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Assessment of casualty and economic losses from earthquakes using semi-empirical model

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Abstract

A complete seismic risk assessment generally takes into consideration the interaction of three components – hazard, exposure and vulnerability – and after these three components are well defined for the purpose of interest, the risk can be assessed by the intersection of these three components, and in turn risk can controlled by countermeasures to each aspect of risk. The goal of this study is to develop and implement a semi-empirical model for casualty estimation that will enable to forecast the extent, types and severity of casualties that may happen in Israel and its surroundings in the case of several scenarios of given earthquakes. The expected deliverables will enable the research team to assess the risk, and develop strategies for retrofitting the vulnerable structures, and improve preparedness of the population in the case of destructive earthquakes.

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1. Introduction

Mitigating the results of potential earthquakes requires an estimation of the casualties that may incur, and accordingly an appropriate response model can be developed. Based on an extensive literature review of the consequences of earthquakes, the following parameters were identified as significant in estimating human casualties: (1) the earthquake hazard in the designated area, such as active faults, liquefactions, landslides and ground motion amplifications; (2) building and structural vulnerabilities to seismic hazards, assessed by an empirical or analytical

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approach combining simulation of seismic events with the data bases of structures, geological data, seismic data; and (3) assessment of the socio-economic conditions in the designated area, in order to estimate the potential population that was present in different building types at the time of the shake-out.

Many studies have focused on the extent of fatalities incurred from the numerous earthquakes that occurred in different parts of the world. In contrast, only a limited number of studies focused on surviving casualties depicting different extent, types and severities of injuries. Generally, the number of casualties and the level of injury are not easily attainable due to the limited quality and lack of information in earthquake casualty data. However, several studies that established casualty rates with respect to various building types and damage levels were published during the last two decades. There are four common approaches that have often been utilized to estimate casualties that might be caused by earthquakes: 1) an empirical approach consists of direct correlation between ground motions and the population that was present in the area at time of earthquake occurrence, based on historic earthquake statistics; 2) a semi-empirical approach takes into account the types of buildings that characterize the area and estimates damage rates according to the different structures; 3) pure analytic approach predicts behavior of buildings and their effects on individuals that are inside them, based on seismic hazard analysis; and, 4) hybrid approach consists of estimating the fraction of the population killed due to collapse of different types of buildings, considering macro-seismic intensities.

The empirical analysis ignores many relevant variables, such as building and structural vulnerabilities, as well as the presence of the population inside the structures during the event. The hybrid and analytic approaches do not address behavior of the numerous types of buildings that might be situated in the area struck by an earthquake and necessitate accumulation of data that are usually difficult to obtain due to inconsistent and poorly characterized historical earthquake casualty data. Therefore, a semi-empirical approach can more effectively estimate the damage and casualties that might be caused by a given earthquake, as it includes the identification of different types of buildings, the presence of the population during different time-frames, and the types of injuries that might be caused taking into account different socio-economic condition. Israel is situated in an area prone to earthquakes. To present, the estimation of casualties that might be incurred during an earthquake in the region has not taken into consideration the different types of buildings and the presence of the population in the different structures at different time-frames. The research employs the semi-empirical approach to estimate the surviving casualties and fatalities that might be caused by a potential earthquake. The city of Tiberius and its surroundings are used as the case-study to develop the model that will then serve as the basis for estimating the overall number of casualties that might be caused in the country.

2. Background

2.1. Natural Risk Assessment and Management

In general, risk mitigation actions include risk avoidance, reduction, transfer and acceptance, which lessen the impact of risk by dealing with its corresponding components of the risk. A large number of researches have studied the loss estimation and corresponding risk mitigation actions in seismic-active areas. For instance, risk avoidance is to reduce the impact of risk by the means of shunning the exposure at risk, as depicted in Fig.1 through actions such as urban plans by not allowing properties to be built on the areas which is consider as being at high risk [1]. For another example, as also depicted in Fig.1, one of the common countermeasures of risk reduction is to reduce the vulnerability of building stock by retrofitting structures to higher standard [2]. However, risk reduction can also be conducted by non-engineering means to lower social vulnerability such as enhancement in public education and awareness of risk [3,4].

For an area with low hazard (e.g. infrequent severe earthquakes), it in fact could be exposed to high risk as a result of its high vulnerability of built environment due to the lack of seismic design and mitigation actions, and lack of public perception and preparation. In addition, the high exposure of interest at risk like population and assets also is another reason making the area at high risk. Therefore, it is obvious that even a low hazard would cause disastrous