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Vulnerability Assessment of Buildings Through Rapid Visual Survey using GIS

A case study of Gandhidham city

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***Abstract*- This paper presents a methodology to predict the qualitative seismic vulnerability of buildings based on a number of structural parameters determined on the basis of engineering knowledge and observations through rapid visual survey (RVS). It's better to evaluate earthquake damage in a probabilistic way due to the uncertainty in occurrence of earthquake and respective structural response. Again, detailed seismic vulnerability evaluation is a technically complex and expensive procedure and can be applied on a very few number of buildings. Therefore, Rapid Visual Survey (RVS) can be much more effective to rapidly evaluate the vulnerability profile of different types of buildings, so that more complex procedures can be applied to the most critical buildings. RVS was carried out in Gandhidham city. Subsequent to RVS database of buildings having various features and having different range of score can be prepared. Further analytical study can be carried out to prepare risk maps for better disaster mitigation strategy. As RVS is the first stage for Seismic vulnerability assessment of the building, after that preliminary and detailed survey is carried out. The study area was divided into 12 wards. For each building, performance score was calculated and using data collected through the RVS, building database was generated using GIS for Apnanagar area of Gandhidham city. Using GIS the performance scores were rationalized and 3D building vulnerability map is generated. Statistical analysis is done using the database generated and conclusion is drawn for the buildings which are vulnerable and the percentage of the undesirable and desirable features of R.C.C. & Masonry building were calculated for Apnanagar area of Gandhidham city.**

Index Terms: Seismic Vulnerability, Rapid Visual Survey, GIS.

I. INTRODUCTION

Urbanization has increased pressure on housing industry, especially in high seismic zones. Many buildings of these zones have been found seismically vulnerable as most of these constructions are without earthquake resistant measures. The damage to the structures during recent earthquake in India has demonstrated the need for seismic risk assessment through which the consequences of earthquakes can be predicted.

Seismic vulnerability is a measure of the capacity of a structure to resist seismic forces and is the main component of seismic risk assessment. Assessment of seismic vulnerability of existing buildings in urban areas would help in disaster mitigation and management by planning mitigation measures before an earthquake strikes. It is also useful to evaluate seismic safety of these constructions and to take necessary steps for their retrofitting so as to protect them from future earthquakes.

II. METHODS FOR ASSESSMENT OF VULNERABILITY

Existing buildings can become seismically deficient when seismic design code requirements are modified to consider advances in engineering knowledge. Buildings built over past two decades are seismically deficient because of lack of awareness regarding seismic resistance measures. Also seismic design is not normally practiced in most of the buildings being built. Therefore, seismic vulnerability estimation is pre-requisite for disaster mitigation & management.

Vulnerability estimation is a complex process, which has to take into account design, deterioration of the material and damage caused to the building, if any.

A. Quantitative Approach (Demand-Capacity Approach):

Quantitative approach for vulnerability assessment consists of a comparison between some measures of demand that the earthquake places on a structure to a measure of capacity of building to resist. The Demand/capacity ratio (DCR), thus evaluated is measure of earthquake resistance of a building.

B. Qualitative Approach (Rapid Visual Survey - RVS):

The Rapid Visual Survey (RVS) is aimed for identifying potentially hazardous buildings in the study area, without going into detailed analysis. The methodology begins with identifying the primary structural lateral load resisting system and materials of the building. The method generates a Structural Score 'S', a low 'S' score suggests that the building is vulnerable and needs detailed analysis, whereas a high 'S' score indicates that the building is probably safe for defined earthquake loads.

III. RAPID VISUAL SURVEY

There are several steps involved in planning and performing a RVS of potentially seismically hazardous building.

The general sequence of implementing the RVS is:

- Pre-planned survey and identify the area to be surveyed.
- Inspect the building from the exterior on all available sides; sketch the plan and elevation.
- If you have access to the interior, verify construction type, plan irregularities, size of the columns and others details.
- Photograph the building with instant or digital camera.
- Check for quality and file the field data in the record keeping system.

Field Survey of Buildings

The RVS uses a methodology based on a "sidewalk survey" of a building and a Data Collection Form, is filled up on visual observation of the building from the exterior, and if possible, the interior. If a building receives a high score (i.e., above a specified cut-off score), the building is considered to have adequate seismic resistance. If not, it should be evaluated by a professional engineer having experience. On the basis of this detailed inspection, engineering analyses, and other detailed procedures are carried out.

In the present study qualitative approach – Rapid Visual Survey (RVS) is followed with reference of Gandhidham city of Zone V and Earthquake of intensity IX or more can be experienced in this zone. As RVS is the first stage for Seismic vulnerability assessment of the building, subsequently preliminary and detailed survey can be carried out. RVS of Gandhidham city was carried out by Institute of Seismological Research and Institute of Technology, Nirma University. Database of RVS was prepared by International Institute of Information Technology, Hyderabad.

The study area of Gandhidham was divided into 12 wards. Formats of RVS form prepared by IIT Kanpur were used. For each building, performance score was calculated and building database was generated using GIS for different area of Gandhidham city.

IV. BUILDING CHARACTERISTICS AND ASPECTS

There are two types of building: RCC & Masonry Buildings. Performance of building is evaluated through scores. Base score, Vulnerability score (VS) and Vulnerability score modifier (VSM) depends on type of buildings and their features.

A. Building height and Natural period of Building

Building height is related to the vulnerability of the building. Low rise buildings are seismically less vulnerable. When building's natural frequency matches with frequency of ground during earthquake maximum damage may takes place.

B. Soft Storey

Figure 1. Picture showing soft storey

Check List of Observables

- Open parking at ground level
- Absence of partition walls in ground or any intermediate storey for shops or other commercial use
- Taller heights in ground or any other intermediate storey

C. Vertical Irregularities

Vertical irregularities can be judged from the structural system like Setbacks in elevation (Fig. 2).

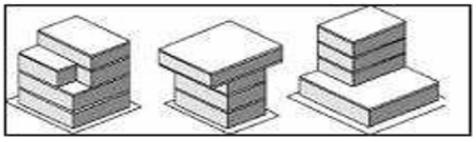


Figure 2. Presence of Setbacks

D. Plan Irregularities

Irregularity in the plan caused due to various shapes (Fig. 3), causes torsion during earthquake and is responsible for major damage.

Check List of Observable Features

- Irregular plan configuration & Reentrant corners

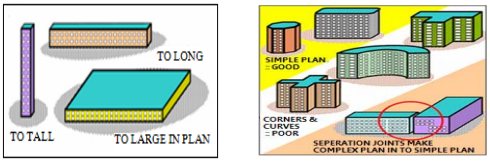


Figure 3. Irregular Plan Configuration & Separation Joints

E. Heavy Overhangs

Heavy overhangs refer to extra projections of a building (Fig.4), can be dangerous because they are subjected to greater seismic forces during an earthquake.

Check List of Observable Features

- Moderate or Substantial horizontal projections

Figure 4. Avoid large projection & Floating columns

F. Water Tank at Roof

It has lot of dead load and if they are placed near the center of plan they may cause large amount of torsion. They can be classified into three categories.

- Doesn't exist
- Capacity < 5000 lit. or Capacity > 5000 lit.

G. Falling Hazards

Falling Hazards have contributed more to the causalities than any feature of a building. Chimney and large hoardings that is likely to fall during earthquake.

Check List of Observable Falling Hazard

Non- structural elements such as,

- Elaborate parapets , AC unit grilles, Hoardings, Heavy Elevation features, Roof signs, Substantial Balconies

H. Soil Condition

Soil is classified as hard, expansive and soft. The hard soil is considered to be better than any other type of soil.

I. Pounding Action

Pounding is the result of irregular response of adjacent building of different heights and different dynamic characteristics. When two buildings are too close to each other, they may pound on each other during strong shaking.

Check List of Observation

- Contiguous buildings
- Poor apparent quality of adjacent buildings

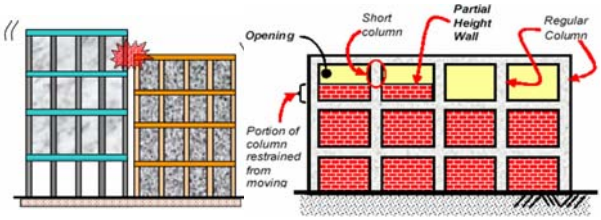


Figure 5. Pounding action

Figure 6. Short column effect

J. Short Column effect

Partial height walls adjoining to columns, give rise to short column effect in RC building (Fig. 6).

K. Frame Action

Frame Action is to be present in the RCC buildings to transfer the load uniformly to the ground (Fig. 7).

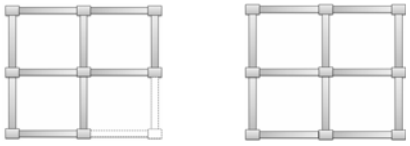


Figure 7. Complete & Incomplete Frame action

L. Apparent Quality

Visible Quality of the material used in the construction works is also known as apparent quality. It also depends upon workmanship and materials used during construction.

Check List of Observation: Apparent Quality

- Apparent quality of materials and construction/Maintenance

M. Various features of Masonry Structures

- Random Rubble Stone Masonry Walls
- Diaphragm Action, Openings and Other Features

IV. STUDY AREA

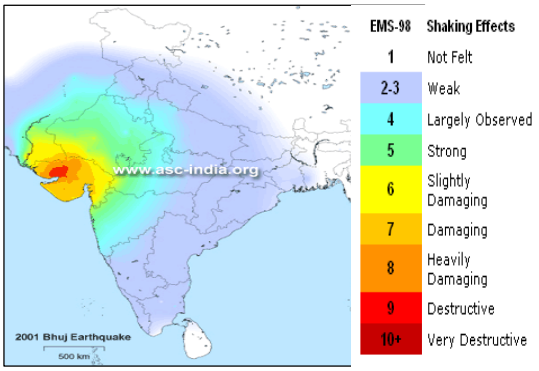


Figure 8. Shaking effects of Bhuj Earthquake

RVS was carried out for whole Gandhidham city. Building Database generation using GIS was carried out for older and higher density Apnanagar area. RVS at Gandhidham City Area

The survey was to be conducted in a phased manner during 9th May to 23rd May 2008. Each group comprised of an M.Tech student, a B.Tech Student of Nirma University and 2 Diploma Students of Tolani Polytechnic. Each group was given a GIS base map of the concerned area which has to be assessed.

Approximately 20,000 structures (mostly residential houses) were surveyed as the city was divided into various wards to be surveyed. Performance forms in detail have been filled and reviewed for approximately 14000 houses of masonry and 6000 houses of RCC frame structure.

GPS (Global Positioning System) survey at Gandhidham using handheld GPS instruments of some building was carried and photographs of some buildings have been taken. To carry out the Rapid Visual Survey, forms containing detailed information about different types of building structures were given to all the participating students. Daily allocation of different areas to the students was done using GIS.

V. AREA ALLOCATION FOR RVS USING GIS

Since students were divided in to 25 different groups, they were named A to X. As Gandhidham and Adipur are divided in wards and sectors, daily allocation of the work was based on giving different wards and sectors numbers to the students. High resolution satellite data of Quick bird was used to get information about ground conditions. Georeferencing of Satellite data was done using Google Earth. Common points in Google Earth Images and Quick bird satellite data were searched and Ground Control Points were given to satellite data for Georeferencing using Arc GIS software. The satellite data was Georeferenced in World Geodic System 1984 projection. Town planning maps were collected from local authorities and also Georeferenced using Arc GIS.

Figure 9. Satellite Image of Apna Nagar

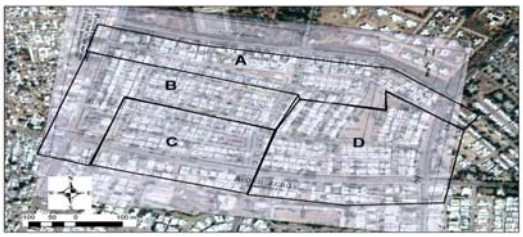


Figure 10. Allocation of the covered areas by group A, B, C, D.

A. Field Work

Approximately 10 days were spent for the data collection in the field. Numbers of buildings were surveyed and information regarding them was collected during this period directly from the field.

B. Post – Field Work

All the information gathered in the fieldwork was tabulated, corrected and imported in Arc-GIS software, where all GIS operations were carried out such as creation of attribute maps, overlaying, georeference and other types of analysis and queries.

C. The following procedure was performed to prepare the GIS data for the analysis.

- Scanning of the town planning map and RVS forms, making excel sheets for the building features.
- Collecting the Imagery of the concerned area from the Quick Bird high resolution images.
- Using Remote Sensing data and Inserting the data into ArcGIS software the layers in the table of content.
- Georeferencing the town planning map & R S map for purpose of digitization.
- Create Shape files of the concerned area houses with the help of ArcCatalog and Adding the Shape files into ArcGIS.
- Digitization, preparation and linking the Database with the Geo-Visualization in ArcGIS as collected using RVS.
- After preparation of data analysis is to be done.

D. Using ArcGIS Software to prepare Building Vulnerability Map

The steps for preparation of Building Vulnerability Map:

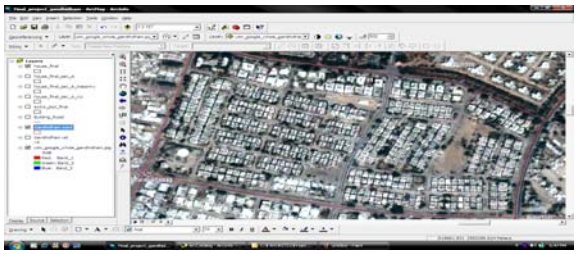


Figure 11. Map of the concerned Area – Apna Nagar (Digitized Image)

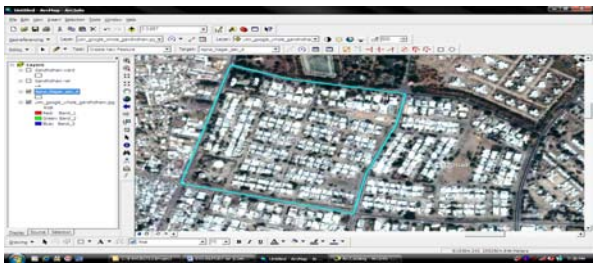


Figure 12. Map showing Apna Nagar sections

E. Building Vulnerability Maps

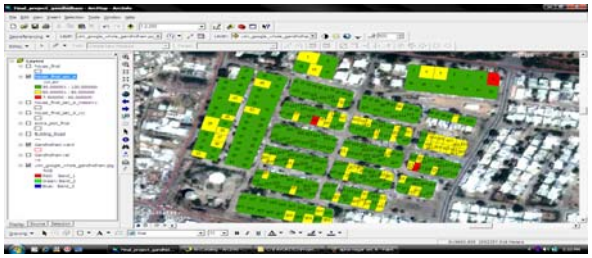


Figure 13. Apna Nagar area Sec A – 2D Map

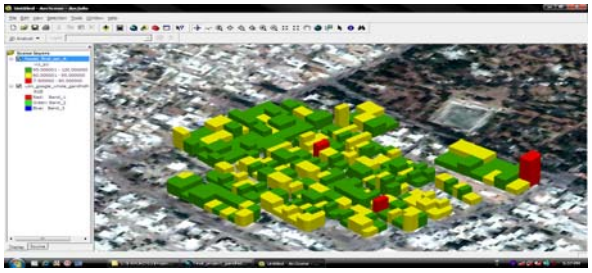


Figure 14. Apna Nagar area Sec A – 3D Map

F. Analysis using ArcGIS Software

- MASONRY Buildings of SEC A

The Fig. 15 shows that the red coloured buildings persists Structural Irregularity, having (-10) score & Fig. 16 Indiactes that out of total 304 buildings, 200 buildings contains Structural Irregularity.

In a similar manner, for MASONRY & R.C.C. Buildings in Sec A and E maps can be prepared for different Characteristics features.

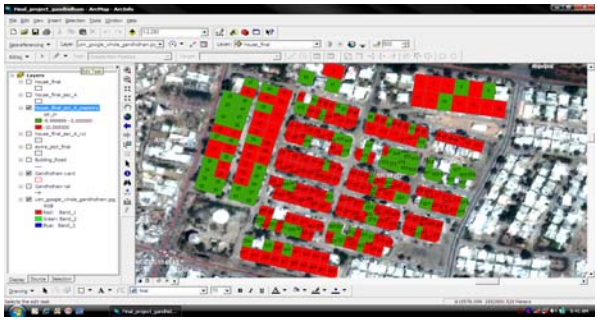


Figure 15. Characteristics features Map (Structural Irregularity)

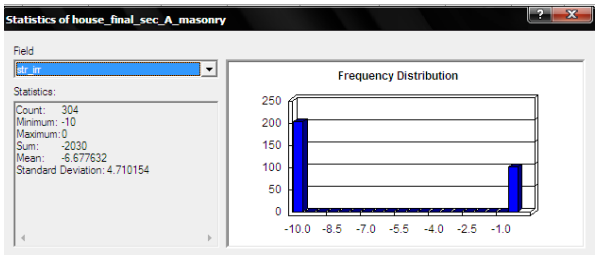


Figure 16. Statistical Analysis

SUMMARY

In present paper procedure for qualitative seismic vulnerability assessment of RC framed and masonry structures through rapid visual survey (RVS) is discussed. RVS was carried out in Gandhidham city. Subsequent to RVS database of buildings having various features and having different range of score can be prepared.

CONCLUSIONS

1. Using the Vulnerability Map of the buildings of Apna Nagar Area prepared using ArcGIS, Fig. 17 shows the percentage of RCC & Masonry buildings:

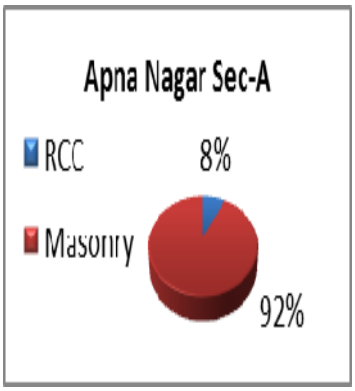
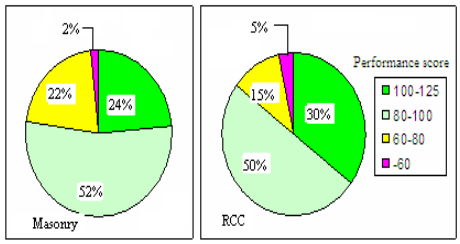


Figure 17. RCC and Masonry Buildings

2. Comparison is made for percentage of buildings that may be Vulnerable. As shown in the Fig. 18.

   - Masonry Building – 2% and RCC Buildings – 5% Which are having performance scores less than 60, thus these buildings of the Apna Nagar area of Gandhidham city may be vulnerable.

Figure 18. Pie chart of RCC and Masonry Buildings



From Fig. 19, it is clear that most of Masonry buildings in Apna Nagar area have Diaphragm action, Horizontal band & Soil Condition as a Positive features, but Large Wall Openings, Apparent Quality & Structural Irregularity as a Negative features.

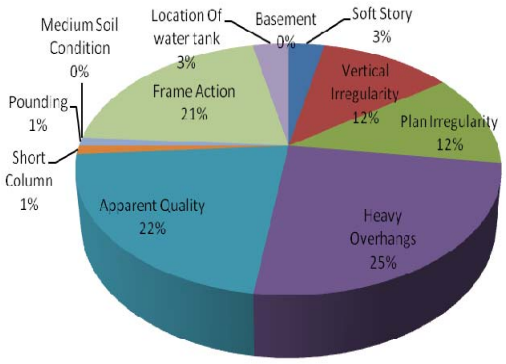


Figure 19.Ccontribution of various features of Masonry Buildings

a. From the Fig. 21, most of RCC buildings of Apna Nagar area have Frame Action as a Positive feature, but Heavy Overhangs, Apparent Quality, Plan Irregularity, Vertical Irregularity, Soft Storey, & Location of Water tank as Negative Features.

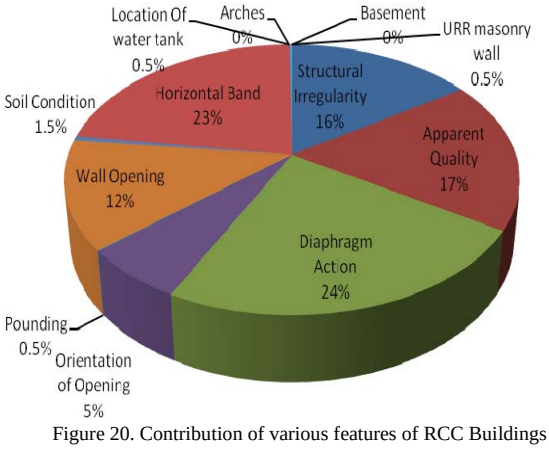


Figure 20. Contribution of various features of RCC Buildings

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REFERENCES

Shailesh Kr. Agrawal and Ajay Chourasia, "Methodology for Seismic Vulnerability Assessment of Building Stock in Mega Cities", A Workshop on Microzonation, Bangalore, pg. 182 – 190.

FEMA 154 :Rapid Visual Screening of Buildings for Potential Seismic Hazards, (ATC-21), USA.

"FEMA 356 :Pre standard and Commentary for the Seismic Rehabilitation of Buildings". American Society of Civil Engineers (ASCE), USA.

C.V.R. Murthy, "E.Q. Tips", Published by Indian Institute of Technology, Kanpur and Building Materials and Technology Promotion Council, New Delhi.