Earthquake Hazard Safety Assessment of Buildings via Smartphone App: A Comparative Study

Ehsan Harirchian1,* and Tom Lahmer1

1The Institute of Structural Mechanics, Bauhaus University Weimar

Abstract. The failure of man-made structures is the main cause of more injuries during an earthquake and more economic losses. In addition, as urban areas continue to develop, the need for an effective disaster management system to develop resilient communities increased. To estimate the severity of a building’s damage, several seismic assessment methods have been introduced. Rapid visual screening methods (RVS) are the fastest and simplest methods developed to evaluate the initial vulnerability profile of the existing building stock, constructed before or after the adoption and enforcement of seismic codes. In this study, FEMA P-154, Indian RVS (IITK-GSDMA), Turkish RVS (EMPI), and EHSAPP method have been utilized on some buildings and their results compared to each other with regard to the real occurring damage after an earthquake on the same buildings. It was observed that the EHSAPP method has a better and more realistic seismic risk assessment than others.

1 Introduction

The importance of studies and research into the prevention of the effects of earthquake has increased after destructive earthquakes and it is necessary to assess the seismic vulnerability of buildings in urban areas as an essential parameter of the earthquake disaster management policy. Therefore, there is an urgent need for reliable vulnerability assessments, appropriate seismic risk management strategies, and rapid response after the disaster to significantly reduce possible losses in future severe earthquakes. The term “seismic vulnerability” is defined as “the susceptibility of a population of buildings to undergo damage due to seismic ground motion” [1]. Rapid Visual Screening (RVS) is the simplest method among other vulnerability assessment methods, performing basic structural calculations for quick evaluation of a large building stock [2]. However, more detailed analysis would give a better assessment, but such an approach would entail unprecedented difficulties when an urban scale mitigation campaign is considered. In this manner, some efforts have been made to develop a tablet-based version of FEMA 154 [3], also to transmit GIS visualization and mobile data for database compiling [4]. Rapid Observation of Vulnerability and Estimation of Risk (ROVER v.1), which is a mobile-device and server-based software for both pre- and post-earthquake building safety screening [5] and ROVER v.2 [6] is the current version of it. Moreover, Wahyuni [7] implemented the FEMA 154 into a smartphone application with regional modification to conduct a quick check on the buildings in Surabaya-Indonesia. Research by Nassirpour [8] evaluates rapidly school buildings in the Philippines against multi-hazard conditions. The Urban Rapid
Assessment Tool (RA T) [9] is another developed smartphone suite that includes seismic performance attributes based on FEMA 154 [10] and FEMA 310 [11]. The aim of this study is to compare our proposed EHSAPP [12] method with the most popular existing regional building vulnerability assessment methods such as FEMA P-154, Indian RVS (IITK-GSDMA), and Turkish RVS (EMPI). For the applicability and comparison of the proposed methodology, the city of Bingöl in Turkey, which is in a highly active seismic region and has experienced a severe earthquake recently, has been selected. The data collection of nine damaged reinforced concrete buildings have evaluating through FEMA P-154, IITK-GSDMA, EMPI and EHSAPP, and the estimation of each method has been compared with the actual damage of the same building.

2 Review on Existing Rapid Visual Screening methods

As was previously mentioned in this paper, a comparison between a new RVS method and other existing methods has been carried out, which is described in the following paragraphs. The initial Rapid Visual Screening (RVS) methodology was proposed by Federal Emergency Management Agency (FEMA), U.S.A in 1988 as Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook and modified in 2002 [13]. Since the publication of the second edition of FEMA 154, there have been many improvements in rapid visual screening of buildings, one of which efforts was the development of the FEMA P-154 [14]. In RVS methodology, a visual inspection involves collecting structural and nonstructural characteristics of a building such as building type, number of stories, soft and weak stories, short columns, openings etc. Based on the data collected during visual inspection, a structural score will be calculated without performing any structural calculations to define the expected damage of a building and whether the building needs the next step of assessment or not. This will lead to saving time and resources that can be respectively used for the buildings that need detailed assessment[14, 15]. In this paper, only the RC buildings have been considered and since the case study is on the high seismic area, the RVS data collection form for high seismic has been selected.

2.1 FEMA P-154

FEMA P-154 provided data forms for different levels of seismicity. Depending on the classification of seismicity, the relevant data form will be taken. The seismicity of the site is determined using site-specific values of seismic hazard for risk-targeted maximum considered earthquake ground motions (MCER) and Soil Type B as provided by the U.S. Geological Survey (USGS). The scoring procedure in FEMA P-154 begins with the selection of the appropriate basic score (B) for buildings that will be modified using modifier scores (M).

2.2 IITK-GSDMA

Indian Institute of Technology, Kanpur (IITK) developed RVS methodology based on FEMA 154 with the support of Gujarat State Disaster Mitigation Authority (GSDMA) in “Seismic Evaluation and Strengthening of Existing Buildings” (IITK-GSDMA-EQ06-V4.0) [16]. It was developed by implementing suitable modifications to FEMA 154 based on Indian conditions. Some building types, like un-reinforced masonry and non-ductile RC frame buildings, have been given special consideration for the assessment within this method.
2.3 EMPI

Turkish RVS methodology was developed by conducting the survey on buildings in Istanbul and is called Earthquake Master Plan of Istanbul (EMPI), which can also be used for other parts of the country [17]. EMPI provided different RVS methods for different types of construction.

2.4 EHSAPP

The Earthquake Hazard Safety Assessment of Buildings via Smartphone App (EHSAPP) is based on the implementation of Analytic Hierarchy Process (AHP) methods to achieve an optimized earthquake hazard safety assessment [12]. For this method, initially a sensitivity analysis has been performed on FEMA P-154 to prioritize and assign weight to criteria. Furthermore, a multi-criteria decision making tool AHP has been utilized to assess seismic vulnerability of buildings. The screen shot of some pages of EHSAPP have been shown on Figure 1 and 2.

![Figure 1. Screenshot of EHSAPP: (a) first page, (b) building information](image1)

![Figure 2. Screenshot of EHSAPP: (c) entering buildings irregularities, (d) building vulnerability assessment](image2)

3 Study area

After May 1, 2003, Bingöl earthquake in the province of the east Anatolian region of Turkey, with a magnitude of 6.4 (Mw), building damage data was collected by a team of researchers
from Middle East Technical University [18]. From that report, nine damaged reinforced concrete buildings have been selected to study. The importance of this area is due to the Bingöl faults under high seismic zone with 10 percent probability in 50 years with PGA of 0.4g. The Vs 30 velocity of soil in Bingöl varies from 620 m/s to 760 m/s with an average Peak Ground Velocity (PGV) of 78.4 m/s.

4 Results and discussion

The main purpose of this paper is to compare the newly developed RVS method via smartphone app (EHSAPP) to the other existing RVS methods. Figure 3 compares the observed damage of the case study buildings (a-i) to FEMA P-154, EHSAPP, IITK-GSDMA, and EMPI based on EMS scale. There are some differences and similarities in the assessment and actual damage scale, and EHSAPP shows a more accurate valuation, as 6 out of 9 buildings had the same assessment as actual damage. In contrast, most of assessments by FEMA P-154 and IITK-GDSMA were overestimated, which are neither economical nor logical. The assessment, based on EMPI were also not satisfactory. In brief, it can be concluded that EHSAPP has a more accurate and realistic assessment compared to others.

![Figure 3. Damage grade comparison based on EMS-98](image)

5 Conclusion

The results of this study suggest that the proposed EHSAPP method, which is based on the application of multi-criteria decisions and its implementation on smartphone apps, generally present a better assessment of the seismic vulnerability of buildings compared to other existing methods. Although the study examined only reinforced concrete buildings in one area, it could be developed for the study of another type and seismicity area.

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