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Rapid visual screening procedure of existing building based on statistical analysis

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ABSTRACT

A statistical regression method was used to model the relationship between the outcome variable, e.g. different damage grade of existing building during an earthquake, and the explanatory variables concerning the building attributes that enhance the vulnerability of building during an earthquake. The analysis was performed by employing a building database of 396 damaged buildings surveyed after the 4th January Manipur earthquake of 2016. It is observed that the type of soil, apparent construction quality, maintenance condition, age of the buildings, substantial overhang and number of storey of the existing buildings are highly significant parameters in analyzing the vulnerability of the building during an earthquake. From the statistical analysis, a rapid visual screening procedure is proposed which can used as preliminary assessment technique for identifying vulnerable buildings in disaster risk reduction programme.

1. Introduction

It is not possible to prevent earthquakes from occurring. However, the disastrous effects of earthquake can be minimized considerably through measures of scientific methods and understanding. The devastating scene after many destructive earthquakes in India has re-emphasized the need for seismic risk assessment. Seismic risks are estimated for purposes of seismic design, rehabilitation of the buildings, disaster mitigation and emergency management. Seismic risk estimation in general has three major components: seismic hazard, vulnerability and its exposure. Exposure is defined by the stock of infrastructure in that location, vulnerability is defined as the susceptibility of the infrastructure stock and hazard is defined by risk of a certain ground motion occurring at a location, which can be defined by deterministic or probabilistic seismic hazard analysis method. Seismic vulnerability is a measure of the seismic strength or capacity of a structure; hence it is found to be the main component of seismic risk assessment. The quantitative approach covers demand-capacity (DCR) computation, while qualitative procedure estimates structural scores for buildings and is known as Rapid Visual Screening (RVS). Many researchers have proposed many seismic vulnerability assessment methodologies (e.g., [4,10,26,28]). Due to mushrooming of vulnerable building stocks, mainly in an urban area, a quick and reliable procedure for identifying the unsafe building is much needed. RVS procedure is a simple procedure for quick evaluation of a large building stock, usually based on walk down surveys on site for each building, which cannot be used to substitute the more advanced methods to evaluate the seismic vulnerability but should be used to provide an indication about the buildings that need more advanced analysis.

In various studies by many researchers, many earthquake inducing building parameters like vertical irregularity, plan irregularity, etc. has shown to influence the different level of damages of the building during natural calamities like an earthquake. In this view, multiple and stepwise regression analysis have been carried out to the present cross-sectional data to explore the effect of such independent variables on the damage level of the building in Manipur, India (Imphal with longitude and latitude corresponding to $93^0 58'$ and $24^0 44'$ respectively). The RCC (Reinforced cement concrete) buildings database was compiled after the 4th January Manipur earthquake for damage building of Imphal city. Here, the damage level is defined as a grade of damage to the building such as grade 1 for slight damage; grade 2 for moderate damage; grade 3 for heavy damage; grade 4 for destruction; and grade 5 for total damage as per damage grade definition given by IS:1893 (2016). The variation in the grade of damage of the buildings is assumed to be functionally related with ten independent variables like soft storey, substantial overhang, floating column, re-entrant corners, age of building, apparent construction quality, and asymmetry of staircase location with respect to plan, maintenance condition, type of soil and number of storey of the building. The non-structural elements are not considered in the proposed RVS method. These expected causal variables are treated to be the independent variables of interest in the regression models. From the regression analysis, a vulnerability

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assessment technology in the form of rapid visual screening is proposed for the study area. In the present study, a review of different seismic vulnerability assessment method has been done and a simple and user-friendly seismic vulnerability technique in the form of rapid visual screening is proposed. The model allows evaluating damage grade on exposed elements mainly considering for Indian condition. The proposed technique has been tested using a case study of a city in India. The estimated result has been analyzed by comparing the result with the actual damage grade distribution obtained during the earthquake to check the correctness of the model.

2. Rapid visual screening

Many RVS methods have been developed worldwide. According to the difference in building codes and construction practices, the scoring system and parameters taken for assessing the vulnerability of buildings also differ from place to place. Some of the famous RVS methods are discussed below.

2.1. U.S.A method [7]

FEMA 154 [7] procedure for RVS was first proposed in the U.S.A in the year 1988. However, the procedure was further modified by incorporating latest technological advancements and lessons from earthquake disasters and published as FEMA 178 [8], FEMA 310 [9] and FEMA 154 [7]. FEMA 154 [7] method assigns a basic structural score based on seismic hazard intensity of the region, building type and lateral load resisting system of the building. Performance modifiers are specified to take into account the effect of a number of storeys, plan and vertical irregularities, pre-code or post-benchmark code detailing, poor condition of the building and type of soil. A score of 2 is suggested as a cut-off and score less than 2 requires detailed analysis.

2.2. RVS method for Indian condition [2]

The procedure for RVS used in India given by Arya [2] utilises a damageability grading system based on the primary structural lateral load-resisting system and building attributes that modify the seismic performance expected for this lateral load-resisting system along with non-structural components. The screening is based on code-based seismic intensity scale, building type and damageability grade as observed in past earthquake and covered in Medvedev Sponheuer Karnik (MSK) and European macro-intensity scale.

2.3. New Zealand method [21]

The RVS method by the New Zealand Society for Earthquake Engineering (NZSEE) proposed in 1996 largely follows the process presented in FEMA 154 [7]. The document places much greater emphasis on the presence of structural irregularities such as torsion and weak storey. A structural score is given based on structural irregularities which are then combined with the building area to decide whether a detailed assessment is required. The building area parameter reflects the occupant population and potential causalities in the event of structural damage. In this procedure, the conclusion for a more detailed evaluation of the building comes from a graph, which is a function of the building gross area and the final structural score.

2.4. European method [5]

This process consists the verification of the seismic resistance of an existing damaged or undamaged building by taking into account seismic and non- seismic actions for the period of its intended lifetime. In order to calculate the design action-effect under the actual condition of the structure, the standard method or the time-domain dynamic non-linear analysis is carried out. A model uncertainty factor covering the additional uncertainties related to the analysis of the pertinent structure is also incorporated. At the end, it gives a procedure for repair or strengthening of buildings.

2.5. Greek method [6]

The Greek method developed RVS procedure in 2000 [6] which needs to identify both the primary structural lateral load resisting system and structural materials of the building. By this identification, the building gets classified in one of 18 structural types and it is awarded an initial structural hazard score. This score will then be modified to get the basic structural hazard score by identifying both the seismic zone and three significant structure characteristics (weak story, short columns and regular arrangement of the masonry). Finally, this score will be modified by identifying modifiers related to the observed performance attributes to arrive at the final score. Buildings having a final score of 2 or less should be investigated in more detail.

2.6. Italy method [1]

Vulnerability assessment methodology developed in Italy [1] is based on eleven building parameters. The eleven parameters are resisting system type and organization, resisting system quality, conventional resistance, location and soil condition, diaphragms, plan configuration, vertical configuration, connectivity between elements, low ductility structural members, non-structural elements and preservation state.

2.7. RVS for Indian condition [16]

Jain et al. [16] developed RVS procedure based on a database of damaged buildings during Bhuj earthquake of January 26, 2001. The parameters considered in this procedure are building typology based on occupancy type (residential or non-residential building), presence of basement, number of storeys, maintenance condition of building, asymmetric location of staircase with respect to plan, presence of re-entrant corners, presence of open storey, presence of stub column, presence of substantial overhang and presence of short column. Based on the type of seismic zone and type of soil, basic score is assigned to the buildings and later on modified based on the parameters mentioned above.

2.8. Turkey method [3]

In RVS procedure in Turkey, a basic capacity index is computed considering the assessed orientation, size and material properties of the component comprising the lateral load resisting structural system. This index is then modified by several coefficients that reflect the quality of workmanship, detailing and architectural factors. The procedure has been developed based on the data compiled from damage surveys conducted after the earthquakes that occurred within the last decade in Turkey.

2.9. Japanese method [17]

The Japanese procedure [17] is based on the seismic index for total earthquake resisting capacity of a storey which is estimated as the product of a basic seismic index based on strength and ductility index, an irregularity index, and a time index.

2.10. Canada method [20]

The RVS method developed by National Research Council, Canada [20] is based on a seismic priority index which accounts for structural as well as non-structural factors including soil condition, building occupancy, building importance and falling hazard to life safety and a