An Earthquake Risk Assessment Study of Khyber Pakhtunkhwa Province Pakistan

Muhammad Abbas Quershi[1]
Pakistan Atomic Energy Comission, Pakistan

Habil Ahmad[2]
City University of Science and Information Technology, Pehawar Pakistan
habil.ahmad89@gmail.com

Atta Ullah Shah[3a], Shaukat Ali Khan[3b]
[3a] *City University of Science and Information Technology, Pehawar Pakistan*
[3b] *National University of Science and Technology Islamabad,Pakistan*

Abstract

Earthquake risk assessment is esseantial for pre-disaster ad post-disaster mitigation strtagies. Wide research is carried out on the assessmet of risk on small regions only, but no research on the assessment of earthquake is carried out at large scale. The objective of this research is assessment of risk asscoiated with earthquake hazard at Provoincial level of Khyber Pakhtunkhwa Province Pakistan. Earthquake hazard is calculated as Peak Ground Acceleration (PGA), being calculated by ERA framework developed by Khan (2011) for risk assessment. Ground Motion Prediction Equation (GMPE) of Ambarasy's is used for hazard Assessment while buiding inventory is developed projecting census data with minimal field sampling. Maximin value of PGA of 0.39g was find out in region of district Mansehra, battagram and shangla. Average Risk per $1000 ranges between ($5 to $145) depends on location and class of building. Pre-earthquake and post-earthquake mitigation strategies are recommended based on results

Keywords

Earthquake Risk Assessment, PGA, PSHA, Attenuation, Vulnerability.

1. Introduction

2005 Kashmir Khyber Pakhtunkhwa and 2008, 2013 Ziarat, Awaran Balochistan earthquakes highlites the need of earthquake hazard and risk assessment at large scale. Few studies have been carried out on hazard assessment of selected parts of the Khyber Pakhtunkhawa Province (Ali Q, 2005; Monalisa et al., 2007; PMD-NORSAR, 2007; Ahmed, 2008; Khan, 2011). But no broad scale study is done so far on Earthquake Risk Assessment (ERA) in Pakistan on national or provincial level. Therefore, the ERA of the Khyber Pakhtukhawa province is selected. KPK is located in the north-west of Pakistan (Shown in Figure 1). The capital of KPK province is Peshawar. The province consists of 24 districts with approximate estimated total population over 25 million (FBS Pakistan, 2012). Hindukush and Some portion of Himalayas range are in KPK which make it seismically active region. Kashmir 2005 earthquake that claimed the lives of more than 86,000 people and a devastation of financial loss of approximately $3.5 billion (ADB-WB, 2005) severely affected some areas of KPK province. Approximately 3.5 million people became homeless, bereaving them of food and shelter (ERRA, 2007).

Earthquake Risk Assessment of unreinforced brick masonry(URBM) structures for Mansehra was carried out by Naveed (2011).For 475 year return period a PGA of 0.25g on soil site estimated by Naveed (2011). He reported that 5% of the total single storey URBM buildings will collapse, 20% of the buildings will attain heavy damages and 21% buildings will be in repairable damages. Only 54% of the buildings will have no damage and estimated total loss of about US$ 7.64 million. Total injuries of 2294 ±459 people and fatalities of 29±6 will be expected for the exposure of 50years.

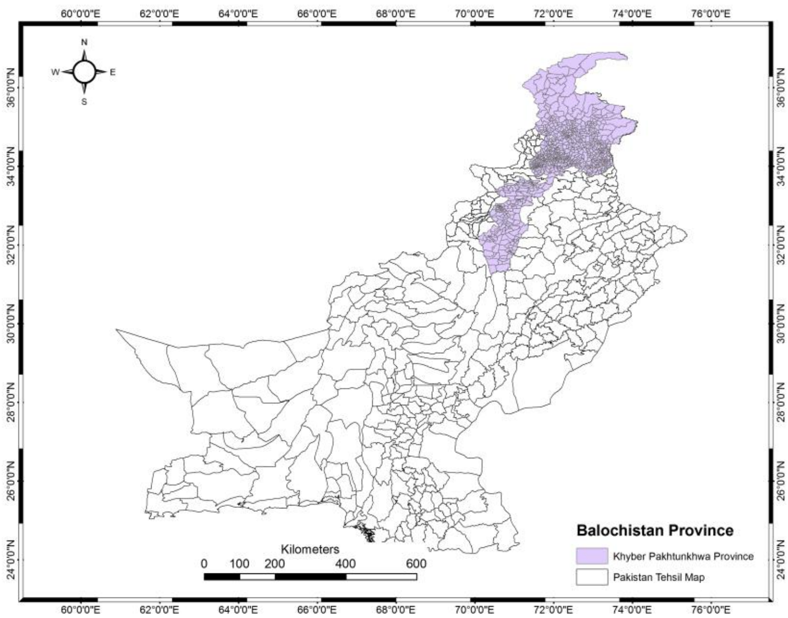

Figure 1: Khyber Pakhtunkhwa Province Pakistan

Framework developed by Khan (2010) is used in this study for hazard and risk assessment of KPK province. This framework is suitable for developing countries where detailed data on seismo-tectonic, vulnerability and building inventory are not readily available.

2. Seismicity

Pakistan is situated on the western-fractured edge of the Indo-Pakistan sub-continental plate and lies on the northwestern corner of the Indian lithospheric plate, the southern part of the Afghan craton, and the northern part of the Arabian oceanic sub-ducting plate (Zaigham and Mallick, 2000). The Indian subcontinent has been impacting with Eurasian sub continent in the course of last 30-40 million years (Aitchinson et al., 2007). Throughout this period continental lithosphere longer than 2000 km has abbreviated to huge mountain ranges. Northern, Western and Southern Pakistan, Kashmir and Northern India and Afghanistan are along zones of high seismic movement. Earthquakes happen along an extremely active thrust fault framework in the locale.

Earthquakes along active faults in Pakistan and adjacent faults in India and Afghanistan are the direct result of the Indian sub-continent moving northward and colliding with the Eurasian continent at a rate of about

5cm/year (Sitharam et al., 2013). Before this collision, this plate was moving with the highest rate of 20cm/year (Kumar et al., 2007). This major tectonic impact is initiating elevate that prepares the most noteworthy mountain tops on the planet incorporating the Himalayan, the Karakoram, the Pamir and the Hindu Kush ranges.

3. Seismo Tectonic

The major tectonic features of Pakistan and surrounding areas are shown in Figure 2 are based on the information provided by Building Code of Pakistan (Khan, 2011). The major fault zones in Pakistan include the Sulaiman stretch in transpression and the Himalayan zone under-thrusting the Eurasian plate (Jadoon, 1992).

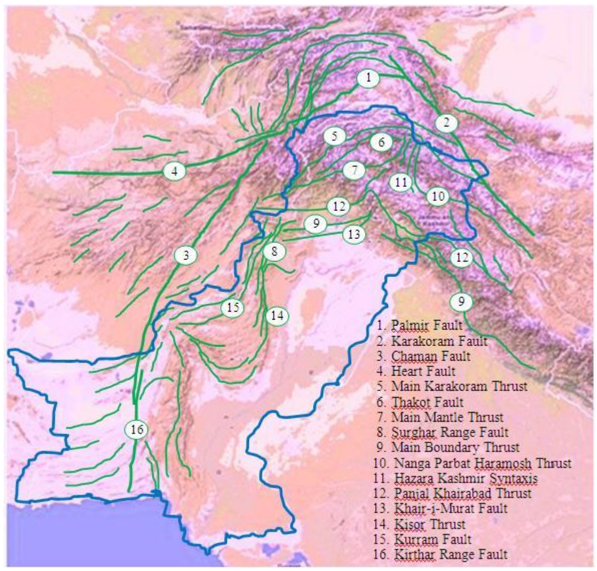

Figure 2: Tectonic features in Pakistan.

4. Earthquake Catalogues

Historical and Instrumental earthquake record are collected from different sources. Historical earthquake records are compiled by Oldham, 1893, Heukroth and Karim, 1970, Ambraseys et al. 1975 and Quittmeyer and Jacob, 1979. As the historical catalogues only contain large magnitude event so these catalogues are incomplete. However historical events plays important role in SHA as these events leads us to the location of seismic source.

Instrument earthquake records are taken for International Seismological Center (ISC, 2012).100 years instrumental records are use in hazard and risk calculation.

5. Seismic Zones

Seismic zones sets by PMD-NORSAR (2007) including the study area and surrounding regions shown in figure (3) are used in this study. This division of seismic source zones is dependent upon seismicity, geology and source mechanism.

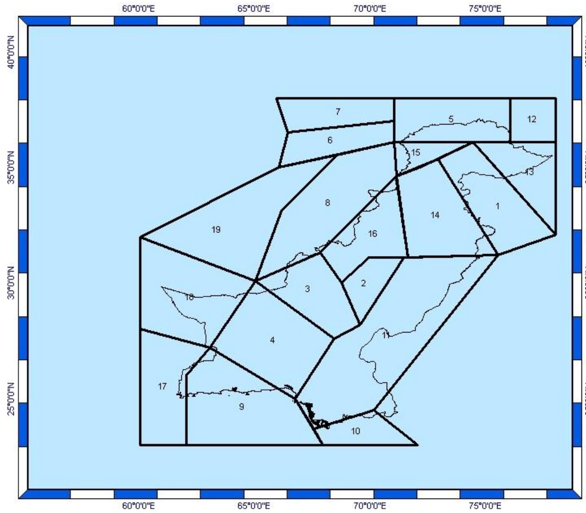

Figure 3: Tectonic features in Pakistan.

6. Development of Building Inventory

Development of building inventories by any method requires extensive computation and time. Very simple approach to this problem is use of census data. In this study projected census data i.e. census 1998 (FBS, 2012) is used with field verification. Buildings in the study area are classified into the following categories.

1. Reinforced Concrete Frames (RCF)
2. Reinforced Concrete Frame with infill masonry (RCI)
3. Un-reinforced Masonry (URM)
4. Rubble Stone Masonry (RSM)
5. Dhajji Structures (DJ)
6. Adobe Structures (AD)

5.1 Reinforced Concrete Frame (RCF)

Reinforced concrete frame exist as commercial units in the urban area and their height may varies from 5 to 10 stories. Large numbers of these building are 3-6 stories. These buildings performed poorly in the Kashmir (2005) Earthquake due to lack of seismic design, soft storey, poor detailing and poor quality of materials.

5.2 Reinforced Concrete Frame with infill masonry (RCI)

Building Stock in the study area contains large number of this type building. These building consist of 3-6 storeys. Reinforce concrete framed with infill masonry is common building type for residential and commercial building in urban areas in study region. Most of buildings are non-engineered and more vulnerable than the RCF due to lack of detailing, poor quality of construction and materials. Performance of these building remained very poor in Kashmir (2005) Earthquake.

5.3 Un-Reinforced Masonry (URM)

This the most common type of residential building throughout the Pakistan as well as in the study region. Brick masonry with Cement-sand Mortar (CSM) is used for this type of building. These building are 1 to 3 storeys with RCC roofing and equally used for residential and commercial purposes. This type of building performed better than RCI and RCF in Kashmir (2005) earthquake.

5.4 Rubble Stone Masonry (RSM)

Dry Rubble or Rubble stone building not only exists in certain rural areas but the construction of these building is still in use. People used locally available stone without dressing for the construction of houses. This type of building is highly vulnerable to earthquake and has shown very poor performance in Kashmir (2005) earthquake (Ahmed, 2012).

5.5 Dhajji Structures (DS)

This structure is mainly located in Northern areas of Pakistan and Kashmir. These are wooden framed with different bracing pattern, the spaces between braces is filled with mud masonry or dry stone. In India and Pakistan this is also known as Dhajji Dewari. Indian Standard Codes referred this type of construction as brick nogged timber frame construction (WHE, 2012).Similar type of construction in Turkey and United Kingdom called as “Himis” and “Fachwerk” respectively. These structures performed very well in Kashmir (2005) earthquake and in rehabilitation phase Earthquake Reconstruction and Rehabilitation Authority (ERRA) recommended to use these structures and more than 100 thousands housed are built using this technique in KPK and Kashmir. The typical example of Dhajji Structures are shown in Figure (4).

Figure 4: Dhajji Structures with mud masonry infill in Union Council Pashto, Battagram

5.6 Adobe Structures or Mud wall Structures (AD)

This is non-engineered and low cost building. These are mud wall structure or mud brick with mud mortar to bind these brick. This type of building exists in rural area of Pakistan. In KPK these type of building exist in rural area of Abbottabad, Mansehra, Battagram ,Shangla, Kohistan, Peshawar, Nowshera, Bannu, Lakki Marwat ,Kohat ete.This type of building is highly vulnerable.

7. Selection of seismic vulnerability

Seismic vulnerability is expressed as Mean Damage Ratio (MDR), which the ratio of cost of damage item to the replacement cost of same item. Vulnerability is relationship between MDR and earthquake intensity. Vulnerability assessment can be done using empirical method and analytical method. In many developing countries like Pakistan there is no previous vulnerability assessment done on the building stock. Many researchers in Pakistan are currently working on development of vulnerability relationship of different building classes Rafi (2012) has recently developed fragility curve for Adobe building. Sohaib (2011) developed vulnerability curve for existing reinforced concrete frames using empirical and analytical techniques. The vulnerability relationship for all different building classes is not yet developed. Due to this reason vulnerability curve for similar type of region will be used.
In this study vulnerability cures developed by GESI (2002) are used for calculation of damage. Vulnerability curves for above mentioned building classes is shown in figure 5.

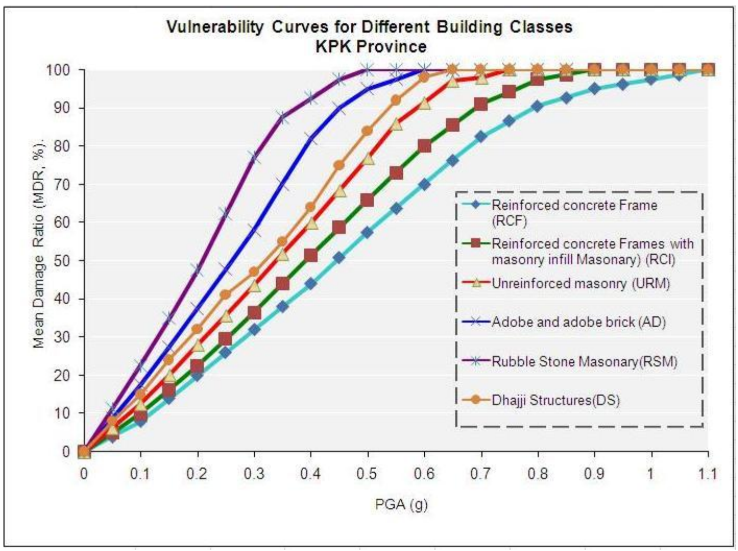

Figure 5. Vulnerability curves for Building stock of KPK

Building density for study region is shown in the Figure 6.It is observed that the building density in rural areas is low and ranges from 0-25 buildings/Km2.whereas building units in some of urban areas is very high.

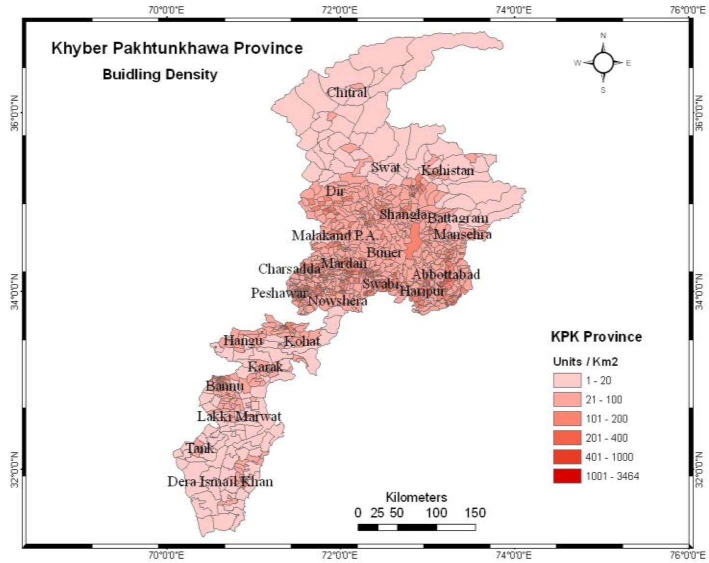

Figure 6. Building density i.e Buildings/Km2

PGA values calculated are then use with vulnerability function to get losses and to add up these losses to get risk.

6. Result and Discussion

The hazard map developed from this study shows that the maximum hazard is in district Mansehra, Batagram and district Shangla. When the results are compared with hazard map of Building code of Pakistan (BCP, 2007), it is observed that overall trend is similar. Hazard Map prepared from this study contain Max. PGA (g) for 100 years.

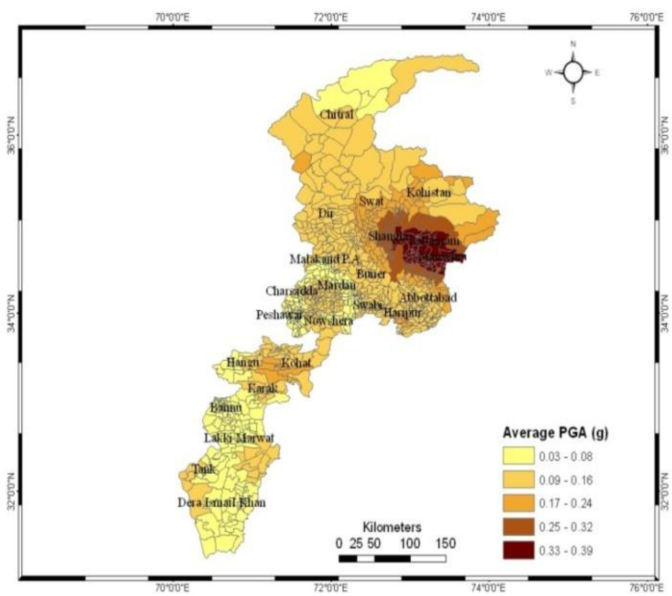

Figure 7. Average, Max. PGA(g) for 100 years

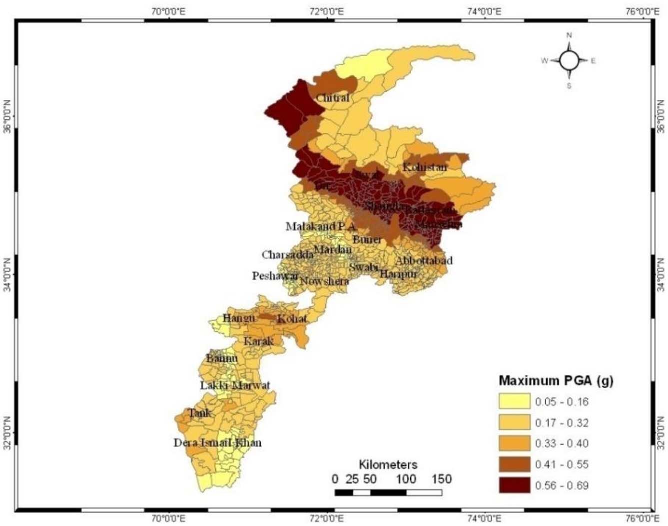

Figure 8. Extreme, Max. PGA (g) for 100 years

Figure.9 shows the spatial distribution of collapsed building in study region. District wise details of collapsed building are shown in table 3.

Table 3.District wise details of collapsed buildings

District	Building Collapse
Battagram	5191
Mansehra	5163
Swat	3338
Shangla	3343
Kohistan	2204
Uper Dir	1734
Chitral	966
Buner	75
Abbottbad	73

Collapsed buildings are mostly consisting of Rubble stone masonry and Adobe buildings with small number of un-reinforced brick masonry buildings.

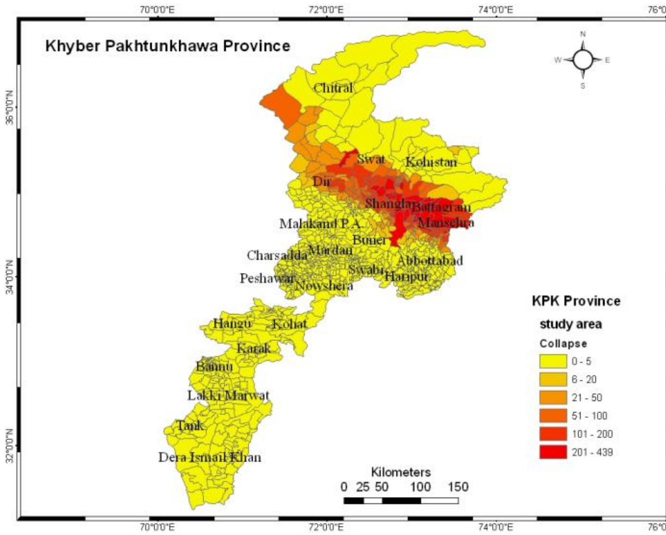

Figure 9. Buildings Collapsed in 100 years

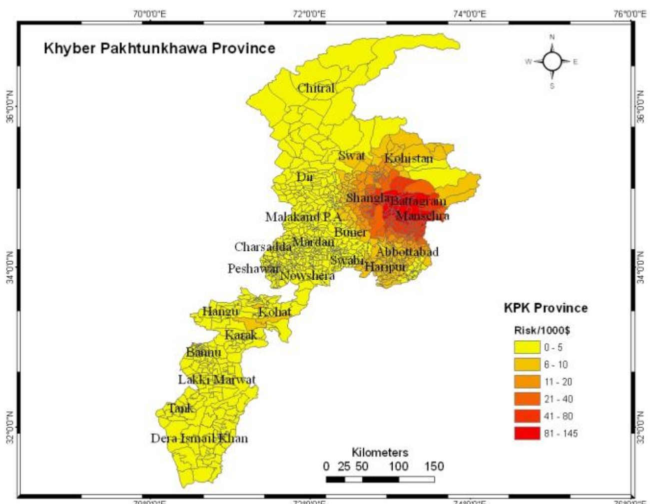

Figure 10. Risk Map of Study region in 100 years (Risk per $1000)

In figure.10 Risk per $1000 is spatially presented. It is observed that monetary risk is high in Mansehra, Battagram and Shangla districts because of high vulnerability of clustered or densely placed building stocks coupled with high earthquake hazard.

7. Conclusion

This paper presents the result of hazard and risk calculated using ERA framework developed by Khan (2010). The Seismic hazard map for 100 years is developed. Maximum PGA is 0.39g for some part of Mansehra, Batagram and District Shangla. Twenty UCs of district Mansehra and district Battagram each and five UCs of Shangla are at Maximum hazard.

Result indicates that seismic risk is concentrated in following six districts in order of severity i.e Masehra, Battagrarm, Kohistan, Swat, Chitral and Abbottabad due to high hazard and vulnerability of building stock. It is concluded that average risk per $1000 ranges between $(5 -145) depending upon the type of building and its location.

8. Recommendations for Risk Mitigation

a) According to risk map Union Council of Mansehra, Battagram and Shangla are at high risk, earthquake resistant construction with quality control is recommended for mentioned for these areas.
b) Seismic retrofitting is recommended for buildings in Mansehra, Battagram, Shangla Swat Abbottabad, and Chitral district.
c) Since Rubble stone masonry is the major contributor of collapsed building therefore, construction of theses building should be prevented in high seismic zones.

References

1. Ali Q, Naeem A, "A critical review of seismic hazard zoning for Peshawar and adjoining areas", Journal of Earthquake Engineering 2005, Vol. 9, No. 5, 587-607 (USA).
2. Monalisa. Seismic hazard assessment of NW Himalayan folds and thrust belt, Pakistan, PhD thesis Report QU, Pakistan 2005
3. Ahmad N, Ali Q. Site specific probabilistic seismic hazard analysis of Mansehra urban area.Technical Report 2008, Earthquake Engineering Center, NWFP University of Engineering and Technology Peshawar, Pakistan.
4. PMD-NORSAR. Seismic Hazard Analysis and Zonation for Pakistan, Azad Jammu and Kashmir, A Report by: Pakistan Meteorological Department (PMD) and NORSAR Norway, July, 2007.
5. Federal Bureau of Statistic (FBS), Population Census Organization (PCO), 2012
6. ADB-WB, Pakistan 2005 Earthquake Preliminary damage and needs assessment, 2005
7. Earthquake Reconstruction and Rehabilitation Authority(ERRA),Annual Report, 2007
8. Ahmad, N. Seismic risk assessment and loss estimation of building stock of Pakistan. Diss. PhD Thesis, ROSE School-IUSS Pavia, Pavia, Italy, 2011
9. Khan S. An Earthquake Risk Assessment (ERA) Framework for Developing Countries, 14 ECEE, 2010,Paper No. 28
10. Zaigham, N.A, Mallick, K.A. Bela opholite zone of southern Pakistan: Tectonic setting and associated mineral deposit. GSA Bull, 2000, v.112, pp.478-489.
11. Aitchison, J. C., J. R. Ali, A. M. Davis, When and where did India and Asia collide?, J. Geophys. Res., (2007) 112, B05423
12. Sitharama T.G., Kolathayar S,Seismic hazard analysis of India using areal sources , Journal of Asian Sci.2013,647-653
13. Kumar P,Yuan X, Kind R,Li X , Chadha R.K, The rapid drift of the Indian tectonic plate, Nature 449,2007 , 894-897
14. Khan.S. An Earthquake Risk Assessment Framework for Developing Countries: Pakistan A Case Study PhD Thesis, 2011, University of Sheffield, UK
15. Jadoon, I. A. K. Thin-skinned tectonics on continent/ocean transitional crust, Sulaiman Range, Pakistan. (Unpubl.) Ph.D thesis 1992, Geology Dept. Oregon State Univ,USA.
16. International Seismological center (ISC) UK, website: http://www.isc.ac.uk/, accessed on March 2012

17. Cornell C. Engineering Seismic Risk Analysis, Bulletin of the Seismological, Society of America. 1968, 58, (5), 1583-1606.

18. Ambraseys N. N., Smit P. M, Douglas J, Sarma S. K. Equations for the Estimation of Strong Ground Motions from Shallow Crustal Earthquakes Using Data from Europe and the Middle East: Peak Ground Acceleration and Spectral Acceleration, Bull of Earthquake Engineering (2005) 3:1–53
19. Rafi MM, Lodhi SH,Varum H,Alam N. Estimation of Losses for Adobe Buildings in Pakistan, WCEE, 2012, Lisboa Portgal
20. Global Earthquake Safety Initiative (GESI), Pilot Project, GeoHazards International (GHI), United Nations Centre for Regional Development, Final Report, June 2001.
21. Ahmad N, Seismic vulnerability of the Himalayan half-dressed rubble stonemasonry structures, experimental and analytical studies Nat. Hazards Earth Syst. Sci., (2012) 12, 3441–3454, 2012,
22. Building Code of Pakistan (BCP), Seismic Provisions (SP-2007), Ministry of Housing and Works, Government of Pakistan, Islamabad.
23. World Housing Encyclopedia Report #146: Dhajji Dewari, Accessed on Dec12, 2013
24. Sohaib, Seismic Vulnerability Assessment of Reinforced Concrete Structures (2011), PhD Thesis, 2011, University of Sheffield, UK