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Seismic Vulnerability Assessment of Buildings in Lucknow

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***Abstract*— In the last few years there are several damaging earthquakes in India demonstrates the seismic vulnerability in India. As a step in understanding the seismic risk in our country, there is a need to determine the vulnerability of prevalent construction types in India, against earthquakes. Lucknow is a city in the northern part of India which falls under the zone 3 of the earthquake zonation map of India according to IS**

1893-2002. This paper presents a vulnerability assessment of various buildings in Lucknow, and indicates the degree of vulnerability of the buildings, and the measures that can be taken to prevent the potential damages.

Keywords*— Basic structural hazard, Demand capacity Ratio, Horizontal acceleration spectrum, Performance modification factor, Response reduction factor, Structural score, Vulnerability assessment.

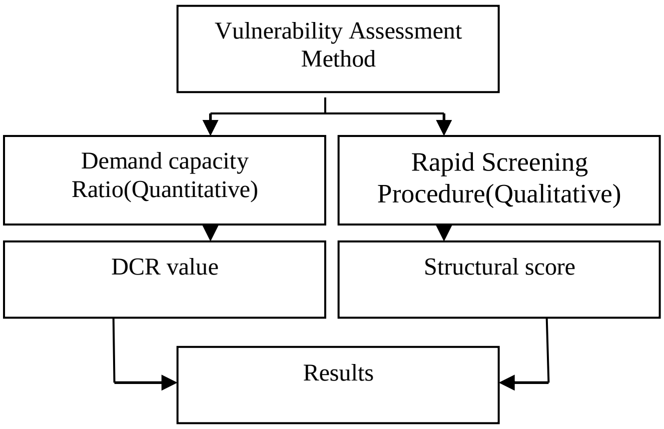
I. INTRODUCTION

A. The rapid growth of Indian cities in the recent past, have accelerated pressure on housing industry, especially in high seismic zone. The built environment in these zones has bee ethod

In this method n seismically found vulnerable as most of these constructions are without earthquake resistant measures. The most challenging task is to evaluate seismic safety of these constructions and take necessary steps for their retrofitting so as to protect them from future earthquakes. Lucknow is a growing city in the northern part of India, which falls under Zone 3 of the earthquake zonation map of India (IS 1893: 2002). In this project there are two buildings which are considered for the analysis purpose. Earthquake vulnerability assessment can be carried out by two methods. The quantitative approach covers demand-capacity computation, while qualitative procedure estimates structural scores based on national & international state-of-the-art procedures viz. Rapid Screening Procedure (RSP).

II. VULNERABILITY ASSESSMENT METHODOLOGY

Vulnerability assessment methods[6] are grouped into two categories for the purpose of this report.



A. Demand-Capacity M

the demand and capacity of the building is calculated. When the ratio of the demand and the capacity of the building s less than 1, then the building is said to be safe otherwise the building is said to be vulnerable. DCR exceeding 1, indicates that building is vulnerable to earthquake loads as defined in IS: 1893-2002.

Calculation of Demand of the Building

The demand of the building refers to the seismic force that may come on structure due to future earthquake.

Design seismic load[3]

The design seismic load is given by-

$$F_i = A_h \times W$$

Where, W= seismic weight of all floors of buildings.
A_h = design horizontal seismic coefficient.
The design horizontal seismic coefficient can be evaluated by the procedure given by clause 6.4.2 in IS 1893-2002.[3]

$$A_h = (Z\ I\ S_a / 2\ R\ g)$$

Where Z= zone factor (Z=0.16, for Lucknow (Zone III))
I= Importance factor (depends upon the types of building)
R= Response reduction factor (from table-6, IS 1893-2002)
S_a/g= Average response acceleration coefficient, it depends upon the natural fundamental time period.

Natural fundamental time period[3]

$$T = (0.009h/\sqrt{d})$$

where d= dimension of building at plinth level.

Over turning moment calculation
Over turning moment is different for the different floors of the building. It depends upon the height of the buildings. the over turning moment at different floors can be calculated by following method-

$$\text{Over turning Moment} = \{(F_i Hi^2/\sum F_i Hi^2) X\ F_i x\ H_i\}$$

Calculation of capacity of the Building
The capacity of the building depends upon the dead load of the building. the resisting moment of the building can be calculated with the help of the dead load of the building. It depends upon the strength of the concrete and the types of structure(framed RCC or brick wall structure).

Factor of safety(f)= (Resisting moment/overturning moment)

DCR of the Building = 1.5/(f)

when the DCR of any building is less than 1 then building is said to be safe or less vulnerable(in case of close 1to) otherwise vulnerable.

B. Rapid Screening Procedure
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.

Generation of structural score(S) comprising of basic structural hazard(BSH) and performance modification factors(PMFs). The structural score related to probability of building sustaining the life-threatening due to earthquake in that region.

Basic structural hazards (BSH)

- Based upon construction practices in India, performance of different types of buildings during past earthquakes and earthquake force likely to be experienced in the study area. BSH are estimated.
- BSH reflects the estimation likelihood of a typical building of that category sustaining major damage given its seismic environment
- these values are determined so that seismically good buildings has a high value, while potentially weak/hazardous buildings has low value.

Performance modification factor (PMFs)[6]

- The significant factors such as high rise quality of construction, vertical and plan irregulation in structure, soft story, pounding, cladding and ground condition and slope ambience can negatively affect the seismic performance of the buildings.
- Primarily, there factors are related to significant deviations from the normal structure practice or conditions, or have to do with effects of soil amplification on the expected ground motion.
- PMFs were assigned values based on judgement by group of experts, such that when added subtracted to BSH, the resulting modified score would approximate the possible major damage.

Final structural score = BSH - ∑PMFs

If the final score of the building is less than 2 the building is said to be vulnerable otherwise it is said to be safe.

III. OBSERVATIONS

The buildings in this analysis are framed structure with in filled brick masonry walls. In the analysis of building A it was found that the building id framed structure in which shear wall is provided. But in the analysis of building B it was found that building is made up by framed structure but the shear wall is not provided. The bearing capacity of the soil at the site is very good and the water table is below danger level. So the chances of liquefaction are negligible.

IV. THEORY OF STRUCTURAL SCORE

The structural score of a building can be identified according to their BSH and PMFs. The performance modification factors depends upon the different conditions

1. height of story
2. vertical irregularity
3. plan irregularity
4. code detailing
5. soil condition

Now considering the above criteria which are suited at the site. BSH is calculated from FEMA-154/ATC-21 Based Data Collection Form. In this Performa all the performance modification factors are also given. From this Performa the final structural score is calculated.

V. RESULTS

The analysis of both the building is done by both method (DCR method and RSP method).The results shows that both the building are safe but in case of high intensity earthquake the building B may fail because the DCR value is close to 1 and the final structural score is also near to 2 , but building A is safe.

Table 1-Final *DCR Value of the buildings*

S.No.	Building name	No. of story	FOS	DCR Value
1	Building A	9	2.981	0.503
2	Building B	10	1.716	0.874

Table-2 Final *Structural score the buildings*

S.No.	Building name	Specifications	observations	Structural score
1	Building A	Framed structure with shear wall	Good	3.20
2	Building B	Framed structure without shear wall	Some cracks from inside	2.12

VI. DISCUSSION

The DCR value and the structural score of both the building is calculated. Both the buildings are assessed from both the methods. from both results the building B which is less vulnerable need to take care of and needs retrofitting and the building A which is safe need not any retrofitting. The building B which is less vulnerable, this is may be due to absence of shear wall and the absence of code detailing and the presence of some crakes in the in filled masonry wall.

VII. CONCLUSION

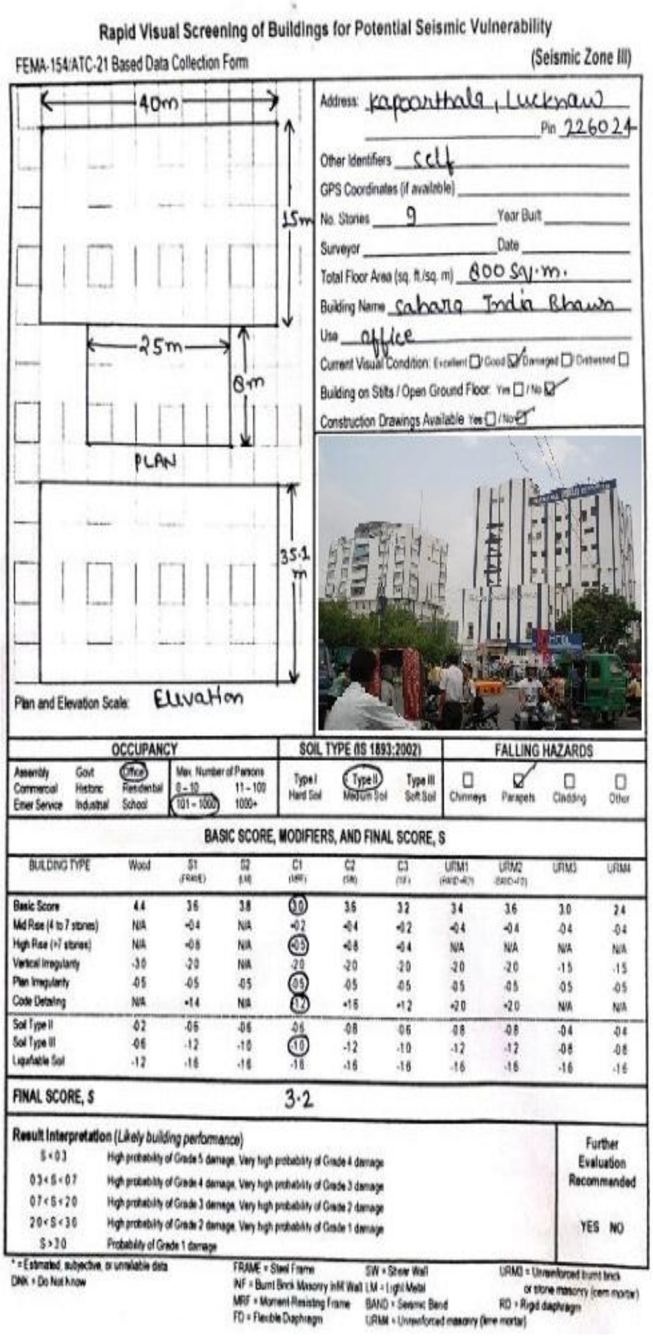
The following conclusion are drawn from this project-

- The demand capacity method which is described in this paper using DCR value which can be effectively used.
- A Rapid screening procedure which is also described in this paper using structural score which can also be effectively used.
- As the codal provisions become more stringent with every revision, these structures may not meet the demands in the years to come.[4]
- Lucknow comes in zone 3 so it is less prone to earthquake but on behalf of earlier earthquake this region can come in more prone earthquake area. so the construction practices should be seismic resistant.
- Building B in need of repair, retrofitting and restoration to comply with the service requirements of the revised code.[1]

VIII. ACKNOWLEDEMENT

We are extremely grateful and remain indebted to our guide Mr. Prashant Mishra (Assistant Professor) Department of Civil Engineering, SRMCEM, Lucknow for being a source of inspiration and for his constant support in the implementation and evaluation of project. We are thankful for his constant constructive suggestions, which benefited us a lot in developing this project. She had been a constant source of inspiration and motivation for hard work. Through this column, it would be our utmost pleasure to express our warm thanks for her encouragement, co-operation and constant support without which we might have not been able to complete the project.

Image-1 Rapid Visual Screening done in the Sahara india bhawan



Rapid Visual Screening of Buildings for Potential Seismic Vulnerability

FEMA-154/ATC-21 Based Data Collection Form (Seismic Zone III)

Address: Kapoorthala, Lucknow
Pin 226024
Other Identifiers: Self
GPS Coordinates (if available)
No. Stories: 9 Year Built
Surveyor Date
Total Floor Area (sq. ft./sq. m): 800 sq.m.
Building Name: Sahara India Bhawan
Use: Office
Current Visual Condition: Excellent / Good / Damaged / Distressed
Building on Stilts / Open Ground Floor: Yes / No
Construction Drawings Available: Yes / No

Plan and Elevation Scale: Elevation

OCCUPANCY		SOIL TYPE (IS 1893:2002)	FALLING HAZARDS
Assembly, Govt, Office, Commercial, Historic, Residential, Emer Service, Industrial, School	Max. Number of Persons: 0 – 10, 11 – 100, 101 – 1000, 1000+	Type I Hard Soil, Type II Medium Soil, Type III Soft Soil	Chimneys, Parapets, Cladding, Other

BASIC SCORE, MODIFIERS, AND FINAL SCORE, S

BUILDING TYPE	Wood	S1 (FRAME)	S2	C1 (MRF)	C2 (SW)	C3 (IF)	URM1	URM2	URM3	URM4
Basic Score	4.4	3.6	3.8	3.0	3.6	3.2	3.4	3.6	3.0	2.4
Mid Rise (4 to 7 stories)	N/A	+0.4	N/A	+0.2	+0.4	+0.2	-0.4	-0.4	-0.4	-0.4
High Rise (>7 stories)	N/A	+0.6	N/A	+0.5	+0.8	+0.4	N/A	N/A	N/A	N/A
Vertical Irregularity	-3.0	-2.0	N/A	-2.0	-2.0	-2.0	-2.0	-2.0	-1.5	-1.5
Plan Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Code Detailing	N/A	+1.4	N/A	+1.2	+1.6	+1.2	+2.0	+2.0	N/A	N/A
Soil Type II	-0.2	-0.6	-0.6	-0.6	-0.8	-0.6	-0.8	-0.8	-0.4	-0.4
Soil Type III	-0.6	-1.2	-1.0	-1.0	-1.2	-1.0	-1.2	-1.2	-0.8	-0.8
Liquefiable Soil	-1.2	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6

FINAL SCORE, S: 3.2

Result Interpretation (Likely building performance)
S < 0.3 High probability of Grade 5 damage. Very high probability of Grade 4 damage
0.3 < S < 0.7 High probability of Grade 4 damage. Very high probability of Grade 3 damage
0.7 < S < 2.0 High probability of Grade 3 damage. Very high probability of Grade 2 damage
2.0 < S < 3.0 High probability of Grade 2 damage. Very high probability of Grade 1 damage
S > 3.0 Probability of Grade 1 damage

Further Evaluation Recommended: YES NO

* = Estimated, subjective, or unreliable data; DNK = Do Not Know
FRAME = Steel Frame; INF = Burnt Brick Masonry Infill Wall; MRF = Moment Resisting Frame; FD = Flexible Diaphragm
SW = Shear Wall; LM = Light Metal; BAND = Seismic Band; URM = Unreinforced masonry (lime mortar)
URM3 = Unreinforced burnt brick or stone masonry (cem mortar); RD = Rigid diaphragm

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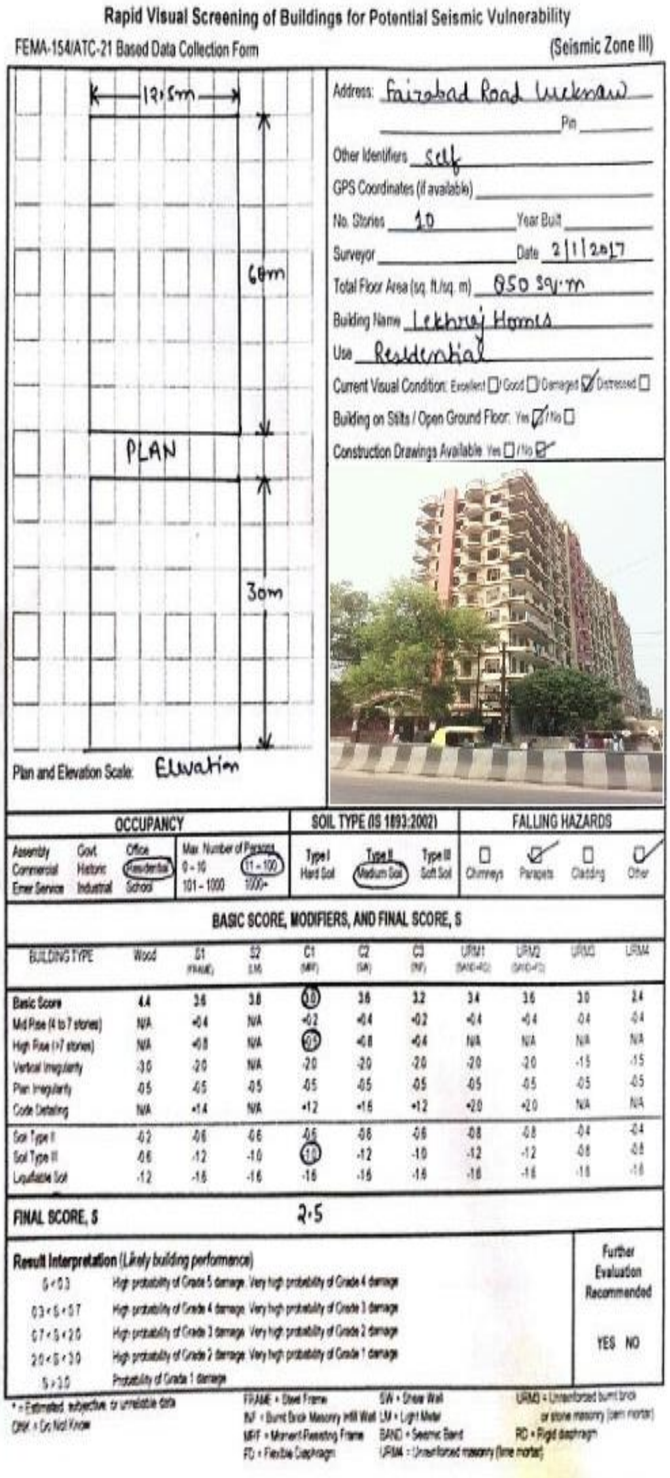
Image-2 Rapid Visual Screening done in the Sahara Lekhraj Homes



BUILDING TYPE	Wood	S1 (FRAME)	S2 (LM)	C1 (MRF)	C2 (SW)	C3 (INF)	URM1	URM2	URM3	URM4
Basic Score	4.4	3.6	3.8	3.0	3.6	3.2	3.4	3.6	3.0	2.4
Mid Rise (4 to 7 stories)	N/A	+0.4	N/A	+0.2	+0.4	+0.2	+0.4	+0.4	0.4	0.4
High Rise (>7 stories)	N/A	+0.8	N/A	0.5	+0.8	+0.4	N/A	N/A	N/A	N/A
Vertical Irregularity	-3.0	-2.0	N/A	-2.0	-2.0	-2.0	-2.0	-2.0	-1.5	-1.5
Plan Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Code Detailing	N/A	+1.4	N/A	+1.2	+1.6	+1.2	+2.0	+2.0	N/A	N/A
Soil Type II	-0.2	-0.6	-0.6	-0.6	-0.6	-0.6	-0.8	-0.8	-0.4	-0.4
Soil Type III	-0.6	-1.2	-1.0	-1.0	-1.2	-1.0	-1.2	-1.2	-0.8	-0.8
Liquefiable Soil	-1.2	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6

Image-3 Response spectra graph

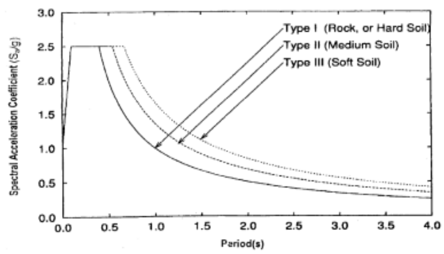


Table-I Performance Modification Factors

Modifiers	Description	Modification Factor
High Rise	Upto 2 storey	0
	Between 3 - 7 storey	-0.2
	More than 7 storey	-0.5
Quality of Construction	High	0
	Medium	-0.25
	Low	-0.50
Vertical Irregularity	Steps in elevation, inclined walls, discontinuities in load path, building on hills	-0.50
	Without vertical irregularity	0
Soft Storey	Open on all sides of buildings, tall ground floor, buildings on stilts	-0.50
	Without soft storey	0
Plan Irregularity	"L", "U", "E", "T", or other irregular building shape	-0.50
	Without plan irregularity	0
Pounding	Floor levels of adjacent buildings not aligned and less than 100 mm of separation per storey	-0.50
	Without pounding	0
Cladding	Many large heavy stone or concrete panels, glass panels and masonry veneer do not qualify	-0.50
	Without vertical irregularity	0
Soil Condition	Buildings founded on rocks (SR)	0
	Buildings founded on cohesionless soil (SC)	-0.3
	Buildings founded on black cotton soil (BC)	-0.6
Ground Condition & Slope Ambience	Buildings in flat/plain land domain	0
	Buildings on hill slopes/tank bunds/reservoir rims with slope > 10° - gentle	-0.10
	-do- - moderate	-0.20
	-do- - steep	-0.30

Table 2 Response Reduction Factor l), *R*, for Building Systems

S.No.	Lateral load resisting frame Building frame system	R
1	Ordinary RC moment-resisting frame (OMRF)	3.0
2	Special RC moment-resisting frame (SMRF)	5.0
3	Steel frame with a) Concentric braces b) Eccentric braces	4.0 5.0
4	Steel moment resisting frame designed as per SP 6	5.0
5	Load bearing masonry wall buildings) a) Unreinforced b) Reinforced with horizontal RC bands c) Reinforced with horizontal RC bands and vertical bars at ***corners*** of rooms and jambs of openings	1.5 2.5 3.0
6	Ordinary reinforced concrete shear walls	3.0
7	Ductile shear walls Buildings with Dual Systems)	4.0
8	Ordinary shear wall with OMRF	3.0
9	Ordinary shear wall with SMRF	4.0
10	Ductile shear wall with OMRF	4.5
11	Ductile shear wall with SMRF	5.0

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