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SEISMIC VULNERABILITY ASSESSMENT USING SATELLITE DATA

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ABSTRACT

The recent earthquakes in India have resulted in huge loss to property, infrastructure and life. This is due to the non standard construction and design practices followed earlier. The vulnerability level of buildings for specified seismic hazard is important to plan the seismic hazard mitigation program, rehabilitation of the structure and to specify the building value for insurance rating and ownership transfer. Conventionally, vulnerability of buildings is assessed by carrying out field survey, using Rapid Visual Screening (RVS) method. This method requires qualitative data which is obtained from manual survey. The Objective of this study is to estimate the seismic vulnerability of buildings by obtaining required parameters of high resolution satellite data and to validate the same by the conventional field survey method.

KEYWORDS

Rapid visual screening, remote sensing, basic structural score, final score

INTRODUCTION

An earthquake is a natural disaster which generally takes place between few seconds to a few minutes, which results in loss of property, life and infrastructure. Since, it is difficult to predict the occurrence of an earthquake, it is important to have a clear understanding of the consequences – pre, during and post earthquake occurrence, so that suitable restoration and rehabilitation measures could be planned.

Earthquakes were not considered as sources of major disaster until the late 1950's since the Deccan Plateau was considered to be a safe and stable zone. However, the recent major Earthquakes (Lathur, Koyna and Bhuj) resulted in the greater damage to civil infrastructure. Earlier India was divided into seven zones based on the seismic occurrence, but after the recent major Earthquakes it was revised and presently there are four seismic zones. According to current seismic zonation, more than 95% of the major cities in India are located in seismic zones of considerable risk. Many cities lack detailed seismic characterization and poor geotechnical data. The urban areas have experienced very high population growth due to the increase in the economic opportunities, resulting in the construction of high rise and inadequately designed structures. Therefore, Seismic Vulnerability Assessment of buildings in urban areas is an essential component of a comprehensive earthquake disaster management policy.

India's national vulnerability methodology, as a component of earthquake disaster risk management framework recommends to follow the following procedures- (1) Rapid Visual Screening (RVS), which requires only visual evaluation and limited additional information. This procedure is recommended for all buildings. (2) Simplified Vulnerability Assessment (SVA), which requires limited engineering analysis based on information from visual observations and structural drawings. This procedure in recommended for all buildings with high concentration of people. (3) Detailed Vulnerability Assessment (DVA), which requires detailed computer analysis, similar to or more complex than that required for the design of a new building. This procedure is recommended for all important and lifeline buildings.

Spatial information – images and maps, forms the foundation and basis for most of the planning and implementation of developmental activities, infrastructure development, disaster management support and other activities. Even a common man requires maps and spatial information for their localized decision making. Though abundant data are available, not much of it is properly organized and analysed. Advanced technologies of satellite remote sensing, Geographic Information Systems (GIS) and Information Technologies (IT) have the capability to generate and integrate data from various resources. In this study an attempt has been made to assess the seismic vulnerability of buildings using modern remote sensing data with GIS (CARTOSAT-2). Since the traditional manual survey of the buildings for the vulnerability assessment is time consuming and also involves the deployment of large manpower and higher costs. The technology of remote sensing can be used in conjunction with the conventional field survey to assess the vulnerability of the buildings.

STUDY AREA

The Bangalore central has been chosen as the study area for which the microzonation parameters are available. Bangalore city covers an area 741 sq. km, at an altitude of 914.4 m above MSL. Bangalore is densely populated and economically and industrially important for India and is one of the fast growing cities in Asia. Eleven densely populated areas with a small stretch of around 50 buildings in each of the areas covering both commercial and residential buildings were chosen for the study. Figure 1 shows the study areas marked in the satellite image.

RAPID VISUAL SCREENING (RVS)

The Rapid Visual Screening was first developed in the US in 1988, which was further modified in 2002 to incorporate latest technological advancements and lessons learnt from the previous earthquakes. The RVS even though originally developed for typical constructions in the US have been widely used in many countries with suitable modifications. The RVS method does not involve any structural calculation instead it uses a scoring system with the building type and the attributes of the building. The most important feature of this procedure is that it permits vulnerability assessment based on walk around the building by a trained evaluator by filling the building parameters in the data collection form. This method can be used for vulnerability assessment of both urban and rural areas. The screening is based on numerical seismic hazard and vulnerability score. The Final Score (S) typically ranges from 0-7, where the higher score corresponds to good seismic performance. This procedure is being incorporated in a GIS platform. The Rapid Visual Screening of Potential Seismic Vulnerability is based on FEMA-154 and is adopted by the National Disaster Management Authority (NDMA), Government of India. Mandatory data to be collected from the RVS is listed below:

- Occupancy

- Building type
- Falling Hazard
- Number of people (0-10, 11-100, 101-1000)
- Soil type
  - Type I – Hard soil
  - Type II – Medium soil
  - Type III – Soft soil
- Number of stories
  - Mid rise (4-7 stories)
  - High rise (>7 stories)
- Vertical Irregularity
- Plan Irregularity
- Code detailing

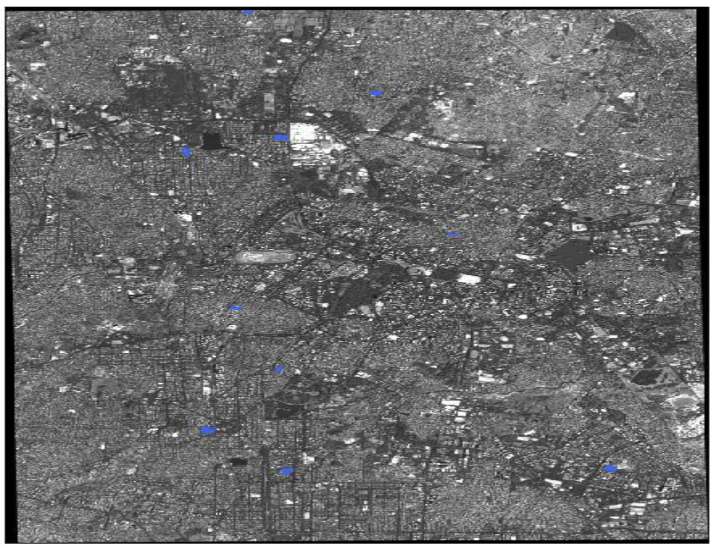

Figure 1. Study areas marked in the satellite image (CARTOSAT-II)

For each of the building types, a basic structural score is computed that reflects the estimated likelihood that building collapse will occur if the building is subjected to the maximum considered earthquake (peak ground acceleration) ground motions for the region. The peak ground acceleration of 0.1 g is considered for the maximum considered earthquake in this study. The basic structural scores are based on the damage and loss estimation functions provided in the FEMA 154 and FEMA 155. For the building parameters collected from the building, the performance modification factors are assigned, based on judgment, such that when added to the basic structural score (or subtracted, depending on whether their effect is to decrease or increase the probability of major damage) the resulting final score would approximate the probability of major damage given in the presence of that factor. The Final Score (S) is an estimate of the probability (or chance) that the building will collapse if ground motions that equal or exceed the maximum considered earthquake ground motions. The acceptable S is decided by selecting the cutoff score, the most compelling benefit is the saving of lives and prevention of injuries due to the damage in the buildings. The reasonable preliminary value suggested by FEMA 154 is 2, below which a detailed seismic evaluation of the building by a professional in seismic design is required.

FIELD SURVEY

Seismic Vulnerability of the building using satellite image is a pilot study in India, it is mandatory to verify RVS score for the buildings obtained from satellite data with the conventional field survey. The map of the study area is taken to the site for reference along with the data collection form (one for each building). The building is identified and the parameters are noted in the data collection form by observing the building and the photography of the building is taken for reference. The vulnerability maps for the study areas are prepared using field data. Table 1 gives the comparison of parameters collected by field survey and from a satellite image of a building. Table 1 also provides information regarding Basic Structural score and Final Structural score. Though Basic Structural scores are more or less similar, the final scores vary considerably depending on the appropriate modifiers. Figure 2 shows the Vulnerability map for Jayanagar area using field survey data.

The buildings with final score > 3.0 indicate Probability of Grade 1 damage (No structural damage, slight non-structural damage), the buildings with final score 2.0 – 3.0 indicate High probability of Grade 2 damage (Slight structural damage, moderate non-structural damage); Very high probability of Grade 1 damage, the buildings with final score 0.7 – 2.0 indicate High probability of Grade 3 damage (Moderate structural damage, heavy non-structural damage); Very high probability of Grade 2 damage, the buildings with final score 0.3 – 0.7 indicate High probability of Grade 4 damage (Heavy structural damage, very heavy non-structural damage); very high probability of Grade 3 damage, the buildings with final score <0.3 indicate High probability of Grade 5 damage (very heavy structural damage); very high probability of Grade 4 damage. [Ravi Sinha and Goyal, 2007]

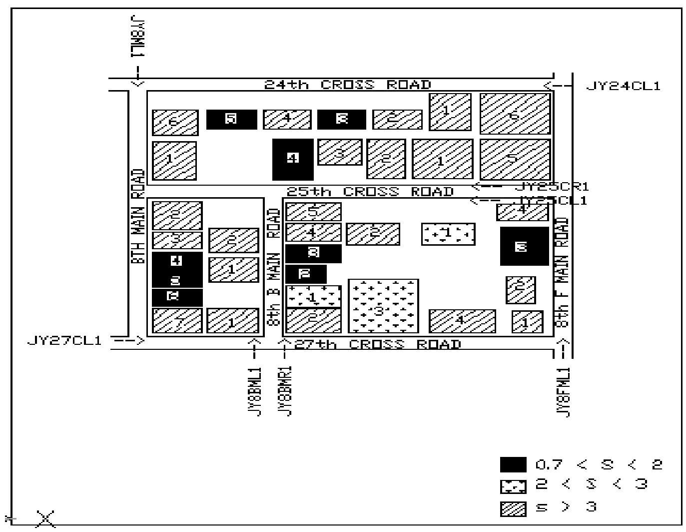

Figure 2. Vulnerability map of Jayanagar using Field data

The above figure 2 represents the buildings in one of the study area (Jayanagar) where 37 buildings were considered for the study, with 51% of the buildings are Moment Resisting frames and 49% of the buildings are Unreinforced Masonry respectively. In this area, 65% of the buildings have the probability of Grade 1 damage, 10% have the probability of Grade 2 damage and 25% have the probability of Grade 3 damage. Similar observations are found in the other 11 study areas. This kind of vulnerability maps will be useful for Disaster Management policy implementation for seismically vulnerable areas.

RESULTS AND DISCUSSIONS

CARTOSAT-2 is an agile satellite launched in January 2007 and it provides a 1 m resolution panchromatic data. This is the highest resolution available from Indian satellite. To cover the study area, availability of archived datasets within the last 6 months was explored. The data were acquired on February 07, 2014 and made available for the project. The data is in Standard Geo-corrected format with Datum WGS 84 and UTM projection. The intended area was covered in two data sets. The first data covers 12.95 to 13.04 North and 77.54 to 77.63 East. The sun elevation is 124.93° and sun azimuth 41.64°. The second data is of 12.91 to 13.00 North and 77.54 to 77.63 East with Sun elevation 124.72° and Sun azimuth 41.76°.

Table 1. Comparison of parameters collected during Field Survey and from Satellite Image

Sl. No.	Parameters	Field Survey	CARTOSAT II	QUICKBIRD
1	ID	JY8FML6	JY8FML6	
2	Occupancy	Commercial		
3	Area			
4	Number of people	11-100		
5	Falling Hazards	YES	YES	
6	Photograph	YES		
7	Current visual condition	GOOD		
8	Building on stilts/Open ground floor	NO		
9	Building type	MRF		
	Basic Structural Score	4.4		
10	Building Height(m)	17.54		
11	Number of stories	G+5		
	Total number of stories	6		
	Modifier for number of stories	0.4		
	Modifier for number of stories	0		
12	Vertical irregularities	YES		
	Modifier for vertical irregularities	-1.5		
13	Plan irregularities	NO	YES	
	Modifier for plan irregularities	0		
14	Soil type	II	II	
	Modifier for soil type	-0.6		
15	Age of the building	NEW		
	Modifier for code detailing	0.6		
	Final Structural Score	3.3		

The results obtained from both field study and Remote Sensing (RS) are discussed in this section. The satellite image obtained from CARTOSAT-2 is saturated and hence the identification of many parameters is not possible, parameters such as falling hazards and plan irregularities which were clearly identified are given in the Table 1. To overcome this problem QUICKBIRD satellite data will be used in the future work. The characteristics of various parameters to be correlated are discussed below.

- Building Type

  It is very difficult to differentiate the building type using the RS data and the field survey, as the interior survey is not always possible. Hence, the data collected from the field studies has to be used.
- Building Height / Number of stories

  This parameter can be easily obtained from the field studies, but from the RS this is assessed from the shadow length and sun elevation.
- Number of people

  This parameter can be evaluated from the floor area
- Soil Type

  It is very difficult to identify this parameter from both the field and RS studies. In the present study these details are collected from Anbazhagan et al (2010)
- Plan Irregularities

  This parameter can be easily evaluated from both the field and RS studies
- Vertical Irregularities

  This parameter can be easily evaluated from the field study, but it is difficult by the RS
- Code Detailing

This parameter cannot be assessed in the field as well as RS studies as owners of buildings may not be willing to share this information and there is no data base from Government offices.

- Current Visual Condition / Open ground floor

  These parameters cannot be obtained from the satellite data

CONCLUSIONS

The seismic vulnerability assessment is presently carried out by the conventional field survey method, which is labour and cost oriented and also time consuming. Therefore, in the present study an attempt is made to assess the seismic vulnerability of the buildings using Remote Sensing data. The work was carried out by using satellite image from CARTOSAT-2 and many of the parameters cannot be evaluated as it is saturated. To overcome this problem the study will be carried out using satellite images from QUICKBIRD. The principal purpose of the RVS is to identify potentially seismically hazardous buildings needing further evaluation. The results from RVS can also be used for ranking a community's seismic rehabilitation needs, designing seismic hazard mitigation program and to specify the building value for insurance rating and ownership transfer.

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