Journal of Civil Engineering (IEB), 38 (2) (2010) 159-172

Journal of Civil Engineering IEB

Seismic vulnerability assessment of buildings of Dhaka city

M. R. Sadat, M. S. Huq, M. A. Ansary

Department of Civil Engineering,
Bangladesh University of Engineering and Technology, Dhaka 1000, Bangladesh

Received 27 June 2010

Abstract

The objective of this study is to assess the seismic vulnerability of R.C.C. structures of the selected area by R.V.S (Rapid Visual Screening) method and The Turkish Method. The areas covered under the survey are Dhanmondi residential area, Lalmatia and the greater Mohammadpur. The survey was mainly focused on earthquake issues such as identifying building type, plot size and shape, clear distances from surrounding structures, road width and basic information of the building: type of foundation, slab type, year of construction, no. of storey, no. of inhabitants etc. The detail analysis (or the level-2 analysis) covered the determination of plinth area (length x width), column size and direction, lift core size, cantilever length of the building etc. Digital photographs of each building from at least two directions were taken. The developers' names concerned with each building are also recorded during the survey. The survey process was conducted between 15-03-07 to 28-05-07. A database was compiled in MS Access. It was found there are approximately 2007 structures in the above areas of them about 1082 buildings are R.C.C structures. About 456 of them are soft storied. The rest 925 buildings are unreinforced masonry (URM). In soft storied buildings, the ground floor is basically being used as parking space. It was also found that most of the buildings of the target areas were constructed without the development of proper disaster prevention system against potential earthquakes. Use of Rapid Visual Screening (RVS) on the study area enables to divide screened buildings into two categories: those that are expected to have acceptable seismic performance and those that may be seismically hazardous and should be further studied. For further analysis of the buildings the help of Turkish method and ETABS Software would be taken.

Keywords: Soft storey, vulnerability parameters, vulnerability score

1. Introduction

F Reinforced Cement Concrete (R.C.C) frame buildings are becoming increasingly common in urban Dhaka city. Many such buildings constructed in recent times have a special feature – the ground storey is left open for the purpose of parking, i.e. the columns in the ground floor do not have any partition walls between them. Such buildings are often termed as 'Soft Storey' buildings.

Open ground storey buildings have consistently shown poor performance during past earthquakes across the world (for example during 1999 Turkey, 1999 Taiwan, 2003 Algeria earthquake, 2001 Bhuj Earthquake and 2005 Kashmir Earthquake), a significant number of them have collapsed. A large number of buildings with open ground storey have been built in Dhaka in recent times. The objective of this study is to compile a database of R.C.C. (With & without Soft Storey) and U.R.M buildings within a specified area of Dhaka City and also to make a vulnerability analysis of those structures.

The objective of this study is to assess the seismic vulnerability of R.C.C. structures of the selected area by R.V.S (Rapid Visual Screening) method and The Turkish Method. These kinds of assessments were previously made in BUET (Bangladesh University of Engineering and Technology) campus and also in Dhaka University Campus. (Reference: Rajon, 2006 and Wahid, 2005)

In order to design simple structures like low rise buildings, engineers idealize earthquake ground acceleration as horizontal forces applied at the elevated floor and roof levels. These horizontal forces are then transmitted to the foundations by specially designed walls called Shear walls. The seismic forces are carried by the floors and roof to the Shear walls. Floor and roof framing specially designed to carry seismic loads to the walls are known as diaphragm to structural engineers. The diaphragm and Shear walls work together to carry the seismic force to the foundation. The particular type of system carries lateral loads in the same way a box resists collapse.

For the past 10 years Bangladesh has had a boom in Real Estate sector. The prime location has been Dhanmondi area with further extension in Lalmatia and Mohammadpur. Worryingly the structures here are mostly Soft storeyed. We focused primarily in these types of apartments in this study. The provision of earthquake resistance and to know how the structures would react was the goal of the study.

2. Selecting the area to be screened

The initial step was to select a community or group of Buildings. The area chosen for the survey started from Road#32, Dhanmondi up to end of Ring Road, Mohammadpur. The two parallel boundaries were the Satmasjid Road and the Mirpur Road. Figure 1(a) shows the surrounding area.

The reason behind selecting this area is that for the last five years realtors were involved in building apartments in this area. These apartments tend to have a weaker ground storey as most of the structures have provisions for parking there. That means less brick walls in the Ground floor. These types of apartment were defined as "Soft Storey" Buildings.

The selected area is basically a residential one. But it has turned into a semi commercial area in the recent past. There has been a growth of Supermarkets, Schools, Universities and commercial structures in an unplanned way. No steps or studies have been taken what are the provisions for earthquake in this populated busy area. This study would help to assess the implications of an earthquake on this area.

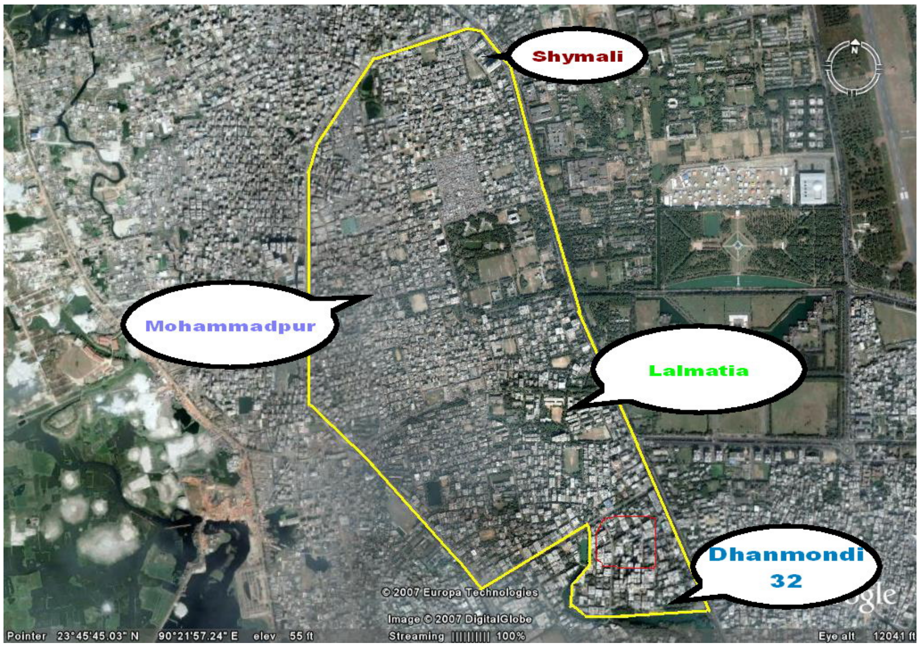

Figure 1a. Aerial View of Surveyed Area (Dhanmondi Rd#32 to Shymali)

Figure 1b. Zoom of Sobhanbag Pocket with High Rise Buildings (>10 stories)

3. Methodology

To assess the buildings of the surveyed area two methodologies were mainly used named R.V.S (Rapid Visual Screening) suggested by FEMA (Federal Emergency Management Agency) and Turkish Method.

3.1 RVS (Rapid Visual Screening)

Rapid visual screening (RVS) of buildings for potential seismic hazards, originated in 1988 with the publication of the FEMA 154 Report, Rapid Visual Screening of Buildings for Potential Seismic Hazards a Handbook. RVS provides a procedure to identify record and rank buildings that are potentially seismically hazardous (FEMA 154, 2002). This screening methodology is encapsulated in a one-page form, which combines a description of a building, its layout and occupancy, and a rapid structural evaluation related to its seismic hazard.

Although RVS is applicable to tall buildings, its principal purpose is to identify (1) older buildings designed and constructed before the adoption of adequate seismic design and detailing requirements (2) buildings on soft or poor soils, or (3) buildings having performance characteristics that negatively influence their seismic response. Once identified as potentially hazardous, such buildings should be further evaluated by a design professional experienced in seismic design to determine if, in fact, they are seismically hazardous.

The rapid visual screening method is designed to be implemented without performing any structural calculations. The procedure utilizes a scoring system that requires the evaluator to (1) identify the primary structural lateral load-resisting system, and (2) identify building attributes that modify the seismic performance expected for this lateral load-resisting system. The inspection, data collection and decision-making process typically occurs at the building site, and is expected to take around 30 minutes for each building. The screening is based on numerical seismic hazard and vulnerability score.

Basic Structural hazard scores for various building types are provided on the RVS form. The screener modifies the basic structural hazard score by identifying and circling score modifiers which are then added (or subtracted) to the basic structural hazard score to arrive at a final structural score, S. The basic structural hazard score, score modifiers, the final structural score S, all relate to the probability of building collapse. The result of the screening procedure is a final score that may range above 10 or below 0, with a high score indicating good expected seismic performance and a low score indicating a potentially hazardous structure. While the score is related to the estimated probability of major damage, it is not intended to be a final engineering judgment of the building, but merely to identify buildings that may be hazardous and require detailed seismic evaluation. If the score is 2 or less, a detailed evaluation is recommended. On the basis of detailed evaluation, engineering analysis and other detailed procedures, a final determination of seismic adequacy and need foe rehabilitations can be made. Figure 2(a) shows a sample R.V.S scoring form.

3.2 Turkish Method

In recent times, after the 1999 earthquake in the cities of Kocaeli and Duzce, Government of Turkey and Japan International Cooperation Agency (JICA) came forward for implementing a regional seismic assessment and rehabilitation program. Researchers from various universities were involved in this program supported by the Government of Turkey and JICA. A simple Two-level Seismic Assessment Procedure for a building stock was proposed (Sucuoglu and Yazgan; 2003). In this most vulnerable buildings that may undergo severe damage in a future earthquake are identified. A survey of 477 damaged buildings (1-7 storey) affected by Duzce earthquake (November 1999) was carried out. This was then complied to form a database of damaged buildings to be used for future research work. This database was employed for developing the performance score (PS) equation to determine the vulnerability of a reinforced concrete building. Figure 2(b) shows a sample Turkish Form.

Level-1 Survey

The trained observers collect data through walk-down visits. The parameters that are selected in Level-1 survey for representing building vulnerability are the following:

a. The number of stories above ground
b. Presence of a Soft Storey (Yes or No)
c. Presence of heavy overhangs, such as balconies with concrete parapets (Yes or No)
d. Apparent building quality (Good, Moderate or Poor)
e. Pounding between adjacent buildings (Yes or No)
f. Local soil conditions (Stiff or Soft)
g. Topographic effects (Yes or No)

All of the above parameters are found to have a negative feature on the building system under earthquake excitations on a variable scale.

Building Performance Score

Once the vulnerability parameters of a building are obtained from two-level surveys and its location is determined, the seismic performance scores for survey levels 1 and 2 are calculated by using Tables 2 and 3, respectively. In these Tables, an initial score is given first with respect to the number of stories and intensity zone. Then the initial score is reduced for every vulnerability parameter that is observed or calculated. A general equation for calculating performance score (PS) can be formulated as follows:

PS = (Initial Score – ∑ (Vulnerability parameter) X (Vulnerability Score)
PS<50 → Vulnerable Structure

Level 2 Survey

Level 2 Survey is done for the buildings of a stock when those are found to be failing into the moderate and high risk levels using level 1 risk assessment. The trained observer teams enter into the basements and ground stories of these buildings for collecting more data for Level 2 risk assessment. Their first task is to confirm or modify the previous grading on soft stories, short columns and building quality, through closer observations. The second and more elaborate task is to prepare a sketch of the ground floor plan and measure the dimensions of columns, concrete and masonry walls. This data is then employed for calculating the following parameters.

Occupancy					Soil Type						FALLING HAZARDS				
Assembly	Govt.	Office	Number of Pers		A	B	C	D	E	F					
Commercial	Historic	Resider	0-10	11-10	Hard	Avg.	Dense	Stiff	Soft	Poor	Unreinfc	Parapets	Claddin	Chimne	Other
Emer. Service	Industri	School	101-1000	1000+	Rock	Rock	Soil	Soil	Soil	Soil					

BASIC SCORE, MODIFIERS AND FINAL SCORE, S															
Building Type	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 RC SW	S5 JRM INF	C1 (MRF)	C2 (SW)	C3 JRM INF	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	4.4	3.8	2.8	3	3.2	2.8	2	2.5	2.8	1.6	2.6	2.4	2.8	2.8	1.8
Mid Rise (4 to 7 Stories)	N/A	N/A	0.2	0.4	N/A	0.4	0.4	0.4	0.4	0.2	N/A	0.2	0.4	0.4	0
High Ries (> 7 Stories)	N/A	N/A	0.6	0.8	N/A	0.8	0.8	0.6	0.8	0.3	N/A	0.4	N/A	0.6	N/A
Vertical Irreg.	-2.5	-2	-1	-1.5	N/A	-1	-1	-1.5	-1	-1	N/A	-1	-1	-1	-1
Plan Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0	-1	-1	-0.8	-0.6	-0.8	-0.2	-1.2	-1	-0.2	-0.8	-0.8	-1	-0.8	-0.2
Post Benchmar	2.4	2.4	1.4	1.4	N/A	1.6	N/A	1.4	2.4	N/A	2.4	N/A	2.8	2.6	N/A
Soil Type C	0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.4	-0.6	-0.6	-0.4	-0.6	-0.6	-0.6	-0.6	-0.8
Soil Type E	0	-0.8	-1.2	-1.2	-1	-1.2	-0.8	-1.2	-0.8	-0.8	-0.4	-1.2	-0.4	-0.6	-0.8
FINAL SCORE, S =										1.2					

Figure 2(a). Sample RVS Scoring Form (FEMA-154, 2002)

4. COLLECTION OF DATA AND THE DATABASE

The whole area was divided into four suitable areas for convenience. The data were collected in a customized form (attached below). The data were basically such that it could be collected from visual inspection. Detailed data were collected for 20% of buildings for level-2 analysis (Turkish Method) which included column and lift core dimensions.

The data was then compiled in an MS-ACCESS Database. With the help of the database we were able to analyze the structures.

Simple Survey Procedure (Turkish) for Risk Assessment of Concrete Buildings

Table A: Initial & Vulnerability Scores for Level - I Survey of Concrete Buildings

No. of Stories	Initial Score (on Soil Zoning)			Soft Story	Heavy Overhang	Apparent Quality	Short Column
	60<PGV<80	40<PGV<60	20<PGV<40				
1, 2	90	125	160	-5	-5	-5	-5
3	90	125	160	-10	-10	-10	-5
4	80	100	130	-10	-10	-10	-5
5	80	90	115	-15	-15	-15	-5
6, 7	70	80	95	-15	-15	-15	-5

Table B: Initial & Vulnerability Scores for Level - II Survey of Concrete Buildings

No. of Stories	Initial Score (on Soil Zoning)			Soft Story	Heavy Overhang	Apparent Quality	Short Column
	60<PGV<80	40<PGV<60	20<PGV<40				
1, 2	95	130	170	0	-5	-5	-5
3	90	125	160	-10	-5	-10	-5
4	90	115	145	-15	-10	-10	-5
5	90	105	130	-15	-15	-15	-5
6, 7	80	90	105	-20	-15	-15	-5

Table B: Contd. For Level - II Survey

No. of Stories	Pounding	Topography	Plan Irregularity	Redundancy	Strength Index
1, 2	0	0	0	0	-5
3	-2	0	-2	0	-5
4	-3	-2	-2	-5	-5
5	-3	-2	-5	-10	-10
6, 7	-3	-2	-5	-10	-10

Table C: Vulnerability Parameters

Soft Story	No (0)	Yes (1)	
Heavy Overhang	No (0)	Yes (1)	
Apparent Quality	Good (0)	Moderate(1)	Poor (2)
Short Column	No (0)	Yes (1)	
Pounding Effect	No (0)	Yes (1)	
Topography Effect	No (0)	Yes (1)	
Plan Irregularity	No (0)	Yes (1)	
Redundancy	Redundant,R (0)	Semi-R (1)	Weakly-R (2)
Strength Index	Strong (0)	Weak (1)	

General Equation for Seismic Performance Scores (PS) for both Levels ("cut-off" PS = 50)

PS =(Initial Score) - ∑ (Vulnerability Parameter) X (Vulnerability Score)

Figure 2(b). Tables and General Equation of Turkish Procedure (Sucuoglu & Yazgan, 2003)

5. Data Analysis

The areas covered under the survey are Dhanmondi residential area, Lalmatia and the greater Mohammadpur. The survey was mainly focused on earthquake issues such as identifying building type, plot size and shape, clear distances from surrounding structures, road width and basic information of the building: type of foundation, slab type, year of construction, no. of storey, no. of inhabitants etc. The detail analysis (or the level-2 analysis) covered the determination of plinth area (length x width), column size and direction, lift core size, cantilever length of the building etc. Digital photographs of each building from at least two directions were taken. The developers' names concerned with each building are also recorded during the survey. A database was compiled in MS Access. It was found there are approximately 2007 structures in the above areas of them about 1082 buildings are R.C.C structures. About 456 of them are soft storied. The rest 925 buildings are un-reinforced masonry (URM).

Figure 3 shows the relation between numbers of buildings with building types (such as RCC, URM ands soft storey). The figure shows that the area under survey has more

URM buildings than R.C.C. Among the R.C.C. structure percentage of Soft storey is higher than without the soft storey.

Figure 4 shows the relation between numbers of buildings with types of slab such as Flat Plate System (FPS), Beam System used in the buildings. The figure shows that most of the buildings are composed of beam system. The flat plate system is more vulnerable to earthquake. There is a considerable increase of building with F.P.S in the recent years.

Figure 5 shows the relation between numbers of buildings with the presence of lift (Yes/No) in the buildings. The figure shows that about 45% of the buildings have the provision of lift. The structures with lift core tend to be stronger than the structures without lift. Due to the presence of shear wall but lift core in a corner of the building makes it subject to Torsional effect.

Entry N	Building	Locatio	Soft St	Shape	Numbe	Plinth Are	Slab Ty	Year of Co	Lift	Lift core	Total N	Apparent	Numbe	Parkin	Cantile	Column n	Colur	Picture Number
1	3/1	AA	☑	Rectangle	9	7,000.00	Beam	2002	☑		32	Good	181	32	3.00		Acros	I-301a,b
2	3/2	AA	☑	Rectangle	8	2,500.00	Beam	1997	☐		8	Good	150	4	2.00		Acros	I-302a,b
3	3/3	AA	☑	Rectangle	6	7,100.00	Beam	2004	☐		1	Good	350	12	1.00		Acros	I-303a,b
4	3/5	AA	☑	Rectangle	6	6,900.00	Beam	2007	☑		20	Good	115	20	5.00			I-305a,b
5	3/9	AA	☑	Rectangle	9	6,800.00	Beam	2000	☑	7x9	32	Good	190	32	5.00	24x24	Acros	I-309a,b
6	3/12	AA	☑	Irrefular	2	I5,000.00	Beam	1989	☐		1	Medium	4000	2	0.00	16x16	Acros	I-312
7	3/19	IR	☑	Rectangle	6	6,580.00	Beam	2003	☑	6X8	20	Good	114	20	4.00			I-319a.b
8	9/1	IR	☑	Rectangle	6	2,400.00	Beam	2007	☑		10	Good	56	7	6.00		Along	I-901
9	9/2	IR	☑	Rectangle	6	4,600.00	Flat	2007	☑	5x8	10	Good	60	12	5.00	30x12	Acros	I-902a,b
10	9/6	IR	☑	Rectangle	6	4,558.00	Beam	2007	☑	5X7	15	Good	92	15	6.00			I-906
11	9/8	IR	☑	Rectangle	6	4,500.00	Beam	2007	☑	5X7	10	Good	62	10	4.00			I-908
12	9/14	IR	☑	Square	4	5,800.00	Beam	2007	☑		20	Good	117	20	6.00			I-914a,b
13	9/20	IR	☑	Rectangle	6	4,500.00	Beam	2001	☑	5X7	16	Good	96	16	5.00			I-920
14	6/4	IR	☑	Rectangle	4	5,920.00	Beam	1998	☐		8	Medium	42	7	0.00			I-604
15	6/7	IR	☑	Rectangle	6	4,500.00	Beam	2007	☑		15	N/A	92	15	0.00			I-607
16	6/6	IR	☑	Rectangle	6	4,300.00	Beam	2007	☑	5X7	15	Good	86	24	4.00			I-606
17	6/5	IR	☑	Rectangle	6	2,900.00	Beam	2007	☑	5X6	5	Good	28	9	5.00			I-605a,b
18	5/7	IR	☑	Rectangle	9	4,580.00	Beam	2001	☑	5X8	24	Good	143	24	4.00			I-507a,b
19	5/8	IR	☑	Rectangle	6	4,350.00	Beam	2006	☑		15	Good	86	15	4.00			I-508
20	5/3	IR	☑	Rectangle	6	4,280.00	Beam	2002	☑		15	Good	85	15	0.00			I-503
21	5/4A	IR	☑	Rectangle	6	4,200.00	Beam	2007	☑	10.5X8	15	Good	82	15	4.00	24x24	Acros	I-504b
22	4/9A	IR	☑	Square	8	2,520.00	Beam	1998	☑		14	Good	82	8	3.00			I-409a
23	4/9B	IR	☑	Rectangle	4	1,400.00	Beam	2000	☐		3	Good	16	3	3.00			I-409b
24	2/14	IR	☑	Rectangle	6	8,100.00	Beam	2007	☑		20	N/A	115	20	3.00			I-214
25	2/13	IR	☑	Rectangle	6	8,000.00	Beam	2002	☑		20	Good	115	20	3.00			I-213
26	2/12	IR	☑	Rectangle	6	4,000.00	Beam	2006	☑		11	Good	63	12	6.00			I-212
27	2/10	IR	☑	Rectangle	6	7,900.00	Beam	2007	☑		20	N/A	113	24	5.00			I-210
28	2/9	IR	☑	Rectangle	4	4,010.00	Beam	1995	☐		1	Medium	700	3	0.00			I-209
29	2/6	MR	☑	Rectangle	9	7,850.00	Beam	2004	☐		8	Good	300	25	4.00			I-206a,b
30	2/1A	MR	☑	Rectangle	9	5,100.00	Beam	2007	☑		1	N/A	250	23	2.00		Along	I-201a
31	2/1	MR	☑	Irregular	6	5,100.00	Beam	2004	☑		14	Good	82	14	3.00		Acros	I-201
32	11/10	IR	☑	Rectangle	6	2,800.00	Beam	2007	☑		10	N/A	55	7	4.00	18X12	Acros	I-1110a,b,c
33	11/4	IR	☑	Rectangle	6	2,700.00	Flat	2007	☑		10	N/A	57	7	4.00	21X13	Acros	I-1104
34	11/3	IR	☑	Rectangle	6	2,550.00	Beam	1996	☐		11	Good	48	6	3.00		Acros	I-1103a,b

Figure 2(c). Microsoft Access Database (Sample)

Figure 6 shows the relation between numbers of buildings with average floor area. It has been found that buildings having an average floor area of 2000-3000 sft are dominant in the area surveyed.

Figure 7 shows the relation between numbers of buildings and Number of Storey. From this figure it is evident that 6 storied buildings are predominant as the RAJUK does not give permission to build structures more than 6 storeys. There are some higher storey structure outside the RAJUK area within Dhanmondi area located between Sobhanbag Mosque and Road # 25. (High-rise pocket shown in Fig. 1)

Figure 8 shows the relation between numbers of buildings with presence of overhangs. The figure indicates most buildings tend to have overhang (mostly verandah). Heavy overhang makes a structure risky for earthquake according to the Turkish Method.

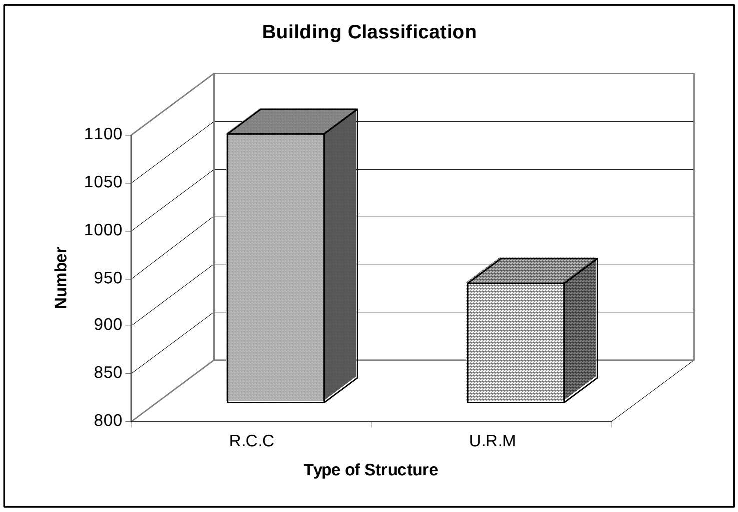

Figure 3a. Relation between numbers of buildings with building classification

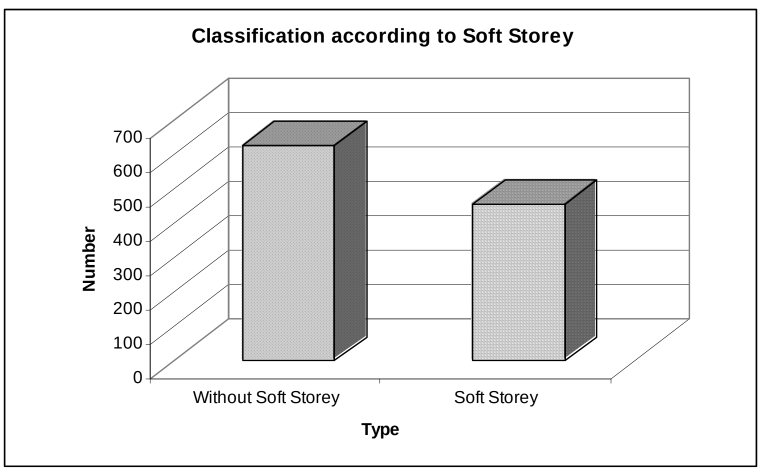

Figure 3b. Relation between numbers of buildings according to Soft Storey

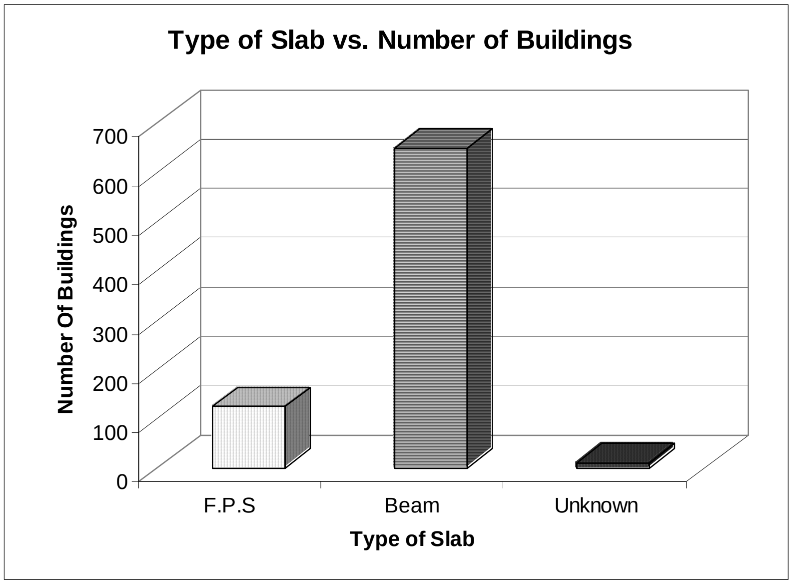

Figure 4. Relations between number of buildings and type of Slab used in the structure

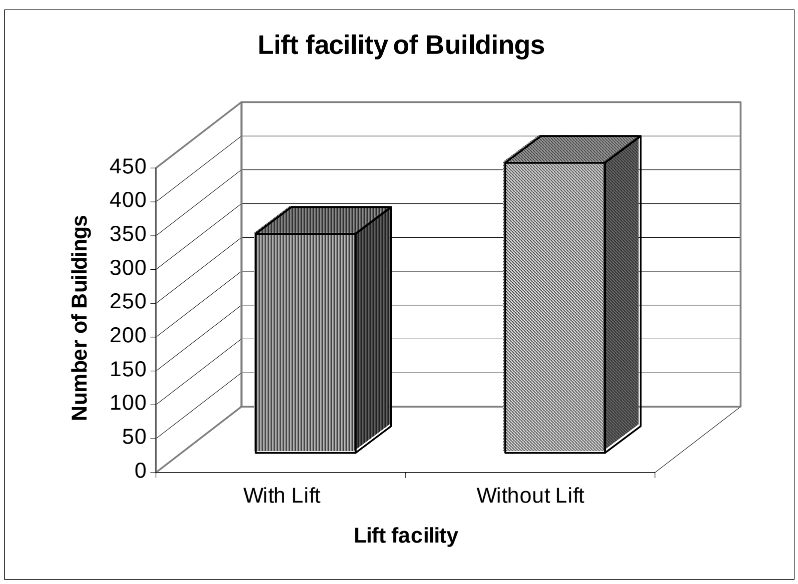

Figure 5. Relations between number of buildings and presence of Lift Core in the structure

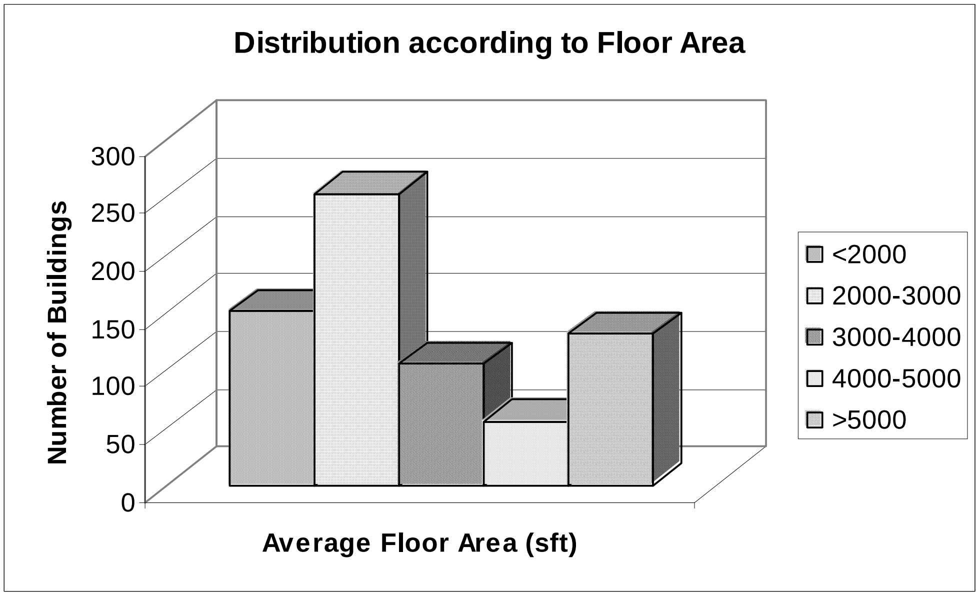

Figure 6. Relations between number of buildings and Average Floor Area

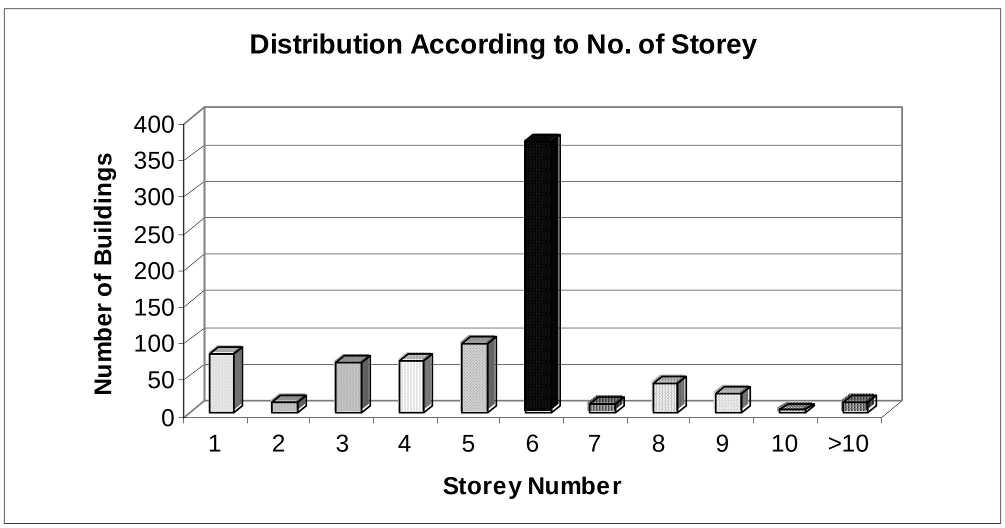

Figure 7. Relations between number of buildings and Number of Storey

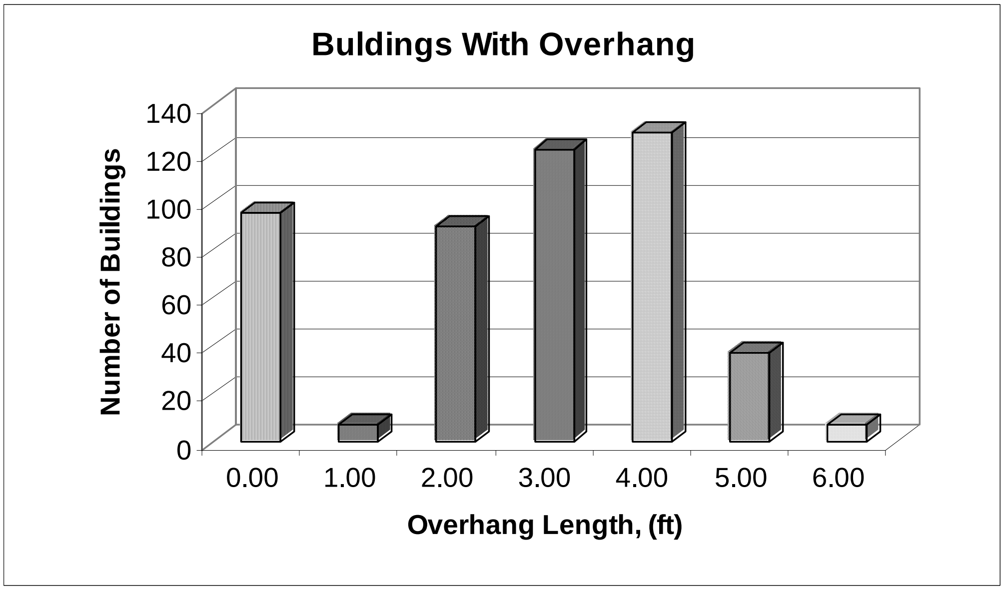

Figure 8. Relations between number of buildings and Overhang Length (ft)

Figure 9 shows the relation between numbers of buildings and the shape of the plot. The figure indicates about 90% of the buildings that were surveyed had a regular type of plot shape. Buildings with irregular plan tend to be more vulnerable to earthquake.

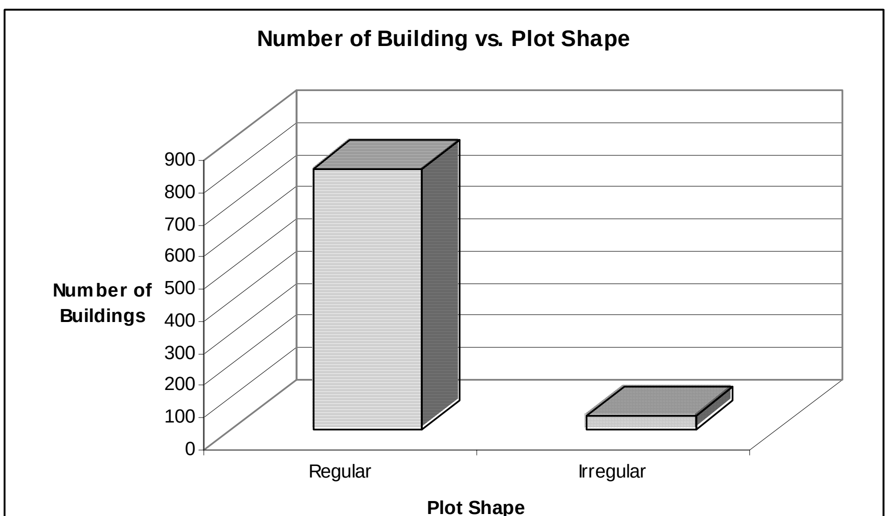

Figure 9. Relations between numbers of Buildings with shape of the plot

Figure 10 shows the relation between numbers of buildings, area of the plot and the number of storey. This figure shows that buildings ranging from 6-8 storeys are dominant. Among those most of them ranged around 2000-3000sft or>5000sft.

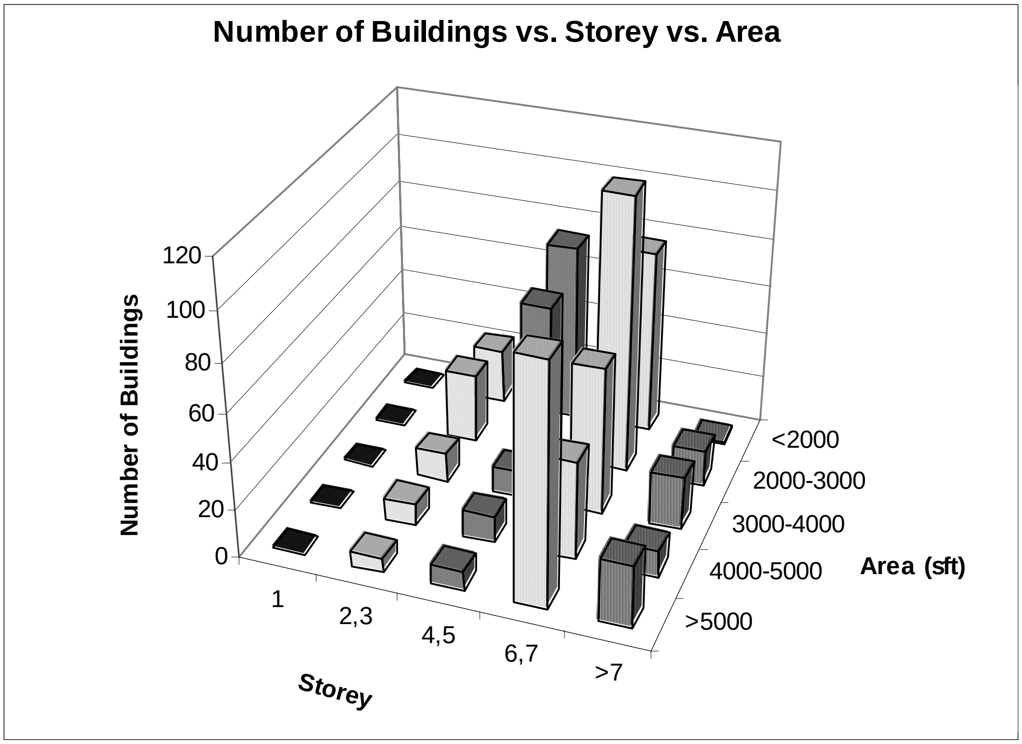

Figure 10. Relations between Number of Buildings, Number of Storey and Area (sft)

Figure 11 shows the relation between numbers of buildings and corresponding Turkish Score. Buildings having a score >50 are considered to be safe in this method.

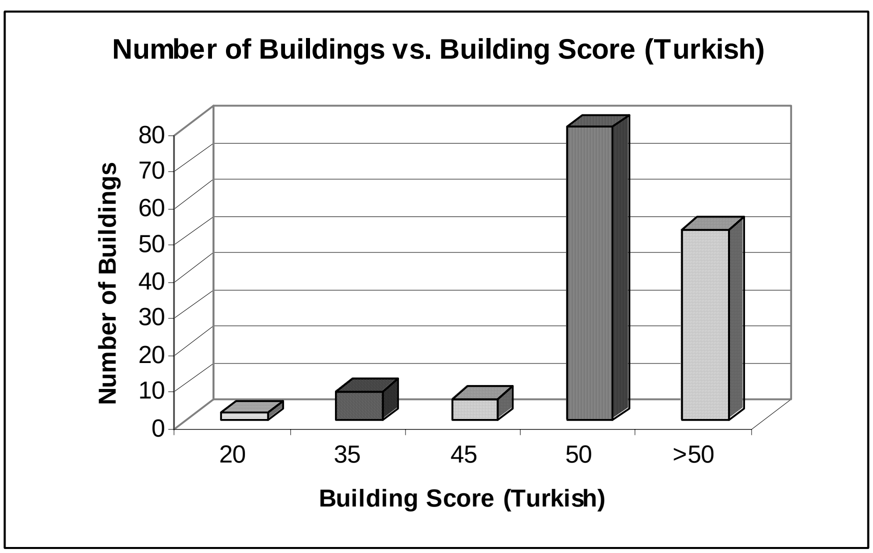

Figure 11. Relations between Number of Buildings & Building Score (Turkish)

Figure 12 shows the relation between numbers of buildings and corresponding R.V.S. Score. Buildings having a score <2 are considered to be dangerous in this method.

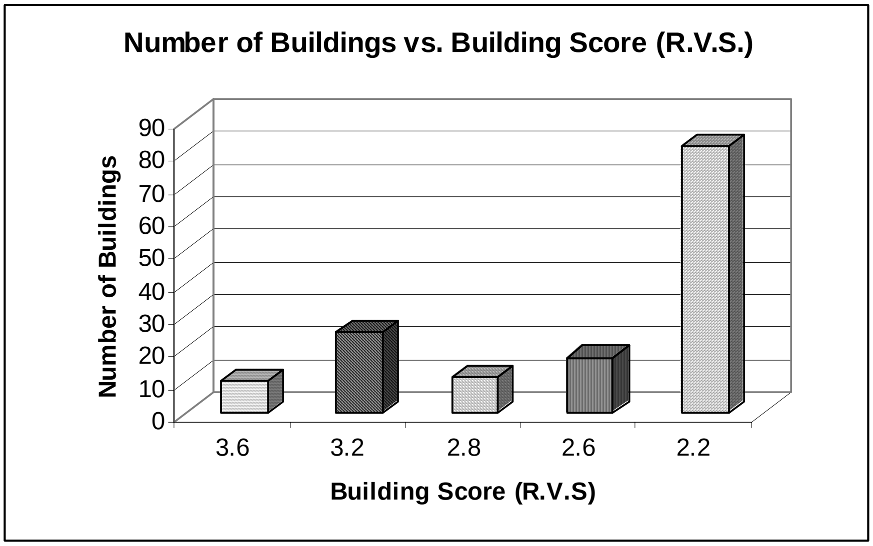

Figure 12. Relations between Number of Buildings & Building Score (R.V.S)

6. CONCLUSIONS

1. Although past earthquakes have scored "direct hits" on cities of less than 100,000 people in the Indian sub-continent (Kathmandu, 1934, Quetta 1935, Muzafferabad 2006 etc) there is no historical example of a major earthquake near or beneath a mega city with a population exceeding 5 million.

2. Earthquakes that have occurred near urban agglomerations consisting of predominantly weak multi-story concrete frame buildings in India, Pakistan, Turkey and China, have resulted in the death of 10-30% of the local population. An unprecedented 1.0-3.0 million death toll could occur were an earthquake to occur near a mega city of 10 million people such as Dhaka city.

3. With a few exceptions, existing earthquake resistant building codes are not applied uniformly to new construction. Unsafe building practices are favored, especially in the private sector, because they may reduce building costs by 10-20%. They can occur because of indifference or corruption in public offices, or simply because an insufficient number of building inspectors are available to enforce a safe construction code.

4. Contractors and workers in the construction trade (as opposed to the earthquake engineering community) are frequently uneducated in often quite simple methods that can help ensure the integrity of concrete frame dwellings.

5. From the year 1995 and onwards, a time during which a building boom was fueled by urban population doubling and redoubling, there were no massive earthquakes.

This lulled the building industry into a state of ignorance and apathy concerning the reality of earthquakes in the Himalaya and elsewhere.

6. Most of the buildings (almost 100%) have no provision of safety route (such as emergency exit). People have very few knowledge how to react when earthquake occurs.

7. About 50% of the building surveyed had lift core in the plan which makes them stronger against earthquake.

References

Roger Bilham and Susan Hough, *Future Earthquakes on the Indian Subcontinent: Inevitable Hazard, Preventable Risk,* South Asian Journal, Feb 2006.

National Report of Commission for the Seismology and Physics of the Earths Interior, Ankara 2007.

Steven M.Vukazich, Guna Selvaduray, Jessica Tran, *Conducting a Soft First-Storey Multi-family dwelling survey:* An Example using Santa Clara Country, California.

Sucuoglu, H. And Yazgan, U. (2003). Simple Survey Procedures for Seismic Risk Assessment in Urban Building Stocks. Seismic Assessment and Rehabilitation of Existing Buildings, 97-118, NATO Science Series, IV/29, Editors: S.T. Wasti and G. Ozcebe, Kluwer

F.E.M.A. Federal Emergency Management Agency 154 (2002).