Saudi Journal of Engineering and Technology (SJEAT)
Scholars Middle East Publishers
Dubai, United Arab Emirates
Website: http://scholarsmepub.com/

ISSN 2415-6272 (Print)
ISSN 2415-6264 (Online)

Implementing New Methodology for Earthquake Risk Mitigation of Developing Countries with High Hazard

Ghazanfar Ali Anwar[1*], Majid Ali[2]
[1]Research Assistant, United Arab Emirates University, Al Ain, United Arab Emirates
[2]Associate Professor, Capital University of Science & Technology, Islamabad, Pakistan

Original Research Article

***Corresponding author**
Ghazanfar Ali Anwar

Article History
Received: 02.12.2017
Accepted: 11.12.2017
Published: 30.12.2017

DOI:
10.21276/sjeat.2017.2.12.3

Abstract: Pakistan, a developing country lies in an earthquake prone region with moderate-to-strong ground motions. Recent earthquakes revealed the seismic vulnerability of existing building stock, leading to monetary loss, casualties and fatalities. Kashmir earthquake (2005) resulted in huge loss of lives and livelihood. However, the country lacks tools for earthquake risk assessment and mitigation. The objective of this research work is to develop seismic vulnerabilities of substandard reinforced concrete frame structures for the determination of risk in terms of monetary loss, casualties and fatalities for the Mansehra district of Pakistan under Kashmir earthquake 2005. CFRP retrofit technique is utilized to improve the seismic vulnerability of existing RC building stock for risk mitigation purposes. A hypothetical four story reinforced concrete frame structure, representative of the construction practices in the study region is designed under gravity load. Vulnerability curve is generated by using capacity spectrum method for unconfined and confined structures. Earthquake risk assessment framework for RC frames is developed for socio and economic analysis. Hazard of the region for a single event of Kashmir earthquake 2005 is determined in ArcGIS environment. Using seismic hazard, and seismic vulnerability of confined and unconfined frames, seismic risk in terms of monetary loss, casualties and fatalities is calculated.

Keywords: Earthquake Risk, kashmir Earthquake, Seismic vulnerability, siesmic Hazard.

INTRODUCTION

Earthquakes are one of most devastating events caused by the natural forces. Risk assessment and risk mitigation techniques are useful to prevent structural damage from natural events like rains and floods. Damage caused because of natural hazards is comparatively larger in Pakistan because of the congested buildings and bad construction practices [1]. Furthermore high seismic vulnerability of existing structures against these hazard increases the risk resulting in loss of lives and property [2, 3]. The earthquake of 2005 has taken approximately 100,000 lives and 400,153 buildings were devastated majority of which were masonry construction [4]. The total economic loss was almost $5.2 billion. Currently Pakistan building stock comprises 10-15% reinforced concrete [5] but rapid urbanization recently has resulted in increased trend in reinforced concrete construction. Existing reinforced concrete construction in Pakistan is gravity load designed with major deficiencies in the design and construction including irregular plans and elevations, soft story mechanisms, weak column-strong beam, poor quality construction material and low concrete compressive strengths. These major deficiencies were highlighted in [6]. It is therefore of extreme importance to quantify vulnerability of existing building stock for earthquake risk preparedness and its probable reduction by using retrofit alternatives. Recent studies have developed seismic vulnerabilities for low- to medium-rise reinforced concrete construction in Pakistan [7-9] and have concluded high seismic vulnerability of existing building stock. This research is conducted to evaluate seismic risk of worse effected Mansehra district of Pakistan during the 2005 earthquake. The study evaluates damage caused during 2005 earthquake and the probable reduction in monetary risk, casualties and fatalities by using CFRP retrofitting technique. Much of the research is being done to study effectiveness and applicability of CFRP retrofit to improve structural performance. Xiao and Wu [10] investigated 27 concrete cylinder providing insight into the application of FRPs. Wu *et al.* [11] investigated the strain softening and strain hardening properties of FRPs. Tastani and Pantazopoulou [12] performed an experimental evaluation using FRP jackets. Yan *et al.* [13]. Investigated the effect of column cross sections on the effectiveness of FRP strengthening. Accurate predictive models of FRP retrofitted concrete columns were developed using the previously developed stress-strain models of FRP confined concrete subjected to cyclic stress behavior Lam and Teng [14]. The proposed numerical model in Teng, et al. [15] subjected to an constant axial compressive force and cyclic lateral loading predicts the hysteretic response of FRP confined concrete columns reasonably close to the actual behavior. Current study utilizes FRP retrofit methodology to reduce seismic risk in terms of monetary loss, casualties and fatalities. On a structure level Van Cao *et al*.[16] studied effect of fiber reinforced polymer on eight story RC building in order to reduce damage of poorly confined frame. Similar mythology is adopted for seismic risk mitigation of Mansehra district under Kashmir earthquake 2005.

Earthquake Risk Assessment (ERA) i.e. the determination of the potential destructiveness of an earthquake event prior to its strike and actual destructiveness after its occurrence [17]. ERA is also a part of the earthquake risk mitigation programs with aim is to reduce the fatalities, injuries, economic losses resulting from an earthquake. ERA forms the basis for the calculation of premium rates for insurance policies and for the determination of the range of probable maximum loss that would be incurred in the event of a catastrophic earth quake [18, 19].This research paper calculates the risk involve in the study region Mansehra which was one of the most affected district because of the Kashmir earthquake on 8th October 2005. The study further investigates the performance improvement of structures using CFRP retrofit options [9].

METHODOLOGY

Background

According to the 1998 census, Mansehra had a population of 1153,839 with the annual growth rate of 2.4%, containing an average of 6.7 persons per house. The map of Mansehra district with union councils is shown in Figure 1. A total of 16 union councils are evaluated and in detail. The predictions are extended for the rest of the area.

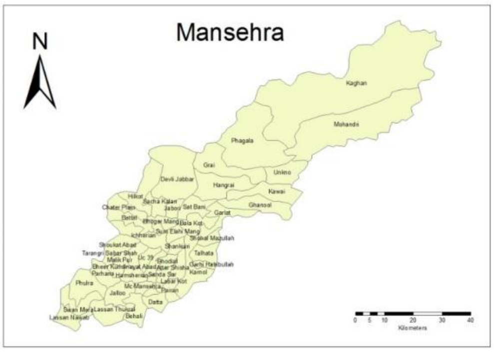

Fig-1: **Union Councils of Mansehra**

Risk assessment parameters

Vulnerability

For determination of seismic risk for Mansehra district, vulnerability for the moment resisting frame structures, without and with CFRP was developed. Reinforced concrete frame structures in Pakistan showed high seismic vulnerabilities because they were designed under gravity loads only. Lack of proper confinement, insufficient lap length, strong beam-weak column and soft story were main cause of high damage index. Absence of nationally accepted building code resulted in poorly designed and detailed buildings. Concrete compressive strengths determined using Schmidt hammer test rarely exceeded 13.75 MPa during a reconnaissance survey [20]. Nonlinear static analysis procedure from [21] was used to develop vulnerability curves using capacity spectrum method which gave a PGA value at structural collapse i.e. 100% damage index. Nonlinear cyclic pushover analysis was carried out to calculate the capacity curves for performance evaluation. The vulnerability curves are shown in Figure 2 [9]. Existing reinforced concrete structures designed under gravity loads exhibit poor structural performance under lateral loads with 100% damage index at around 0.43g whereas retrofitting beam-column joints with CFRP wraps can improve the ductility and seismic performance of sub-standard reinforced concrete frame structures considerably as shown in vulnerability curve with CFRP retrofitting where structure has a 100% damage index around 0.65g.

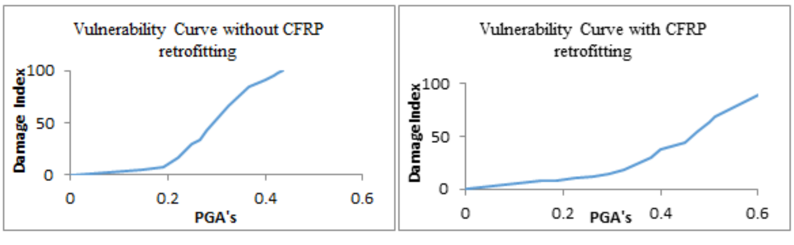

Fig-2: **Vulnerability curves with and without retrofit**

Evaluation of Hazard

Seismic hazard gives probability of occurrence of an earthquake and is calculated in terms of peak ground accelerations using Probabilistic Seismic Hazard Analysis. ArcGIS software is used for seismic hazard distribution input for Mansehra district. Historic catalogue of earthquake 2005 is used for the seismic hazard data since it was a rare earthquake event of 7.6 Mw. Seismic hazard assessments involves sophisticated analysis and historic data for the precise estimation of seismic hazard distribution. ArcGIS is used for the seismic hazard distribution and plotting of geographic information. Hazard assessment is carried out using probabilistic seismic hazard analysis technique using historic catalogue of earthquake 2005. The hazard distribution plotted in ArcGIS is shown in Figure 3. Legend showing dark areas have high seismic hazard as compared to the light areas which can be due to many reasons involving attenuation factors, soil surface interactions, type of soil, topography, etc. The figure shows horizontal peak ground accelerations averaged per union council for Kashmir earthquake 2005 event. A single earthquake catalogue is used to determine horizontal PGAs shown below. Regions with darker shades have a high peak ground acceleration values than lighter regions.

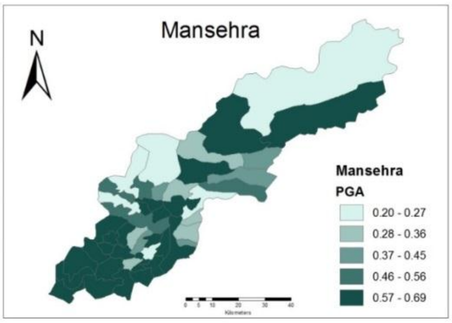

Fig-3: **Hazard Map of Mansehra**

Evaluation of Value

The distribution of the reinforced concrete structures scattered over the study area is collected from National Engineering Services Pakistan (NESPAK). Worth of a grey structure is reasonably approximated around 40, 00,000 Pakistani Rupees. Number of reinforced concrete structures available in a particular union council is given in the figure 4.

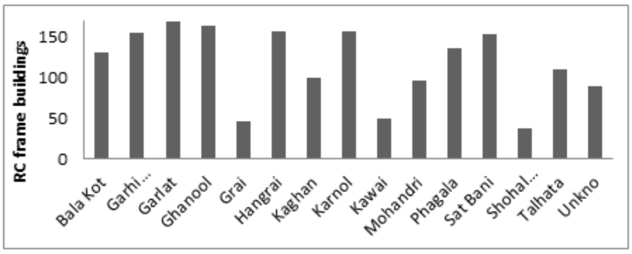

Fig-4: **Number of RC buildings per union council**

Earthquake risk assessment

Seismic risk assessment in terms of monetary loss, fatalities and injuries is determined considering vulnerability, hazard and value.

Monetary loss assessment

Number of building collapsed per union council is determined using structural vulnerability and seismic hazard. Monetary loss is calculated using reasonably estimated value of structures collapsed.

Fatalities assessment

Fatalities per union council are calculated by multiplying the "expected average deaths per collapsed structure" with "total number of collapsed buildings per union council."

Injuries assessment

Injuries in a union council are calculated by multiplying the "expected average survivals per collapsed structure" with "total number of collapsed buildings per union council."

ANALYSIS AND RESULTS

Monetary loss assessment

For the monetary loss assessment average risk per building for different unions is generated for unconfined and confined RC structures using vulnerability curves, hazard and reasonably estimated worth of a structure. Figure 5 shows the map generated in ArcGIS for un-retrofitted and retrofitted frames after the seismic risk analysis. The areas having high hazard and high vulnerability have high seismic risk. Total monetary loss in percentage of the replacement cost for un-retrofitted and retrofitted structures is presented.

Seismic risk is reduced in some regions of moderate peak ground acceleration values after CFRP retrofit showing effectiveness of retrofit technique in seismic risk mitigation strategies.

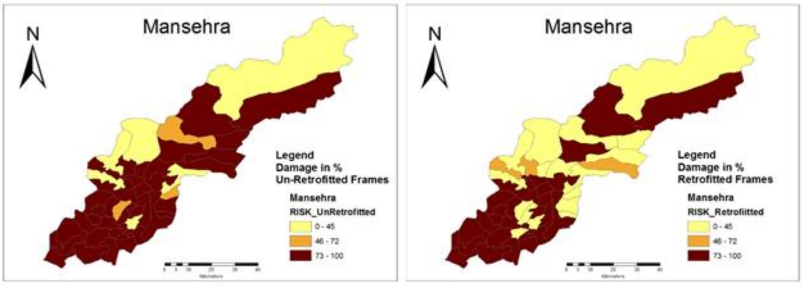

Fig-5: **Risk Map of Mansehra**

Fatalities assessment

Fatalities are determined by calculating total number of structures collapsed per union council using seismic hazard and vulnerability studies. Mansehra district document [22] states average 6.7 persons per apartment in a reinforced concrete structure during the earthquake 2005. The average number of apartments per building is reasonably estimated around 6, making total number of people per structure equal to 40.

Incorporating this data, number of deaths is calculated. Figure 6 shows ArcGIS plots of fatalities for retrofitted and un-retrofitted frame structures in study region. Number of fatalities recorded per union council is shown in the legends. The fatalities are reduced in each union council after retrofit showing the efficiency of CFRP technique in reducing fatalities.

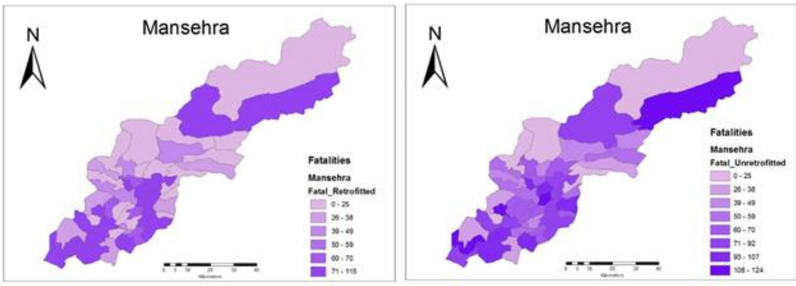

Fig-6: **Fatalities Map of Mansehra**

Injuries Assessment

For the injuries assessment, same procedure is followed. All the data is plotted in the ArcGIS using PSHA calculating the number of buildings collapsed during the earthquake 2005. Trapped survivors can be determined from total fatalities and average number of people living per building. Figure 7 shows injuries for un-retrofitted and retrofitted structures per union council. Number of persons injured is considerably reduced by increasing performance of structures using CFRP wraps around beam column joints.

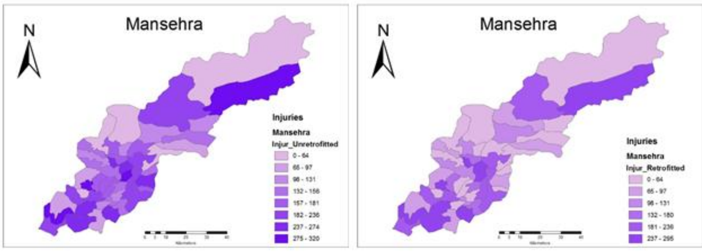

Fig-7: **Injuries Map of Mansehra**

CONCLUSIONS

Seismic risk is calculated for both confined and unconfined reinforced concrete frame structures. Study indicates the reduced seismic risk in terms of monetary loss, fatalities and injuries. Around 60% percentage reduction in monetary risk calculated is achieved using beam-column CRFP retrofitting technique in the study region. The approach presented in this paper can be used for seismic risk assessment of developing countries with limited resources. This easy and quick approach focusses on PSHA developed in VBA utilizing structural vulnerability to calculate seismic risk. Significant cost savings can be achieved utilizing this approach. Furthermore, this approach can help in risk mitigation strategies, saving lives and important facilities.

Following conclusions can be made from earthquake risk assessment of Mansehra

- The reduction in seismic risk in terms of monetary loss could have been 65% by confining the structures with CFRP's in the study region.
- The lives of 48% people could have been saved and almost 49% reduction in injuries could have been made possible using CFRP confinement in reinforced concrete frame structures in Mansehra before Kashmir earthquake 2005.

RECOMMENDATIONS

An easy and quick approach is utilized on RC frame structures for the determination of monetary loss, fatalities and injuries for the study region against single seismic hazard catalogue. This approach can be used to determine risk assessment of reinforced concrete frame structures for future earthquakes by using records with probability of occurrence of a major event in different regions. Future studies are recommended to verify the accuracy of this approach. Furthermore, it can also be extended to masonry and other structural systems to include wider structural configurations for better estimate of seismic risk involved.

REFERENCES

1. Durrani, A. J., Elnashai, A. S., Hashash, Y., Kim, S. J., & Masud, A. (2005). The Kashmir earthquake of October 8, 2005: A quick look report. *MAE Center CD Release 05-04*.
2. Karimzadeh, S., Feizizadeh, B., & Matsuoka, M. (2017). From a GIS-based hybrid site condition map to an earthquake damage assessment in Iran: Methods and trends. *International Journal of Disaster Risk Reduction*, *22*, 23-36.
3. Maqsood, S. T., & Schwarz, J. (2008). Seismic vulnerability of existing building stock in Pakistan. In *Proceedings of the 14th World Conference on Earthquake Engineering, Beijing, China. Paper* (No. 09-01, p. 122).
4. Haseeb, M., Xinhailu, A. B., Khan, J. Z., Ahmad, I., & Malik, R. (2011). Construction of earthquake resistant buildings and infrastructure implementing seismic design and building code in northern Pakistan 2005 earthquake affected area. *International Journal of Business and Social Science*, *2*(4).
5. Badrashi, Y. I., Ali, Q., & Ashraf, M. (2010). Reinforced Concrete Buildings in Pakistan, World Housing Encyclopedia. *Earthquake Engineering Research Institute (EERI) & International Association of Earthquake engineering (IAEE), Report*, *159*.
6. Bothara, J. K., & Hiçyılmaz, K. (2008). General observations of building behaviour during the 8th October 2005 Pakistan earthquake. *Bulletin of the New Zealand society for earthquake engineering*, *41*(4), 209-233.
7. Ali, M. U., Khan, S. A., Anwar, M. Y., & Gabriel, H. F. (2015). Probabilistic application in seismic vulnerability assessment of deficient low-to medium-rise reinforced concrete buildings in Pakistan. *Arabian Journal for Science and Engineering*, *40*(9), 2479-2486.
8. Ali, M. U., Khan, S. A., & Anwar, M. Y. (2017). Application of BCP-2007 and UBC-97 in seismic vulnerability assessment of gravity designed RC buildings in Pakistan. *Frontiers of Structural and Civil Engineering*, 1-10.
9. Anwar, G. A., Anwar, J., & Versaillot, P. D. (2016). Effect of CFRP Retrofitting on Seismic Vulnerability of Reinforced Concrete Frame Structures in Pakistan. *American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)*, *26*(1), 145-158.
10. Xiao, Y., & Wu, H. (2000). Compressive behavior of concrete confined by carbon fiber composite jackets. *Journal of materials in civil engineering*, *12*(2), 139-146.
11. Wu, G., Lü, Z. T., & Wu, Z. S. (2006). Strength and ductility of concrete cylinders confined with FRP composites. *Construction and building materials*, *20*(3), 134-148.
12. Tastani, S. P., & Pantazopoulou, S. J. (2004). Experimental evaluation of FRP jackets in upgrading RC corroded columns with substandard detailing. *Engineering structures*, *26*(6), 817-829.
13. Yan, Z., Pantelides, C. P., & Reaveley, L. D. (2007). Posttensioned FRP composite shells for concrete confinement. *Journal of Composites for Construction*, *11*(1), 81-90.
14. Lam, L., & Teng, J. G. (2009). Stress–strain model for FRP-confined concrete under cyclic axial compression. *Engineering Structures*, *31*(2), 308-321.
15. Teng, J. G., Lam, L., Lin, G., Lu, J. Y., & Xiao, Q. G. (2015). Numerical simulation of FRP-jacketed RC columns subjected to cyclic and seismic loading. *Journal of Composites for Construction*, *20*(1), 04015021.
16. Van Cao, V., & Ronagh, H. R. (2014). Reducing the seismic damage of reinforced concrete frames using FRP confinement. *Composite Structures*, *118*, 403-415.
17. Dowrick, D. J. (2009). *Earthquake resistant design and risk reduction*. John Wiley & Sons.
18. Rauch, E., & Smolka, A. (1992). Earthquake insurance: Seismic exposure and portfolio dispersal; their influence on the probable maximum loss. In *Earthquake Engineering 10th World Conference, Balkema, Rotterdam* (pp. 6101-6104).
19. Dowrick, C., Kokanovic, R., Hegarty, K., Griffiths, F., & Gunn, J. (2008). Resilience and depression: perspectives from primary care. *Health:*, *12*(4), 439-452.

20. Naseer, A., Khan, A. N., Hussain, Z., & Ali, Q. (2010). Observed seismic behavior of buildings in northern Pakistan during the 2005 Kashmir earthquake. *Earthquake Spectra*, *26*(2), 425-449.
21. Kalkan, E., & Kunnath, S. K. (2006). Adaptive modal combination procedure for nonlinear static analysis of building structures. *Journal of Structural Engineering*, *132*(11), 1721-1731.
22. Carmona, L., Descalzo, M. A., Perez-Pampin, E., Ruiz-Montesinos, D., Erra, A., Cobo, T., & Gómez-Reino, J. J. (2007). All-cause and cause-specific mortality in rheumatoid arthritis are not greater than expected when treated with tumour necrosis factor antagonists. *Annals of the rheumatic diseases*, *66*(7), 880-885.