 0 | -0.5 | 0 |
| Pre-Code | 0 | -1 | 0 |
| Post-Benchmark | 0 | N/A | 0 |
| Soil Type C | 0 | -0.6 | 0 |
| Soil Type D | 1 | -1 | -1 |
| Soil Type E | 0 | -1.6 | 0 |
| | | Total Score 'S'= | 2.2 |
| | | Probability of collapse at Maximum Considered Earthquake | 1% |

| **RVS SCORE-Building C** | | | |
|---|---|---|---|
| Seismic zone | Moderate | | |
| Building Type | C3 | | |
| Vulnerability Factors | Presence of Vulnerability Factors | Basic Score & Score Modifiers | Total Score |
| Basic Score | | 3.2 | 3.2 |
| Mid Rise (4 to 7 stories) | 0 | 0.2 | 0 |
| High Rise (> 7 stories) | 0 | 0.4 | 0 |
| Vertical Irregularity | 0 | -2 | 0 |
| Plan Irregularity | 0 | -0.5 | 0 |
| Pre-Code | 0 | -1 | 0 |
| Post-Benchmark | 0 | N/A | 0 |
| Soil Type C | 0 | -0.6 | 0 |
| Soil Type D | 1 | -1 | -1 |
| Soil Type E | 0 | -1.6 | 0 |
| | | Total Score 'S'= | 2.2 |
| Probability of collapse at Maximum Considered Earthquake | | | 1% |

| RVS SCORE-Building D | | | |
|---|---|---|---|
| Seismic zone | Moderate | | |
| Building Type | C3 | | |
| Vulnerability Factors | Presence of Vulnerability Factors | Basic Score & Score Modifiers | Total Score |
| Basic Score | | 3.2 | 3.2 |
| Mid Rise (4 to 7 stories) | 0 | 0.2 | 0 |
| High Rise (> 7 stories) | 0 | 0.4 | 0 |
| Vertical Irregularity | 0 | -2 | 0 |
| Plan Irregularity | 1 | -0.5 | -0.5 |
| Pre-Code | 0 | -1 | 0 |
| Post-Benchmark | 0 | N/A | 0 |
| Soil Type C | 0 | -0.6 | 0 |
| Soil Type D | 1 | -1 | -1 |
| Soil Type E | 0 | -1.6 | 0 |
| | | Total Score 'S'= | 1.7 |
| | | Probability of collapse at Maximum Considered Earthquake | 2% |

# *Annex 4: Turkish Level 1 and Level 2*

## Building A. Level 1

| Turkish Level 1 Score | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Building ID** | Number of Story | Zone I | Zone II | Zone III | Soft Story | Heavy Overhang | Apparent Quality | Short Column | Pounding | **PS** |
| | 5 | 80 | 90 | 115 | -15 | -15 | -15 | -5 | -3 | |
| **S1** | **VSM** | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | **55** |
| | **∑VSM X VS** | 0 | 90 | 0 | -15 | 0 | -15 | -5 | 0 | |
| **Remarks** | | | | | **Moderate** | | | | | |

## Building A. Level 2

| Turkish Level 2 Score | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Building ID** | Number of Story | Zone II | Soft Story | Heavy Overhang | Apparent Quality | Short Column | Pounding | Topog. Effects | Plan Irreg. | Redundancy | SI | **PS** |
| | 5 | 105 | -15 | -15 | -15 | -5 | -3 | -2 | -5 | -10 | -10 | |
| **S1** | **VSM** | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | **30** |
| | **∑VSM X VS** | 0 | -15 | 0 | -15 | -5 | 0 | 0 | -5 | -10 | -10 | |
| **Remarks** | | | | | | **Severe** | | | | | | |

## Building B. Level 1

| Turkish Level 1 Score | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Building ID** | Number of Story | Zone I | Zone II | Zone III | Soft Story | Heavy Overhang | Apparent Quality | Short Column | Pounding | **PS** |
| | 2 | 90 | 125 | 160 | -5 | -5 | -5 | -5 | 0 | |
| **1** | **VSM** | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | **110** |
| | **∑VSM X VS** | 0 | 125 | 0 | 0 | -5 | -5 | -5 | 0 | |
| **Remarks** | | | | | **None** | | | | | |

## Building B. Level 2

| Turkish Level 2 Score | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Building ID** | Number of Story | Zone II | Soft Story | Heavy Overhang | Apparent Quality | Short Column | Pounding | Topog. Effects | Plan Irreg. | Redundancy | SI | **PS** |
| | 2 | 130 | 0 | -5 | -5 | -5 | 0 | 0 | 0 | 0 | -5 | |
| **1** | **VSM** | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | **80** |
| | **∑VSM X VS** | 0 | 0 | -5 | -5 | -5 | 0 | 0 | 0 | 0 | 0 | |
| **Remarks** | | | | | | **Low** | | | | | | |

## Building C. Level 1

| Turkish Level 1 Score | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Building ID | Number of Story | Zone I | Zone II | Zone III | Soft Story | Heavy Overhang | Apparent Quality | Short Column | Pounding | PS |
| | 3 | 90 | 125 | 160 | -10 | -10 | -10 | -5 | -2 | |
| 1 | **VSM** | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | **115** |
| | **∑VSM X VS** | 0 | 125 | 0 | 0 | 0 | -10 | 0 | 0 | |
| **Remarks** | | | | | | **None** | | | | |

## Building C. Level 2

| Turkish Level 2 Score | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Building ID | Number of Story | Zone II | Soft Story | Heavy Overhang | Apparent Quality | Short Column | Pounding | Topog. Effects | Plan Irreg. | Redundancy | SI | PS |
| | 3 | 125 | -10 | -5 | -10 | -5 | -2 | 0 | -2 | 0 | -5 | |
| 1 | **VSM** | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | **75** |
| | **∑VSM X VS** | 0 | 0 | 0 | -10 | 0 | 0 | 0 | 0 | 0 | -5 | |
| **Remarks** | | | | | | | **Moderate** | | | | | |

## Building D. Level 1

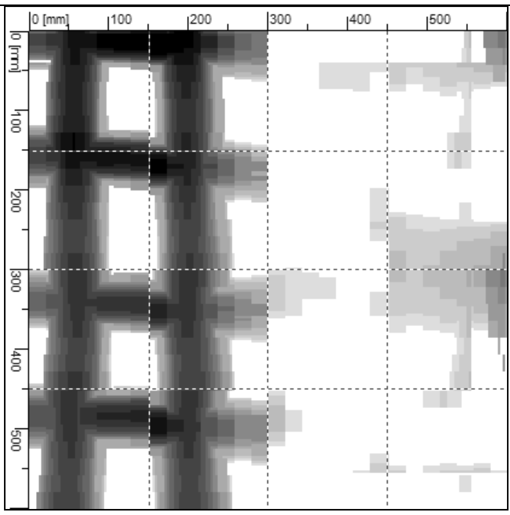
| Turkish Level 1 Score | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Building ID | Number of Story | Zone I | Zone II | Zone III | Soft Story | Heavy Overhang | Apparent Quality | Short Column | Pounding | PS |
| | 3 | 90 | 125 | 160 | -10 | -10 | -10 | -5 | -2 | |
| 1 | **VSM** | 0 | 1 | 0 | 0 | 0 | 2 | 1 | 0 | **100** |
| | **∑VSM X VS** | 0 | 125 | 0 | 0 | 0 | -20 | -5 | 0 | |
| **Remarks** | | | | | | **None** | | | | |

## Building D. Level 2

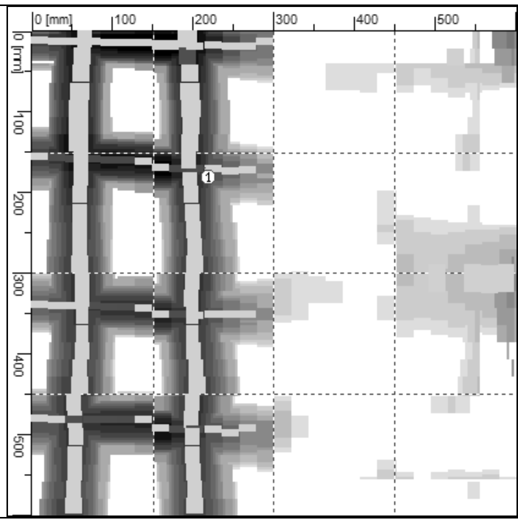
| Turkish Level 2 Score | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Building ID | Number of Story | Zone II | Soft Story | Heavy Overhang | Apparent Quality | Short Column | Pounding | Topo. Effect | Plan Irreg | Redundancy | SI | PS |
| | 3 | 125 | -10 | -5 | -10 | -5 | -2 | 0 | -2 | 0 | -5 | |
| 1 | **VSM** | 0 | 1 | 0 | 2 | 1 | 0 | 0 | 1 | 1 | 2 | **43** |
| | **∑VSM X VS** | 0 | -10 | 0 | -20 | -5 | 0 | 0 | -2 | 0 | -10 | |
| **Remarks** | | | | | | | **Severe** | | | | | |

# Annex 5: Non-Destructive Testing

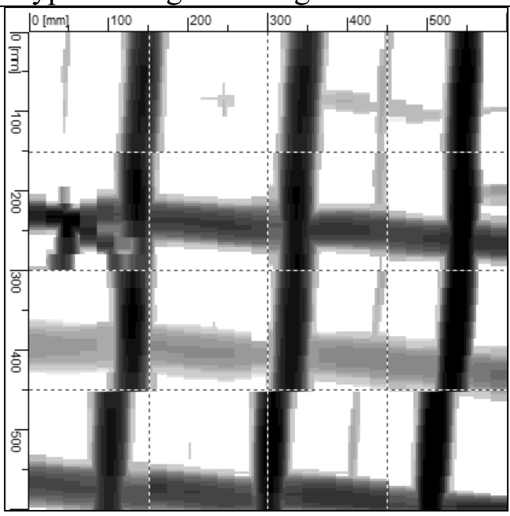
## A. Detection of Steel Bar



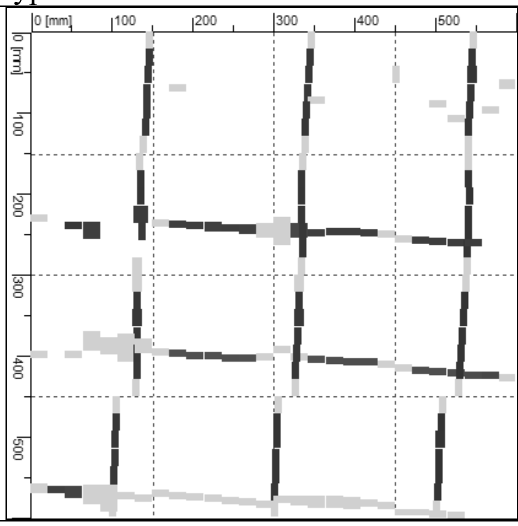

Typical image Scan figure for column




Typical orientation of Steel bar in column




Typical image Scan for slab




Typical orientation of Steel bar in slab

## B. Transverse Reinforcement Requirements

| Column ID: | Building A: C1-GF | | | | |
|---|---|---|---|---|---|
| | C1 | C2 | $L_0 \geq$ | | |
| Column Dimension | 12 | 12 | Larger of C1 or C2 | 12 | in |
| Column Height (Clear Span) | 11 | ft | Clear Span/6 | 22 | in |
| | 132 | in | 18" | 18 | in |
| | | | | | |
| Longitudinal Bar Used | 5 | # bar | | | |
| Diameter , D | 0.625 | in | | | |

| | | | | |
|---|---|---|---|---|
| Max. Value between tie (in a plane), $h_x$ | 6.5 | in | | |
| End Strip Length | 22 | in | | |
| Middle Strip length | 88 | in | | |
| | | | | |
| Spacing Recommended for End Strip : | | | S≤ | |
| S | 3 | in | 0.25 X Smaller of C1 or C2 | 3 in |
| Existing Spacing | 10 | in | 6 X Longitudinal Bar Diameter, D | 3.75 in |
| Remark | Not Satisfied | | $S_x = 4+[(14-h_x)/3]$ | 6 in |
| | | | | |
| Spacing Recommended for Middle Strip : | | | S≤ | |
| S | 3.75 | in | 6" | 6 in |
| Existing Spacing | 14 | in | 6 X Longitudinal Bar Diameter, D | 3.75 in |
| Remark | Not Satisfied | | | |

| **Clear Cover Check** | | |
|---|---|---|
| Cover depth ≥ | 38.1 | mm |
| Existing min Depth | 35 | mm |
| Remark | Not Satisfied | |

| **Column ID:** | **Building A: C3-4F** | | | | |
|---|---|---|---|---|---|
| | C1 | C2 | $L_0 \geq$ | | |
| Column Dimension | 12 | 12 | Larger of C1 or C2 | 12 | in |
| Column Height (Clear Span) | 9.5 | ft | Clear Span/6 | 19 | in |
| | 114 | in | 18" | 18 | in |
| | | | | | |
| Longitudinal Bar Used | 5 | # bar | | | |
| Diameter , D | 0.625 | in | | | |
| Max. Value between tie (in a plane), $h_x$ | 5 | in | | | |
| End Strip Length | 19 | in | | | |
| Middle Strip length | 76 | in | | | |
| | | | | | |
| Spacing Recommended for End Strip : | | | S≤ | | |
| S | 3 | in | 0.25 X Smaller of C1 or C2 | 3 | in |
| Existing Spacing | 9 | in | 6 X Longitudinal Bar Diameter, D | 3.75 | in |
| Remark | Not Satisfied | | $S_x = 4+[(14-h_x)/3]$ | 6 | in |
| | | | | | |
| Spacing Recommended for Middle Strip : | | | S≤ | | |
| S | 3.75 | in | 6" | 6 | in |

| | | | | | |
|---|---|---|---|---|---|
| Existing Spacing | 10 | in | 6 X Longitudinal Bar Diameter, D | 3.75 | in |
| Remark | Not Satisfied | | | | |
| **Clear Cover Check** | | | | | |
| Cover depth ≥ | 38.1 | mm | | | |
| Existing min Depth | 39 | mm | | | |
| Remark | Satisfied | | | | |

| **Building B: Transverse Reinforcement Requirements** | | | | | |
|---|---|---|---|---|---|
| Column ID: | C1-GF | | | | |
| | C1 | C2 | $L_0 \geq$ | | |
| Column Dimension | 11.5 | 16 | Larger of C1 or C2 | 16 | in |
| Column Height (Clear Span) | 9.5 | ft | Clear Span/6 | 19 | in |
| | 114 | in | 18" | 18 | in |
| | | | | | |
| Longitudinal Bar Used | 5 | # bar | | | |
| Diameter , D | 0.625 | in | | | |
| Max. Value between tie (in a plane), $h_x$ | 7 | in | | | |
| End Strip Length | 19 | in | | | |
| Middle Strip length | 76 | in | | | |
| | | | | | |
| Spacing Recommended for End Strip : | | | S≤ | | |
| S | 2.875 | in | 0.25 X Smaller of C1 or C2 | 2.87 | in |
| Existing Spacing | 11 | in | 6 X Longitudinal Bar Diameter, D | 3.75 | in |
| Remark | Not Satisfied | | $S_x = 4+[(14-h_x)/3]$ | 6 | in |
| | | | | | |
| Spacing Recommended for Middle Strip : | | | S≤ | | |
| S | 3.75 | in | 6" | 6 | in |
| Existing Spacing | 12 | in | 6 X Longitudinal Bar Diameter, D | 3.75 | in |
| Remark | Not Satisfied | | | | |

## *C. Image Scan Results for Slab*

| Num | X | Y | Coverage | Diameter | Orientation | Overlay | RealDiam | X | Y | Coverage |
|---|---|---|---|---|---|---|---|---|---|---|
| | mm | mm | mm | | | mm | mm | in | in | in |
| 1 | 74.3 | 244.3 | 40 | #7 | H | 0 | 22 | 2.925 | 9.619 | 1.58 |
| 2 | 374.3 | 246.5 | 38 | #3 | H | 0 | 10 | 14.736 | 9.704 | 1.501 |
| 3 | 104.4 | 502.9 | 32 | #3 | V | 0 | 10 | 4.108 | 19.798 | 1.265 |
| 4 | 131.2 | 352.9 | 32 | #4 | V | 0 | 13 | 5.164 | 13.892 | 1.265 |
| 5 | 135.3 | 224.3 | 35 | #6 | V | 0 | 19 | 5.327 | 8.83 | 1.383 |
| 6 | 141 | 117.1 | 32 | #3 | V | 0 | 10 | 5.551 | 4.612 | 1.265 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 7 | 302.5 | 524.3 | 28 | #3 | V | 0 | 10 | 11.911 | 20.641 | 1.107 |
| 8 | 339.3 | 117.1 | 32 | #3 | V | 0 | 10 | 13.357 | 4.612 | 1.265 |
| 9 | 504.4 | 524.3 | 27 | #3 | V | 0 | 10 | 19.859 | 20.641 | 1.068 |
| 10 | 534 | 352.9 | 27 | #3 | V | 0 | 10 | 21.025 | 13.892 | 1.068 |
| 11 | 540.8 | 117.1 | 28 | #3 | V | 0 | 10 | 21.292 | 4.612 | 1.107 |

## *D. Beam Reinforcement Requirements*

| **Building A: Transverse Reinforcement Requirement for Beam (ACI 2002)** | | | | | |
|---|---|---|---|---|---|
| Beam height, h | 17 | in | | | |
| Effective depth, d | 14 | in | | | |
| Smallest Longitudinal Bar Used | 5 | # | | | |
| Diameter, D | 0.625 | in | | | |
| Hoop bar Used | 3 | # | | | |
| Hoop bar diameter, $d_1$ | 0.375 | in | | | |
| End Strip Length, 2h | 34 | in | | | |
| End Strip | | | S ≤ | | |
| Recommended S | 3.5 | in | d/4 | 3.5 | in |
| Existing Spacing | - | in | 8D | 5 | in |
| Remark | - | | $24d_1$ | 9 | in |
| | | | 12" | 12 | in |
| 1st Trans. Bar from column face | - | in | | | |
| Remark | - | 1st Trans. Bar from column ≤ 2" | | | |
| Middle Strip | | | | | |
| Recommended S | 7 | in | S ≤ | | |
| Existing Spacing | 5 | in | d/2 | 7 | in |
| Remark | Satisfied | | | | |
| Clear Cover | | | | | |
| Cover depth ≥ | 38.1 | mm | | | |
| Existing min Depth | 46 | mm | | | |
| Remark | Satisfied | | | | |

| **Building C: Transverse Reinforcement Requirement for Beam (ACI 2002)** | | | | | |
|---|---|---|---|---|---|
| Beam height, h | 25 | in | | | |
| Effective depth, d | 23 | in | | | |
| Smallest Longitudinal Bar Used | 5 | # | | | |
| Diameter, D | 0.625 | in | | | |
| Hoop bar Used | 3 | # | | | |
| Hoop bar diameter, $d_1$ | 0.375 | in | | | |
| End Strip Length, 2h | 50 | in | | | |
| End Strip | | | S ≤ | | |
| Recommended S | 5 | in | d/4 | 5.8 | in |

| | | | | | |
|---|---|---|---|---|---|
| Existing Spacing | 4.6 | in | 8D | 5 | in |
| Remark | Satisfied | | $24d_1$ | 9 | in |
| | | | 12" | 12 | in |
| Existing 1st trans. bar from column face | 4 | in | | | |
| Remark | Not Satisfied | 1st Trans. Bar from column ≤ 2" | | | |
| Middle Strip | | | | | |
| Recommended Spacing | 11.5 | in | S ≤ | | |
| Existing Spacing | 9.5 | in | d/2 | 12 | in |
| Remark | Satisfied | | | | |
| **Clear Cover** | | | | | |
| Cover depth ≥ | 38.1 | mm | | | |
| Existing min Depth | 30 | mm | | | |
| Remark | Not Satisfied | | | | |

# *Annex 6: Building Drawings*

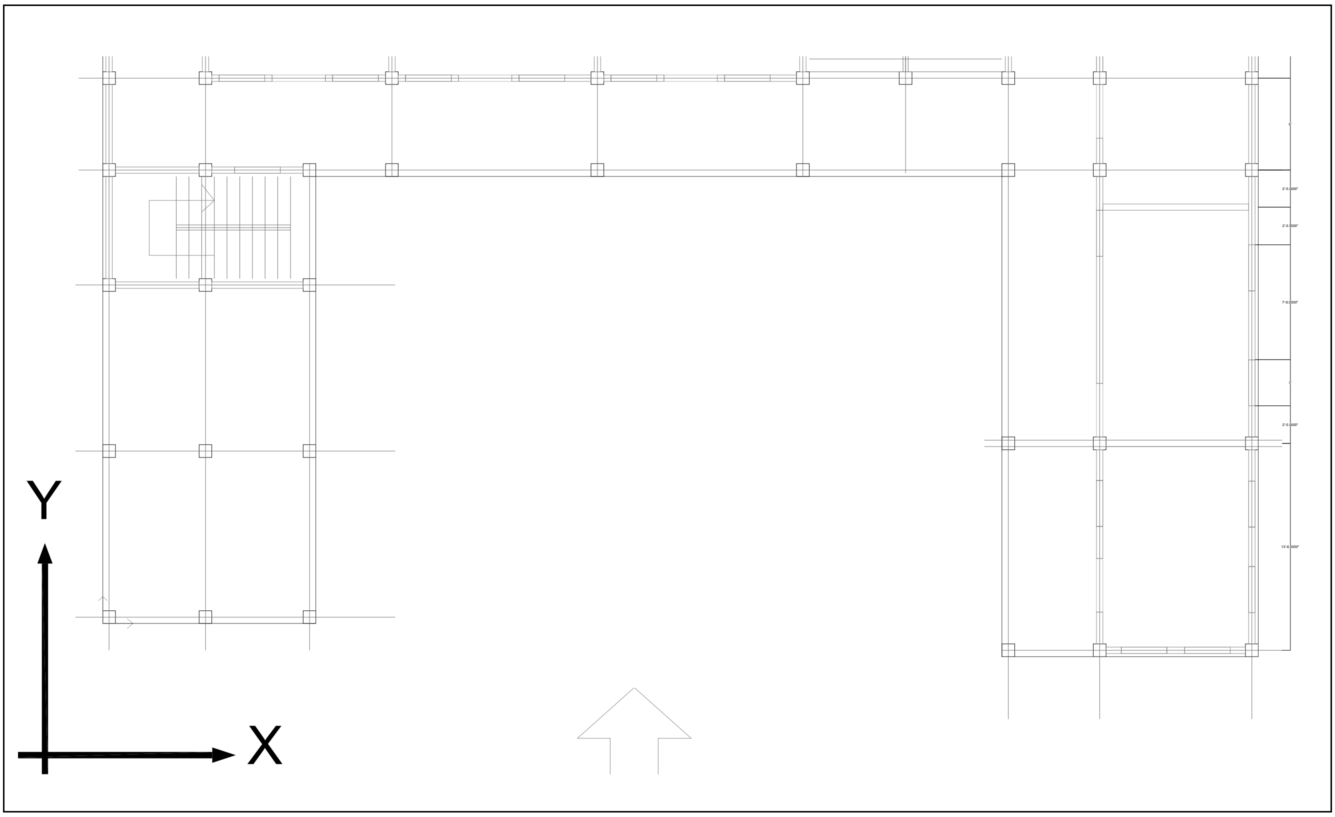



Figure: Ground Floor Plan of Building A.

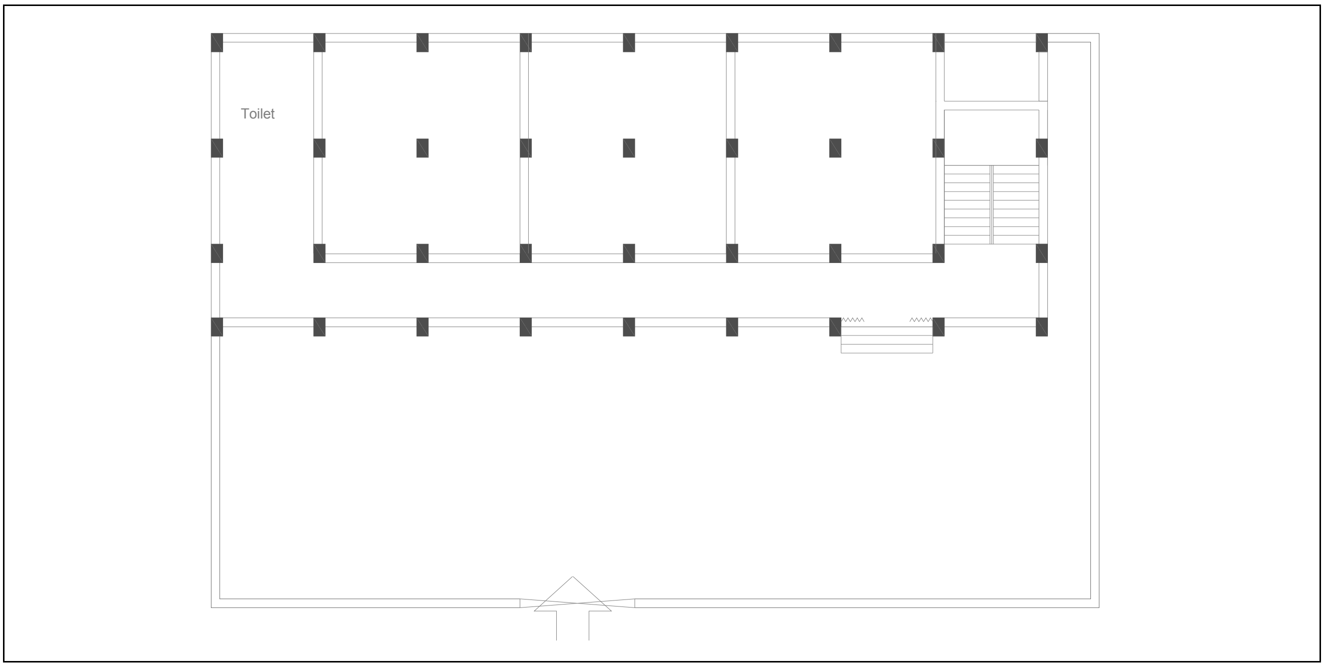



Figure: Ground Floor Plan of Building B.

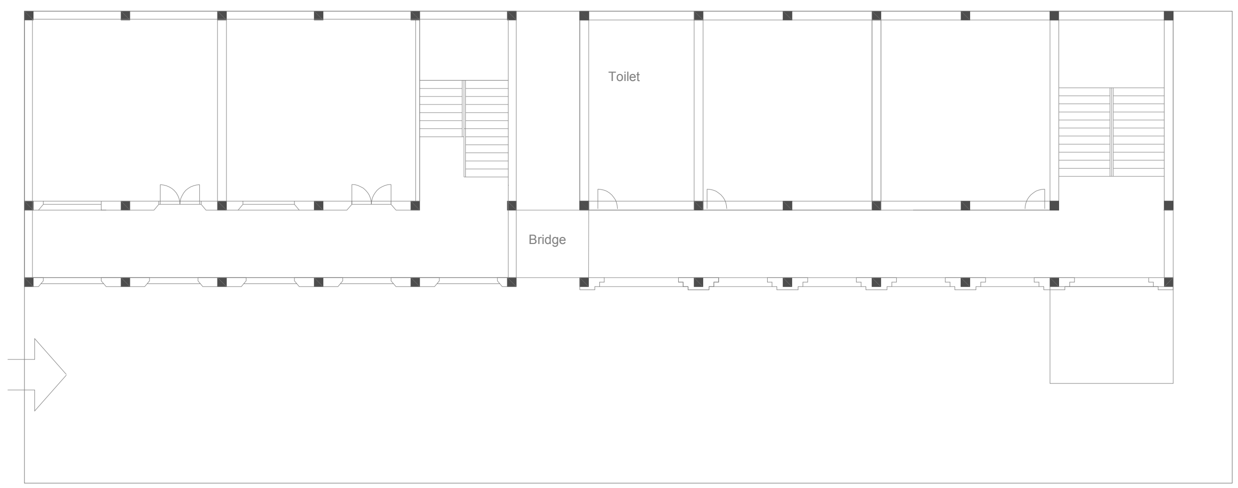



Figure: Ground Floor Plan of Building C.

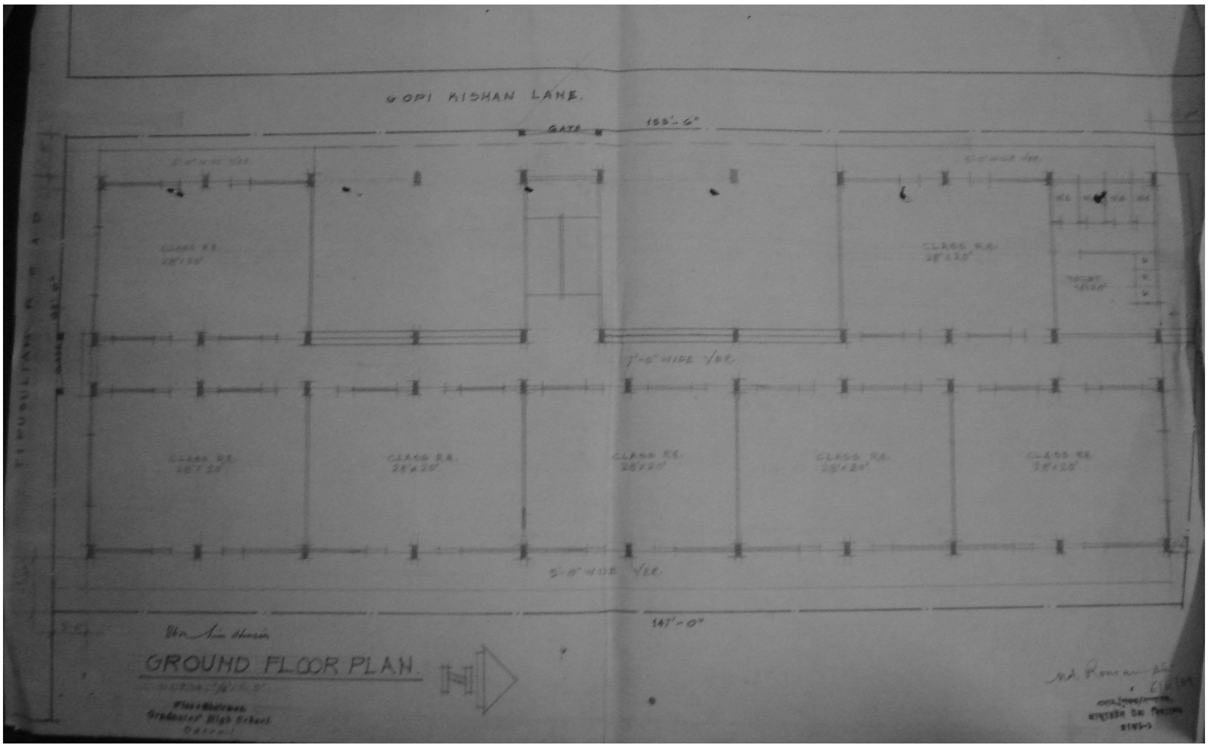


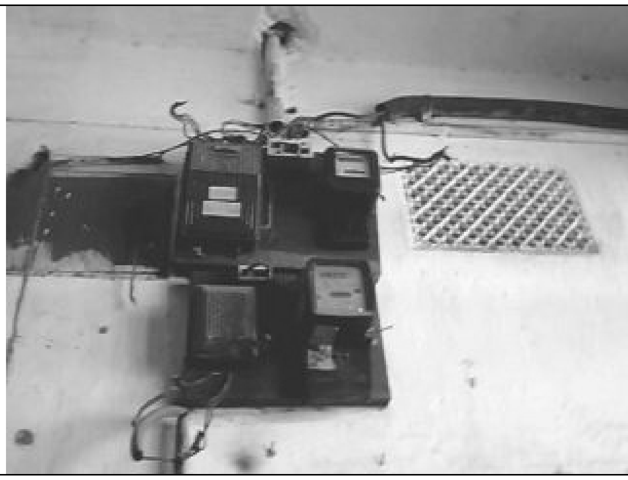

Figure: Ground Floor Plan for Building D.

# *Annex 7: Photographs*

| | |
|---|---|
|  |  |
| Soft Storey | 1st -4th floor (Overhang) |
|  |  |
| Beam column junction | Ferro-Scan Testing |
| Building A | |

| | |
|---|---|
|  |  |
| Front view of the Buildings | Short Column |
|  |  |
| Broken glass of the window | Obstacle in stair |
| Building B | |

| | |
|---|---|
|  |  |
| Verandah | Beam |

| Building C | |
|---|---|
|  |  |
| Crack in Beam | Poor Electrical Condition |
|  |  |
| Non Structural Components | Ferro-Scan Testing |
| Building D | |

# PART-VIII

# MASON TRAINING PROGRAM

## BANGLADESH NETWORK OFFICE FOR URBAN SAFETY (BNUS), BUET, DHAKA

**Prepared By: Saidur Rahman**

**Mehedi Ahmed Ansary**

# MASON TRAINING PROGRAMME ON MULTI HAZARD RESILIENT CONSTRUCTIONS

**Duration: 02-06 December, 2010**

**Venue: IR Project Office, Sylhet.**

**Building Disaster Resilient and Safer communities Under 5th DIPECHO Action Plan**

**Organized by**

**Islamic Relief worldwide Bangladesh**

## BANGLADESH NETWORK OFFICE FOR URBAN SAFETY (BNUS)

Bangladesh is a moderate seismic country in the world. Major earthquake have been occurred in Sylhet areas of Bangladesh in the past. Therefore, seismic resistant building construction in these areas is mandatory for the building disaster resilient and safer communities. That’s why the Islamic Relief Worldwide Bangladesh and Bangladesh Network office for urban safety (BNUS) arranged the five days mason Training on **Multi Hazard Resilient Constructions** in Sylhet in order to make Building Disaster Resilient and Safer community from December 2 to December 6, 2010. The purpose of this training was to share knowledge with local masons about seismic resistant building construction in Sylhet. Various topics of sustainable building construction have been dicussed in this programme. We, two stuff of BNUS (Dr. Mehedi Ahmed Ansary and Md. Saidur Rahman) and two trained masons of BUET (Md. Motiur Rahman and Md. Khurshed Alam), participated the five days Training course. This training was very significant to develop knowledge among the masons from the root level of construction. A model building (10 feet length, 10 feet width and 10 feet height) has been erected considering all seismic criterion. Stirrups and ties are bent 135° angle in both beam and column. This criterion is very important according to seismic resilient building. Seismic criteria for building construction are not considered most of the building in our country. That’s why the message of following these criteria is spread among the masons who are involved directly in any construction. Certificate for the successfully completion of training have been issued by BNUS in this programme. In addition to this, the training on seismic protected buildings has been arranged for professional engineers and house owners in another programme under Bangladesh Network Office for Urban Safety (BNUS). Some pictures of the training session have been shown in Figure 1 and 2.

Figure 1: Group Photo of Mason training program at IR Project Office, Sylhet

| | | |
|---|---|---|
|  |  |  |
| **Training class at IR Project office** | **Open discussion with local mason** | **Making a stirrup** |
|  |  |  |
| **Making 135° angle stirrup** | **Placing of stirrups in a beam** | **Arrangement of anchor reinforcement in beam and column** |

**Figure 2: Mason training programme at Sylhet**

# MASON TRAINING PROGRAMME ON MULTI HAZARD RESILIENT CONSTRUCTIONS

## Duration: 03-08 October, 2010

## Venue: IR Project Office, Netrokona.

## Earthquake Resistant Building construction Under European Commission

## Organized by

## Islamic Relief worldwide Bangladesh

### BANGLADESH NETWORK OFFICE FOR URBAN SAFETY (BNUS)

The Islamic Relief Worldwide Bangladesh and Bangladesh Network office for urban safety (BNUS) arranged the six days mason Training on **Multi Hazard Resilient Constructions** in Netrokona in order to make Earthquake Resistant building Construction Under European Commission from October 3 to October 08, 2010. We, three stuff of BNUS (Dr. Mehedi Ahmed Ansary, Md. Saidur Rahman and Md. Qurban Ali) and two trained masons of BUET (Md. Motiur Rahman and Md. Khurshed Alam), participated the six days Training course. To demonstrate seismic protected building a model building (10 feet length, 10 feet width and 10 feet height) has been built considering all seismic criterion. Some photographs of mason training at Netrokona have been shown in Figure 3.

| | |
|---|---|
|  |  |
| Model building for mason training at Netrokona | Open discussion with mason in Netrokona |

# PART-IX

# WORKSHOPS, SEMINARS AND TRAINING COURSES

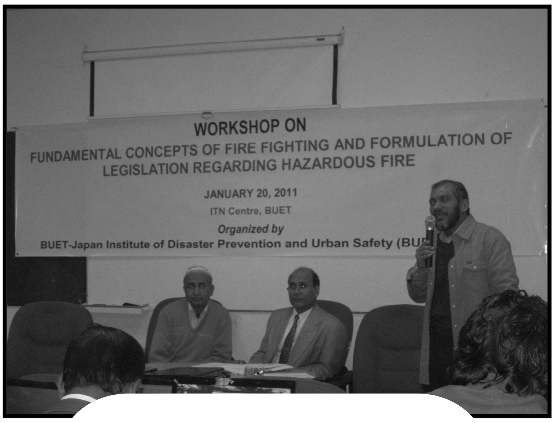
## BANGLADESH NETWORK OFFICE FOR URBAN SAFETY (BNUS), BUET, DHAKA

**Prepared By: Sharmin Ara**

**Mehedi Ahmed Ansary**

## Workshop on Fundamental concepts of fire fighting and formulation of legislation regarding hazardous fire

A workshop on **Fundamental Concepts of Fire Fighting and Formulation of Legislation Regarding Hazardous Fire** was held on **January 20, 2011** at ITN center, BUET. This day long workshop was organized by BUET- Japan Institute of Disaster Prevention and Urban Safety (BUET-JIDPUS). The workshop was divided into two sessions and there were two experts who gave lecturers on different issues regarding basic concepts of fire hazard, fire fighting system, design standard, standard rules and regulation and laws practiced in Bangladesh. The main lecturer of the workshop was Architect Tajuddin Ahmed Chowdhury ana Dr. Md. Maksud Helali, Professor of Mechanical Engineering department, BUET. Architect Tajuddin Ahmed Chowdhury mainly covered his lecture from National Fire Protection Association (NFPA-2000). **Forty** participants took part in this workshop from different professional group. A research planner (Sharmin Ara) of BNUS participates in this day long workshop. All participated members were come from different professional group and academician. But especially this workshop was very helpful for the fire fighters of Fire Service and Civil Defense (FSCD).




Inauguration session of the workshop

Participants of the workshop listening the lectures

Architect Tajuddin giving his lectures on different terrible fire incidents in Bangladesh

Professor Helali giving his lectures on basic concepts of fire

## Lecture Course and Seminar on Urban building fire mitigation and safety issues in Asian Mega cities: Bangladesh Chapter

Researchers of BNUS were participated in the lecture course and seminar in Bangladesh on '**Urban building fire mitigation and safety issues in Asian Mega cities: Bangladesh Chapter'**. This was a 3days long seminar held on 21st December to 23rd December 2010 at Public Works Department, Dhaka. It was a collaborative research study of Tokyo University of Science (TUS); Building Research Institute, Japan; Bangladesh University of engineering and Technology, American International University Bangladesh; Fire Service and Civil Defense (FSCD); Ministry of Housing and Public Works, Bangladesh. Total no of participants were fifty. This lecture course has been designed for the students of architecture and engineering disciplines, fire professionals and other concerned officials as well. In this lecture experts were gave emphasis on urban building fire issues. The seminar was divided into number of sessions with some lectures rendered by experts and professionals on urban fire mitigation and safety issues. Professor Sugahara Shinichi, Professor Kyoichi Kobayashi, Professor Sugawa Osami gave lectures on different urban building fire and shared their experiences on this issue. At the end of the seminar certificate was awarded to each participant by Professor Sugahara Shinichi of Tokyo University of Science.

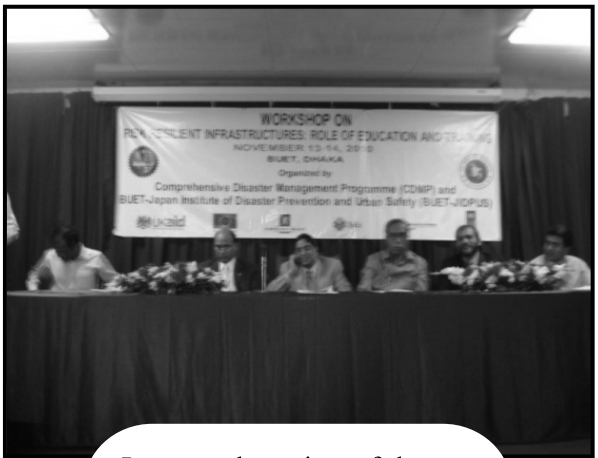
Participants from different professional groups

Certificates awarded to the participated professional groups

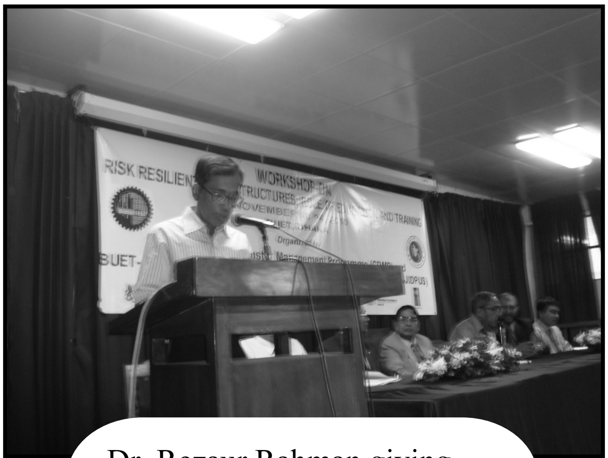
## Workshop on Risk Resilient Infrastructures: Role of Education and Training

All BNUS members were participated on the two day long workshop on **Risk Resilient Infrastructures: Role of Education and Training**. This workshop was jointly organized by

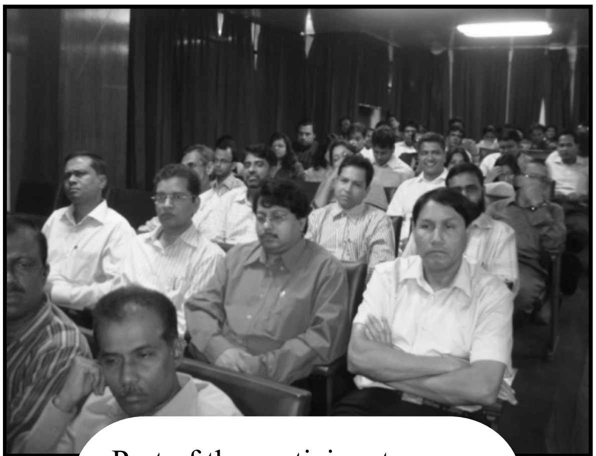
BUET- Japan Institute of Disaster Prevention and Urban Safety (BUET-JIDPUS), Comprehensive disaster Management program (CDMP), UNDP and Ministry of Food and Disaster Management, Bangladesh on 13th and 14th November, 2010 at BUET, Dhaka. The chief guest of the workshop was honorable minister of food and disaster management, Dr. Muhammad Abdur Razzaque. Professor Dr. Mehedi Ahmed Ansary was the key note speaker. This two day long workshop is divided into number of sessions. Different session focuses on different issues like environmental issues, architectural issues, civil engineering issues, water resources issues, planning issues etc. Professionals and experts of these issues presented lectures on different session. A large number of participants (134) from different organization took part in this workshop, among them academicians and professional groups were major in proportion. At the end of each session there was an open discussion session where participants asked questions to the speaker of each presentation.




Inaugural session of the workshop



Dr. Rezaur Rahman giving welcome address



Part of the participants on the workshop

One of the participants asking questions to the speaker

## Training course on GIS

A training course on **Application of GIS for Natural Hazard and Risk Assessment** was held on 25th -29th September, 2010 at Dhaka. It was organized by Asian Disaster Prevention Center (ADPC). Total number of participants was 35 and from BNUS a Research Planner (Sharmin Ara) took part in this training. The 5days long training course's objective was to develop basic skills on GIS analysis and application of GIS & Remote Sensing Techniques for Disaster Risk Reduction among the trainee. The total training course has been divided into five modules and each module provides practical knowledge on different issues and the respective trainer assigned hands on exercise to the all participants. This course was designed to assist disaster management practitioners to enable them to use GIS. On the last day of the training, participants received certificates for the completion of course.

Expert from AIT giving lectures on different satellite and image processing

Participants doing an assigned class work


Participants of the training course

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