POSSIBILITIES OF USING INSURANCE FOR EARTHQUAKE RISK MANAGEMENT IN PAKISTAN

N. Peiris[1]

[1] *Risk Management Solutions Ltd., 30 Monument Street, London EC3R 8NB*
Email: navin.peiris@rms.com

ABSTRACT :

Pakistan, a developing nation with a population of 169million is located in world's one of the most seismically active and geologically complex regions. The most recent large magnitude event to occur was the October 8, 2005 Magnitude 7.6 Kashmir Earthquake. Over 80,000 people were killed and the violent ground shaking led to the collapse and extensive damage to over 450,000 buildings, leaving 2.8million people without shelter and an estimated public and private asset loss of US$2.3billion. The aftermath of this event presented many challenges to those involved in the recovery process due to insufficient availability of funds, resources and institutional capacity. The reconstruction cost of US$3.5billion, was in large part funded by external donors in packages of aid and loans over several phases. Over two years following the event, the reconstruction of homes is yet to be completed. This raises questions as to whether the availability of capital immediately following the event could have shorten the recovery time of the housing sector. This paper presents the work from an ongoing research initiative to develop an insurance led risk financing model to manage the earthquake risk in Pakistan. The catastrophe modelling approach was adopted to develop the loss metrics, exceedance probability (EP) and average annual loss (AAL) for residential occupancies in the Kashmir Earthquake affected provinces. This preliminary study shows that the pure premium per household exceeds the affordable level of insurance premium and hence alternative risk transfer schemes should be devised to provide earthquake insurance coverage for homeowners.

KEYWORDS: Pakistan, Kashmir, seismic, vulnerability, loss, insurance

1. INTRODUCTION

Pakistan, a developing nation with a population of 169million is located in world's one of the most seismically active and geologically complex regions. Numerous moderate to large magnitude earthquakes have occurred with devastating consequences (Bilham, 2005, Mona Lisa, et al., 2005). The most recent large magnitude event to occur was the October 8, 2005 Magnitude 7.6 Kashmir Earthquake. Over 80,000 people were killed and about 70,000 people were injured (ADB-WB, 2005). The violent ground shaking led to the collapse and extensive damage to over 450,000 buildings, leaving 2.8million people without shelter and an estimated public and private asset loss of US$2.3billion (ADB-WB, 2005). Over two years following the event, the reconstruction of permanent homes is yet to be completed. This raises questions as to whether the availability of capital immediately following the event could have shorten the recovery time of the housing sector. This paper presents the preliminary work from on an ongoing research initiative to develop an insurance led risk financing model to manage the earthquake risk in Pakistan. The study focuses on residential properties in cities of Muzaffarabad, Balakot, Abbottabad and Islamabad (Figure 2), which were within a radius of 100km from the epicentre of the October 8, 2005 Kashmir Earthquake. The paper discusses the development of loss metrics, exceedance probability (EP) and average annual loss (AAL) following a catastrophe modelling approach. Finally, the possibility of providing homeowner insurance was discussed based on the affordability of insurance in the selected locations.

2. EARTHQUAKE GROUND MOTION

The hazard component of a catastrophe model consists of an earthquake event set to simulate the spatial and temporal occurrence of earthquakes, and a predictive relationship(s) to determine the ground motion at the location of interest. The following sections describe the development of the event set based on a seismotectonic source model and magnitude recurrence, and the calibration of the source model using a probabilistic seismic hazard assessment at the locations selected for the study.

2.1 Tectonic Setting

Pakistan is surrounded by complex geological and active tectonic structures; Himalayan ranges in the northeast, the Karakorum-Hindukush block in the north and northwest, Suleman-Changai arc ranges in the southwest, Makran subduction zone in the south-southwest and the Indian shield in the southeast (Mona Lisa et al., 2005). The formation of the Himalayas is the result of the collision of the Indian and the Eurasian plates. In relation to Eurasia, the Indian plate is converging northward at a rate of about 37mm/year near the western termination of the Himalayas.

The active fold and thrust belt along the northwestern margin of the Indo-Pakistan plate (at the western termination of the Himalayas) can be divided into two parts – the Sulaiman belt and the NW Himalayan fold and thrust belt (Mona Lisa et al., 2005). The former is along a zone of transpression, which is considered to be the result of Chaman and Ornach-Nal fault zones forming the western plate boundary. The latter is associated with the main zone of Himalayan convergence. Figure 1 shows the structural and tectonic map of this zone of convergence (Mona Lisa et al., 2005). The major tectonic structures that demarcate this zone of convergence are Main Karakorum Thrust (MKT) also known as Shyok Suture Zone, Main Mantle Thrust (MMT) also known as the Indus Suture Zone, Main Boundary Thrust (MBT) and the Salt Range Thrust (SRT). The region between the MMT and SRT is referred to as the NW Himalayan fold and thrust belt (Armbruster et al., 1978), which is bounded by the Nanga Parbat Haramosh Massif and Hazara-Kashmir Syntaxis (HKS) in its eastern boundary. Armbruster et al (1978) studied the micro-seismicity and indicated an active seismic zone northwest striking about 20-40km wide and 100km long between the MMT and the nose of the HKS. This zone is known as the Indus-Kohistan Seismic Zone (IKSZ) and the October 8, 2005 Kashmir Earthquake and its aftershock distribution lies within the IKSZ and extended southeast to be within the HKS.

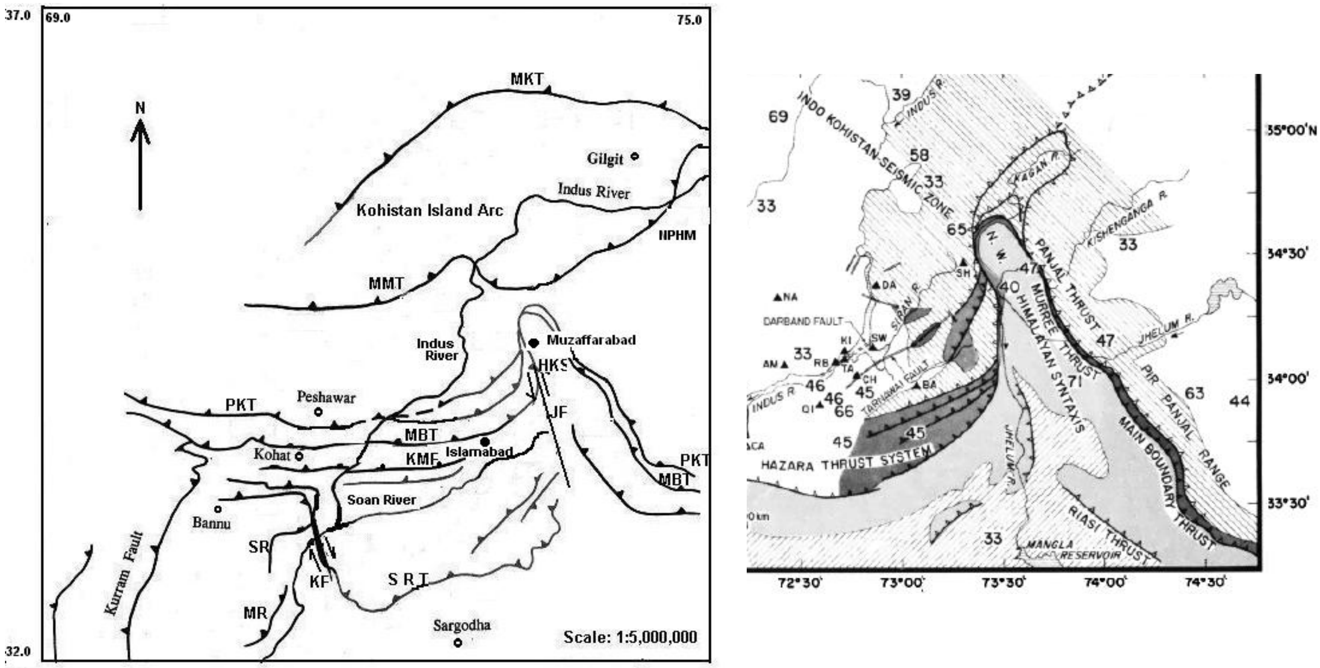


Figure 1 Tectonic map of the study area (Mona Lisa et al., 2005). Geology and tectonics around the HKS and Tarbela reservoir region (Armbruster et al., 1978)

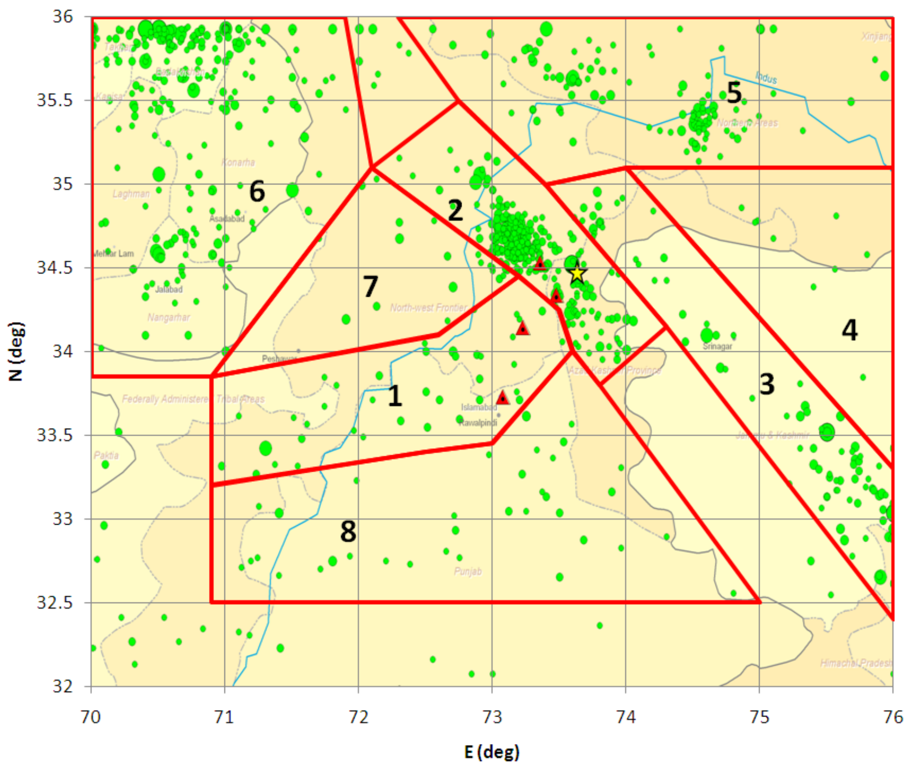


Figure 2 Combined earthquake catalogue in the study area and the seismotectonic source model

2.2 Seismicity

A study region bounded by latitudes 32.0°N to 36.0°N and longitudes 70.0°E to 76.0°E were chosen such that seismicity within a radius of 300km is captured from the locations of the cities considered in this study. Any events outside of this radius were considered not to impact the study locations due to large source-to-site distances. An earthquake catalogue consisting of 1830 records was compiled from historical and instrumental earthquake data dating back to 1555AD and in terms of moment magnitude M_w. The source of the earthquake data are International Seismological Centre (ISC) catalogue, National Earthquake Information Centre (NEIC) historical and instrumental catalog and published historical earthquakes (Bilham and Ambraseys, 2004, Quittmeyer and Jacob, 1979). Earthquakes of magnitude less than 4.0M_w were removed from the catalogue since these were considered not to be significant from a damage perspective. Figure 2 shows the combined earthquake catalogues for the study area. It is assumed that the occurrence of earthquakes are independent in space and time i.e. they conform to a Poisson process, hence the fore and aftershocks, which are dependent on the main shock was removed from the combined catalogue following the methodology proposed by Gardner and Knopoff (1974). The catalogue in this study dates back to 1555AD (453years) and the number of events in the study area is 729 after removing aftershocks, the catalogue cannot be considered to be complete. The catalogue completeness was assessed using the conventional Gutenberg-Richter magnitude-recurrence relationship. The following completeness periods; 1500 to 2008 for $Mw \geq 7.0$, 1900 to 2008 for $Mw \geq 6.5$, 1940 to 2008 for $Mw \geq 5.5$, 1964 to 2008 for $Mw \geq 5.0$ and 1980 to 2008 for $Mw \geq 4.5$.

2.3 Seismotectonic Source Model

Several seismotectonic source models exist in the literature developed for the probabilistic seismic hazard assessment of Kashmir as well as Pakistan as a whole (Mona Lisa et al., 2005, Rafi et al., 2007 and Zhang et al., 1999 for the Global Seismic Hazards Assessment Program (GSHAP). Although several source models exist, it was decided to develop a detailed seismotectonic source model for the study area based on the geologic and tectonic structures. This allows an independent assessment to be made of the seismic hazard and evaluated against other models, which could then be incorporated in a broader study considering the uncertainties associated with the definition of source delineation. Figure 2 shows the seismotectonic source model adopted for the present study overlaid on the combined catalogue. Zone 1 represents the Hazara Thrust System (HTS) which consists of several thrust fault between the MMT and SRT (see Figure 1). Zone 2 is the IKSZ also extended to cover part of HKS. Zone 3 is the MBT that underlies the Pir Panjal Range. Other zone delineations were done based on the seismicity patterns and the tectonic and geologic structures in the study region.

2.4 Magnitude Recurrence

The magnitude-recurrence was described in terms of Gutenburg-Richter recurrence relationship for annual number of earthquakes, N greater than magnitude, M, $\text{Log}_{10} N = a - bM$ and maximum magnitude, M_{max} for each source zone. The activity rate, "a" (defined as the annual number of earthquakes greater than 4.0M_w), gradient, b were derived using the Weichert (1980) methodology applied to the earthquake catalogue, which considers multiple completeness periods of an earthquake catalogue. These parameters were also adjusted looking at the actual recurrence data, especially where insufficient earthquake data exists within a zone. M_{max} was estimated by rounding up the largest event magnitude within each source zone. Table 2.1 summarizes the magnitude-recurrence parameters where those in parentheses are original values before adjustment.

Table 2.1 Magnitude-recurrence parameters

Zone	**a**	**b**	**M_{max}**
1	1.203 (1.203)	1.0 (1.1)	6.5 (6.3)
2	1.300 (0.801)	1.0 (0.83)	8.0 (7.7)
3	2.210 (2.21)	1.0 (1.06)	8.0 (7.6)
4	1.100*	1.0	5.5 (4.5)
5	1.300 (1.122)	1.0 (0.95)	7.0 (6.5)
6	5.324 (5.324)	1.0 (1.07)	7.0 (6.8)
7	1.100*	1.0	5.5 (5.2)
8	1.100 (0.766)	1.0 (0.67)	5.5 (5.2)
Entire Area	14.32	1.0 (1.12)	8.0 (7.7)

*Values assumed since Weichert methodology cannot generate values

2.4 Earthquake Event Set

An earthquake event set consisting of 10,081 events compatible with the magnitude-recurrence parameters of each zone were created covering the entire study area. The study area was divided into 0.1° by 0.1° mini-zones where the earthquakes were assumed to occur at the centroid of each mini-zone. The magnitudes and the rates of earthquakes within each mini-zone were selected from the magnitude-recurrence relationship of the corresponding source zone.

2.4 Ground Motion Prediction

The ground motion in terms of PGA and spectral acceleration (SA) at a location was predicted using the relationship by Ambraseys et al (1996) developed for shallow crustal events although the dataset used was from Europe, Middle East and Africa. This was used since no such relationships exist specifically for Pakistan. This relationship produces the largest random value of the horizontal ground motion. The site conditions considered for the selected city locations of this study were rock, site class $S_{B,}$ Uniform Building Code, (UBC) 1997, where the shear wave velocity of the upper 30m is between 760m/s and 1500m/s.

2.5 Hazard Calibration using PSHA

The calibration of the hazard event set was done by carrying out a probabilistic seismic hazard assessment (PSHA) using the magnitude-recurrence relationships and ground motion predictive relationship described above. The logic tree methodology was adopted to address the epistemic uncertainty of b-value and maximum magnitude, M_{max}. The aleatoric uncertainty in the predictive relationship was addressed by use of a standard deviation parameter. Table 2.2 compares the PGA values for 475year return period with other studies. The PGA values for Islamabad were predicted to be lower than for Muzaffarabad in the present study, which appears consistent with the tectonics and seismicity. The opposite trend is shown by the results of other studies except Rafi et al., 2007. The PGA values in the present study are comparable to the GSHAP study but almost double those from Mona Lisa et al (2005).

Table 2.2 Comparison of PSHA results

Location	**PGA (g) at 475yr Return Period**			
	This Study	**Mona Lisa et al. (2005)**	**Rafi et al. (2007)**	**Zhang et al. (1999)**
Islamabad	0.195	0.1-0.15	0.150	0.24-0.32
Muzaffarabad	0.260	0.1-0.13	0.204	0.16-0.24
Abbottabad	0.210	-	-	0.16-0.24
Balakot	0.270	-	-	0.16-0.24

3. CAPACITY SPECTRA AND VULNERABILITY FUNCTION DEVELOPMENT

The loss estimation methodology in this study utilized the capacity spectrum method described in HAZUS-MR2 to determine the spectral displacement in order to use the fragility curves and vulnerability functions to estimate the mean loss. Capacity spectra, fragility curves and vulnerability functions were developed for the residential building typologies in the study area; unreinforced stone masonry (locally known as “Katcha” or non-permanent housing) and unreinforced concrete block or brick masonry (locally known as “Pucca” or permanent). These structures have URM bearing walls supporting an RC slab roof or a timber frame roof with metal sheathing roof cover (EEFIT, 2008). The “Katcha” housing is more common in rural areas while “Pucca” housing is more common in city and urban areas.

There are no data available in the literature to define the capacity spectra and fragility curves for the Katcha and Pucca housing types. The HAZUS-MR2 capacity spectrum for low rise URM (URML) were therefore modified to account for the reduced shear capacity of the Pucca and Katcha houses compared with the URM structures in the US. Figure 3(a) shows the linearized approximation of the non-linear capacity spectrum for HAZUS URML and the adjusted curves for Pucca and Katcha houses used in this study. The fragility curves from HAZUS for

URML were used as a starting point and these were adjusted based on loss calibration with the October 8, 2005 Kashmir Earthquake footprint loss and author's field experience in the EEFIT field mission (EEFIT, 2008).

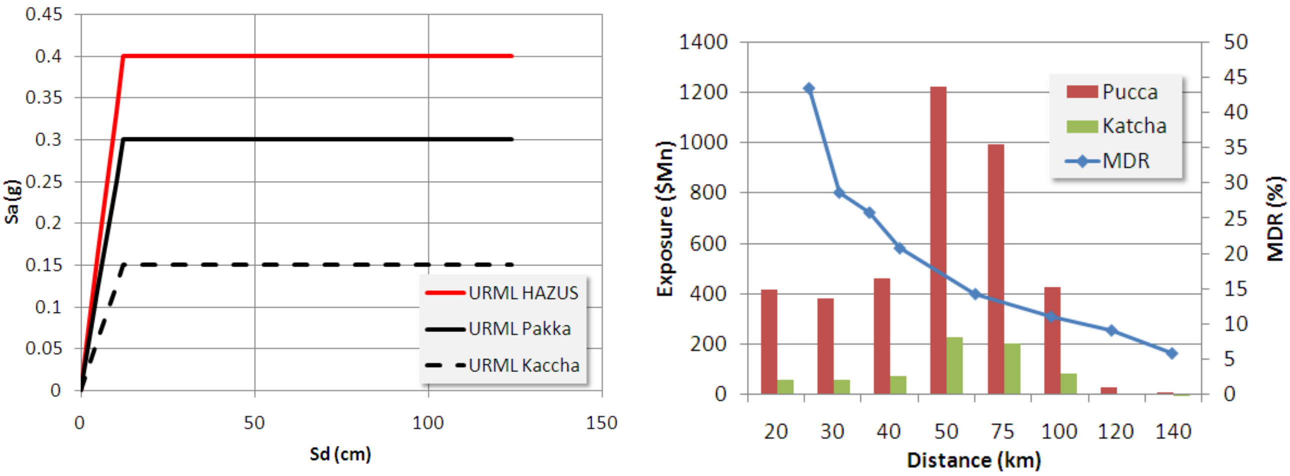


Figure 3 (a) Capacity spectra for Pucca and Katcha houses, (b) Exposure distribution from the Kashmir Earthquake epicentre and MDR variation with epicentral distance for the final iteration of fragility curves

The damage to houses in the Kashmir earthquake resulted in an asset loss of US$1.03bn in the provinces of NWFP and AJK (ADB-WB, 2005). An exposure database for Pucca and Katcha houses in the affected districts of NWFP and AJK provinces was developed based on 1998 census data (www.risepak.com) inflated to year 2005 and assigning typical rebuilt values of Rs.300,000 (US$5,000) and Rs.100,000 (US$1700) respectively (Mahmood, 2008). Total exposure value was US$5.08bn, hence the Kashmir event loss ratio for residential properties was 20.3%. Figure 3(b) shows the exposure distribution with epicentral distance where Pucca houses dominate the residential inventory. The modelled loss using HAZUS capacity and fragility curves for both Pucca and Katcha houses was US$328m. Hence the fragility curves were adjusted until the modelled loss is close to the actual. Figure 4(a) compares the HAZUS URML and final Pucca fragility curves and Figure 4(b) compares the vulnerability functions.

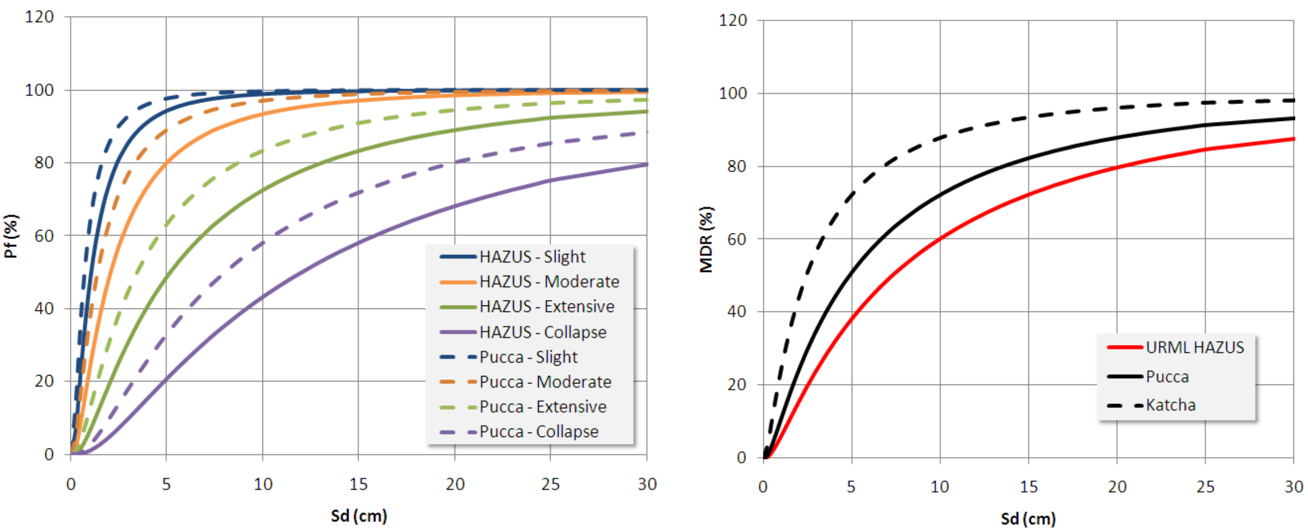


Figure 4 (a) HAZUS URML and Pucca fragility curves, (b) vulnerability functions

Figure 3(b) plots the MDR variation with distance on exposure distribution. The event loss ratio of 20% occurs at location of high exposures at around 50km. The variation of MDR is such that it is about 10% at around 100km, which is the distance to Islamabad. Based on author's field observations, this may be higher. However, the MDR of 18.0% at 50km, the distance to Abbottabad is comparable to field observations hence the iterated fragility curves and adjusted capacity spectra could be considered to be reasonably representing the Pucca and Katcha housing vulnerability.

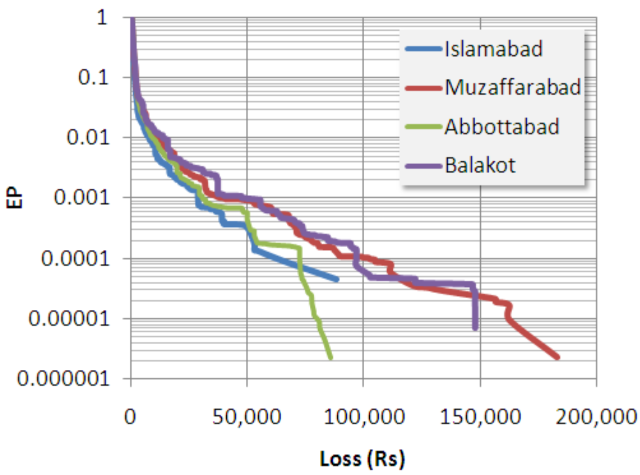
4. LOSS ASSESSMENT AND INSURANCE

The earthquake event set together with the vulnerability functions developed using the Kashmir Earthquake loss calibration were used to calculate the exceedance probability (EP) curve and the average annual loss (AAL) for Pucca and Katcha houses in the cities of Muzaffarabad in AJK, Balakot, Abbottabad and Islamabad in NWFP. The typical value of a Pucca house is estimated at Rs.300,000 (US$5,000) and Rs.100,000 (US$1700), (Mahmood, 2008). Table 4.1 summarizes the AAL and AAL ratio.

Table 4.1 Summary of AAL and AAL ratio for study cities in AJK and NWFP

Location	Pucca		Katcha	
	AAL	AAL ratio	AAL	AAL ratio
Islamabad	Rs.3390 (US$57)	0.0113	Rs.4480 (US$75)	0.0448
Muzaffarabad	Rs.3930 (US$66)	0.0131	Rs.5240 (US$88)	0.0524
Abbottabad	Rs.3720 (US$63)	0.0124	Rs.4950 (US$83)	0.0495
Balakot	Rs.4080 (US$69)	0.0136	Rs.5390 (US$91)	0.0539

The average annual income in Pakistan is about US$420.00 (www.islamic-relief.com), while a labor survey by FBR (2006) indicates an income of US$975.00 for NWFP averaging for urban and rural areas. Considering the latter figure is representative of today's income levels, the AAL with respect to income varies between 5.8-7.1%, for Pucca houses, which is a very high proportion of the income. Given that the labour force participation rates are very low and the household income generally support large families averaging 7.0 (ADB-WB, 2005) raises questions as to the affordability of homeowner insurance to fully cover the earthquake risk.



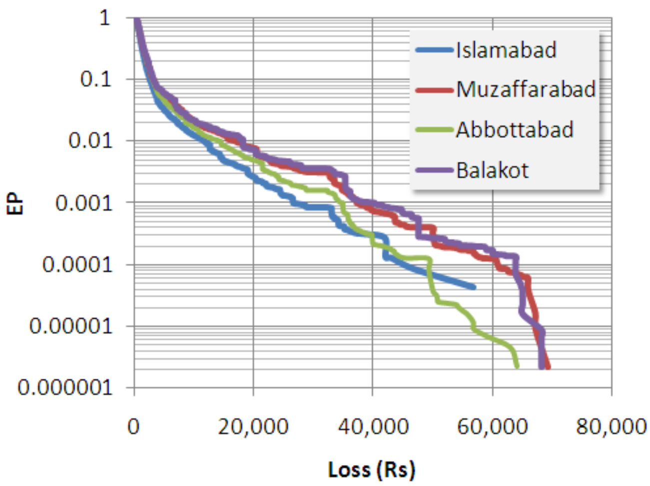


Figure 5 Exceedance probability (EP) curves for study cities

Figure 5 shows the exceedance probability (EP) curves for Pucca and Katcha houses in the studied cities. Islamabad and Abbottabad EP losses are lower than those for Muzaffarabad and Balakot and the gap widens with lower EP or higher return period. The 500yr return period loss in a Pucca house in Islamabad is about Rs.20,000 (US$340) and in Muzaffarabad Rs.31000 (US$520). The 10year return period losses are Rs.1660 (US$28) and Rs.2100 (US$35) respectively. These metrics also indicate that the risk is high enough to be transferred solely to the homeowner. The Kashmir earthquake mean loss ratio of 20% is equivalent to a Pucca house loss of Rs.60,000 (US$1000). This loss corresponds to an EP of about 0.001 or a return period of about 1000years. This level of risk could be underwritten in reinsurance contracts since for instance the loss of US$1.03bn is less than the typical natural hazard insurance losses for similar return periods.

5. CONCLUSIONS

The possibilities of providing homeowner insurance for earthquake risk management in the October 8, 2005 Kashmir Earthquake affect region was investigated using a catastrophe model and a study of the loss metrics AAL and EP losses for cities of Muzaffarabad, Balakot, Abbottabad and Islamabad, and for Pucca and Katcha houses. The study shows that the earthquake risk cannot be wholly transferred to the homeowners given the low levels of income. However alternative financing strategies could be investigated such as subsidized homeowner coverage, reinsurance coverage in terms of excess of loss contracts or a state led catastrophe insurance pool. The metrics provided by this study could be used for a preliminary investigation into alternative risk transfer strategies.

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