Proceedings of 10th Global Engineering, Science and Technology Conference
2-3 January, 2015, BIAM Foundation, Dhaka, Bangladesh, ISBN: 978-1-922069-69-6

Vulnerability Analysis of Buildings in Dhaka City

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In this study, seismic vulnerability of existing buildings in Dhaka city has been analyzed. The European Macroseismic Scale-1992 (EMS) is consulted in this regard. The study area is Motijheel Commercial Area. Initially, a database of buildings has been prepared by questioning the inhabitants of the area. Data from 253 buildings is first compiled. Microsoft Access Software is used for this purpose. Most of the buildings are commercial except a few residential buildings. The building information that are accumulated include the area of the buildings, their usages, types, existence of shear wall, basement, lift, number of storey, typical column sizes, presence of plan and vertical irregularities etc. Based on this information, vulnerability of the buildings is assessed as per EMS-1992.

Field of Research: Civil Engineering (Structural)

Keywords: European Macroseismic Scale (EMS), Masonry, Reinforced Concrete (RC), Vulnerability.

1. Introduction

Earthquake is an unavoidable natural disastrous calamity and accordingly its effects are common for an affected area. It occurs at various places of this planet with the span of time in a cycle, approximately each and every hundred or fifty years calculated period. Now-a-days, science has reached an ultimate peak by gradual development almost in every discipline. But, in this category, scientists yet have not found any definite prevention. Since it cannot be prevented, seismologists and engineers are trying to alleviate the vulnerability and damage due to earthquake. Among them the work of Medvedev, Sponheuer and Karnik are quite remarkable and they altogether worked under European Seismological Commission and developed "MSK[1] (Medvedev, Sponheuer and Karnik)" scale to a new scale named (European Macroseismic Scale)[2]. Macroseismic intensity means a classification of the severity of the ground shaking on the basis of observed effects in a limited area. The new arrangement of scale is (1) effects on human, (2) effects on objects and nature, (3) damage to the buildings.

The development of the scale can be seen most clearly in the consideration of damage and building types. The updated version of the MSK scale incorporates a compromise, in which fairly crude differentiation of the resistance of buildings to earthquake shaking has been employed in order to give a simple and robust way of differentiating the way in which buildings may respond to earthquake shaking. The macro seismic study of the building data of Motijheel and Dilkusha area of Dhaka city had been done in the two stages as given below:

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a) Data collection or acquisition by questionnaire survey, field visit, appeals for information or other means.

b) Data sorting or organization of the data into a form in which it can be interpreted by the user.

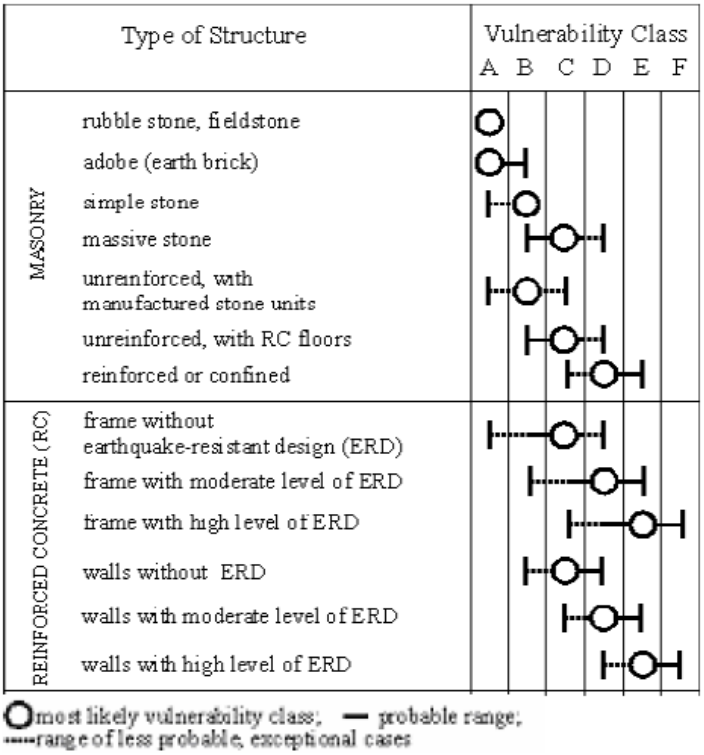
The objectives of this pilot study are as follows:

1. To collect information regarding buildings, roadway width, inhabitants.
2. To predict building vulnerability class.

2. Vulnerability Classification

Previous version of MSK scale defined building classes solely on the types of construction. In this study, it has been attempted to move closer to classes directly representing vulnerability. Accordingly, six classes of decreasing vulnerability (A to F) are proposed of which first three represent the strength of a typical adobe house, brick building and reinforced concrete structures. They should be compatible with building classes 'A' to 'C' in the MSK-64 and MSK-81 scales. Classes 'D' to 'F' are intended to represent approximately linear decreases in vulnerability as a result of improved level of Anti Seismic Design (ASD).

Table 1: Correlation between Vulnerability Classes and Typologies According to the EMS-1992



Since vulnerability is something which is very difficult to quantify in such a way as to be useful to the user of the scale, it is still necessary to define vulnerability in terms of building types. Vulnerability also depends on other factors such as state of disrepair, quality of construction and irregularity of building shapes etc.

Well built (Non-Engineered) wooden or masonry structures can believe in fashion comparable to buildings with ASD typical for vulnerability classes 'D', 'E' or 'F'. In the case of these buildings, appropriate selection of vulnerability class should be made on the level of quality (strength of materials and workmanship) and the regularity.

Figure 1: Map of Study Area (Motijheel and Dilkusha, Dhaka, Bangladesh)

3. Data Analysis and Result

After data collection, EMS scale has been used to analyze the data and find out the possible damage of the structures and the effects on human beings in that area. First of all, vulnerability classes of the structures have been determined depending on their types as per specification of the scale. Actually, three types of structures have been found. These are (1) Masonry structures (2) RC frame structures (3) RC frame structures with shear walls. Analysis of the individual type of structures for various classes carried out as mentioned above is as follows:

- For masonry structures, unreinforced bricks with RC floor for which vulnerability class ranges from 'B' to 'C' have been considered. Since the quality control of construction material, structural design and foundation design are not maintained as per specification, so all masonry buildings have been considered in vulnerability class 'B'.
- For RC structures, RC structures without anti-seismic design have been considered because almost all the RC structures in this locality do not cater for anti seismic design (ASD). These structures range from vulnerability class 'B' to 'D' as per scale. Due to not controlling quality of construction materials, proper design and soil test, vulnerability class have been restricted to 'C'.

- For huts, tin sheds and wooden structures are classified as vulnerability class 'D' though it ranges from vulnerability class from 'C' to 'F'.

Massive data had been collected keeping main focus on the building structures. In this regard, other related data were collected by questioning the people of that area. These data were arranged, scrutinized and reviewed using the program of Microsoft Access. Vulnerability of the buildings was determined using the EMS Scale.

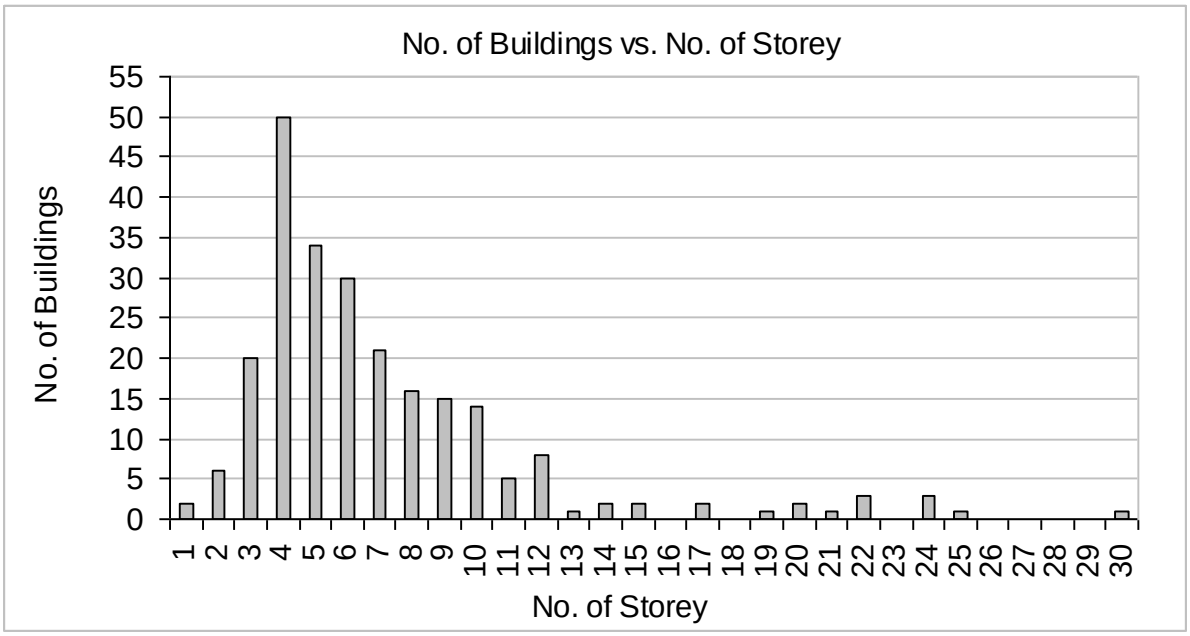


Figure 2: Classification of buildings on the basis of No. of storey

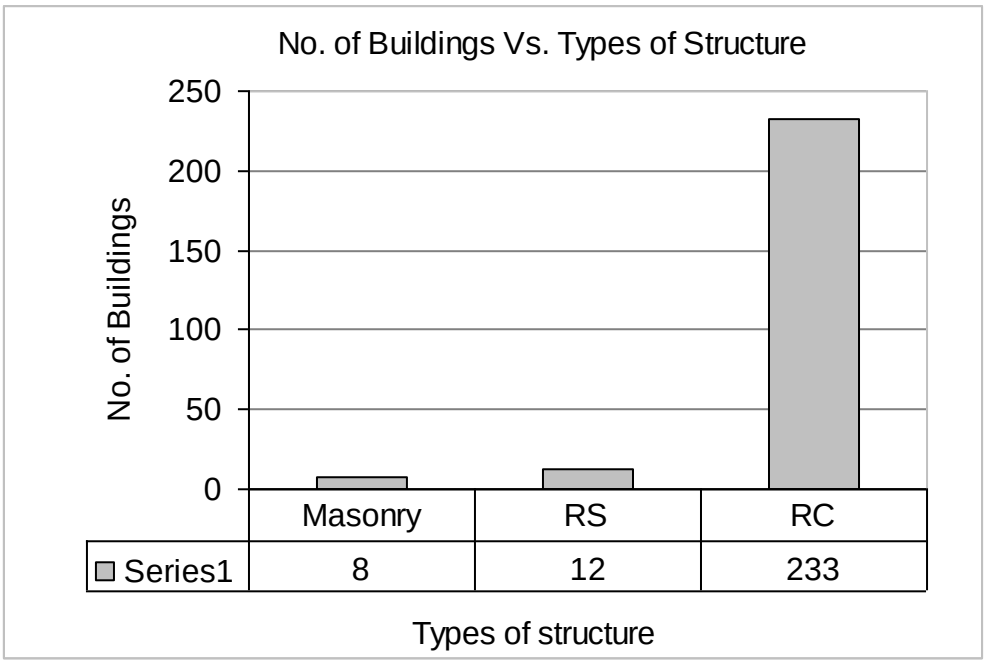


Figure 3: Classification of buildings on the basis of types of structure
(RS: RC building with shear wall & RC: RC building without shear wall)

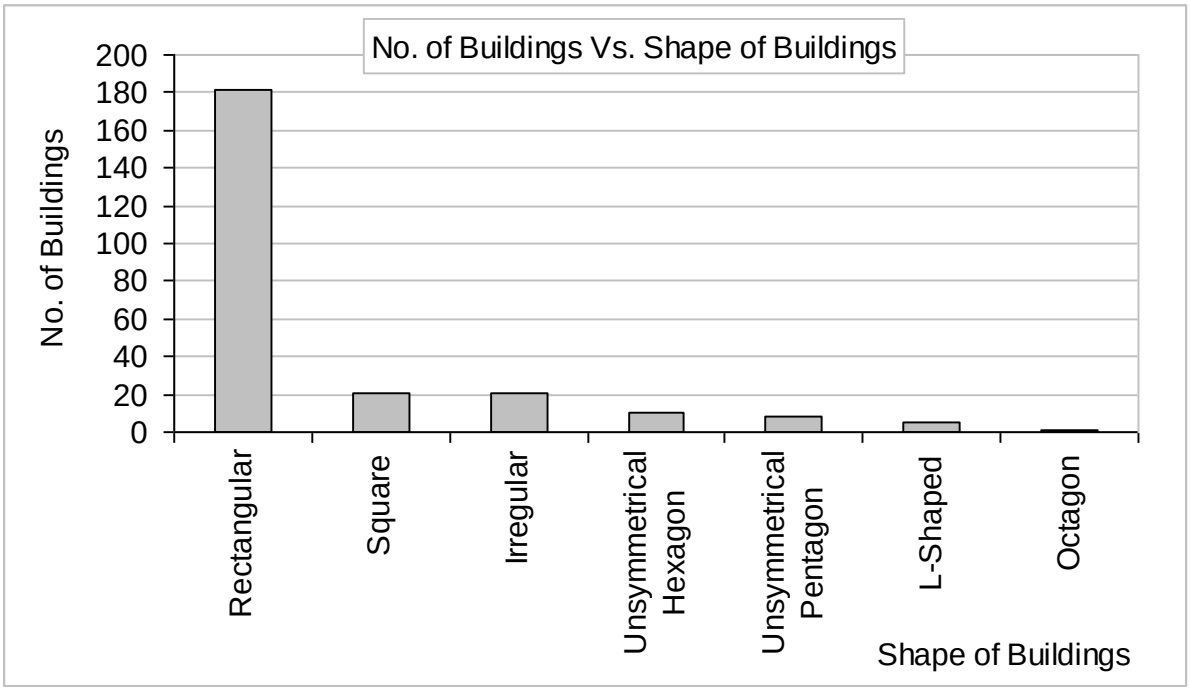


Figure 4: Classification of buildings on the basis of shape of structures

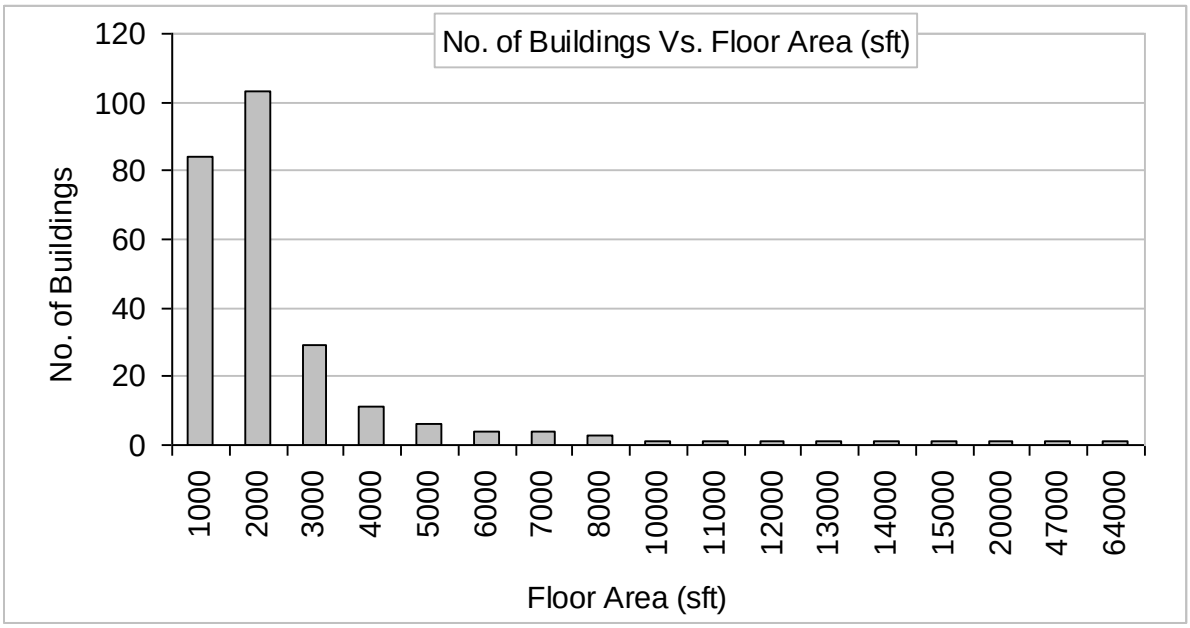


Figure 5: Classification of buildings on the basis of floor area of structures

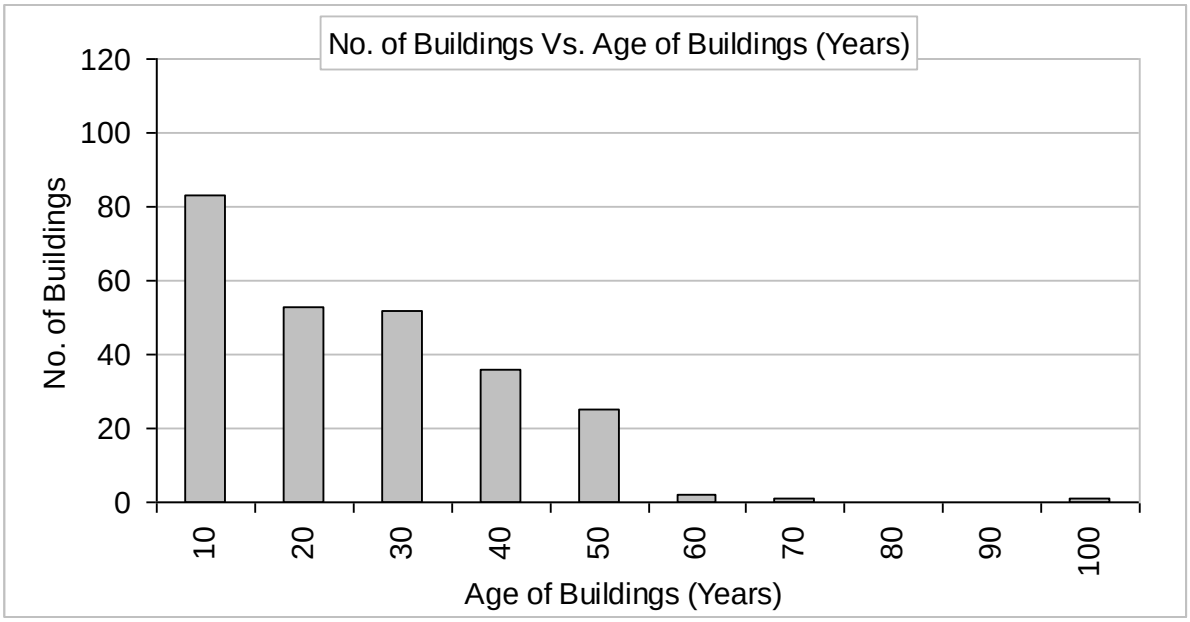


Figure 6: Classification of buildings on the basis of age of structures

Table 2: Estimation of floor space for 'C' type buildings in Motijheel C/A

Vulnerability Classification	Area (sft)	Storey	Total Floor Space (sft)	Vulnerability Classification	Area (sft)	Storey	Total Floor Space (sft)
C	400	4	1600	C	1400	7	9800
C	400	4	1600	C	1400	5	7000
C	420	5	2100	C	1400	4	5600
C	440	4	1760	C	1400	4	5600
C	440	4	1760	C	1440	24	34560
C	450	4	1800	C	1440	7	10080
C	484	3	1452	C	1450	8	11600
C	500	12	6000	C	1500	5	7500
C	510	4	2040	C	1500	4	6000
C	550	4	2200	C	1500	7	10500
C	550	6	3300	C	1500	3	4500
C	560	5	2800	C	1500	22	33000
C	560	9	5040	C	1500	3	4500
C	576	2	1152	C	1540	6	9240
C	600	4	2400	C	1550	2	3100
C	600	4	2400	C	1560	4	6240
C	600	4	2400	C	1600	5	8000
C	600	5	3000	C	1600	2	3200
C	600	4	2400	C	1600	11	17600
C	600	2	1200	C	1600	3	4800
C	621	6	3726	C	1650	3	4950
C	625	4	2500	C	1650	6	9900
C	625	2	1250	C	1680	9	15120
C	630	4	2520	C	1700	6	10200
C	630	4	2520	C	1705	8	13640
C	684	6	4104	C	1728	9	15552

Vulnerability Classification	Area (sft)	Storey	Total Floor Space (sft)	Vulnerability Classification	Area (sft)	Storey	Total Floor Space (sft)
C	720	4	2880	C	1750	7	12250
C	720	2	1440	C	1750	2	3500
C	728	5	3640	C	1800	9	16200
C	750	5	3750	C	1800	3	5400
C	756	4	3024	C	1800	6	10800
C	768	4	3072	C	1950	5	9750
C	800	2	1600	C	2000	22	44000
C	800	2	1600	C	2000	8	16000
C	800	4	3200	C	2000	3	6000
C	800	12	9600	C	2000	5	10000
C	800	5	4000	C	2100	8	16800
C	800	14	11200	C	2160	7	15120
C	800	3	2400	C	2200	10	22000
C	875	5	4375	C	2200	6	13200
C	875	3	2625	C	2200	2	4400
C	896	7	6272	C	2240	9	20160
C	900	5	4500	C	2250	3	6750
C	900	8	7200	C	2300	14	32200
C	900	6	5400	C	2310	5	11550
C	900	5	4500	C	2340	20	46800
C	900	4	3600	C	2400	10	24000
C	900	4	3600	C	2400	7	16800
C	900	6	5400	C	2400	6	14400
C	900	2	1800	C	2400	6	14400
C	900	5	4500	C	2400	6	14400
C	960	4	3840	C	2500	12	30000
C	972	2	1944	C	2500	9	22500
C	1000	21	21000	C	2500	9	22500
C	1000	6	6000	C	2580	10	25800
C	1000	4	4000	C	2600	5	13000
C	1000	3	3000	C	2600	5	13000
C	1000	7	7000	C	2700	10	27000
C	1015	3	3045	C	2700	7	18900
C	1035	4	4140	C	2850	5	14250
C	1040	9	9360	C	2888	5	14440
C	1050	8	8400	C	3025	7	21175
C	1050	9	9450	C	3200	12	38400
C	1050	8	8400	C	3200	20	64000
C	1100	7	7700	C	3240	17	55080
C	1100	3	3300	C	3240	13	42120
C	1100	4	4400	C	3360	10	33600
C	1120	7	7840	C	3400	4	13600
C	1200	5	6000	C	3575	7	25025
C	1200	3	3600	C	3600	4	14400
C	1200	5	6000	C	3600	6	21600
C	1200	3	3600	C	4400	22	96800
C	1200	10	12000	C	4800	5	24000

Vulnerability Classification	Area (sft)	Storey	Total Floor Space (sft)	Vulnerability Classification	Area (sft)	Storey	Total Floor Space (sft)
C	1225	3	3675	C	4860	11	53460
C	1225	8	9800	C	4900	10	49000
C	1248	5	6240	C	5670	5	28350
C	1250	11	13750	C	6400	9	57600
C	1250	2	2500	C	6400	6	38400
C	1250	4	5000	C	6480	12	77760
C	1250	2	2500	C	6600	5	33000
C	1250	3	3750	C	7650	6	45900
C	1260	10	12600	C	10000	30	300000
C	1280	7	8960	C	10800	10	108000
C	1320	6	7920	C	15000	8	120000
C	1400	4	5600	C	19800	9	178200
C	1400	8	11200	C	46080	4	184320

Total Buildings = 176
Total Floor Space = 3726256 sft
Total Floor = 1169
Average Floor Space = 3188 sft

Table 3: Estimation of floor space for 'D' type buildings in Motijheel C/A

Vulnerability Classification	Area (sft)	Storey	Total Floor Space (sft)	Vulnerability Classification	Area (sft)	Storey	Total Floor Space (sft)
D	180	6	1080	D	1100	6	6600
D	300	6	1800	D	1155	7	8085
D	450	3	1350	D	1176	4	4704
D	560	9	5040	D	1200	4	4800
D	600	5	3000	D	1200	8	9600
D	630	5	3150	D	1225	6	7350
D	660	5	3300	D	1360	5	6800
D	700	10	7000	D	1375	3	4125
D	720	11	7920	D	1400	4	5600
D	720	4	2880	D	1400	6	8400
D	768	2	1536	D	1500	3	4500
D	800	8	6400	D	1600	6	9600
D	800	5	4000	D	1680	8	13440
D	800	5	4000	D	1800	1	1800
D	875	4	3500	D	1848	10	18480
D	875	7	6125	D	1872	4	7488
D	896	3	2688	D	2000	4	8000
D	968	4	3872	D	2000	10	20000
D	1000	12	12000	D	2016	5	10080
D	1000	9	9000	D	2500	4	10000
D	1035	8	8280	D	4000	4	16000

D	1050	6	6300	D	5600	24	134400
D	1050	5	5250	D	6000	11	66000
D	1080	10	10800	D	11400	6	68400
D	1080	7	7560	D	12900	15	193500
D	1100	4	4400	D	1600	12	19200
D	1200	4	4800	D	1440	5	7200
D	360	6	2160	-	-	-	-

Total Buildings = 55
Total Floor Space = 802143 sft
Total Floor = 358
Average Floor Space = 2241 sft

Table 4: Estimation of floor space for 'E' type buildings in Motijheel C/A

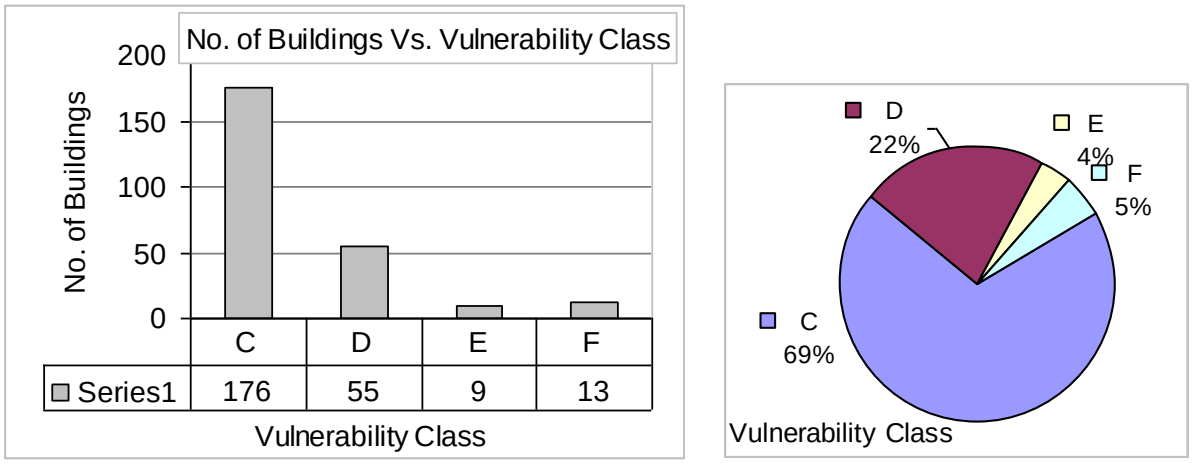
Vulnerability Classification	Area (sft)	Storey	Total Floor Space (sft)	Vulnerability Classification	Area (sft)	Storey	Total Floor Space (sft)
E	1024	9	9216	E	7500	4	30000
E	1000	8	8000	E	1920	7	13440
E	2500	8	20000	E	5625	7	39375
E	2624	2	5248	E	1650	1	1650
E	1200	4	4800	-	-	-	-

Total Buildings = 9
Total Floor Space = 131729 sft
Total Floor = 50
Average Floor Space = 2635 sft

Table 5: Estimation of floor space for 'F' type buildings in Motijheel C/A

Vulnerability Classification	Area (sft)	Storey	Total Floor Space (sft)	Vulnerability Classification	Area (sft)	Storey	Total Floor Space (sft)
F	990	4	3960	F	7700	17	130900
F	4800	9	43200	F	1280	6	7680
F	1100	12	13200	F	1500	6	9000
F	1520	9	13680	F	1200	7	8400
F	1920	10	19200	F	4320	15	64800
F	1350	6	8100	F	13152	24	315648
F	1210	4	4840	-	-	-	-

Total Buildings = 13
Total Floor Space = 512928 sft
Total Floor = 129
Average Floor Space = 3976 sft



(a) (b)

Figure 7: Vulnerability Classification of Buildings (a) in Numbers & (b) in Percentages

4. Conclusion

Collected data had been analyzed from different points of view such as number of storey, age of the structure, shape, structural system and area of the buildings. All of the findings are summarized below:

(a) Storeywise classification shows that four storied buildings are of highest number. The number of buildings increases from storey 1 to storey 4 and there is a decrease in numbers of stories after storey 4.

(b) From shapewise classification, 181 buildings are of rectangular shape, 21 are square, 21 are irregular, 10 are unsymmetric hexagonal, 8 are unsymmetric pentagonal, 5 are L-shaped and only one is octagonal.

(c) The highest number of buildings in between 1000 & 2000 square feet area is 103, 80 numbers of buildings is within 1000 square feet and building areas having more than 2000 square feet follows a decreasing pattern.

(d) From areawise classification, it has been observed that the number of buildings decreases with age and this indicates that plenty of buildings are newly constructed.

(e) Structurewise classification gives that RC, RS & Masonry type buildings are in the number of 233, 12 & 8 respectively. This indicates that most of buildings are RCC type in comparison with others two type.

(f) From vulnerability classification, it signifies that 176 buildings lie in Class ‘C’. The number of buildings in Class ‘D’, ‘E’ and ‘F’ are 55, 9 and 13 respectively.

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