Damage to Building Structures due to 2005 October 8 Pakistan Earthquake

Yoshiaki NAKANO[1], Takao NISHIKAWA[2], Yoshihiro TSUCHIYA[3], Yasushi SANADA[4], and Hiromi SAMESHIMA[5]

ABSTRACT: Following the 2005 October 8 Pakistan Earthquake, the Japan Society of Civil Engineers (JSCE) and the Architectural Institute of Japan (AIJ) dispatched a joint reconnaissance team to investigate damage to residential buildings and civil infrastructures in the affected areas and to recommend actions to be taken on the damaged structures. This report briefly describes the damage investigation results on building structures due to the event.

Key Words: Pakistan Earthquake, Building damage, Seismic capacity, Quality of materials, Reinforcement details

INTRODUCTION

An earthquake of magnitude 7.6 (USGS) jolted the northeastern region of Pakistan at 8:50 local time, October 8, 2005. The strong shaking devastated the epicenter region, causing more than 73,000 fatalities and 69,000 injuries (as of November 20, 2005, UN OCHA Situation Report No. 24). It was felt in Islamabad, about 100km SSW of the epicenter, and one high-rise residential building collapsed.

Immediately after the event, the Japan Society of Civil Engineers (JSCE) dispatched an advance team led by Dr. K. Konagai, Professor of the Institute of Industrial Science, the University of Tokyo, to survey damage to residential buildings and civil infrastructure etc. The team also discussed to seek future collaborations on damage assessment and restoration strategies with experts from both Pakistani and Japanese organizations.

Following the discussion above, the Japan Society of Civil Engineers and the Architectural Institute of Japan jointly organized a reconnaissance team (JSCE-AIJ Joint Reconnaissance Team) consisting of experts on earthquake engineering covering geology, geotechnical engineering, and building engineering, to investigate damage to structures related to their fields in detail and to recommend actions to be taken on the damaged structures. **Table 1** lists the members of the JSCE-AIJ Joint Reconnaissance Team.

This report is a part of Quick Report* compiled by the building investigation team of JSCE-AIJ Joint Reconnaissance Team. The team investigated building damage in the affected areas including Islamabad, Abottabad, Battal, Balakot, Muzaffarabad etc. during the period of November 19 to 26, 2005. In this report, damage observations, issues derived from the observations, and seismic capacity

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* This report is primarily based on "Quick Report of Damage Investigation on Buildings and Houses due to October 8, 2005 Pakistan Earthquake" submitted to the Capital Development of Authority (CDA), Islamabad, Pakistan.

evaluation and quantitative damage assessment of example buildings, are briefly summarized.

Table 1. JSCE-AIJ Joint Reconnaissance Team

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Dr. Omer AYDAN, Professor, Tokai University
Dr. Masakatsu MIYAJIMA, Professor, Kanazawa University
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Mr. Noboru KONDO, Adviser, NHA/JICA
Mr. Shigeki TAKATSU, Researcher, Japan Society of Civil Engineers
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Mr. Hiroyuki KODAMA, Manager, Tobishima Corporation
* Mr. Yoshihiro TSUCHIYA, Chief Engineer, Tobishima Corporation
*: Members of building investigation team

Damage Observations

Figures 1 and **2** show the map of investigated areas. In the following sections, the outline of building damage in each investigated area is briefly described.

Islamabad

Islamabad is located about 100km SSW of the epicenter. The ground shaking there was reportedly not so intense and most buildings in the city survived the earthquake. Some buildings, however, were seriously damaged and one high-rise residential building totally collapsed.

(1) Margala Towers, Islamabad
* Construction: RC with URM* (hollow cement block) walls, constructed in 1992
* Number of Stories: 10 (reportedly 12 in building No. 4)
* Use: Apartment house

The apartment house consisted of 5 building (**Photo 1-1**). Expansion joints were provided between each building. One building (No. 4) was completely fell down, destroying a part of building No. 5. Although other buildings well survived the shaking and had little major structural damage, URM walls had extensive cracks in the interface between wall and boundary RC frame (beam and column) as well as shear cracks in the wall (**Photo 1-2**). It should be pointed out, however, that these towers were the only buildings that were severely damaged in Islamabad.

The arrangement of hoops of an RC column was investigated with a rebar detector in the survived building No. 2. They were provided at a space of 30cm in the mid-span and of 15cm at both ends. Their hooks were found 90-degree from exposed hoops although the structural drawing specified 135-degree hooks (**Photo 1-3**).

Schmidt hammer tests were made on RC columns (**Photo 1-4**) and the estimated strength was in the range of 12 to 17 N/mm^2 (reaction factor $R = 29$ to 36).

Since the collapsed tower was already demolished when the team investigated it, it was quite difficult to identify the cause of collapse. It should be noted, however, that the concrete strength obtained from the survived buildings was even lower than neighboring buildings (Al-Mustafa Towers and Park Towers) which performed well during the event, as will be described later.

* Unreinforced Masonry

The towers were reportedly situated on the reclaimed soil of a rainwater rivulet locally called *nallah*. It is however still uncertain whether or not this caused more serious damage to the towers. To find soil amplifications through microtremor measurements of surface soil including the site and its vicinity as well as to investigate the soil profile would be therefore one possible way to identify their effects on the structural response.

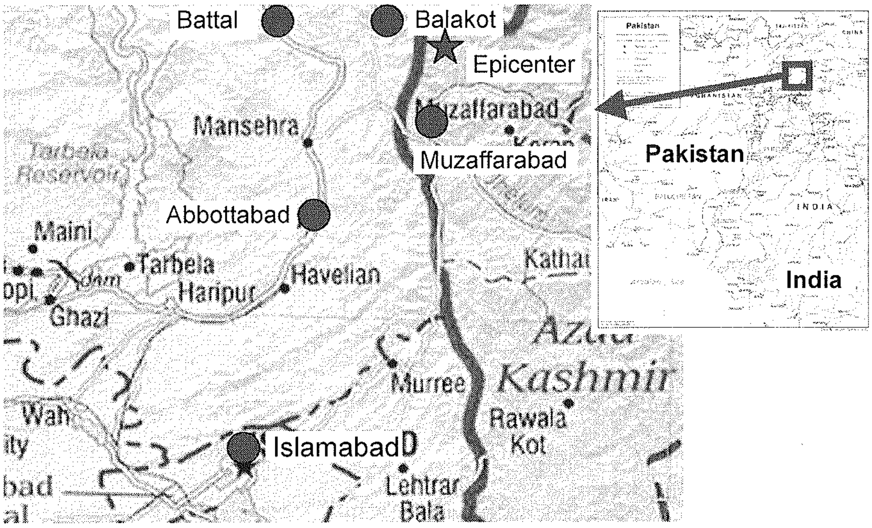

Figure 1. Map of investigated areas (epicenter and its vicinity)

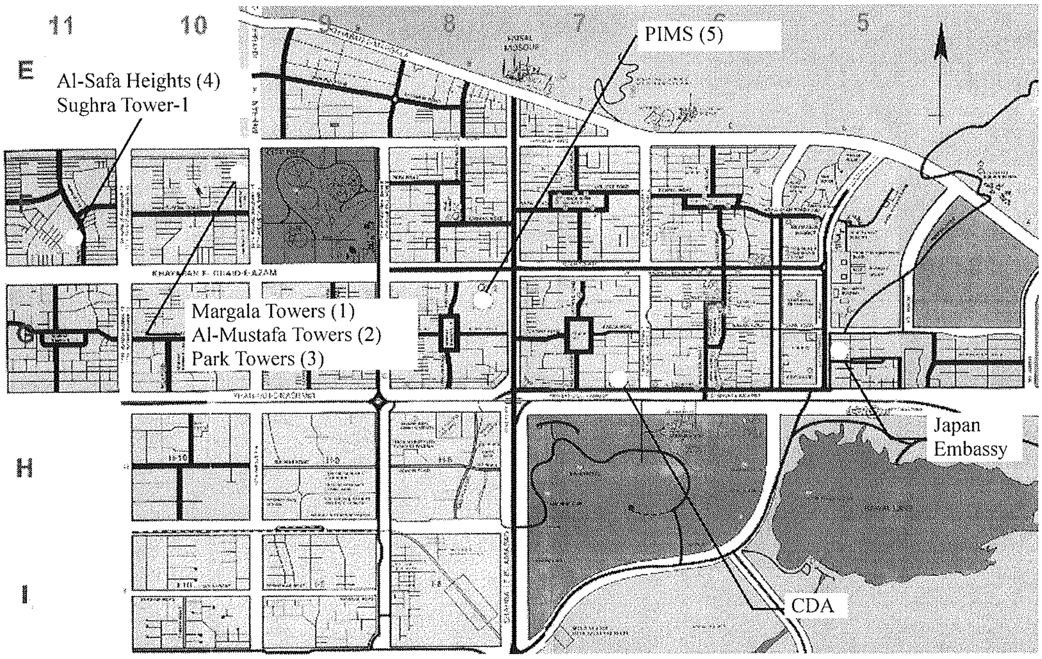

Figure 2. Map of investigated areas (central Islamabad)

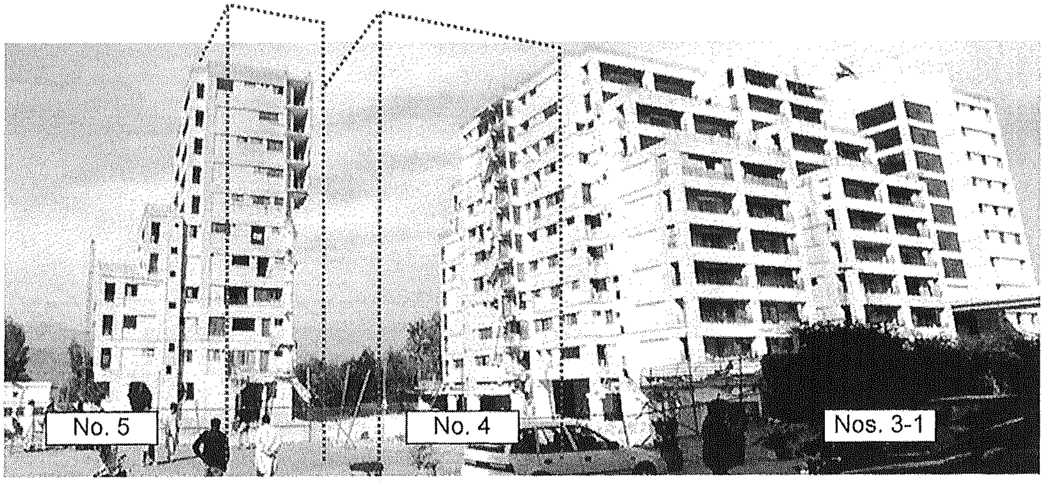

Photo 1-1. General view of Margala Towers

Photo 1-2. Damage to URM walls

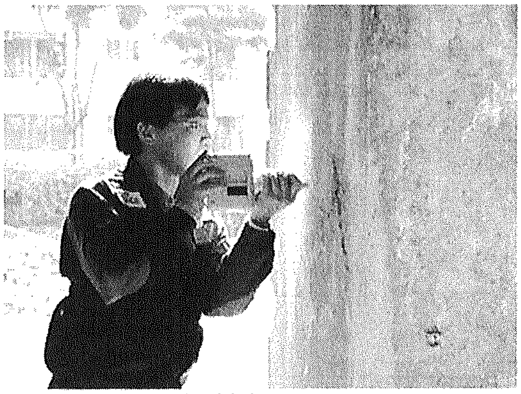

Photo 1-4. Schmidt hammer test

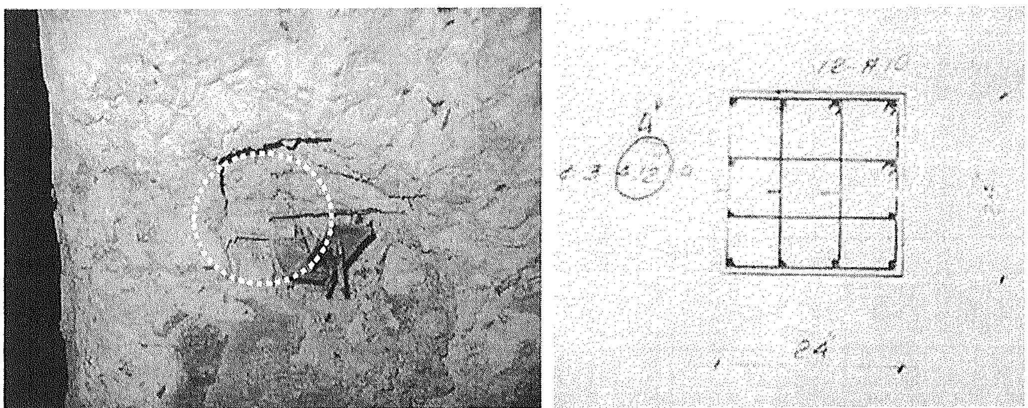

Photo 1-3. 90-degree hook in RC column (structural drawing specifies 135-degree hooks)

(2) Al-Mustafa Towers, Islamabad
* Construction: RC with URM walls, constructed in 2002
* Number of Stories: 11 + B1
* Use: Apartment house

The towers were located neighboring Margala Towers (**Photo 2-1**). Some visible cracks were observed in URM (solid cement block) walls but no structural damage was apparently found in RC columns and shear walls. They were under repairing at the time of the investigation (**Photo 2-2**). The spacing of lateral and vertical reinforcement of an RC wall investigated with a rebar detector was 20cm and 12cm, respectively. According to the structural engineer who designed the building, the diameter of the lateral and vertical reinforcement of the wall was 13mm and 10mm, respectively.

Schmidt hammer tests were made on an elevator core wall and the estimated strength was 28 N/mm^2 ($R = 47$).

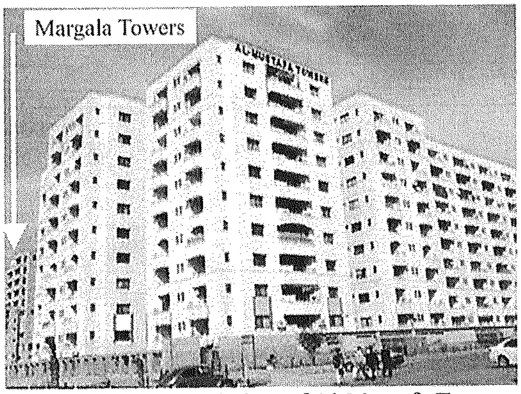

Photo 2-1. General view of Al-Mustafa Towers

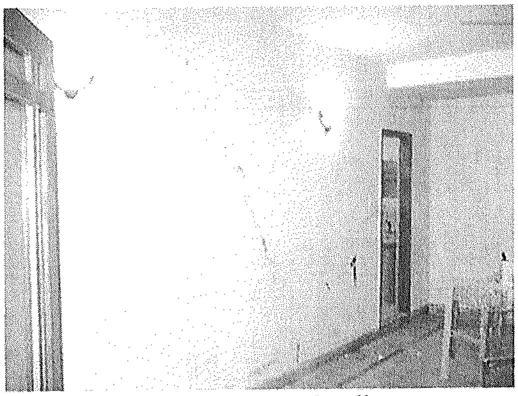

Photo 2-2. Damage to URM wall

(3) Park Towers, Islamabad
* Construction: RC with URM walls, constructed in 1995-1996
* Number of Stories: 10 + B1 + PH
* Use: Apartment house

The apartment house consisted of 3 buildings (west, center, and east building) (**Photo 3-1**). Expansion joints were provided between each building. Major structural damage was found in beams.

In the basement, cracks were mainly observed in the mid-span of beams (**Photo 3-2**), which implied that they were caused by vertical loads and were likely initiated before the earthquake. More cracks were found in the west building than in the east building. Some of them were repaired with CFRP sheets applied on the bottom of beam and epoxy mortar at the cracks.

In most upper stories of the west and east buildings, cracks were found in beam-ends of open corridor in the NW-SE direction. They were repaired with epoxy mortar with epoxy injection (**Photo 3-3**). Since their crack patterns traced from the repaired evidence were almost identical in both buildings (**Figure 3**), the two buildings therefore were considered to have behaved in the same manner.

Expansion joints between each building were also damaged due to pounding resulting from their insufficient gaps (**Photo 3-4**). Narrow gaps were often found in other buildings and wider gaps were strongly recommended to prevent pounding damage during strong shaking.

Schmidt hammer tests were made on columns of the basement floor and the estimated strength was 33 N/mm^2 ($R = 54$).

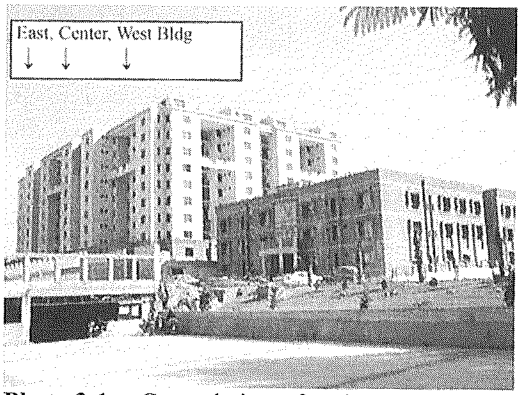

Photo 3-1. General view of Park Towers

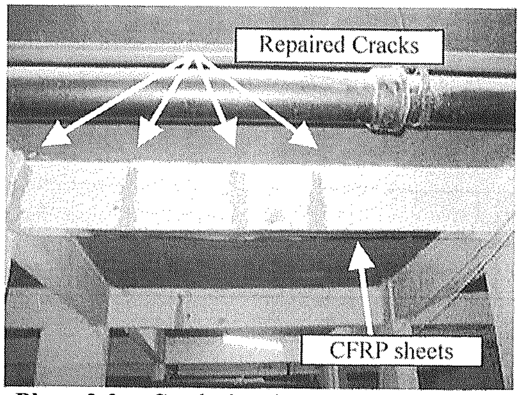

Photo 3-2. Cracks in mid-span beams

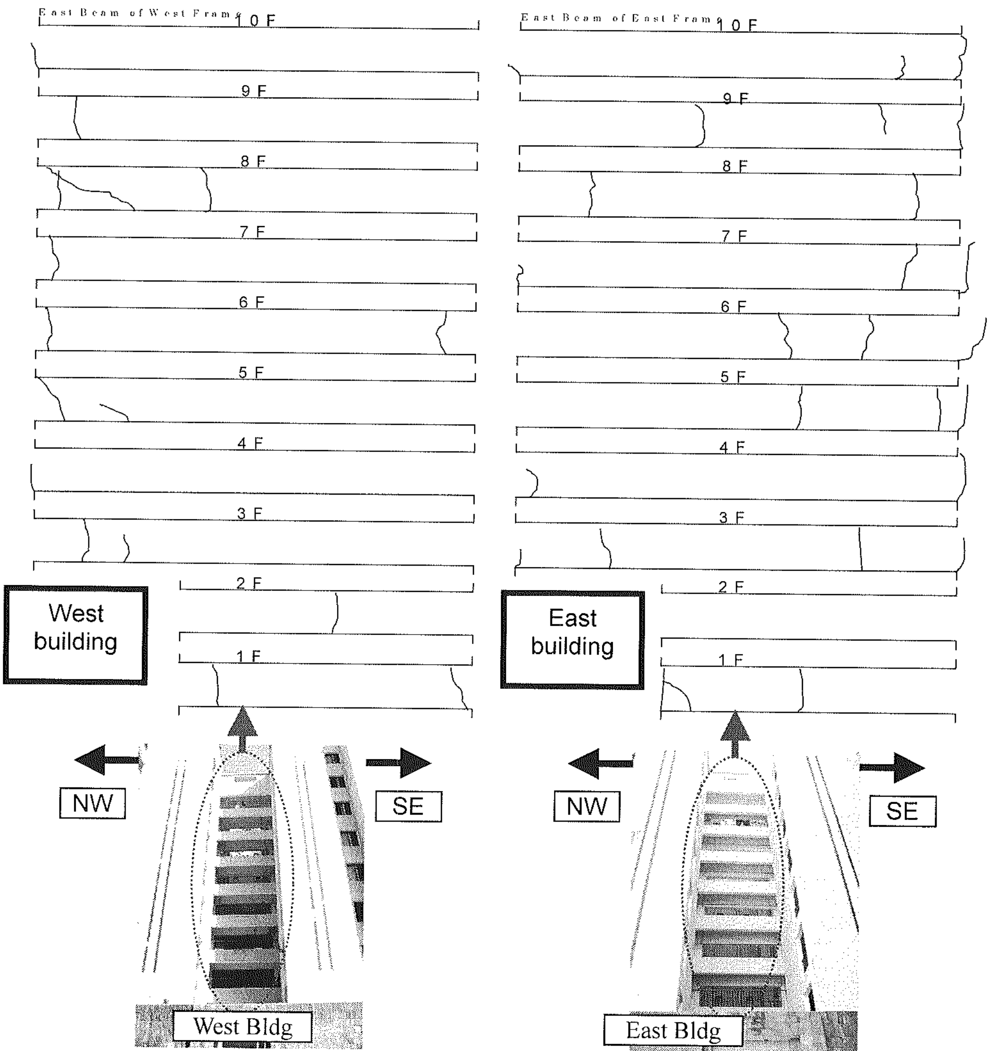

Figure 3. Crack patterns observed in beams of open corridor

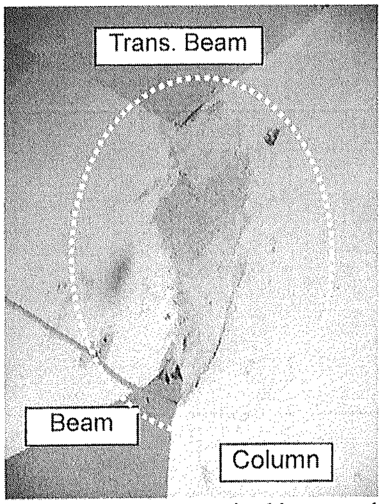

Photo 3-3. Repaired beam end

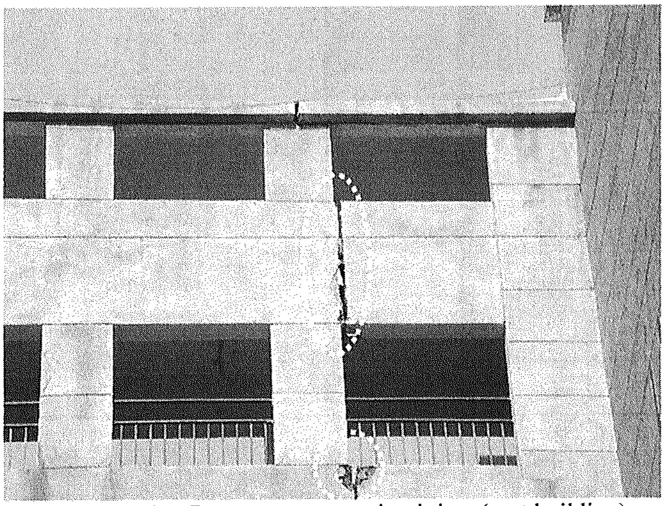
Photo 3-4. Damage to expansion joints (east building)

(4) Al-Safa Heights, Islamabad
* Construction: RC with URM (hollow cement block) walls, under construction
* Number of Stories: 7 (5 + B2 in the front elevation)
* Use: Apartment house

The building was under construction at the time of investigation (**Photo 4-1**). The typical column section was rectangular with 30cm width and 70cm depth. The hoops had 90-degree hooks (**Photo 4-2**). According to the structural engineer who designed the building, the width-to-depth ratio of typical RC columns in Islamabad was 1/2 to 1/3, and URM (hollow cement block) walls were 20cm thick for exterior walls and 15cm thick for interior walls. Some longitudinal rebars of beams were placed out of beam-column joint core concrete. Honeycombs were found in some concrete members. No structural damage was, however, apparently found in the building.

Schmidt hammer tests were made on a column in the 3rd story and the estimated strength was 26 N/mm^2 ($R = 40$).


Photo 4-1. General view of Al-Safa Heights

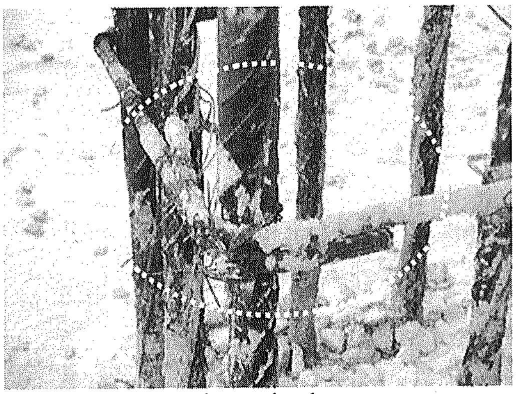
Photo 4-2. 90-degree hooks

(5) General/Private Ward, MCH, PIMS, Islamabad
* Construction: RC with URM walls, constructed in 1999
* Number of stories: 2 (+ partially B1)
* Use: Hospital

Photo 5-1 shows the general view of the building. The building had some minor cracks in URM walls. Cracks were also found in the interface between URM walls and boundary RC frame (beam and column) (**Photo 5-2**). Most of them were likely initiated before the event and widened due to shaking.

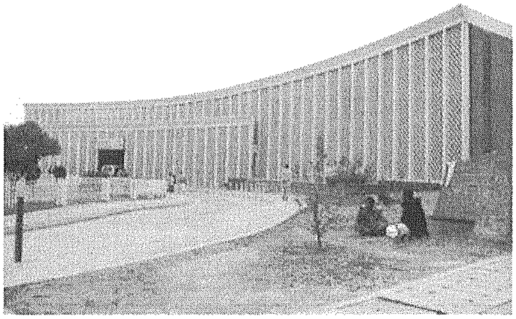

Photo 5-1. General view of G/P Ward

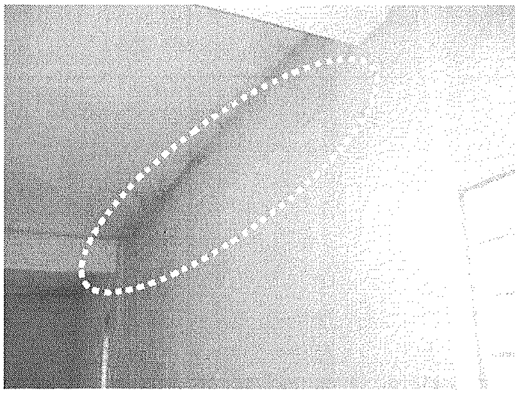

Photo 5-2. Horizontal cracks between URM and beam

Battal

Battal is located about 30km NW from the epicenter. In some villages, houses, schools, mosques etc. were devastated, and people were displaced to refugee tents.

(6) Primary School, Battal
* Construction: RC with URM (solid brick) wall walls, constructed in 1997
* Number of stories: 2
* Use: Primary School

This building was situated on a hillside in Battal along the National Road N-35 running through the village (**Photo 6-1**). The building was designed and constructed in accordance with the Japanese building code since its construction was financially supported by the Japanese Government. It had flexural cracks at the top of a column with exposure of reinforcing bars (**Photos 6-2** and **6-3**). The shear reinforcement of 2-D10 (#3) was provided at a spacing of 10cm with 135-degree hooks (**Photo 6-4**). Although some cracks were found in the core concrete of the damaged part, no buckling of main bars was observed. The damage level of the column was identified to be level III in accordance with the Japanese Damage Level Evaluation Guidelines[*1]. Minor flexural cracks were also found in almost all other columns in the corridor side ranging from damage level I to II.

In the URM wall adjacent to the column with major flexural damage stated earlier, extensive shear cracks were found (**Photo 6-5**). Minor cracks were also found in other URM walls. Some furniture in classrooms was found toppled down (**Photo 6-6**), and buildings close to the school had serious damage. Although such strong ground shaking evidence, the school building was identified to be *Light Damage* in accordance with the Damage Level Evaluation Guidelines.

Seismic capacity of the building was preliminarily calculated according to the Japanese Standard for Seismic Evaluation[*2], neglecting the effects of URM walls to structural behavior. The structure was

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[*1] Japan Building Disaster Prevention Association: Guidelines for Post-earthquake Damage Evaluation and Rehabilitation, 2001. The outline of the Guidelines can be found in the following paper.
Yoshiaki Nakano et al. "GUIDELINE FOR POST-EARTHQUAKE DAMAGE EVALUATION AND REHABILITATION OF RC BUILDINGS IN JAPAN", Proceedings of the 13th World Conference on Earthquake Engineering, August 2004.

[*2] Japan Building Disaster Prevention Association: Seismic Evaluation and Retrofit (English Version, 1st)

estimated to fail in flexure and its ultimate strength was 0.48 in terms of base shear coefficient.

Schmidt hammer tests were made on beams of the 1st story framing into the damaged column and the estimated strength was 21 N/mm^2 ($R = 40$).

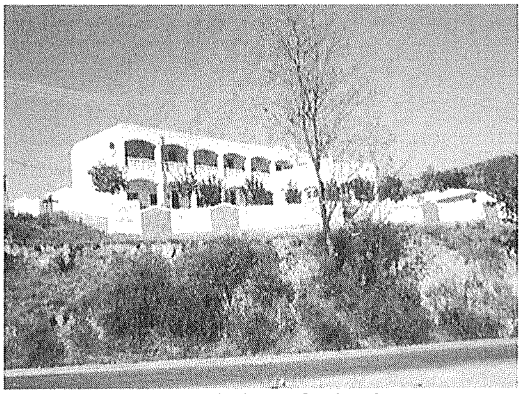


Photo 6-1. General view of school

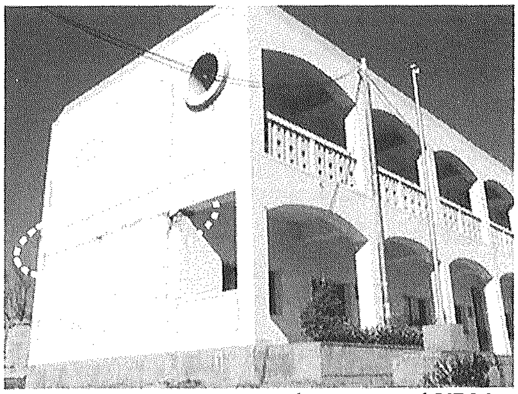


Photo 6-2. Damage to column top and URM

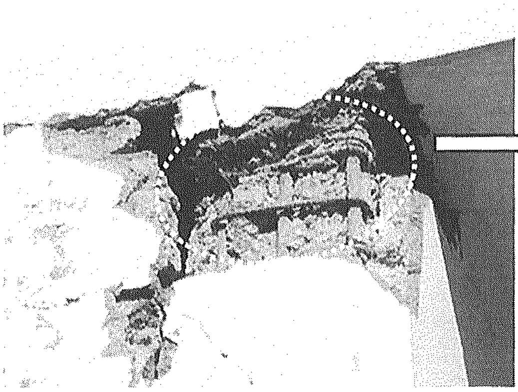


Photo 6-3. Close-up view of damage

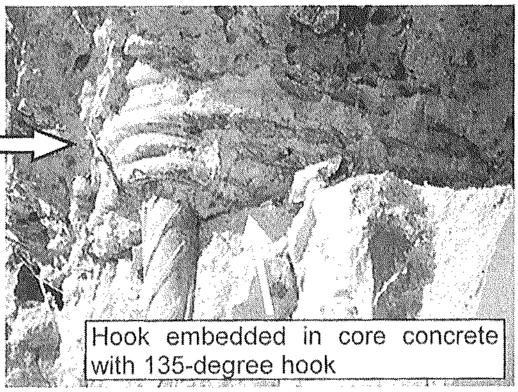


Photo 6-4. 135-degree hook


Photo 6-5. Damage to URM wall

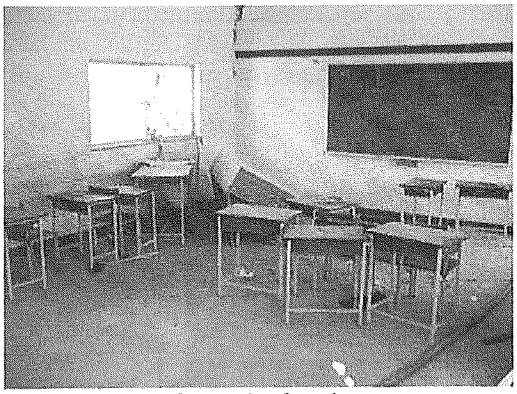


Photo 6-6. Aftermath of quake

(7) Primary and High School for Girls, Battal
* Construction: Stone masonry
* Number of stories: 1 for high school and 2 for primary school
* Use: School

Two buildings were situated at the site; one was a two-story URM primary school and the other a single-story URM high school. Both buildings had RC beams on URM walls but no reinforcement was provided to connect them. They had tin roofs on timber trusses.

The two-story primary school was completely devastated, showing pancake collapse (**Photo 7-1**). The single-story high school buildings were seriously damaged with extensive cracks and out-of-plane failure of URM walls, although it did not result in total collapse primarily due to light building weight (single story) and tin roof system (**Photo 7-2**). The building collapse reportedly killed 37 students out of some 500 students.

Schmidt hammer tests were made on a beam of the primary school and the estimated strength was 8 N/mm^2 ($R = 20$).

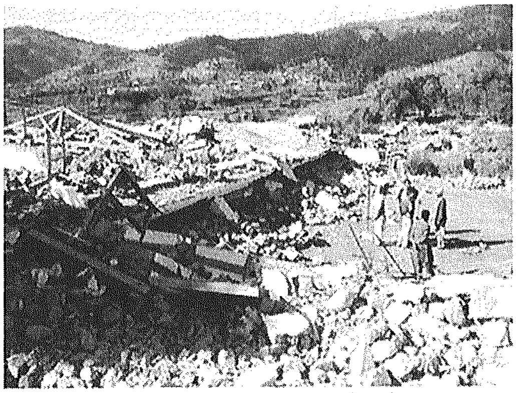


Photo7-1. Collapsed primary school

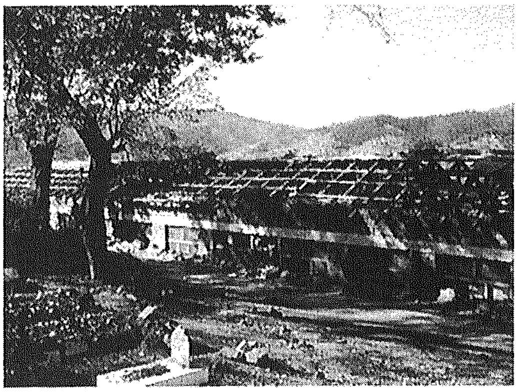


Photo 7-2. Damaged high school

(8) Jamia Mosque Battal, Battal
* Construction: RC with URM walls
* Number of stories: 2
* Use: Mosque

The Mosque (**Photo 8-1**) was located close to the Primary and High School for Girls described earlier. Some columns were seriously damaged resulting in partial collapse in the first story (**Photos 8-2** and **8-3**). Extensive shear cracks were found in URM walls (**Photo 8-4**).

Seismic capacity of the collapsed building was preliminarily calculated according to the Japanese Standard for Seismic Evaluation, neglecting the effects of URM walls to structural behavior. The structure was estimated to fail in flexure and its ultimate strength was 0.14 in terms of base shear coefficient.

(9) High School, Battal
* Construction: RC with URM (brick) walls
* Number of stories: 1
* Use: School

The school consisted of several URM buildings (**Photo 9-1**). Two of them were completely destroyed (**Photos 9-2** and **9-3**). The building collapse reportedly killed 35 and injured 150 out of 450 students.

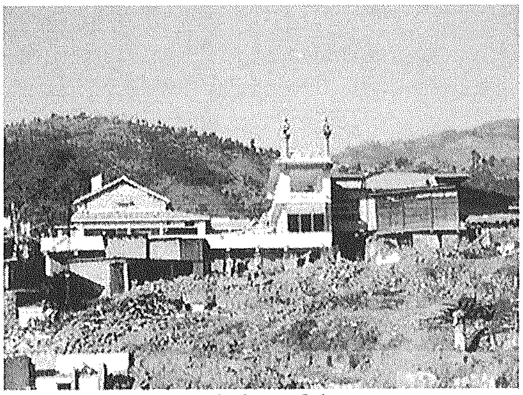


Photo 8-1. General view of the mosque

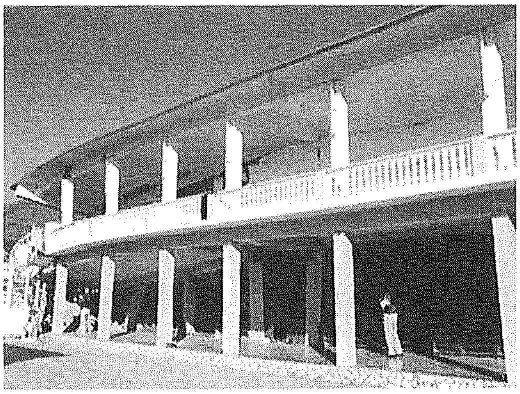


Photo 8-2. Collapsed building


Photo 8-3. Interior damage


Photo 8-4. Damage to URM wall

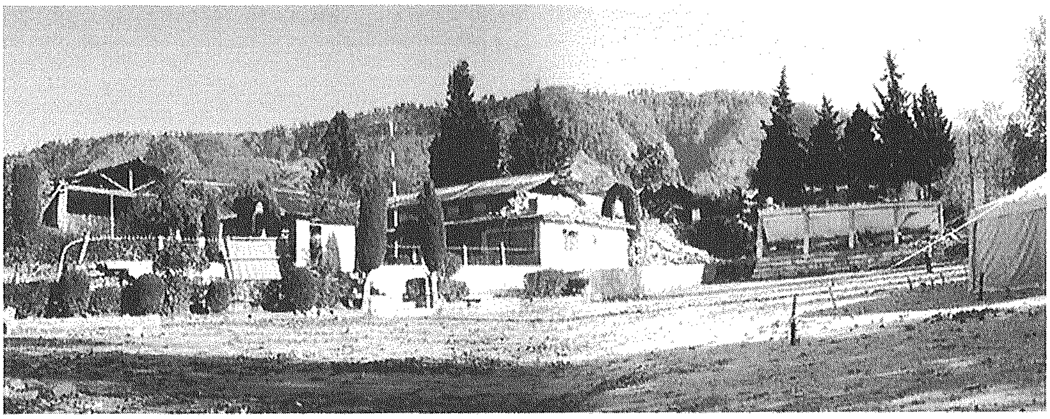


Photo 9-1. General view of school

Photo 9-2. Collapsed school

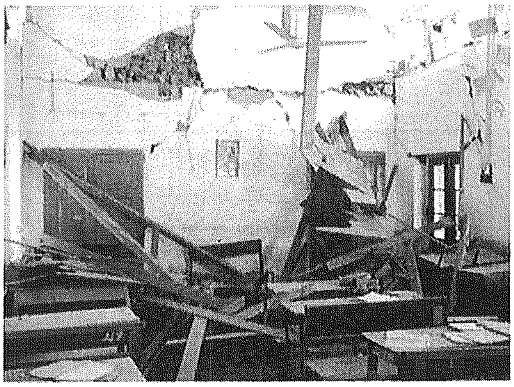


Photo 9-3. Interior damage to classroom

Abottabad

Abottabad is located about 40km SW from the epicenter. Serious damage to beam-column connections resulting from poor reinforcement detailing was found in RC buildings. It should also be pointed out that some damaged buildings were not properly repaired.

(10) Restaurant Building (name unknown)
* Construction: RC with URM walls, constructed in around 1998 to 2000
* Number of stories: 3
* Use: Restaurant

This building was located on the National Road N-35 (Abottabad-Mansehra Road) and lost its first and second stories (**Photo 10-1**). Beam reinforcement was straightly anchored in exterior columns and was not bent and embedded into beam-column core concrete (**Photo 10-2**). Beam-column joints did not have lateral reinforcement. Such detailing did not form rigid connections and moment resisting frames, and it could easily lead to beam-column connection failure.

Typical column sections were 25cm x 40cm. Their lateral reinforcement having a diameter of 7mm was provided at a space of 30cm with 90-degree hooks at ends (**Photo 10-3**).

Schmidt hammer tests were made on a beam of the building and the estimated strength was 17 N/mm^2 ($R = 32$).

Damage was also found in some neighboring buildings (**Photo 10-4**). They were, however, simply repaired with replacement of bricks in damaged URM walls and/or newly providing narrow URM brick walls underneath beams (**Photo 10-5**), although the structures were still tilted and rebars in columns were buckled (**Photo 10-6**).

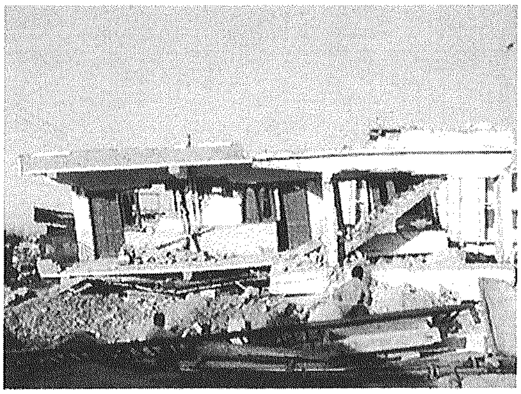


Photo 10-1. General view of collapsed restaurant

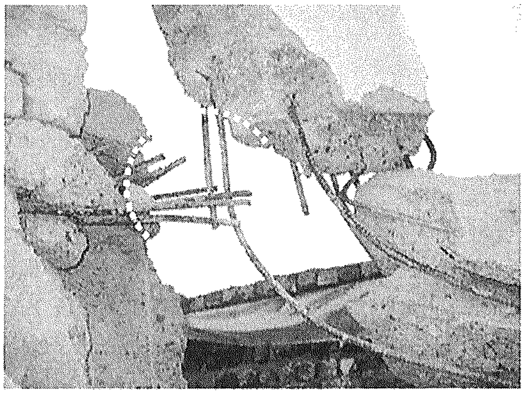


Photo 10-2. Poorly detailed beam rebars

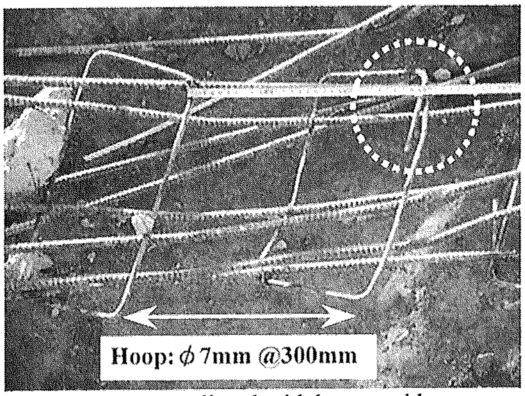


Photo 10-3. Small and widely spaced hoops

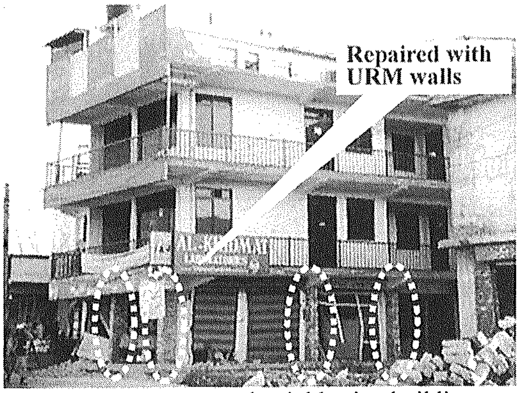


Photo 10-4. Damaged neighboring building

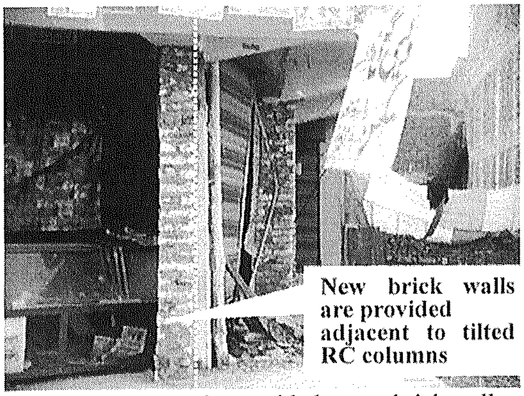


Photo 10-5. Newly provided arrow brick wall

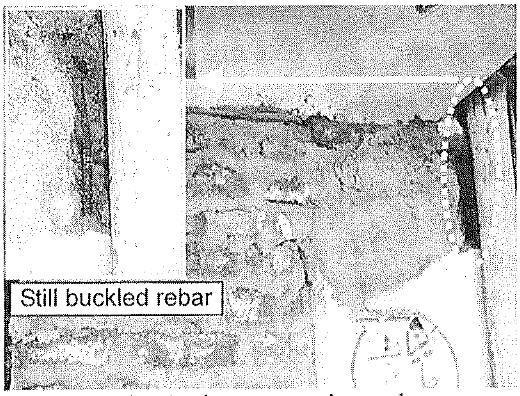


Photo 10-6. Inadequate repair at column top

(11) Department Store (name unknown)
* Construction: RC with URM walls, constructed in 2004
* Number of stories: 3
* Use: Department store

This building was located on the National Road N-35 and failed in the first story (**Photo 11-1**). Beam reinforcement was straightly anchored within a narrow column. Beam reinforcement in the transverse direction straightly went through the beam-column connection and terminated at the column surface without any bent anchorage into the core concrete (**Photo 11-2**). Since no lateral reinforcement was provided in the beam-column joints as was the common practice in Pakistan, the concrete cover spalled off the joint exposing buckled column rebars (**Photo 11-3**). Reinforcing bars failed in a brittle manner without showing necking at the fractured section (**Photo 11-4**).

Schmidt hammer tests were made on a column of the first floor and the estimated strength was 22 N/mm^2 ($R = 38$).

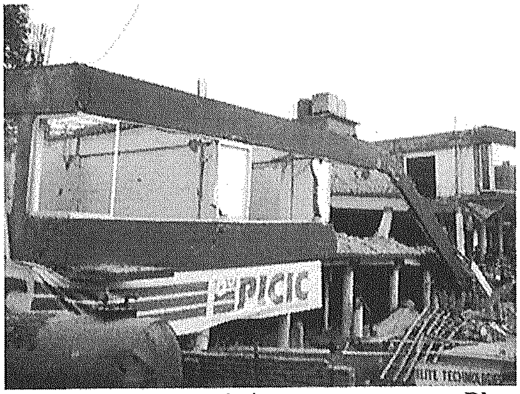


Photo 11-1. General view

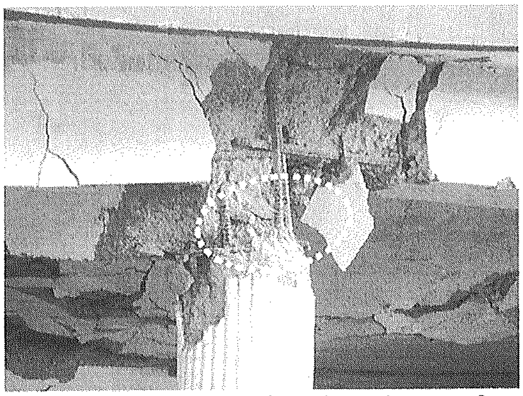


Photo 11-2. Beam rebars terminated at column surface

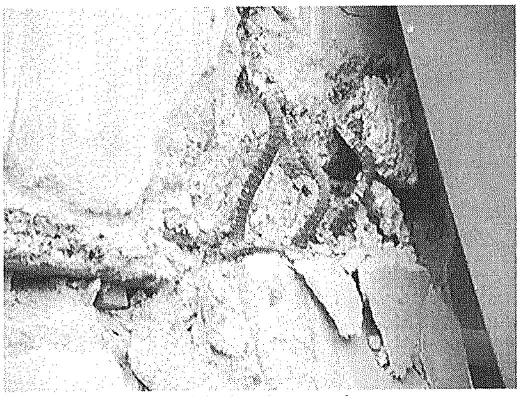


Photo 11-3. Buckled column rebars

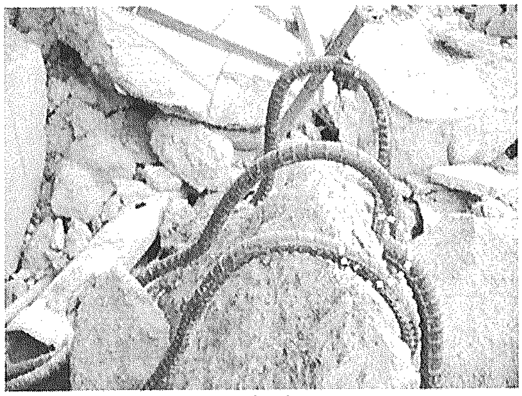


Photo 11-4. Fractured rebar

Balakot

(12) Houses in Balakot

Balakot is located about 25km NW from the epicenter. In central Balakot, 70% to 80% (visual survey) RC buildings and houses were totally destroyed (**Photo 12-1**). Damage was especially devastating on the hillside areas, and almost all buildings there were totally destroyed due to landslide and shaking (**Photo 12-2**). Poor reinforcement details were generally found in beams such as: (a) beam rebars running outside the column reinforcement cage as shown in **Photo 12-3**; (b) beam rebars straightly terminated at the surface of exterior columns without bent anchorage into core concrete; (c) no shear reinforcement at beam-column joints; (d) insufficient overlap length at rebar splice joints in beams and slabs, leading to their pull-out failure.

Schmidt hammer tests were made on a beam of a collapsed house and the estimated strength was 15 N/mm^2 ($R = 33$).

Muzaffarabad

(13) Houses and buildings in Muzaffarabad

Muzaffarabad is located about 10km SW of the epicenter. Buildings and houses were often constructed on steep slopes and they were eventually devastated associated with slope failures (**Photo 13-1**). Other structural damage to RC houses and buildings was attributed to the poor anchorage at beam-column connections as was found in other cities (**Photo 13-2**). Since beam rebars were straightly developed and terminated in the connection, they were easily pulled out of the connection and did not form RC moment resisting frames. Reinforcement was often found less ductile, and rebars did not show necking at their fractured sections.

Schmidt hammer tests were made on a survived ward of the Combined Military Hospital (**Photo 13-3**) which partially lost the first story and the estimated strength was 20 N/mm^2 ($R = 39$).

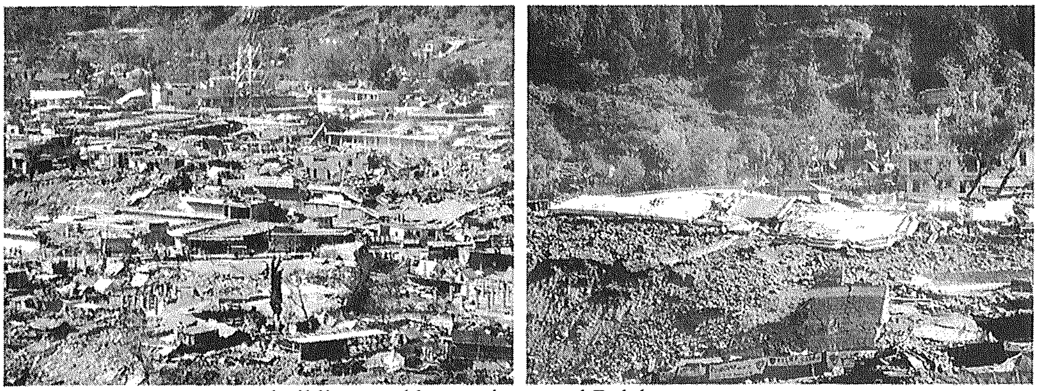


Photo 12-1. Damage to buildings and houses in central Balakot

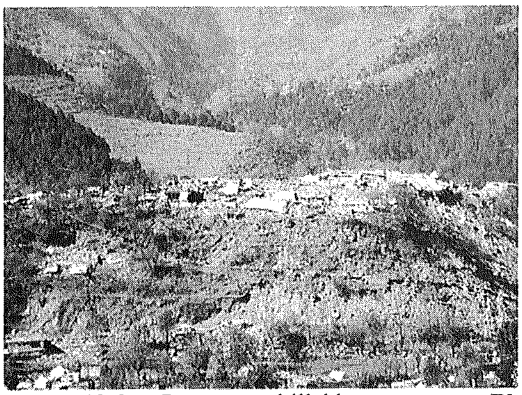


Photo 12-2. Damage to hillside area

Photo 12-3. Beam rebars outside reinforcement cage

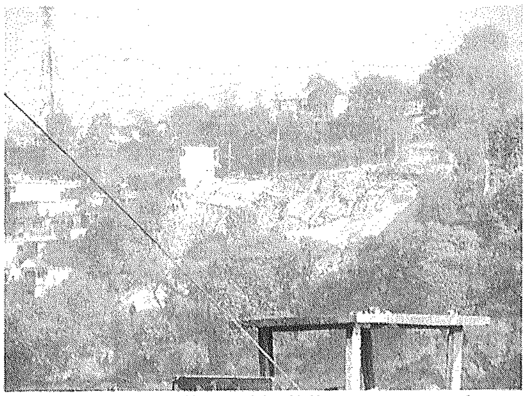


Photo 13-1. Collapsed buildings on steep slope

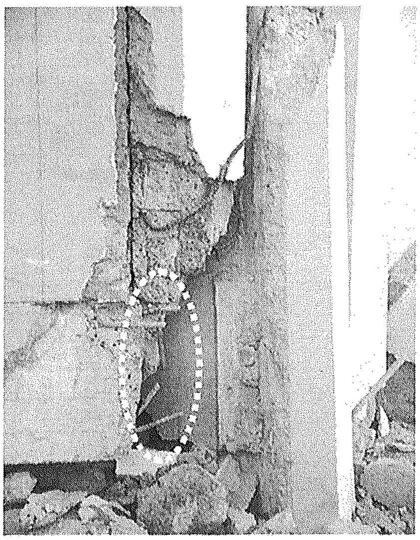


Photo 13-2. Poor detail at connection

It should also be noticed that some buildings with serious damage and tilting were occupied as they were before the quake, although they were potentially vulnerable to aftershocks (**Photos 13-4** and **13-5**). Development of quick inspection system and technical guides to identify buildings potentially vulnerable to aftershocks was needed in this city.

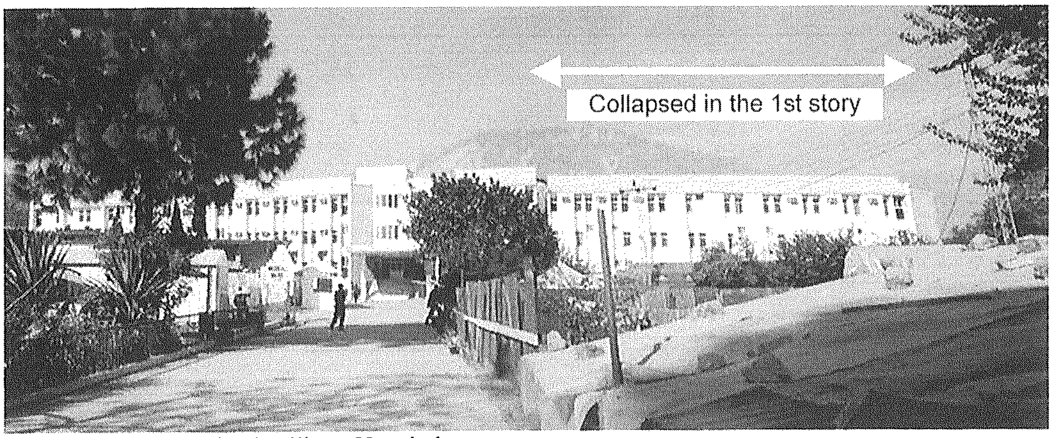


Photo 13-3. Combined Military Hospital

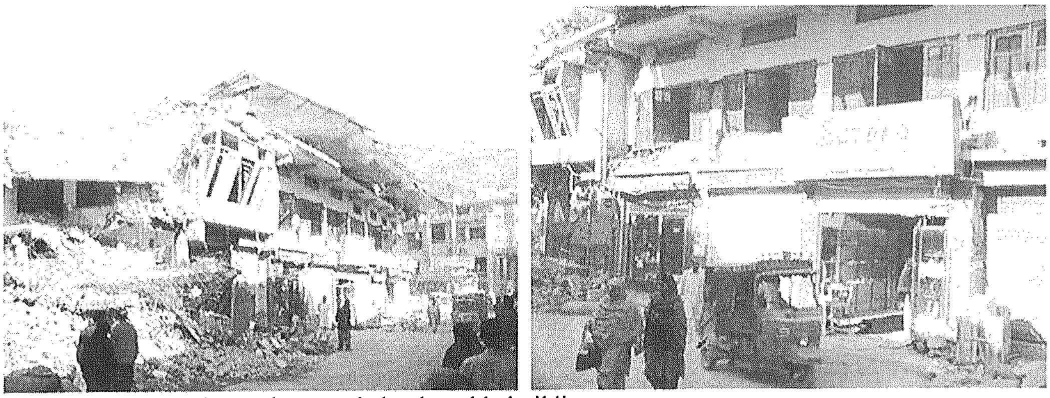


Photo 13-4. Continuously occupied vulnerable buildings

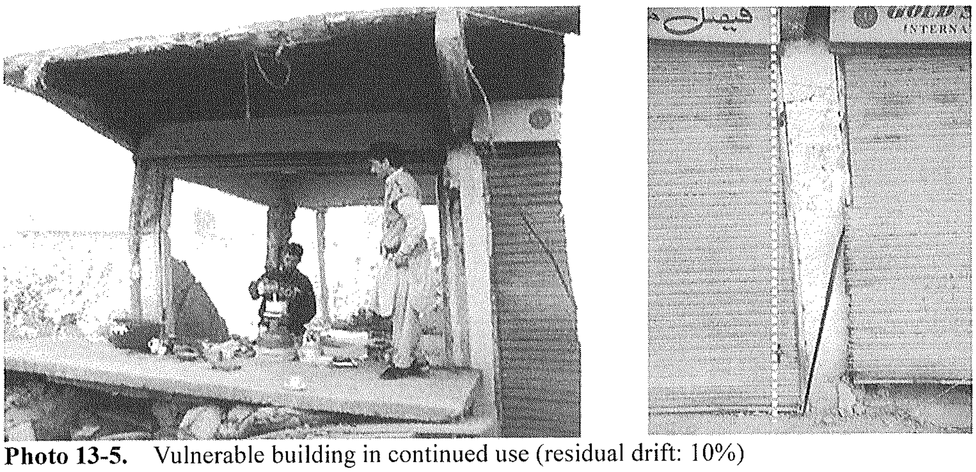


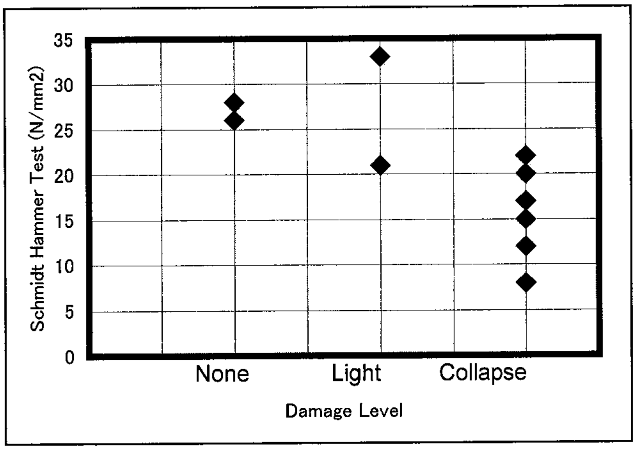
Photo 13-5. Vulnerable building in continued use (residual drift: 10%)

Findings from Damage Observations and Recommendations

(1) Concrete Quality: In Islamabad and other affected areas, no ready-mixed concrete is used at construction sites. Honeycombs are often found in members and the ratio of coarse and fine aggregate is different in each construction. Concrete strengths estimated from Schmidt hammer tests in some investigated buildings are summarized below together with their structural damage.

Building	Structural Damage	Estimated Strength(s) (N/mm^2)
(1) Margala Towers	Building No.4 collapsed	12*, 17*, 15
(2) Al-Mustafa Towers	No damage	28
(3) Park Towers	Light (Cracks in beams)	33
(4) Al-Safa Heights	No damage	26
(6) Primary Schoo, Battal	Light	21
(7) Primary and High School, Battal	Collapsed	8
(10) Restaurant, Abottabad	Collapsed	17
(11) Department Store, Abottabad	Collapsed	22
(12) Collapsed House, Balakot	Collapsed	15
(13) Hospital, Muzaffarabad	Collapsed	20*

* Test results taken from survived buildings



Comparison of damage level and Schmidt hammer test results

As can be found above, buildings with lower concrete strength generally have more serious damage. Good quality of concrete should be therefore achieved for a better seismic performance.

(2) Reinforcement detail and its quality: In some buildings in Islamabad and most buildings in Abottabad, Balakot, and Muzaffarabad, reinforcing bars in beams are not properly anchored within the beam-column joint core concrete. They are straightly developed and terminated at the surface of exterior columns, or placed outside the column reinforcement cage. Lap splice joints of beam rebars are often too short to properly transfer forces acting on joints. Poorly detailed reinforcement may be easily pulled out of the core and/or may cause separation of shell concrete from the core, and the beams and columns do not form rigid connections. This would therefore lead to a premature failure like pin-connected frames rather than moment resisting frames, as is often found during field surveys, before the members attain their potential strength and ductility during shaking. This can be avoided through placing the beam reinforcement into the column reinforcement cage, and providing enough development length bent into joint core concrete to form plastic hinges at member ends.

Rebars are often found failed in a brittle manner, showing no necking at the fractured section. Ductile reinforcement is significantly essential for ductile behavior of structures.

(3) Shear Reinforcement and Concrete Confinement: The sizes of shear reinforcing bars are often too small (6mm to 8mm) and they are provided with a space generally wider than 25cm at mid-span of columns. Hooks are generally 90-degree even when the structural drawing specifies 135-degree, and the shear reinforcement would easily open following the spalling of concrete cover. Concrete cores well confined with closely spaced lateral reinforcement having 135-degree hooks are most essential for higher ductility (lateral deformation capacity under shaking) and axial load carrying capacity.

(4) Nonstructural Damage to URM walls: Damaged block/brick infilled walls are observed in many buildings. Falling debris from failed wall are significantly hazardous and even life threatening to occupants. Such damage to nonstructural walls should be avoided through proper detailing.

The lack of lateral stiffness and deformability of the structural members appears to be the cause of collapse in many buildings. As is found in previous damaging earthquakes in the world, the better performance can be achieved through providing RC shear walls and/or RM (reinforced masonry) walls in both principal axes of a building. RC shear walls and RM walls would be good candidates to mitigate nonstructural damage and to improve seismic performance of buildings.

(5) Beam-column Joints: No lateral reinforcement is generally placed within the beam-column joints in practice. Concrete spalling at the joints is observed in some buildings, exposing the buckled longitudinal reinforcement. Properly confined beam-column joints are most essential for RC structures to perform successfully during earthquakes.

(6) Pounding: Closely neighboring buildings with narrow gaps at expansion joints sustain pounding damage. Expansion joints should be therefore designed and constructed properly considering deformations expected during shaking.

(7) Site Effects: In general, site effects and resulting amplified ground motions significantly affect structural responses. It should be noted that microtremor measurements at the building site and its vicinity would help understand the relationship between site effects and damage to the collapsed tower.

(8) Strong Ground Motion Observations: Strong motion records are significantly valuable information to understand the relationship between observed damage and input ground motions during earthquakes. They are also informative to identify design seismic loads. Although some records are reportedly obtained during the event, a more densely installed strong motion network is recommended.

(9) Quantitative Post-earthquake Damage Inspection: Some seriously damaged buildings are still in continued use before properly rehabilitated. One may find such examples in commercial buildings and shops in Muzaffarabad. To mitigate life-threatening hazard of damaged buildings due to aftershocks, quick inspection system and inspection engineers are most needed.

(10) Rehabilitation Strategies and Techniques: In some areas, damaged buildings are not properly repaired or strengthened. Problems found during the survey can be listed below:

* Damaged members are not repaired to have the same section size and/or performance prior to damage.
* Buckled rebars are not replaced nor additionally confined.
* Tilted buildings are not re-centered nor no additional members are provided to avoid further inclination.

If the damaged buildings are not repaired properly, the seismic performance to be achieved by the rehabilitated structure is quite questionable. The development of a technical manual is most essential to provide good information to guide engineers and practitioners for appropriate rehabilitations.

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