General Methodology for Seismic Evaluation of Buildings

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Abstract – *India faces serious earthquake problems by a rapid growth of urban population. Reconnaissance survey reports suggested that the need for seismic evaluation of existing buildings. Different methods for seismic evaluation of existing buildings have developed in various countries. Most of the methods follow three level assessment procedures (or something quite similar to it) namely, (a) rapid visual screening, (b) preliminary assessment, and (c) detailed evaluation. The RVS methodology is referred to as a "sidewalk survey" in which an experienced screener visually examines a building to identify features that affect the seismic performance of the building. A performance score is calculated for the building based on numerical values on the RVS form corresponding to these features. The performance score is compared to a "cut-off" score to determine whether a building has potential vulnerabilities that should be evaluated further by an experienced engineer.*

Key Words: *Survey, RVS form, Rapid Visual Screening, Vulnerability, Seismicity.*

1. INTRODUCTION

In recent past due to rapid growth of Indian cities, there is a tremendous increase on housing industry. As most of these constructions are without earthquake resistant measures, the built environment in these zones has been found seismically vulnerable. Since Indian cities are built with varied varieties of building typologies, comprising of poorly designed and less maintained ones, the seismic safety of these constructions became the most challenging task. 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. Different methods for seismic evaluation of existing buildings have developed in various countries. Most of the methods follow three level assessment procedures. (ASCE, 2003)

(a) Phase-I: Rapid visual screening,

(b) Phase-II: Preliminary assessment, and

(c) Phase-III: Detailed evaluation.

Detailed seismic vulnerability evaluation is a technically complex and expensive procedure and can only be performed on a limited number of buildings. It is therefore very important to use simpler procedures that can help to rapidly evaluate the vulnerability profile of different types of buildings (Mishra, 2014). RVS is the first step towards assessing the vulnerability of buildings. RVS is used as a tool to identify the buildings which require further attention for strengthening their safety. Rapid Visual Screening (RVS) methodology was first developed by "Applied Technology Council" in the late 1980's and published in FEMA 154 in 1988. RVS format was first time introduced for a masonry building in Indian building code in 2009 i.e. IS 13935:2009 "Seismic Evaluation, Repair and Strengthening of Masonry Buildings - Guidelines".

2. LITERATURE STUDY

Various researches have been made to study the existing RVS methodologies developed by various researchers from India and from developing countries. The different authors describe their contribution to Rapid visual screening of the building in different areas which is explained below.

FEMA 154, (2002) has been formulated to identify, inventory, and rank buildings that are potentially seismically hazardous. If a building receives a high score above a specified cut-off score the building is considered to have adequate seismic resistance. The RVS procedure utilizes a scoring system that requires the user to (1) identify the primary structural lateral-load-resisting system; and (2) identify building attributes that modify the seismic performance expected of this lateral-load-resisting system.

Agrawal, S., and Chourasia A. (2007) proposed an approach to estimate seismic vulnerability of existing buildings of a city in Indian context. The scheme estimates seismic vulnerability of existing building stock quantitatively and qualitatively. The quantitative approach covers demand-capacity computation, while qualitative procedure estimates structural scores on the basis of national & international state-of-the-art procedures viz. Rapid Screening Procedure (RSP). This methodology will help to identify buildings that might pose risk during damaging earthquake. Sinha, R., and Goyal, A. (2011) presented RVS procedure, objectives and scope, uses of RVS results, building types considered in RVS procedure were explained in this paper. Seismic vulnerability classification for different structural types, classification of damage to buildings and expected damage level as function of RVS score. Mishra, S., (2014) intended a guide book to serve as guiding document of conducting the RVS of buildings in India. Seismic safety features of both masonry and reinforced concrete frame (RC) buildings required during field survey is cited here. Non-structural hazards are also covered briefly in this guide book as they share a large percentage in terms of economic damage and also pose threat to human safety. Sarraz et al. (2015) discusses the Seismic Vulnerability Assessment of Existing Building Stocks at Chandgaon in Chittagong city, Bangladesh. The earthquake vulnerability of Chandgaon Residential Area had been assessed on the basis of potential structural vulnerability of more than 300 buildings. The study comprised of a detailed survey on 310 buildings of Chandgaon R/A. Considering Chittagong as a high Seismic Risk zone, the cut off value was determined as 2.0. The results show that no score for any building was found to touch the cut off value according to FEMA method and all of them require further detailed analysis. El-Betar et al. (2016) raises to study the vulnerability of buildings in Egypt to avoid a serious risk. This paper highlights the significant contributions in the field of seismic vulnerability evaluation of buildings in order to suggest a suitable procedure for seismic evaluation of existing R.C. buildings in Egypt. Seismic evaluation was applied on the selected two case studies, one represents the gravity loads only (GLD) buildings and the other represents the buildings designed according to Egyptian code. This paper concludes that, GLD school buildings tend to be more vulnerable under high seismic loads, while school buildings designed according to Egyptian code have a high capacity to resist earthquakes.

3. METHODOLOGY

The general procedure to be followed in the Rapid Visual Screening methodology is discussed.. The general sequence of implementing the RVS procedure is explained below. FEMA 154, (2002)

3.1 Survey Implementation Sequence

Performing a rapid visual screening involves several steps such as data collection, planning etc. for seismically hazardous buildings. As a first step, a general procedure should be approved. Second, the appropriate people should be informed about the purpose of the survey and how it will be carried out. Then there are many decisions to be made, such as use of the survey results and actions to be taken. These decisions are very specific to each application of the procedure described in this manual. The general sequence of implementing the survey methodology is as shown below. This sequence may be altered where field inspection is replaced by inspection of drawings.

3.2 Budget Development and Cost Estimation:

Many of the decisions that are made about the level of detail documented during the rapid visual screening procedure will depend upon budget constraints. Although the RVS procedure is designed so field screening of each building should take no more than 15 to 30 minutes time and funds should also be allocated for pre-field data collection. However, it can be extremely useful in reducing the total field time and can increase the reliability of data collected in the field. This might be readily available from building department files but is much more difficult to estimate from the street. Another issue to consider is travel time, if the distance between buildings to be screened is large. Because pre-field data collection and travel time could be a significant factor in budget allocations, it should be considered in the planning phase. Other factors that should be considered in cost estimation are training of personnel and the development and administration of a record keeping system for the screening process. The type of record keeping system selected will be a function of existing procedures and available funds as well as the ultimate goal of the screening.

3.3 Pre-Field Planning:

It may be decided, due to budget, time, or other types of constraints, that priorities should be set and certain buildings surveyed immediately, whereas others can be surveyed at a later time, because they do not pose immediate life-safety issues. An area may be selected because it has a higher density of potentially seismically hazardous buildings relative to other areas. For example, an older part of a community that consists mainly of commercial unreinforced-masonry buildings may be of a higher priority than a newer area with mostly warehouse facilities, or a residential section of the city consisting of wood-frame dwellings. A mapping system for the survey areas is extremely important in the initial planning phase as well as in the scheduling of inspectors. Maps of soil profiles, liquefaction potential, landslide potential, and active faults provide useful information about the relative hazard indifferent areas. Maps of lots will be useful in scheduling inspectors and as data are collected, identifying areas with many potentially hazardous buildings. Another important phase of pre-field planning is interaction with local building officials. Discussions should include verification of when certain aspects of seismic design and detailing were adopted and enforced by the municipality. This will be used to determine the scoring factors and final score for each building. As discussed in the previous section, the record-keeping system will vary for each project depending on needs, goals, budgets, and other constraints; it may, in fact, consist of several systems. Part of this planning phase may include deciding how buildings are to be identified. Some suggestions are street address, tax assessor's parcel number, and lot number, or owner. Consideration should be given to developing a computerized database. The advantage here is that lists of potentially hazardous buildings and their owners are easily generated. The disadvantage is that graphical data such as sketches and photographs are not easily stored in the computer. Microfilm is a good storage medium because photographs, building plans, survey forms and subsequent follow-up documentation can be kept together and easily copied. Another method that has been used is to generate a separate file for each building as it is surveyed, containing the screening form and all support material and photographs. A disadvantage of this system is that the files rapidly grow and become unmanageable.

3.4 Selection and Review of the Data Collection Form:

According to the study develop the new form for RVS system which is helpful to the vulnerability of the structure. The data collection form provides space to record the building identification information, draw a sketch of the building (plan and elevation views), attach a photograph of the building, indicate occupancy, indicate the soil type, document the existence of falling hazards, develop a Final Structural Score, S, for the building, indicate if a detailed evaluation is required and provide additional comments. The screening procedure should not be modified without input from a professional engineer familiar with earthquake resistant design and construction practices of the local community.

3.4.1 Determination of Seismicity Region:

To select the appropriate Data Collection Form, it is first necessary to determine the seismicity region in which the area to be screened is located. The seismicity region (High, Medium, or Low) for the screening area can be determined by finding the location of the surveyed region on the seismicity map and identify the corresponding seismicity region.

3.4.2 Determination of Cut-Off Score:

Use of the RVS on a community-wide basis enables the RVS authority to divide screened buildings into two categories: those that are expected to have acceptable seismic performance, and those that may be seismically hazardous and should be studied further. This requires that the RVS authority determine, preferably as part of the score. An *S* score of 2 is suggested as a “cut-off”, based on present seismic design criteria. Using this cut-off level, buildings having an *S* score of 2 or less should be investigated by a design professional experienced in seismic design.

3.5 Qualifications and Training for Screeners:

It is anticipated that a training program will be required to ensure a consistent, high quality of the data and uniformity of decisions among screeners. Training should include discussions of lateral force-resisting systems and how they behave when subjected to seismic loads, how to use the data collection form, what to look for in the field, and how to account for uncertainty. In conjunction with a professional engineer experienced in seismic design, screeners should simultaneously consider and score buildings of several different types and compare results. This will serve as a “calibration” for the screeners.

3.6 Survey tools to be taken in the field:

The screening procedure is intended to be rapid, simple, and standardized as to data collection. Relatively few tools or equipment are needed. The following is a checklist of items that may be needed in performing a rapid visual survey as described in this manual:

- Clipboard for holding survey forms
- pen or pencil
- camera, preferably instant (e.g., Polaroid)
- flashlight
- tape or stapler (for affixing photo)
- straight edge (optional for drawing sketches)
- copy of manual
- a simple hand calculator

3.7 Acquisition and Review of Pre- Field Data:

Information on the structural system, age or occupancy may be available from supplemental sources. These data, from assessor and building department files, insurance maps, and previous studies, should be reviewed and collated for a given area before commencing the field survey for that area. Some sources of supplemental information are as follows:

3.7.1 Assessor’s Files:

Although such files may contain information about the age of the building, the total area and the number of storey, most information relates to ownership and assessed value of the land and improvements, and thus is of relatively little value for rapid screening purposes. One should be aware that the construction type indicated is often incorrect and in most cases should not be used. In addition, it should be noted that the age of a building retrieved from assessor's files may not and most likely is not the year that the structure was built. Usually, assessment files contain the year that the building was first eligible for taxation. Because the criteria for this may vary, the date may be several years after the building was designed or constructed. If no other source of information is available, this will give a good estimate of the era during which the building was constructed. However, this date should not be used to establish conclusively the code under which the building was designed. Tax assessment offices may have parcel or lot maps, which may be useful for locating sites or may be used as a template for sketching building adjacencies on a particular city block.

3.7.2 Building Department Files

Building department files will vary greatly from jurisdiction to jurisdiction. For example, in some locations all old files have been thrown out, so there is not information on older buildings. In general, files (or microfilm) may contain permits, plans and structural calculations required by the city. Sometimes there is occupancy and use information, but little information about structural type will be found except by reviewing plans or calculations.

3.7.3 Previous Studies:

In a few cases, previous building inventories or studies of hazardous buildings or hazardous non-structural elements (e.g., parapets) may have been performed. These studies may be limited to a particular structural or occupancy class, but they may contain useful maps or other relevant structural information and should be reviewed. Other important studies might address related seismic hazard issues such as liquefaction or landslide potential. Local historical societies may have published books or reports about older buildings in the community. Fire departments are often aware of the overall condition and composition of building interiors.

3.7.4 Soils Information:

Because soil conditions are a major factor in the risk to the building, the screening procedure includes a screening factor for soil conditions. Since soil conditions cannot be readily identified by visual methods in the field, geotechnical, geologic, or liquefaction potential maps and other information should be collected and put into a readily usable map format for use during the field survey.

3.8 Review of Construction Documents:

Whenever possible, design and construction documents should be reviewed prior to the conduct of field work to help the screener identify the type of lateral-force- resisting system for each building. The review of construction documents to identify the building type substantially improves the confidence in this determination.

3.9 Field Screening of Buildings:

RVS screening of buildings in the field should be carried out by teams consisting of two individuals. Teams of two are recommended to provide an opportunity to discuss issues requiring judgment and to facilitate the data collection process. If at all possible, one of the team members should be a design professional who can identify lateral-force resisting systems.

3.10 Checking the Quality and Filing the Field Data in the Record- Keeping System:

The last step in the implementation of rapid visual screening is checking the quality and filing the RVS data in the record-keeping system established for this purpose. If the data are to be stored in file folders or envelopes containing data for each building that was screened, or on microfilm, the process is straightforward, and requires careful organization. If the data are to be stored in digital form, it is important that the data input and verification process include either double entry of all data, or systematic in-depth review of print outs (item by item review) of all entered data. It is also recommended that the quality review be performed under the oversight of a design professional with significant experience in seismic design.

4. CONCLUSION:

In the present work, general methodology to be adopted for carrying out rapid visual screening is discussed. The following conclusions can be drawn as follows:

A] The occurrence of earthquakes is a part of the natural process in the earth's geophysical system. The earthquake tremors cannot be stopped or reduced and the causalities and damages are caused mainly due to the collapse of the infrastructures. The infrastructures of different areas will not be equally vulnerable to any earthquake.

B] The RVS methodology is a method that can be used to quickly identify potentially hazardous buildings via a sidewalk survey without conducting preliminary assessment and detailed evaluation.

C] Buildings having an *S* score of 2 or less should be investigated by a design professional experienced in seismic design whereas buildings having S score of more than 2 are safe from seismic point of view.

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