[ISSN 0254-7821]

ISO-9001:2000
Certified

QUARTERLY

MEHRAN UNIVERSITY RESEARCH JOURNAL OF ENGINEERING & TECHNOLOGY

MISSION

The Mehran University of Engineering and Technology, believers in establishing conducive environment for top of the class professional education and research. We aim to produce quality professionals who upto and advance for the integrity, honor, and dignity of their profession, while taking active part in the Development of the society.

VOLUME 27 NUMBER 3 JULY, 2008

CONTENTS

VOLUME 27 **NUMBER 3** **JULY, 2008**

1. **FIAS-Validation Against Microscopic Traffic Flow Characteristics**
   H. Kim, and S.A.A. Shah 243

2. **Particle Size Analysis of Coal and Lime Stone Used in FBC Power Plant at Lakhra**
   S. Aziz, S.A. Soomro, and Z.M. Ali 249

3. **Groundwater Quality and Soil Salinization in a Canal Command Area and Management Options**
   M. Latif, and M.Z. Ahmad 257

4. **Performance of Masonry Structures During Earthquake-2005 in Kashmir**
   M. Javed, A.N. Khan, and G. Magenes 271

5. **Optimizing the Bagasse Based Co-Generation: A Case Study of Dewan Sugar Mill, Thatta, Pakistan**
   H.A. Durrani, M.I. Panhwar, and K. Harijan 283

6. **Computer-Based Irrigation Scheduling for Cotton Crop**
   K.Q. Laghari, B.K. Lashari, and H.M. Memon 293

7. **Oxidation of Light Crude Oil in Porous Media**
   A.H. Tunio, M.K Memon, H.R. Memon 307

8. **Petrographic Study of Core Plugs from Lower Goru Sandstones**
   M.K. Memon, A.H. Tunio, and A. Leghari 319

9. **Application of ANN for Predicting Water Quality Parameters in the Mediterranean Sea along Gaza-Palestine**
   H.A. Zaqoot, A.K. Ansari, and M.A. Unar 331

10. **Traffic Management at Selected Signalized Junctions of Karachi: A Case Study**
    M.J. Iqbal, A.S. Qureshi, and G.B. Khaskheli 339

Published by: **Publication Division,**
Mehran University of Engineering & Technology, Jamshoro, Sindh, Pakistan
Phones: (+92-22) 2772274, 2772276 Fax: +92-22-2771382

Printed by: **T&Q Printers**
Hyderabad, Sindh, Pakistan
Mobile: 0345-3608402

Performance of Masonry Structures During Earthquake-2005 in Kashmir

MUHAMMAD JAVED*, AKHTAR NAEEM KHAN**, AND GUIDO MAGENES***

RECEIVED ON 24.11.2007 ACCEPTED ON 18.03.2008

ABSTRACT

The Kashmir earthquake of October 8th, 2005 was one of the deadliest earthquakes according to the number of fatalities in the history of indo-Pakistan subcontinent. More than 70,000 people were killed, mainly due to collapse of masonry buildings being widely used in Kashmir and Northern Pakistan. Major causes of damages/ collapse of masonry buildings were: poor quality of mortar, undressed stones, flexible roofs not bonded to supporting walls, lateral thrust from inclined roofs, unbraced parapet and gable walls, non-anchored infilled walls, wide openings without surrounding reinforcement, heavy roofs resting on poor quality masonry walls, etc. A critical review of damages to masonry structures is presented in the paper along with measures that need to be taken in future construction. In order to minimize the losses in masonry structures in case of future seismic activities, strategies such as loss assessment are discussed, a part of which has already been taken as a research project by the authors.

Key Words: **Unreinforced Masonry, Stone Masonry, Brick Masonry, Peak Ground Acceleration, Modified Mercalli Intensity Scale, Intensity, Magnitude, In-Plane Forces, Out-of-Plane Forces, Diaphragm, Infilled Walls.**

1. INTRODUCTION

An earthquake (M_w= 7.6) jolted the Kashmir and Northern Areas of Pakistan on October 8th,2005 at 8:50:40 AM as per local time at epicenter. The epicenter was estimated to have latitude and longitude of 34° 29' 35" N and 73° 37' 44" E, respectively with a distance of 15 km from MuzaffarAbad, the administrative capital of Azad Jammu and Kashmir. Focal depth was estimated to be 26km.

More than 73,000 people were killed, 70,000 left injured, 2.5 million people were displaced and 3.3-3.5 million people were affected on about 30,000 km2 area. According to Asian development Bank and World Bank the total economic loss of the earthquake was estimated to be US$ 5.2 billion. 455,000 buildings were partially or fully damaged.

* Assistant Professor, Department of Civil Engineering, NWFP University of Engineering & Technology, Peshawar.
** Professor, Department of Civil Engineering, NWFP University of Engineering & Technology, Peshawar.
*** Associate Professor, Department of Structural Mechanics, University of Pavia, Pavia, Italy.

Three strong motion instruments recorded the ground motion acceleration of the main shock occurred on October 8th, 2005. The closest instrument was installed in Abbotabad, a city located at distance of 52 km from the epicenter. The strong motion data of the seismograph is shown in Fig. 1.

2. STRONG GROUND MOTIONS

In the absence of strong ground motion data, a possible way to have an estimate of ground accelerations is use of attenuation relationships. The attenuation relationship developed for medium soils by Saragoni et al.[1] for earthquake resulting from seismic activities in subduction zones was used for this purpose.

$$\ln a_g = 7.74 + 0.71\, M_s - 1.6 \ln (R+60) \quad (1)$$

Where a_g is ground acceleration in cm/sec^2, M_s is the Surface wave magnitude and R is the distance from epicenter in Km. Where M_s can be calculated [2] using the relations shown as:

$$\log(M_o) = 17.40 - 0.895(M_s) + 0.170(M_s)^2 \quad (2)$$

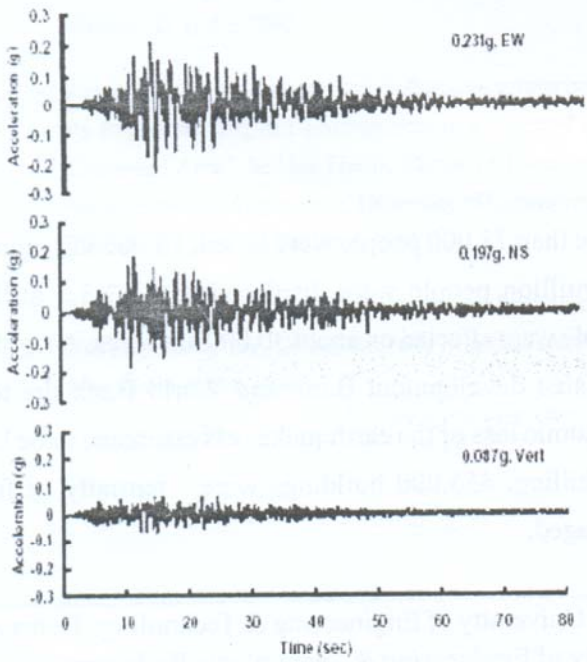

FIG. 1. STRONG MOTION RECORDS AT ABBOTTABAD [2]

$$M_w = \frac{2}{3}\log(M_o) - 6.0 \quad (3)$$

In which M_o and M_w are seismic moment and moment magnitude, respectively.

The saragoni equation was specifically selected due to the reason of giving well matching results (for accelerogaph installed in Meteorological department of Peshawar city) for past earthquakes in Hindukush region. In addition, the equation estimated a ground acceleration of 0.27g (g= acceleration due to gravity) in comparison to PGA (Peak Ground Acceleration) of 0.23g given by the E-W component of accelerogram data for Abbotabad city [3] (Fig. 1). Ground acceleration estimated from Saragoni equation for various localities are summarized in Table 1.

Another approach regarding estimation of site specific ground acceleration is to use correlations between ground acceleration and observed damage based on some suitable intensity scale. Use of intensity scale has the advantage of automatically incorporating site effect. Several visits were made to earthquake affected areas in order to identify damages based on intensity sale. Based on specifications regarding damages of various levels to various categories of buildings mentioned in MMI (Modified Mercalli Intensity) scale various localities were classified to suffer intensities of earthquakes as mentioned in Table 2.

To have an idea about ground shaking, results of PHGA (Peak Horizontal Ground Acceleration) determined from following equations are also summarized in Table 2.

Richter [4]: $\text{Log } a_g = 0.33\ \text{MMI} - 0.50$ (4)

Murphy and O'Brien [5]: $\text{Log } a_g = 0.25\text{MMI} + 0.25$ (5)

Margottini et al. [6]: $a_g = 3.353\ 100.2201\text{MMI}$ (6)

Where as a_g is measured in cm/sec^2

3. STRUCTURAL DAMAGES IN MASONRY BUILDINGS

Structural damages have been classified and reported according to the possible inferred causes. Both Global failure mechanisms (such as in-plane, out of plane wall failure modes) as well as local failure mechanisms due to intrinsic vulnerability of the material or unsuitable structural details were observed and discussed in report.

Structures with proper connections between orthogonal walls, as well as between walls and floors, improves the in-plane seismic resistance of walls and the building. Damages associated to this kind of response are generally related to the in-plane response of masonry walls. Depending on the geometry and position of the walls and on the distribution of the openings, these damages tend to be located in specific portions of masonry such as masonry piers and spandrel beams.

In presence of low quality construction and inadequate structural details, the response of the masonry building tends to be governed by local phenomena and damage mechanisms. In poor quality masonry walls, made of two leaves of irregular stones and no transverse connection offered by through elements, a typical resulting failure is the out of plane crumbling of the external veneer (observed also in other earthquakes which affected similar structures in different parts of the world). Similarly, absence of good connections between floors and walls or roofs and walls, and absence of out-of-plane restraints (such as ties or ring

TABLE 1. GROUND ACCELERATION PREDICTED BY SARAGONI'S EQUATION FOR VARIOUS LOCALITIES AFFECTED BY KASHMIR EARTHQUAKE OF OCTOBER 8TH, 2005

City/Town	Distance from Epicenter (Km)	Ground Acceleration in Fraction of g Estimated from Saragoni's Equation
Abbotabad	52	0.27
Mansehra	42	0.31
Batal	52	0.27
Battagram	58	0.25
Garhi Habibullah	25	0.42
MuzzafarAbad	18	0.48
Bagh	59	0.24
Balakot	25	0.42

TABLE 2. EARTHQUAKE INTENSITIES AS PER MMI SCALE AND PEAK HORIZONTAL GROUND ACCELERATION (IN TERM OF G) FOR VARIOUS EARTHQUAKE AFFECTED AREAS BY USING EQUATIONS 4 TO 6

City/Town	Intensity of Earthquake as per MMI Scale Based on Observed Damage	PHGA by Equation (4)	PHGA by Equation (5)	PHGA by Equation (6)
Abbotabad	VIII	0.15	0.18	0.20
Mansehra	VIII	0.15	0.18	0.20
Batal	VIII	0.15	0.18	0.20
Battagram	VIII	0.15	0.18	0.20
Garhi Habibullah	IX	0.32	0.32	0.33
MuzzafarAbad	IX	0.32	0.32	0.33
Bagh	IX	0.32	0.32	0.33
Balakot	X	0.69	0.57	0.54

beams, proper quoins) give rise to out-of-plane overturning of single walls. Several past earthquakes, such as those occurred in Italy (Friuli earthquake 1976, Irpinia earthquake 1980 and Umbria-Marche earthquake 1997) have also shown the relevance and frequence of these kind of damages, typical of the most vulnerable classes of masonry buildings [7].

In the following sections several examples of observed damage are presented and subdivided according to the different failure modes. Some of the typical damages are summarized in Fig. 2.

4. IN-PLANE DAMAGE

4.1 Shear Cracks

In-plane diagonal cracks and X-diagonal cracks (Fig. 3) result from lateral forces in the plane of the walls. Depending on the level of drift demand, the damage can be moderate and easily repairable, or severe to the extent that the buildings are usually unfit for further use. However, the consequences to the people are significantly less serious than in the case of out of plane wall overturning. Such types of cracks were mostly observed in Muzaffarabad, Bagh, Balakot and Garhihabibullah

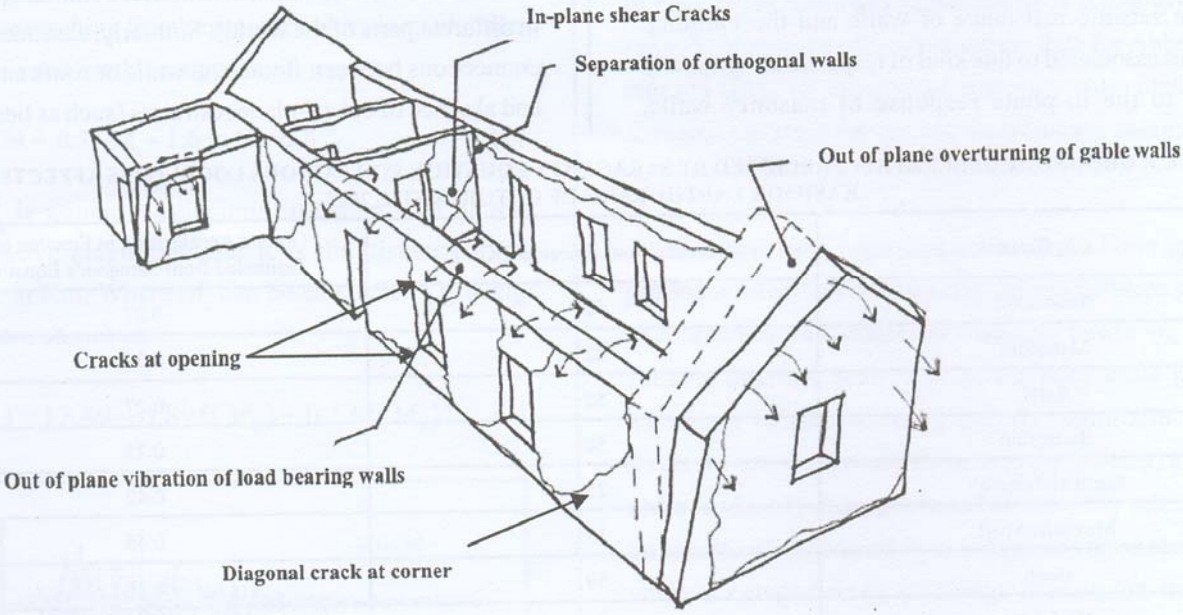

FIG 2. TYPICAL FAILURES IN UNREINFORCED MASONRY BUILDINGS UNDER SEISMIC ACTION

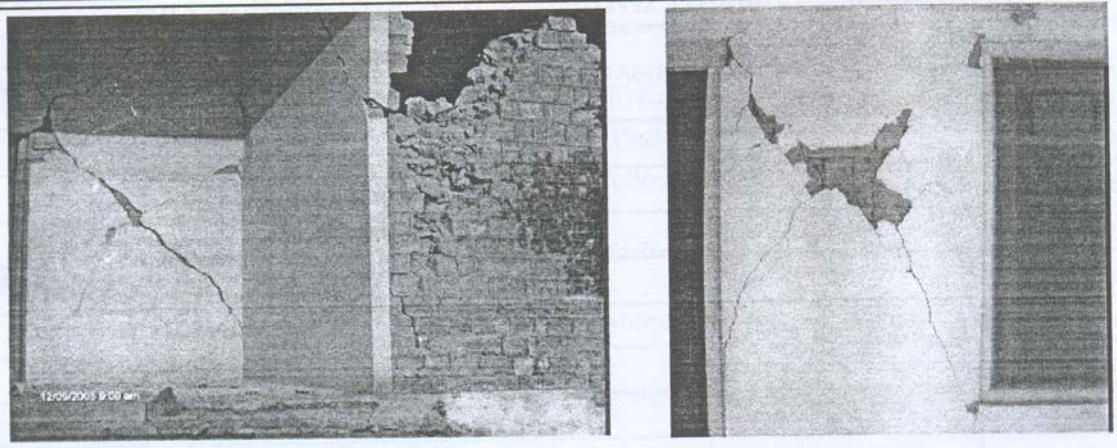

FIG 3. TYPICAL DIAGONAL SHEAR CRACKS IN MASONRY BUILDINGS

4.2 Crack Damage at Openings

These cracks (Fig. 4) can be a result of both in-plane shear forces and out-of plane flexure of the wall, and are initiated from concentration of stresses produced at the corners of the openings. They are not particularly serious unless the relative displacement across the cracks is large, in which case instability of the section of the wall above the opening becomes an issue. Such cracks in stone masonry and concrete block masonry were mostly observed in Battal, Battagram, Garihabibullah, Bagh, MuzzafarAbad and Balakot. Whereas in brick masonry such damage were observed in Garihabibullah, Bagh, MuzzafarAbad and Balakot.

4.3 Pier Flexural-Rocking Failure

Cracks of such types are produced in portions of walls between openings. Such portion of walls (piers) with higher aspect ratio can fail in flexure under alternating bending caused by cyclic nature of seismic forces.

Failures of the above mentioned types were observed in Battal, Battagram, Garihabibullah, Bagh, Muzaffarabad and Balakot. Very few cases of such failures were also observed Abbotabad and Mansehra (Fig. 5).

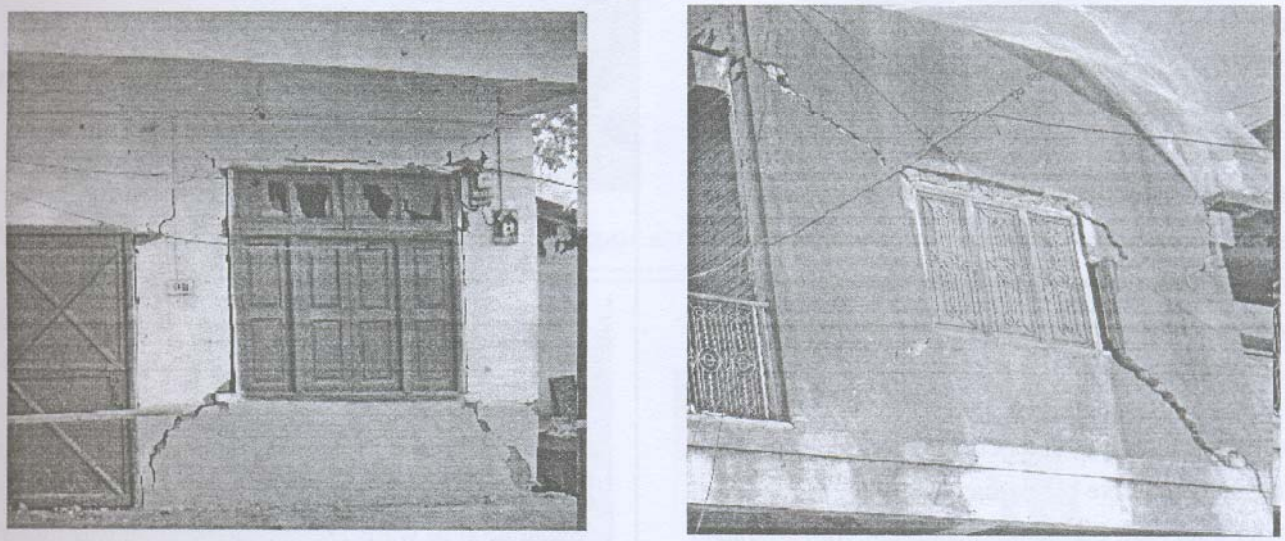

FIG 4. TYPICAL CRACKS ORIGINATING FROM CORNERS OF OPENINGS

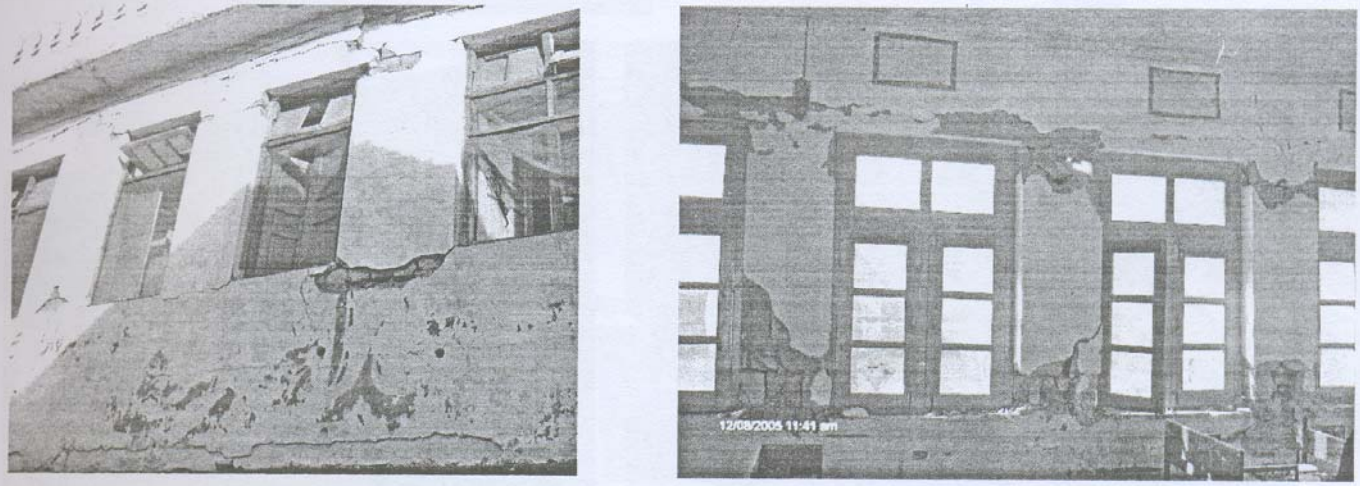

FIG 5. ROCKING/TOE CRUSHING FAILURE OF MASONRY PIERS

5. OUT OF PLANE AND LOCAL DAMAGE MECHANISMS

5.1 Lateral Thrust from Roofs

Out-of-plane lateral thrust at roof level due to inclined roofs added to inertial forces can become a significant cause of collapse of masonry structures. A number of cases were observed where masonry buildings supporting sloping roofs were either collapsed or badly damaged while nearby structures having the same type of brick/ stone units and binding material but non-thrusting roof diaphragms, experienced less damage.

In addition to the roof lateral thrust, another observed reason for out-of-plane failures is the lack of connection between walls and supporting roof (made of thin corrugated galvanized iron sheets, normally 1.5mm in thickness) nailed to wooden roof trusses. The roof trusses just rest on walls and provide no out-of-plane restraint, nor a ring beam is usually present, consequently the building is unable to develop 'box action' against vibrations induced by an earthquake.

Failure of the above mentioned type in stone masonry buildings and concrete block masonry were mostly seen in Battal, Battagram, Garihabibullah, Bagh, Muzaffarabad and Balakot. However, few cases of such failures in the case of brick masonry walls were also seen in Balakot and some areas of Muzaffarabad and Bagh (Fig. 6).

5.2 Wedge Type Separation at the Top of Wall Junctions Due to Lateral Thrust from Roof Truss

Such types of localized failures were seen in masonry as well as adobe walls supporting roofs inclined in both directions. Masonry gets separated in the form of wedges below roof the level due to thrust from roof purlins in addition to inertial forces. These kind of mechanisms where mostly observed in case of openings close to the corner. Such types of failures were observed in all localities mentioned in Table 1 (Fig. 7).

5.3 Lack of Connection Between Orthogonal Walls

Such type of failure was among the most common, resulting from out-of-plane vibration of the walls. As the wall bends outward the intersecting perpendicular walls offer a restraint that relies on tensile strength of masonry. Orthogonal walls are separated when the outward force exceeds the tensile strength of masonry. Intersection of orthogonal walls is also characterized by shear stresses due to flange-web action that can further facilitate cracking. Separation of walls at their intersection was found in all areas mentioned in Table 1 (Fig. 8).

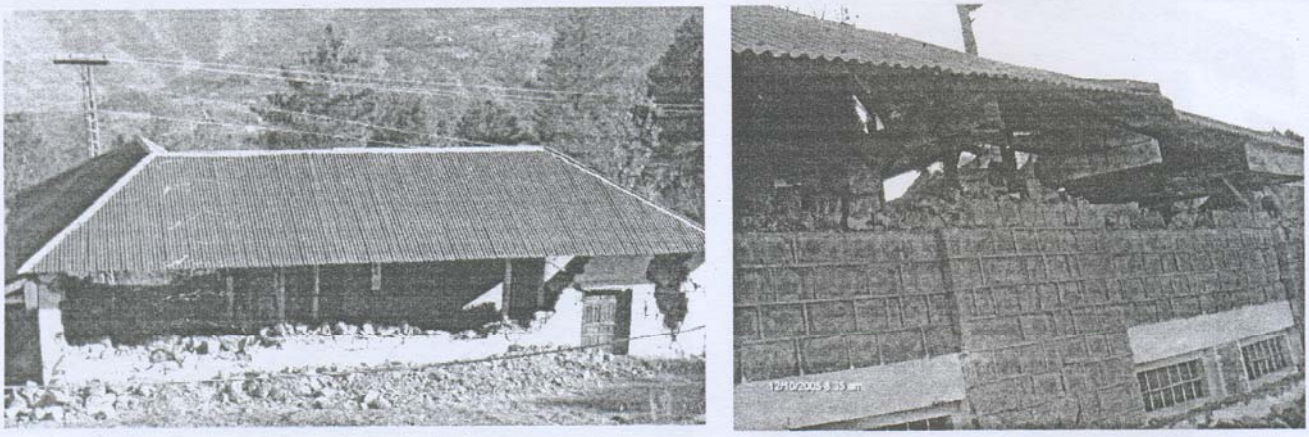

FIG. 6. OUT OF PLANE BENDING FAILURE OF MASONRY WALLS DUE TO ADDITIONAL THRUST FROM ROOF TRUSSES

5.4 Damage at Wall-to-Roof Connections

Damage of such type occurs as a result of the forces transmitted between walls and roof, mostly due to out-of plane horizontal excitation of the walls but also due to vertical ground accelerations which could be very high in localities very close to the fault rupture (e.g. Balakot). The top of the wall may slip out from underneath the roof and/or crush under dynamic loading, in particular in the case of poor quality masonry (rubble stone) and relatively heavy and rigid roofs non properly connected. Also, in the case of light roofs, the friction under the roof bearing may not be sufficient to avoid slippage.

Such types of damages, mostly in stone masonry, were observed in Battal, Battagram, Garihabibullah, Bagh, Muzaffarabad and Balakot (Fig. 9).

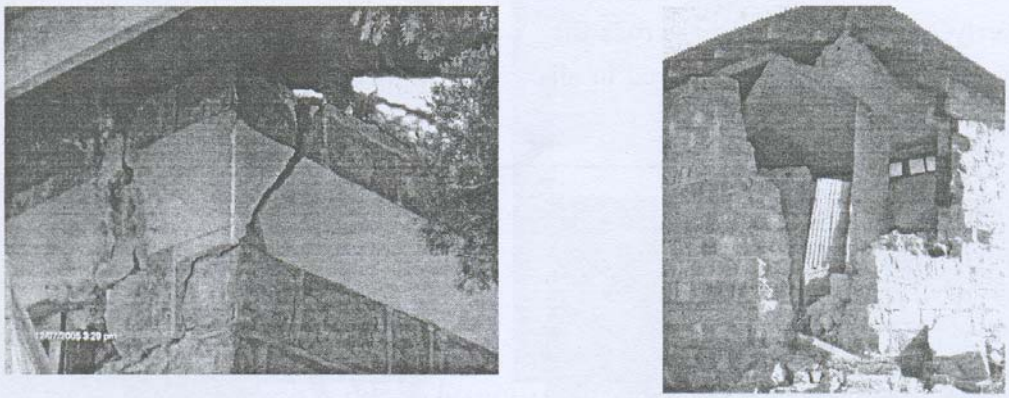

FIG. 7. SEPARATION OF MASONRY WEDGE BELOW ROOF PURLINS AT THE CORNER

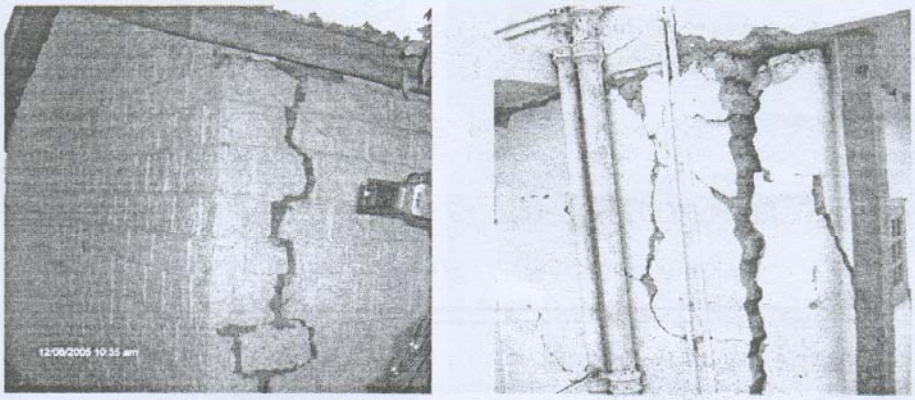

FIG. 8. SEPARATION OF ORTHOGONAL WALLS MADE OF STONE MASONRY (LEFT) AND OF BRICK MASONRY (RIGHT)

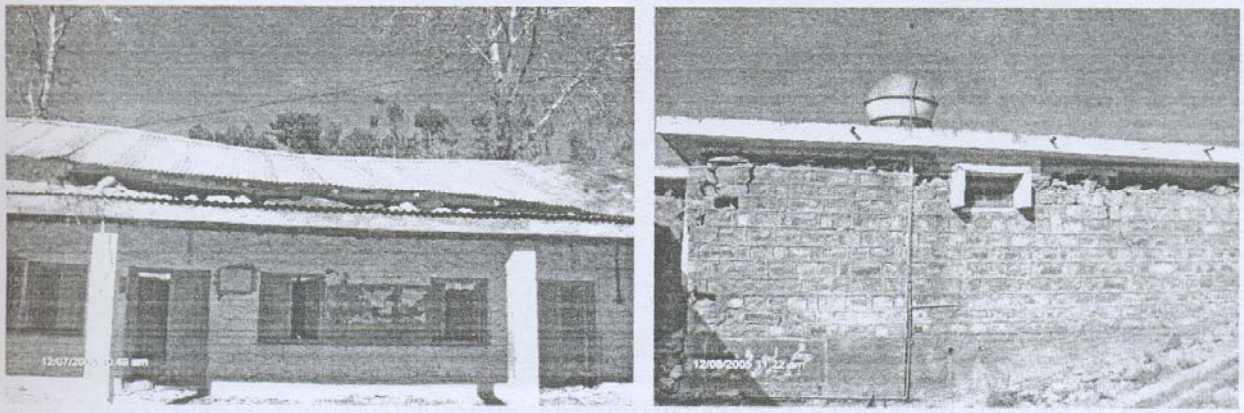

FIG. 9. FAILURE OF THE TOP COURSES OF MASONRY DUE TO THE LOCAL INTERACTION WITH THE ROOF

5.5 Out of Plane Overturning of Gables

Gables, due to absence of vertical load and lateral restraint essentially behaves like parapet walls. Such failures were observed in all localities listed in Table 1 (Fig. 10).

5.6 Diffusion of Stone Masonry External Veneer

Such types of damages were found in double-leaf stone masonry walls. In most cases no through stones were provided to properly connect the leaves across the thickness. Such types of failures were observed in all locations listed in Table 1 (Fig. 11).

6. DAMAGES TO MASONRY NON-STRUCTURAL ELEMENTS

6.1 In Plane Failure of Infill Walls

It is a general practice in Northern Pakistan to provide 110 or 225mm thick infill walls in RC framed structures made either of bricks or concrete block masonry. A number of cases were observed (especially when the thickness of infill wall was as small as 110mm), where the masonry failed in shear with diagonal cracks. In some cases poorly detailed columns also failed in the proximity of the beam-column joints due to transfer of horizontal forces from the infills to the columns (Fig. 12).

FIG. 10. TYPICAL OVERTURNING OF GABLES

FIG. 11. CRUMBLING OF SEPARATED EXTERNAL VENEER IN DOUBLE-LEAF STONE MASONRY WALLS WITHOUT TRANSVERSAL CONNECTIONS

6.2 Out of Plane Failures of Infill Walls

The acceleration in a structure increases with the increase in height. If not anchored properly, the nonstructural components can overturn in out of plane direction. Overturning of non anchored masonry infilled walls was observed in first and above floors of RC buildings constructed in Bagh, MuzzafarAbad and Balakot (Fig. 13).

6.3 Failure of Boundary and Parapet Walls

Boundary walls and parapet walls are more susceptible to overturning due to the cantilever type boundary conditions. Such walls easily overturn when not properly braced. Failures of such types were observed in localities listed in Table 1 Fig. 14).

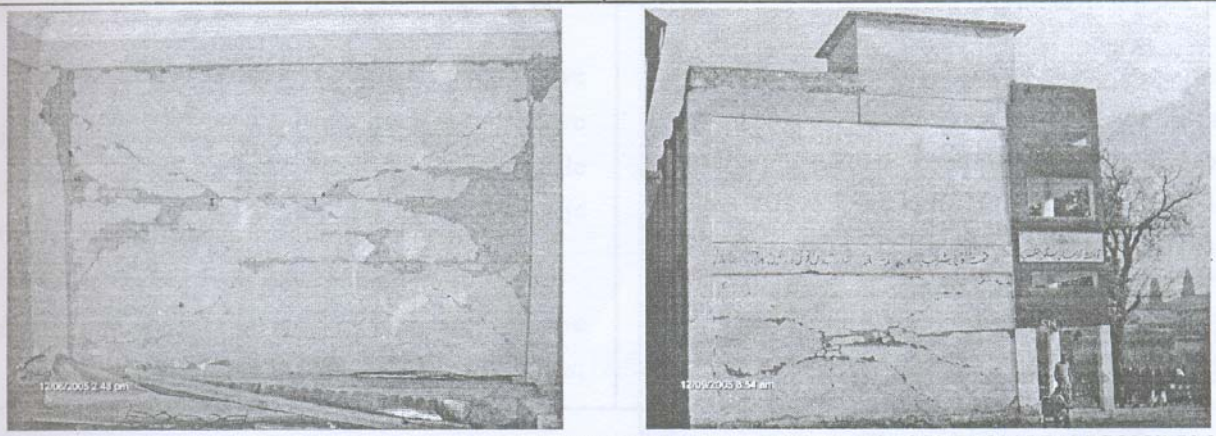

FIG. 12. FAILURE OF INFILLED MASONRY WALLS DUE TO DIAGONAL COMPRESSIVE FORCES FROM BEAM-COLUMN JOINT

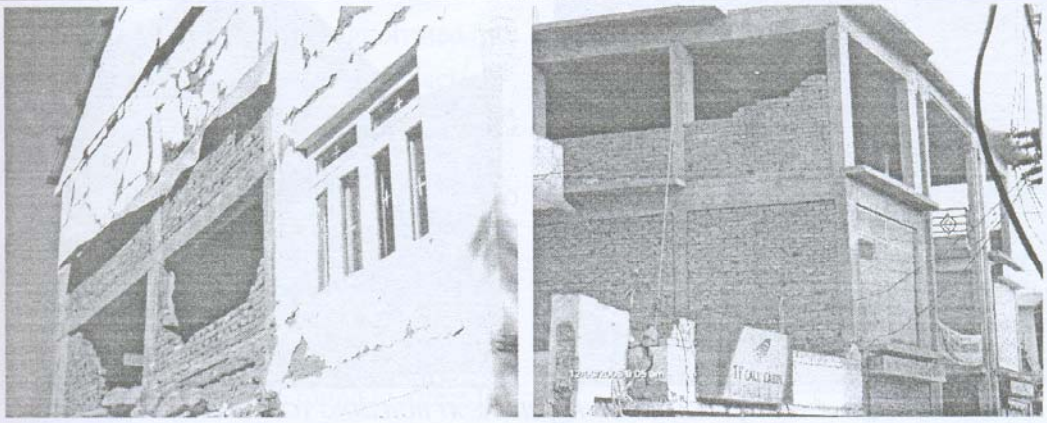

FIG. 13. OVERTURNING OF FREE STANDING MASONRY WALLS IN OUT OF PLANE DIRECTION

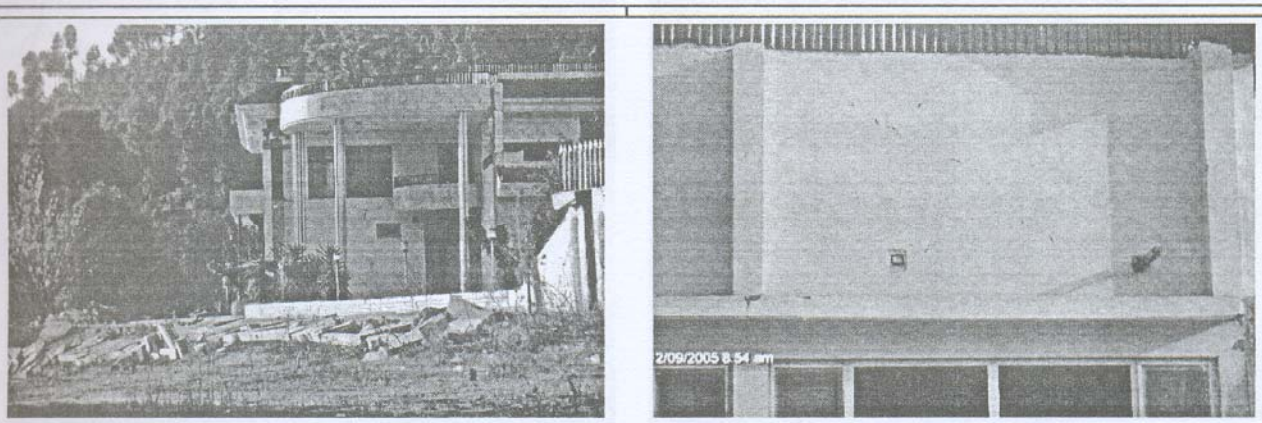

FIG. 14. TYPICAL FAILURE OF BOUNDARY WALLS (LEFT) AND OVERTURNING OF A SLENDER PARAPET PREVENTED BY PROPER BRACING ACROSS THE LENGTH

6.4 Failure of Appendages Supported on URM

These include flexible and low mass structures connected to main structures like pent houses, low capacity water tanks at top floor, sign boards, etc. Damage may result from excessive accelerations of appendages and deformations that cause connection failures between appendages and the structures.

It is a common practice in Pakistan to build a small water storage tank in dwellings at some height above the top floor, with capacity to fulfill the demand of water required for the family living in house. Most of the times the water tank is not connected to URM pillars on which it is supported. High acceleration and displacement demand at the connection, also due to the amplification along the height, lead to failure of the support.

Most failures of such types were seen in MuzzafarAbad, Bagh and Balakot (Fig. 15).

7. MASONRY BRIDGES

Many bridges in the earthquake affected area are made of masonry. A large number of these masonry bridges suffered earthquake damages and in many cases they were unusable for a long time, also reducing the rescue ways in the emergency and rehabilitation period.

Most common seismic damages to masonry bridges are presented in Fig. 16, such as the out-of-plane overturning of lateral gable walls in arch bridges (involving the dynamic interaction with the incoherent filling material [8]) and shear or rocking damages to masonry abutments under RC pennons in cable stayed bridges.

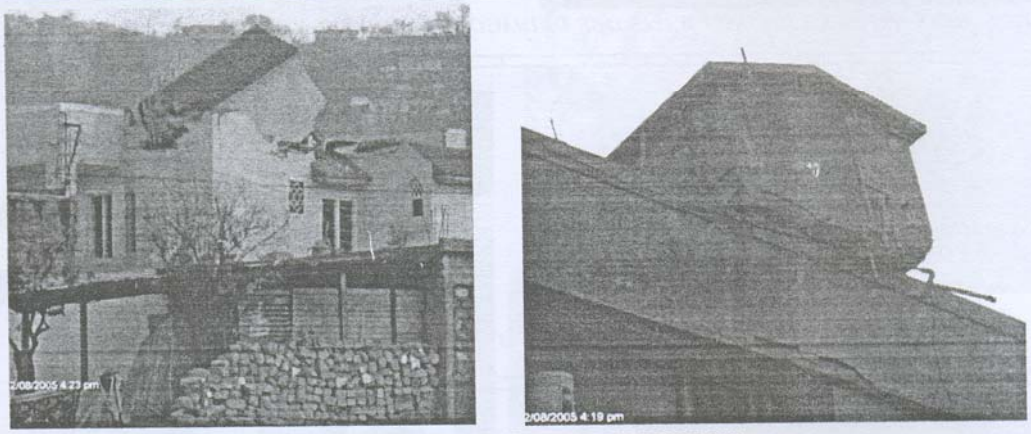

FIG. 15. WATER TANK FAILURE AT BUILDING TOP

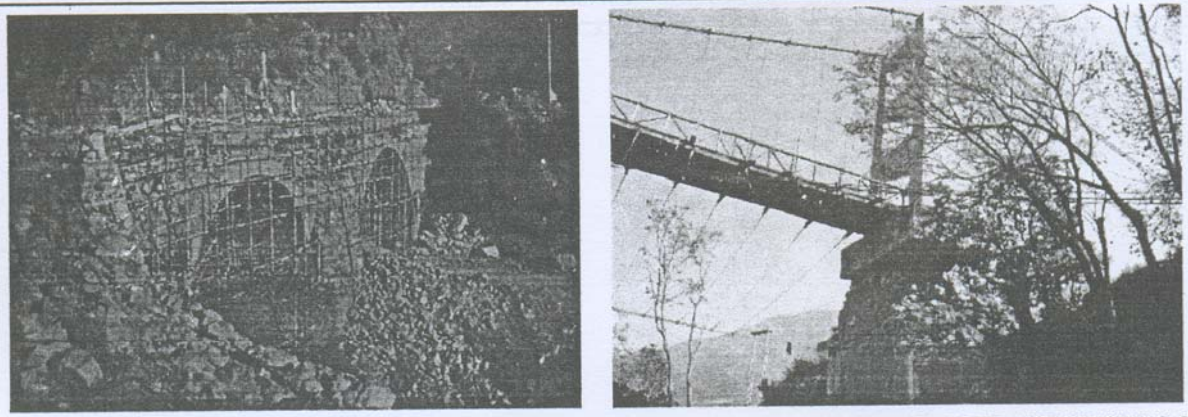

FIG. 16. OUT-OF-PLANE OVERTURNING OF LATERAL GABLE WALLS IN A MASONRY ARCH BRIDGE (LEFT) AND CRUSHING OF A MASONRY ABUTMENT IN A SUSPENSION BRIDGE

8. CONCLUSIONS

The majority of buildings that suffered failure or damage were non engineered, low quality constructions, for which the primary causes of failure can be attributed to:

(i) The use of poor quality cement sand mortar or of mud mortar in the majority of stone masonry.

(ii) Use of undressed stone masonry.

(iii) Use of concrete block masonry with compressive strength as low as 1.0 MPa. Such compressive strength in case of URM result in very low tensile strength and is not appropriate to resist seismic forces [9].

(iv) Lack of transverse connection through the thickness of double-leaf stone masonry walls, absence of quoins.

(v) Lack of connection between flexible roofs and masonry walls (the situation was aggravated by lateral thrust from sloping roof), and lack of bonding or tying elements at the floor or roof levels.

(vi) The presence of heavy roofs on poor masonry.

Unreinforced brick masonry behaved relatively well and was able to survive collapse of in most of highly affected areas except Balakot. The damage was found to affect to a different extent (in order of increasing damage) the following classes of masonry:

(a) Unreinforced brick masonry in cement sand mortar.

(b) Stone masonry with cement, sand and stone dust mortar.

(c) Stone masonry with cement and sand mortar.

URM infills in many buildings suffered extensive damage except where the thickness of infill walls was at least 225mm.

9. RECOMMENDATIONS

Based on structural damages observed in earthquake affected area it is recommended, for the purpose of design, to use following intensities of earthquake for various localities:

(i) MMI=VIII for Abbotabad, Mansehra, Batal and Battagram.

(ii) MMI=IX for Garhi Habibullah, MuzzafarAbad and Bagh.

(ii) MMI=X for Balakot.

The reported damage to masonry buildings confirms the sources of vulnerability that were also recognized in previous earthquakes in different areas of the world regarding non engineered masonry construction. The needed improvements in the construction practice in seismic areas of Pakistan will necessarily comprise:

(a) Ensure proper connection of locally used light weight roofing system with supporting walls by RC bond.

(b) Beams, and provide suitable bracing to roof diaphragms.

(c) Discourage the use of stone masonry in areas that experienced earthquake intensity of MMI? IX, and promote a better workmanship to enhance robustness of masonry construction.

(d) Use masonry units and mortar, each having a minimum compressive strength of 5 MPa, as recommended by Euro code, necessary for efficient performance during earthquakes.

(e) Provide proper reinforcement in masonry to ensure ductility in future seismic events (use of confined or reinforced masonry).

(f) Provide reinforcement around openings to prevent penetration of cracks originating from their corners.

(g) Properly brace freestanding portion of walls such as parapet walls, boundary walls, gables.

(h) Properly connect infill walls with surrounding columns.

Last but not least, The Seismic Risk Assessment for masonry structures for various typologies keeping in view type of masonry, diaphragm behavior, story heights shall be carried out (at least for highly populated towns). As a result the losses to masonry structures can be estimated for various possible levels of ground shaking. Consequently, planning can be carried out in order to minimize the structural damages against future seismic activities.

A part of work related to seismic risk assessment of brick masonry building of Northern Pakistan is already being undertaken by first author as his Ph.D. research work. Tests on URM walls for various geometries and vertical loading were recently conducted. Results of these tests and seismic Risk assessment of masonry buildings based on these test results will be presented in a series of papers in near future

ACKNOWLEDGMENTS

Writers are most grateful to Higher Education Commission, Pakistan (HEC) for providing financial support to visit various earthquake affected areas. Special thanks are also due to Mr. Mansoor Ahmed Khan, Lecturer, Department of Civil Engineering, and Mr. Ishfaqm Sub-Engineer, NWFP University of Engineering & Technology, Peshawar, and Abbotabad Campus, respectively, for assistance to the first author during a visit to earthquake affected areas.

REFERENCES

[1] Saragoni, R., Crempian, J., and Araya Y., "Características De Los Movimientos Fuertes en Chile", Publication No. SES I 164, Department of Civil Engineering, University of Chile, 1980.

[2] Ambraseys, N.N., and Free, M.W., "Surface-Wave Magnitude Calibration for European Region Earthquakes", Journal of Earthquake Engineering, Volume 1, pp. 1-22, Imperial College, London, 1997.

[3] Durrani, A.J., Elnashai, A.S., Hashash. Y.M., et. al., "The Kashmir Earthquake of October 8, 2005, A Quick Look Report", Mid-America Earthquake Center, Report No. 05-04, University of Illinois, Urbana Champaign, 2005.

[4] Richter, C., "Elementary Seismology", Freeman and Co. Publishers, pp. 768, San Francisco, 1958.

[5] Murphy, J.R., and O'Brien, L.J., "The Correlation of Peak Ground Acceleration Amplitude with Seismic Intensity and Other Physical Parameters", Bulletin of the Seismological Society of America, Volume 67, No. 3, pp. 877-915, California, 1977.

[6] Margottini, C., Molin, D., Narcisi, B., and Serva, L., "Intensity Versus Ground Motion: A New Approach Using Italian Data", Engineering Geology, Volume 33, pp. 45-48, 1992.

[7] Magenes, G., "Masonry Building Design in Seismic Areas: Recent Experiences and Prospects from a European standpoint", Keynote at the 1st European Conference on Earthquake Engineering and Seismology, Geneva, Switzerland, 3-8 September, 2006.

[8] Rota, M., Pecker, A., Bolognini, D., and Pinho, R., "A Methodology for Seismic Vulnerability of Masonry Arch Bridge Walls", Journal of Earthquake Engineering, Volume 9, Special Issue 2, pp. 331-353, Imperial College, London, 2005.

[9] Eurocode 8, "Design of Structures for Earthquake Resistance-Part-1: General Rules, Seismic Actions and Rules for Buildings", prEN 1998-1, Brussels, December, 2003.