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# EARTHQUAKE RISK ASSESSMENT FOR SINGLE STOREY RESIDENTIAL BUILDINGS- AN OVERVIEW

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***Abstract-*** Earthquake is the most dangerous natural hazard as compared to other natural hazards. New methods and technologies are being explored for earthquake risk assessment. Many scholars have looked into earthquake risk assessment for high-rise buildings, but none have looked into earthquake risk assessment for single-story residential buildings. This study focuses on earthquake risk assessment for single storey residential buildings. Many researchers investigated that single storey buildings have more ability to stand against earthquake than high rise buildings. The results have established that buildings are designed to bear shaking along horizontal X and Y direction to counter earthquake inertia force. This study determines the future directions for exploring the earthquake risk assessment for single storey residential buildings to reduce the consequences of the earthquake.

***Keywords-*** Earthquake risk assessment, Inertia force, Natural hazard, Residential buildings

## 1 Introduction

The systematic recording of weather, stream heights, and then earthquakes began the process of risk estimation in the late 19th century. A detached section that consists of a ground storey only, with a roof to which only repair or maintenance access is provided may be classified as a single storey building. To achieve design strategies and risk levels that are consistent with tenant expectations and social objectives, building design and construction procedures should address the entire risk to residential construction from many hazards. According to a 2000 study by the Federal Emergency Management Agency FEMA 2000a, hurricanes and earthquakes are among the most costly natural hazards that affect residential construction in the United States, with annual economic losses averaging $5.4 billion for hurricanes and $4.4 billion for earthquakes [1]. Intensity measures (IMs) provide a link between probabilistic seismic hazard analysis and probabilistic structure response analysis in the performance-based earthquake engineering (PBEE) framework created by the Pacific Earthquake Engineering Research (PEER) Center. Mean annual rates of exceedance of different levels of IMs are estimated for the site of interest in the probabilistic seismic hazard analysis, whereas the seismic response of the structure subjected to different levels of IM is investigated in the probabilistic structural response analysis [2].

The number of casualties is directly proportional to the damage to civil engineering structures such as buildings. The frequent occurrence of damaging earthquakes highlights the urgent need for research into earthquake risk assessment (ERA) methods for buildings to effectively reduce earthquake impact in the city. Buildings are typically categorized based on a mix of building attributes (for example, structural system, height, or the number of floors) as well as the type of occupation (e.g., residential structures, hospitals, offices, schools). Single-family dwellings with one and two stories have traditionally been bundled together by the insurance business. Regional risk analyses were also based on the insurance practice [3]. An earthquake is known as a natural disaster. Earthquake risk assessment for single storey residential buildings are also very important. An earthquake occurs when two earth blocks unexpectedly slip past each other. The surface where the earth surface slips are known as the fault plane. In the literature, earthquake is declared second dangerous natural disaster. Earthquake is an out of control natural disaster and can cause much destruction to human beings.

## 2 Causes of earthquake

Earthquake is the main problem in the modern age and not clears any acceptable solution. Today's world discovered many technologies but we cannot prevent natural disasters and their dangerous effects [4]. The earthquake occurred in turkey in 2020 with a magnitude of 6.8 and caused serious damages to human life and property [5]. It is reported that change in groundwater can cause some sizable earthquakes. It is reported that if the time window is 90 days and the correlation coefficient is higher than 0.10 then sizable earthquakes occurred with the $M \geq 5$ During the 45 days with 200 kilometres while all the conditions are the same but correlation coefficient is higher than 0.65 than earthquakes occurred with 150killometer during the 45 days [6]. It is reported that more than 50 % of death happened in an earthquake than other types of disasters [7]. The earthquakes that occurred by the crack of rock zones are known as shortcomings. Seven large lithospheric plates and smaller plates in the earth crust. These plates moved towards each other are known as convergent boundary and when these plates' moves apart then they are called divergent boundary. If these plates are passed each other then they are called transform boundary.

In the earth crust when suddenly released stress toward faults occurred then an earthquake happened. The motion of tectonic plates developed a built-up pressure in the rock strata on sides of the fault and the stress is great which produced jerk movement. The waves which are produced through these situations propagate through the ground and its surface and these shaking we take as an earthquake. Earthquakes caused by tectonic plates are known as tectonic quakes. In the world, most earthquakes occurred on the boundaries of tectonic plates. Induced earthquakes are caused by human activities because of major technological activity i.e. mining, open pit mining etc. performed by the human and small earthquake occurred on the surface. It is reported that water can also cause earthquakes because water seeps into the subsoil increased the pore pressure and reduced internal friction so the strength of the rock decreased and rock breaks and earthquakes occurred. Volcanic earthquakes are caused by active volcanism. Figure 1 shows different tectonic plates around the globe.


*Figure 1: Boundaries of tectonic plates [8]*

## 3 Earthquake risk assessment for single storey residential buildings

The purpose of a seismic risk assessment (SRA) is to forecast the likelihood of building and infrastructure damage, as well as economic losses, in the event of a hypothetical seismic hazard or scenario earthquake. In general, it consists of two steps: assessing structural vulnerability and analyzing seismic hazard. SRA's main focus is on assessing structural vulnerability. Open SEES was used to create nonlinear structural models for single-story industrial steel buildings, which were then used in static and dynamic seismic assessments. The following modelling criteria were used i.e. adoption of simple yet generic methodologies based on accessible data, such as geometry and material qualities and avoidance of empirical models requiring calibration based on experimental tests as much as possible. The seismic performance of various design parameters (geometry, seismic hazard, soil typology) and modelling assumptions (bare-frame model, frame including cladding panels, effect of vertical accelerations, and influence of uncertainties in the steel yield stress and brace equivalent imperfections) was evaluated using multi-stripe analyses [9]. The probabilistic seismic hazard analysis and the probabilistic structure response analysis are linked by ground motion intensity measures (IMs). IMs that are well correlated with the structural reaction enable a low-risk (high-efficiency) calculation of the structure's seismic reaction, minimizing the computational effort required for structural response analysis.

A spatial correlation model must be available to employ an IM for regional seismic risk assessments. These studies look at the seismic risk of a group of structures that are spread out throughout a region. As a result, during an earthquake, the analyst must take into account the link between IMs affecting various areas. The regional seismic risk of high-consequence events may be drastically underestimated if the spatial link is either ignored or undervalued. The HAZUS is an earthquake risk assessment instrument created in the United States that assesses the impact of earthquakes on the built environment and population in urban settings. MunichRe, Risklink (RSM), CAT MAP (Air), CATEX, EPEDAT (Early post-earthquake damage assessment tool, Image Cat), RADARS (Risk from earthquake damage to highway system), and risk management solutions are among the software's used in the commercial approaches for risk assessment [10]. Using simple models and first principles, this researcher assesses the relative seismic risk of 1- and 2-story houses. Simulated lumped-mass models are used to evaluate the impact of the fundamental period of vibration, lateral stiffness in each storey, mass distribution, and nonlinear effects on the seismic response of 1- and 2-storey houses for this purpose.

As a result, 2-story residences have a much higher risk of damage and predicted losses than 1-story buildings. This result is in line with the damage seen following other historical earthquakes, where two-story houses have performed worse than their one-story counterparts. Quantifying predicted losses from natural catastrophes and creating appropriate risk management strategies require structural reliability-based methodologies that explain natural hazard and structural system response probabilistically. It is reported that for the earthquake probability assessment data availability required i.e. slope, elevation, magnitude density, depth density, epicentre density, proximity to fault and geology [11]. Earthquake risk assessment of single-story residential buildings necessitates the consideration of Triggering factors of single-storey residential buildings, spatial occurrence, Duration of the event, Time of onset, Frequency, Magnitude/intensity, Derived/secondary events. Table 1 shows that vulnerability is categorized as very high, high, moderate, low and very low. The percentage of high vulnerability is 28.28 % because of the greater population at risk as shown in table 1.

***Table 1- The details of earthquake based population at risk, percentage and number of families [12]***

| **Vulnerability** | **Percentage** | **Population at risk** | **Number of Families** | **Area (m 2)** |
|---|---|---|---|---|
| Very High | 25.39 | 15415 | 4596 | 10728300 |
| High | 28.28 | 45162 | 13772 | 11949800 |
| Moderate | 22 | 75592 | 22513 | 9297200 |
| Low | 12.88 | 67818 | 21322 | 5445600 |
| Very Low | 11.45 | 130846 | 41564 | 4837900 |

## 4 Effects of earthquake on residential buildings

The earthquake occurred at Zagreb in March 2020 with a magnitude of 5.5 which cause serious damages to the architectural achievements and historical centre of Zagreb [13]. The research revealed that earthquake directly affects severe damages to structures and also indirectly cascade the results of infrastructure damages [14]. It is reported that aftershocks increased the losses by around 10 % [15]. The researchers revealed that the seismic response on the masonry structures and near and far-fault records are different. It is reported that near-fault earthquakes have the potential to more damages the structures than far fault records [16]. It is reported that small stories have more capacity to stand against earthquakes than large stories buildings. Level of shaking by earthquake cause minor damages, major damages, and interior finishes cracking, nonstructural damages i.e. plumbing and heating etc. It is reported that ground shaking intensities are very important against building response [17]

In structures destruction, the most dangerous natural hazard is an earthquake. When an earthquake hits the structure then it generates inertia of forces which caused destruction and horizontal and vertical shaking. The capacity of any roof structure to remain in its original position is known as inertia. Greater mass i.e. high rise building have the inertia of force so a single story or two stories building has a better capacity to stand against earthquake. It is reported that when an earthquake occurs and ground shaking occurred then the base of the structure also moved with the shaking. This movement creates internal forces in the columns of the buildings. These internal forces are also known as stiffness forces. It is investigated that the stiffness forces are higher as column height increased. The earthquake caused shaking the building in three directions X, Y and Z. In common practice buildings are designed for vertical loads and buildings to stand against earthquake to vertical loads by safety factor in the design. But horizontal shaking of the building in X and Y direction caused lateral displacement and inertial forces. Tsunami, landslides and liquefaction are the indirect effects on the structure [18].

# 5 Consequences of earthquake

It is reported in the literature that the consequences of the earthquake have positive and negative interactions. The researchers revealed that the earth not only damaged the structure but also creates problems for the living conditions of survivors. It is reported that the consequences of an earthquake can not only be evaluated by structural damages but also evaluated residual damages [19]. A consequence of earthquake includes loss of life and both social and economic loss. For finding the consequences of an earthquake for a nation or country, city and individual the common term used seismic risk assessment instead of earthquake loss estimation. Seismic risk assessment finds out the economic and social results of an earthquake will be equal or greater values in areas where the earthquake occurred. The main purpose of earthquake loss estimation is to find out not only the physical expected damages and social and economic losses that are connected direct or indirect way by the earthquake [20].

In any assessment, the consequences of earthquakes include the cost of repair of the buildings, causalities and downtime. It is reported that earthquake destroys the economy of any country. The earthquake occurred at any time and without any warning and can be caused damaged structure and human lives. It is reported that if the epicentre of the earthquake is in populated areas then they create a large disturbance. These earthquakes are known as urban earthquakes. The rescue operation can be very complex and reduced the capacity to reduce the consequences [21]. Table 2 shows the consequences of the different earthquake in Pakistan from 2005-2019. Deaths in 2005 and total affected are very high as compare to other earthquakes as shown in table 2. Dis mag value is same in 2005, 2013 and 2015 but total damaged that occurred in the 2005 earthquake is much higher than earthquakes.

***Table 2-Consequences of different earthquakes in Pakistan 2005-2019 [22]***

| Year of Earthquake | Dis Mag Value | Total Deaths | Total Affected | Total Damages ('000 US$) |
|---|---|---|---|---|
| 2005 | 8 | 73338 | 5128309 | 5200000 |
| 2008 | 6 | 166 | 75320 | 10000 |
| 2011 | 7 | 2 | 1000 | - |
| 2013 | 8 | 41 | 15175 | - |
| 2013 | 8 | 399 | 185749 | 100000 |
| 2013 | 7 | 22 | 50 | - |
| 2015 | 8 | 280 | 502590 | - |
| 2015 | 6 | 3 | 85 | - |
| 2016 | 7 | 6 | 142 | - |
| 2019 | 6 | 39 | 130398 | 17000 |

# 6 Conclusion

The purpose of this study is to provide an overview of earthquake risk assessment for single-story residential buildings, as well as earthquake effects on residential buildings and earthquake repercussions. The following conclusions are obtained from the literature.

- Single-story buildings can withstand earthquakes significantly better than high-rise structures.
- Residential buildings in urban areas much need more attention.
- A seismic vulnerability map for single-story residential buildings will be created to help mitigate the effects of earthquakes.
- The design of high-rise buildings includes a safety factor for horizontal shaking in both the X and Y directions.

As a result of the preceding conclusion, earthquakes are a significant natural hazard; therefore earthquake risk maps for residential buildings are essential.

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