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ASSESSING DAMAGE GRADES OF BUILDINGS AND THEIR RELATIONSHIP WITH SEISMIC RISK PERCEPTION, A CASE STUDY OF PABBI, KHYBERPAKHTUNKHWA

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Abstract- The aim of the study is to accomplish seismic vulnerability appraisal of buildings in the town of Pabbi (Nowshera district) of Khyber Pakhtunkhwa (KPK) province and to observe the relationship between risk perception and vulnerability assessment, if any. The paper describes building structures, damage grades and their relationship with people risk perception, based on the current physical condition of buildings. The vulnerability assessment of the existing buildings was carried out using customized FEMA P-154 form. The investigation of the present condition of buildings revealed that due to old age, plan and vertical irregularities, unplanned settlement, rapid urbanization, buildings constructed on soft soil and no implementation of seismic design codes; most of the buildings were vulnerable to earthquake loading. It was observed that most of the buildings (>50%) fall in damage grade 3 and 4, implying strong probabilities of heavy structural and non-structural damages and require detail evaluation.

The people risk perception study was carried out using face to face interviews which revealed that the people perceive the chances of earthquake in future. An empirical relationship between damage grades and people seismic risk perception were developed using regression analysis. The results revealed that people risk perception and damage grades of their buildings have a reasonably good relationship with an R^2 value of 0.57. The study is an important step for the institutions, policy makers, designers and researchers to reduce the risk associated with earthquake and thereby reducing loss of lives and assets.

Keywords- Damage grades, Earthquake risk perception, Rapid visual screening, Vulnerability assessment.

1 Introduction

The intrinsic vulnerability to seismic action of unreinforced brick masonry structure is perceived as deficient despite several decades of academic research. The seismic activities are considered one of the most destructive natural disaster and damages associated has significantly increased[1]. There are various methods and procedures are available in the literature for determining earthquake vulnerability of the existing building structures[2]. The procedures vary from complex finite element analysis of each building to the simple ones based upon Rapid Visual Screening (RVS) which can help in predicting the future vulnerability of structures[3]. The former is a computationally expensive, laborious and time consuming exercise, while the latter is a simple sidewalk survey which can be completed for a building stock with a significantly less effort and time [4].

The term risk refers to probable degree of damage and associated injury likely to occur over a specified period of time from the exposure of people and property. The risk perception directly alters one's action before and during a hazard[5]. The earthquake risk assessment is the estimation of maximum loss i.e. infrastructural, economical, and social which can help in developing earthquake risk maps[6].The perception of risk from hazard relationships have been studied by various researchers and it was concluded that perceived risk from natural hazard is influenced by many factors such as age, gender, education[7] location of residence[8] and duration of stay[9]etc.

The objective of the study is to carry out seismic vulnerability assessment of buildings; people risk perception survey and their inter-relationship in the city of Pabbi of Nowshera district in the KPK province. The study can be used for mitigation of future earthquake hazards through awareness and preparedness.

2 Methodology

2.1 Case study area and sample size

Pabbi is tehsil of Nowshera district of Khyber Pakhtunkhwa province of Pakistan. It is located at Grand Trunk (GT) road around 20km from Peshawar. It has a latitude of 34^0 00' 34" N and has a longitude of 71^0 47' 40" S. The Pabbi tehsil has an urban population of 55,255 according to Pakistan Bureau of statistics[10]. In the past, the city was basically a residential dominant area; however in the recent past due to rapid urbanization it has grown into zones of commercial, semi commercial and residential areas. For conducting the vulnerability assessment of buildings using RVS procedure, 400 samples as per Yamane formula[11]have been selected and investigated from the area as shown in Figure 1.

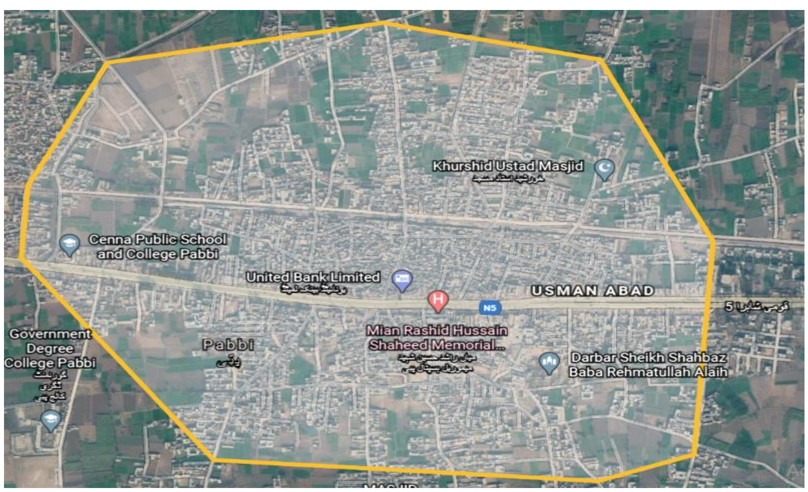

Figure 1: Arial view of the surveyed area

2.2 Vulnerability assessment of buildings using RVS procedure

A building's response to earthquake is associated to earthquake intensity and duration along-with building's lateral load resisting system, materials and construction quality, soil strata, plan and vertical irregularities, wall opening, damage from past hazards etc. Following are the factors which are considered for RVS survey for vulnerability assessment:

Earthquake hazard intensity— Damage to building is directly associated to this and it is a part of RVS.

Building type— Building response to earthquake mainly relies on its lateral load resisting system[12].

Building height─ It is proved that low rise buildings are generally less vulnerable than high rise building[13].

Vertical irregularity─ Since vertical irregularity has adverse affect on seismic performance and its score modifier is taken as negative for all building types[14].

Plan irregularity─Buildings having plan irregularities are considered more vulnerable that of regular one[15].

Construction quality─ Poor construction quality exhibits poor performance during earthquake[16].

Soil type─Structural damage associated with amplitude and duration of shaking and soil types has major influence upon these[17]. To classify soil type during planning stage if sufficient data are not available then soil type E should be assumed[18].

Pre code construction─ Buildings constructed before the adaptation of seismic codes are vulnerable and have poor performance during an earthquake[19].

2.3 Risk perception assessment

Focusing on the issues associated to risk appraisal the field of risk analysis has developed expeditiously. The risk perceived covers the factors such as vulnerability, character and cognition[20] .The basis of the risk research can be traced back at the time of initial nuclear debate in 1960. The analysis of earthquake risk perception in Pakistan is vital in drafting the earthquake risk communication plan. The scheme needs to address the current risk perception of the community on the land of Pabbi city district Nowshera. Risk perception and awareness is not only rely upon individual risk and risk past events. To introduce risk awareness, another way is by establishing and promulgating information and communication tools and coordinating risk alertness campaign.

Using an extensive literature review, based on the nine selected indicators shown in Table 1, risk perception index has been developed. The indicators include like probability of earthquake occurrence in future, probability of future harm by an earthquake, loss of lives, ability to cope, level of last seismic event harming, your structure resistance etc. A value of 1 and 0 has been assigned to each indicator representing no risk and maximum risk respectively. Mean Risk perception index (RPI) value has computed using the following equation for each indicator.

Table 1 The details of earthquake risk perception indicators

S. No	Attributes	Category	Weightage	Explanation	Proof
1.	How likely an earthquake will occur in future?	Very high High Medium Low Very low	1 0.8 0.6 0.4 0.2	Those perceiving likelihood of an earthquake would perceive more risk.	[21-24]
2.	The probability of future harms by an earthquake.	Very high High Medium Low Very low	1 0.8 0.6 0.4 0.2	Those perceiving likelihood of destruction of an asset by earthquake would perceive more risk.	[25]
3.	How much are you afraid of an earthquake?	Very high High Medium Low Very low	1 0.8 0.6 0.4 0.2	Those afraid relatively more from an earthquake would perceive more risk.	[22, 26]
4.	The level of understanding of emergency protocols.	Very high High Medium Low Very low	1 0.8 0.6 0.4 0.2	The knowledge about emergency protocols would perceive low risk.	[22, 25]

5.	The level of loss of lives in earthquake.	Very high High Medium Low Very low	1 0.8 0.6 0.4 0.2	Those who believe loss of lives in future earthquake perceive more risk.	[21, 22, 27, 28]
6.	The ability to cope with a future earthquake.	Very low Low Medium High Very high	1 0.8 0.6 0.4 0.2	A better economy of households with high capability perceives low risk.	[29, 30]
7.	The level of harm/damage in the last seismic event.	Very high High Medium Low Very low	1 0.8 0.6 0.4 0.2	The people affected from past earthquake will Perceive more risk.	[28]
8.	The structure resistance to an earthquake.	Very high High Medium Low Very low	1 0.8 0.6 0.4 0.2	The perceived more building resistance will have low risk perception.	[21, 24, 26, 31]
9.	The age of the respondent.	>35 31—35 26—30 21—25 <25	1 0.8 0.6 0.4 0.2	The risk perception increases with age.	[7]

$$RPI = \Sigma(W1 + W2 + W3 + \cdots W9)/9 \qquad (1)$$

3 Results and discussions

3.1 Building vulnerability assessment and grading

Based on lateral load resisting system, base score is assigned to each building which reflects probability of damage if exposed to maximum considered earthquake (MCE) ground motion. The basic structural hazard score, score modifier and final structural score (SS) has been calculated on RVS data collection form and then correlated with damage grades (DG). The recommended minimum score was encircled in case of the SS less than the minimum score. A value of 1 for SS means that at MCE the calculated probability of building collapse is 10^{-1} i.e. 1 in 10. Similarly, a value of 2 or 3 for SS means that at MCE the calculated probability of building collapse is 10^{-2}or 10^{-3} respectively[32].

The final structural score (SS) as mentioned above is correlated with damage grades (DG).The researchers have used different relationships for correlating SS score with DG[33]. The short period spectral acceleration (S_s) and long period spectral acceleration (s_1) values for the selected region have been obtained from a previous study[34]. The MCE level ground motion values are not available; therefore these were determined from design basis earthquake (DBE) values by multiplying with 1.5 as a standard practice. Based upon the values of spectral accelerations (S_s and S_1), the current study area has been placed in moderately high seismicity region according to FEMA P-154[18].According to the European macro seismic scale, damage to buildings have been categorised in various grades as shown in Table 2. This classification helps in evaluation of seismic intensity and is used in RVS to predict probable damage to a building.

Table 2- **Structural score along corresponding damage potential[35]**

Rapid Visual screening score	Potential Damage Grade (G)
S < 0.3	High chance of G5 damage; very high likelihood of G4 damage
0.3 < S < 0.7	High chance of G4 damage; very likelihood of G3 damage
0.7 < S < 2	High chance of G3 damage; very high likelihood of G2 damage
2 < S < 2.5	High chance of G2 damage; very high likelihood of G1 damage
S > 2.5	Possibility of Grade 1 damage

During the field survey, plan and vertical irregularities, poor materials and construction quality, lack of implementation of seismic design codes and diaphragm insufficient thickness were observed in the study area. These factors influence seismic performance of structures[16].

The surveyed buildings have been categorized into four classes, viz. residential, commercial, educational and other. The other building structures in the study area found were semi commercial and health centres etc. Most of the investigated buildings were unreinforced masonry and ordinary moment resistance frame structures. The overwhelming majority of the investigated fall into damage grade 3 (DG3) and 4 predicting high structural and non structural damage. The result in Figure 2 revealed that 56% of residential, 42% of commercial, 56% of educational and 52% of other buildings fall under DG3 and 4.

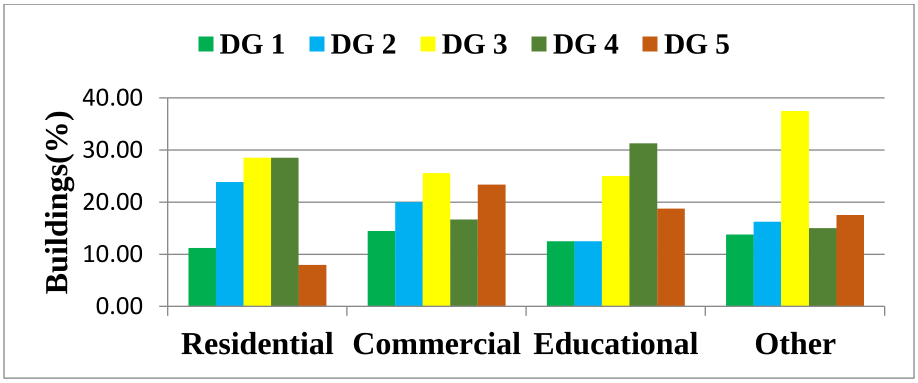

Figure 2: The building categories with determined damage grades

A detail evaluation of a structure is determined on the basis of final structure score SS. The buildings with SS value less than 2 should need to be assessed in detail. However, this figure varies from country to country[35, 36]. The result from Figure 3 revealed that more than fifty percent of buildings of all categories in the study area required detail evaluation. From the study, 137 out of 217 (63.13%) residentail, 58 out of 89 (65.16%) commercial, 12 out of 16 (75%) educational and 55 out of 78 (70.51%) other buildings required detail evaluation due to low final score. Such low final score was mainly due to plan and vertical irregularities, buildings constructed on soft soil and pre code construction.

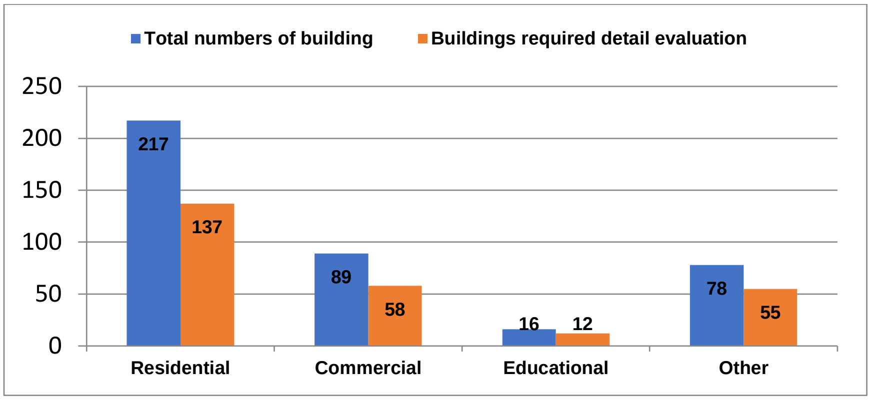

Figure 3: The buildings of all categories which require detail evaluation

3.2 People risk perception results

The risk perception is an important element of comprehensive disaster risk evaluation. The risk perception index was calculated for each household using face to face interview. The results revealed that perceived risk increases with increase in seismic vulnerability of buildings. In risk perception, the majority of variations observed was due to past earthquake losses, fear from seismic events, emergency protocol understanding level, capability to cope with future earthquake and supplies disruption.

3.3 Relationship between damage grades and people risk perception

A relationship has been developed between people risk perception and damage grades of their buildings using linear regression analysis. The result shown in Figure 4 disclosed that there is a positive relation between people risk percpetion and damage grades. The value of R^2 is 0.572, this means that the relationship accounts for 57.2% of the total variation. It reflects that community house hold risk percpetion increases with increase in damage grade (DG) of building. A possitive correlation between both assessment imply that people are comprehensive of the vulnerability of the stucture and may take precustionary and preparedness measures against future earthquak hazard. There are other factors as well which influence the relationship between people risk perception and damage grades and the results presented here may not be considered conclusive here. As a measure of eathquke hazard mitigation, pople risk perception can be considered a reasonable substitue in case of missing hard data.

$$RPI = 0.485 + 0.432 * DG \qquad (2)$$

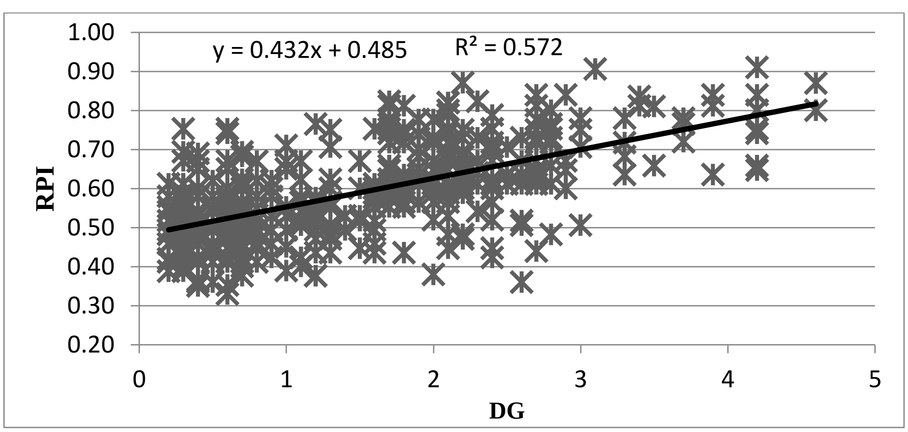

Figure 4: The corelation between damage grades and people risk perception

4 Conclusions

In this paper RVS has been used to collect data of 400 buildings in Pabbi City of District Nowshera KPK. The vulnerability assessment has been carried out using latest modified FEMA P-154 form. The percentage of various buildings categories with different damage grades recorded for the study area gives an idea of buildings requiring detail assessment. Over all maximum percentage of buildings lie in DG3 and DG4, representing moderate to heavy structural and non-structural damage. The results in term of damage grades disclosed that more than fifty percent of building of all categories require retrofitting or need to be replaced. Most of the surveyed buildings were unreinforced masonry residential structures. It has concluded and is rational that people risk perception increases with increase in damage grade of their buildings.

People customarily spend in their buildings maintenance and on advanced decoration; however by warning them about the situation large numbers would coincide care with retrofitting. During the survey it was observed that the recent seismic events caused momentous damages to unconfined brick masonry buildings. Severe vertical irregularities, heavy overhangs, short column, vertical setback and plane irregularity were noticed in reinforced concrete structures.

5 Practical implementation

The adverse impacts of earthquakes on a community can be minimized using buildings vulnerability assessment and developing correlation between damage grades and people risk perception which the current study addressed. For mitigation of earthquake disaster, the concern authorities must ensure alertness amid communities regarding protected building construction methods and implementation of building regulations in the area.

6 Appendix Acknowledgment

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