SURVEY REPORT ON NORTHERN KASHMIR EARTHQUAKE OF OCTOBER 8, 2005 FROM THE INDIAN KASHMIR SIDE OF THE LINE OF CONTROL

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This report is from observations made from a trip into the Indian side of Kashmir from October 24 to 29, 2005, including a trip into the damage district as far as Uri on October 25. This survey is limited to observations made along state highway 1A from Srinagar to Baramula and Uri. This survey of the damage was facilitated by the Archaeological Survey of India, and included visits to four historical monuments and archeological sites on this route that are under their jurisdiction. The trip to the damage district also included visits to the historic city of Baramula, to Uri, and several villages in the same region.

The balance of the visit to Indian Kashmir was spent in Srinagar, surveying the current condition of the historic city and its environs after the period of approximately 15 years during which the militancy has affected life in Kashmir, an area that was formerly fabled for its beauty, but is now almost unknown to the rest of the world. During this trip, these conditions were clearly evident by the frequent pillboxes and checkpoints with the large number of armed soldiers and police in Srinagar and on the road to Uri. [Figure 1]

Figure 1: Military checkpoint, 4th Bridge, Srinagar

Building Damage Description

After learning of the extent of the devastation the earthquake had wrought in the Azad Kashmir (the Pakistan portion of Kashmir), it was striking to see how little the damage was east of Uri in Indian Kashmir. News reports had indicated that Srinagar had suffered damage, but no significant damage was seen in that city, despite the fact that it rests on a notoriously soft soil site of a pre-historic lake.

Closer to the epicenter, damage could be seen in the city of Baramula, but it was quite limited, as will be explained below. As one approached Uri, there was increasing evidence of rock falls from the earthquake, and increased amount of damage to buildings. In Uri itself, the damage was significant, but far less than total. The areas where damage was reported to be nearly total were beyond Uri along the "Line of Control" border with Pakistan, but these areas were beyond the scope of my visit.

This limitation of the damage is itself interesting, especially in light of the severity of the effects of the earthquake near to the epicenter, and the wide area of land in which its shaking was felt. In **Delhi**, the shaking was enough to precipitate evacuation of buildings, especially the newer buildings in **Gurgaon**, an area recently developed to serve the international "call center" industry. [Figure 2] There the tall multi-story apartment blocks swayed sufficiently to precipitate large-scale evacuations of the people.

Figure 2: Gurgaon highrise during evacuation (photo from India Today)

Srinagar: In Srinagar, **125 km** (75 miles) from the epicenter, the shaking also was strong enough to precipitate building evacuations. In an interview of a Kashmiri colleague working in the offices of INTACH (Indian Trust for Art and Cultural Heritage) in central Srinagar, he reported that the hanging lamps along the building balcony hallway on cords of about 1 foot in length swayed sufficiently to touch the ceiling, and, after descending the staircase from the 3rd floor to the ground, he witnessed the tall poplar trees [Figure 3] swaying sufficiently to touch each other. He, like many others, described the shaking as having lasted for two minutes. Because he was on the third floor at an end of the building remote from the stairs, and he described the swaying of the trees which he could only have witnessed from the ground at the opposite end of the building, the lengthy duration is plausible. In spite of the shaking that was experienced, the only damage that I was able to find in Srinagar itself was seen in the Heemal Hotel, next to Dal Lake, where a slight crack at ground floor level could be seen between the RC frame and masonry infill. [Figures 4&5]

Figure 3: Srinagar. These poplar trees were reported as swaying to the point of touching during the earthquake

Figure 4: Interior of five story Heemal Hotel showing location of crack in figure 5.

Figure 4: This crack shows how minor the earthquake damage is, because it is only the propagation through the surface plaster of the interface between infill and the RC frame.

When traveling towards Uri, the first half of the trip was in a trajectory directly towards the epicenter. From 10 km prior to arrival in Baramula, the road turns towards the southwest, on a more oblique trajectory towards the epicenter. The first part of the trip crosses the Vale of Kashmir, a vast pre-historic lake bed that was landlocked between the mountains. This is now a fertile plane that is farmed for rice, as well as apples and other crops. The shallow lakes, including the fabled Dal Lake in and around Srinagar are the remainder of this prehistoric lake, and the Jelum River drains through the valley by flowing to the northwest, before descending through the mountains bordering Pakistan in a canyon. The road leaves the Vale of Kashmir soon after Baramula, entering the mountains before arriving in Uri.

As one approached Uri from the Vale of Kashmir, one enters a landscape that becomes progressively more mountainous. The route follows the Jelum River for the entire distance from Srinagar, as the Jelum flows northwest out of Srinagar, and then angles to the southwest until Uri, when it again turns northwest towards Muzaffarabad, passing close to the earthquake epicenter as it descends into Pakistan. While the surrounding mountains rise above the Vale of Kashmir, the water flows out of the valley in a canyon carved between these mountains into Pakistan, such that the valley between the mountains is lower than Srinagar, and the daytime temperature in Uri on this day, October 25, was more mild than in Srinagar. [Figures 5-8]

Figure 5: Rice paddies in the Vale of Kashmir near to Dwer Village 35km from Srinagar

Figure 6: Old city area of Baramula, looking westward towards the mountains.

Figure 7: Jelum River valley in foothills of mountains, 11 km west of Baramula

Figure 8: Jelum River Canyon near Uri.

Shanker Gaury Shovra Temple: This archeological site is **25km** from Srinagar. It is the ruins of a stone temple, with freestanding walls without a roof. There was no evidence of damage at the site.

First Damage: The first earthquake damage witnessed while proceeding towards the damage district was a collapsed section of the perimeter of a military compound **39km** from Srinagar (approximately 86km from the epicenter). No other earthquake effect was visible until arriving in **Baramula**.

Baramula: Baramula (Figure 6) is **60km** from Srinagar and approximately **70 km** from the epicenter. Damage could be seen, but was not extensive. In interviews with residents of Baramula, people said that the shaking made it difficult to stand. One person said the earthquake knocked him over. Only one building was seen that was severely damaged. This was a five story building in the heart of the historic center. (I was unable to access this building close enough to see the base. It may have been four stories with a tall first floor.) This building appeared to be one of the tallest in that section of the city, with its roof appearing much higher than the surrounding structures when viewed from across the river. The damage consisted of the collapse of the front load bearing masonry wall up to the level of the top story of Dhajji Dewari construction, which remained in place. [Figures 9 & 10]

Figure 9: Large house in Baramula showing collapse of URM wall, leaving Dhajji Dewari construction wall in place above.

Figure 10: Detail of collapsed wall in building shown in Figure 9.

The remarkable bridging effect of the surviving walls at the top of the structure was a condition seen also in a number of photographs posted from media reports of the earthquake. The Dhajji Dewari construction – frequently used for the upper floors of masonry buildings, has proved to be remarkably resilient in this earthquake, even when all support from the walls below has fallen away.

A tour of a portion of the historic center of Baramula brought to our attention that this area contains many well preserved examples of traditional Kashmiri architecture, both of the *Taq* (timber laced masonry bearing wall) and *Dhajji Dewari* (timber frame with infill masonry) construction. (Figures 11 & 12). No other buildings seen in the approximately 5 block area inspected had any significant damage. Other damage in this area was limited to the falling out of minor amounts of brickwork and one case of pounding damage. Across the river, one building was seen to have lost its masonry gable, a condition that may have been repeated a number of times. On the whole, however, the damage was not widespread enough from which to draw conclusions on which buildings were weak and which were more robust. The one conclusion that may be drawn from the building with the collapsed wall is that it may have experienced a greater resonance with the earthquake because of its height, and this resonance proved to be capable of precipitating the out of plane collapse of the wall. There was no evidence of ties between the floors and the collapsed masonry wall.

We had time to be invited into one home in the historic center. In the interior of this house, the evidence of earthquake damage was limited to hairline cracks in the plaster over Dhajjis Dewari walls where the infill masonry walls contacted the timber. Larger cracks could be found on the inside face of the exterior and party walls with the neighboring house at the corner of the stairway. None of these cracks indicated a threat to the stability of the building, but the occupants expressed a degree of concern as they are unfamiliar with what the cracks signify. [Figure 13]

Figure 11: Narrow lane in Baramula Old City with Dhajji Dewari top floor construction.

Figure 12: Timber lacing in URM wall of house in Baramula.

Figure 13: Interior of ca. 1900 house in Baramula showing cracks where the people are pointing. The cracks are limited to plaster cracks around the Dhajji Dewari infill panels.

Fatehgarh: The village of Fatehgarh is 7 KM from Baramula and is the location of the Shiva Temple, a 9th or 10th Century archeological site. At this site, the ASI staff explained that the earthquake had made some existing dislocations of the large ashlar blocks larger, and, in one location, one large and one small block fell. [Figures 14-16] Because the temple is an incomplete ruin, the individual sections of stonework are free to vibrate independently, so such damage would not be unexpected. The fact that the damage was not greater, together with the low level of damage in the village, indicates that the shaking at this location was not severe.

Figure 14: Shiva Temple, Fatehgarh. Stones in Fig.15 show some shifting from earthquake.

Figure 15. Top right corner of wall in Fig.14.

Figure 16: This large stone block under the man's hand is the only block to fall off the wall in the earthquake.

Across the way from the temple is a small mosque of recent origin. Damage visible on the interior was limited to cracks above the windows. One barn seen in the village had lost some of the masonry from between the wood studs of its Dhajji Dewari upper gable, and in the location where the timber was missing there was evidence that the timber had been weakened because of heavy infestation by insects. [Figure 16] Another house in this village was found to have vertical cracks revealing the empanelling of the masonry construction that is characteristic of traditional bearing wall construction in Kashmir, known as *Taq*. In this form of construction, rather than walls of uniform thickness of bonded masonry, the masonry is constructed as a series of thick piers, and with thinner walls in between that are not bonded to the piers. In this form, the masonry is all held together usually with horizontal timbers above and below the windows, and at the floor levels. The damage caused by the earthquake vibrations in this house serves to reveal this feature of the masonry construction, which may have been devised to allow for differential settlement on soft soil sites, avoiding the development of X cracks. (Figure 17)

Figure 16: Dhajji Dewari wall in barn that partially collapsed because of insect infested timbers.

Figure 17: Taq construction house where movement from the earthquake reveals where the masonry panels are disconnected from the piers.

Buniyar Temple: The Buniyar Temple (ca. 9^{th}-12^{th} Century Hindu Temple), is located 23 km from Uri and 22km from Baramula. It is now surrounded by an Indian Army base, and the army shares responsibility for it with ASI. This was the first of the archeological monuments seen during this survey to have suffered significant damage. The top arch and lintel of the main gateway collapsed, and the large stone blocks from this were still lying at the base outside the wall of the compound. One of the causes for this may have been the compression failure of the round column to the left of the doorway, which can be seen lying in front of the door with the broken shaft visible. A similar diagonal break can be seen in the still standing column on the interior of the gateway that is now leaning dangerously outward, held only by the weight of the shifted large stone lintel above. This column and lintel were the only items seen in the ASI monuments of an immediate life safety risk. This element should be shored, and dismantled to avoid eventual collapse that will destroy the stones. [Figures 18 & 19]

Figure 18: Buniyar Temple gate showing fallen stones from the collapsed column and top lintel.

Figure 19: Leaning column. Bell chain shows vertical line.

Figure 20: Stone encrusted with mineral byproducts of deterioration.

It appeared on examination that the stone of this monument has suffered from deterioration from weathering. The stone appears to be a kind of weathered conglomerate that has developed mineral crusts that are easily broken off, carrying away the original dressed surface with the crust. [Figure 20] Inspection of the cracked and leaning column on the inside of the gateway indicat

es that the stone has lost a considerable portion of its dimension at the base of the round shaft from such deterioration, and that the remaining stone is weak and friable.

The gateway was the only portion of this monument that suffered from partial collapse. The main temple showed evidence of the enlargement of pre-existing cracks. The exterior pilasters have separated from the body of the temple slightly. The roof is of modern light-weight construction over modern brick masonry that sits on the historic masonry, but lacks any tension ties to hold it together, so it shows some cracks and signs of spreading, much of which may have come from the earthquake. On the whole, however, the damage to the main sanctuary is minor, indicating that the shaking at this site was not great, particularly in the higher frequencies that would have had more of an impact on these stiff structures.

Detha Mandir Temple: This temple is approximately **13km** from Uri and **32 km** from Baramula. This name means “ruined temple.” Like the Buniyar temple, the roof on the temple and gatehouse have been constructed in modern times on top of what had been open ruins. In this case, the roofs are flat slabs of reinforced concrete resting on a combination of the dressed ashlar and rubble stonework. The concrete slab on the sanctuary is recessed back from the edge, and portions of the missing walls have been reconstructed in concrete block to form a level base for the roof.

The earthquake caused some stones to fall from the right side of the main sanctuary and caused the separation of many of the stones at the top of the structure. The section of concrete block did manage to stay together as one piece, but the stones around the edge of the roof were disturbed, with large cracks having opened up from the spreading of the stones, few of which were adequately mortared together. The existence of what appeared to be a modern reinforced concrete roof may have contributed to the damage to the masonry, but the roof itself remained intact. [Figure 21 & 22]

Figure 21: Detha Mandir Temple showing stones thrown off from the top of the wall. It appears that unconsolidated and deteriorated stone work surrounded a later reinforced concrete roof, which is set back from the edge of the structure. Differences in the vibrations between the roof and surrounding stonework may have contributed to the damage.

Figure 22: A small military structure near to the Detha Mandir Temple provides an example of damage associated with rigid concrete roofs on rubble masonry walls. A nearby similar structure with a timber and heavy sod roof remained completely intact.

Timber-laced masonry house: Opposite this temple we visited the family living in one dwelling, and we inspected the damage to the two and a half story house. It was of relatively recent construction. This structure was a masonry bearing wall structure with interior partitions of Dhajji Dewari construction. The earthquake revealed that there was timber lacing in the exterior bearing walls - at least on the ground floor. The exterior had been stuccoed with concrete stucco. There were many cracks in the structure, but it had held together well. The movement served to reveal the Dhajji Dewari by opening up a crack around each of the panels through the paint and plaster, but the walls themselves were not reduced in capacity. The government had provided a tent for the family, in which the family stayed immediately after the earthquake, but they soon moved back into the dwelling, and no repairs had been undertaken. The damage to the structure did not appear to have reduced its capacity significantly, although cracks were to be seen in all of the rooms of the house. [Figures 23 & 24]

Figure 23: The earthquake caused stresses in the ground floor wall to cause the shedding of the concrete stucco, but the horizontal timber lacing helped hold the wall from cracking and collapsing.

Figure 24: The interior of the same house shows how the plaster cracks reveal the location of the Dhajji Dewari construction infill panels.

As one approached Uri, over the last 20 km there were increasing numbers of rock falls onto the road. There were many large rocks that had fallen, which were resting beside the highway, and some small landslides that had been cleared from the road. My trip into the damage district was terminated at Uri, as the limits on time and daylight prevented moving beyond Uri to the villages nearer the border and epicenter. Many of these villages reportedly were almost totally destroyed, either from the effect of the earthquake vibrations on the concrete and rubble stone structures themselves or from landslides that swept into the villages.

Uri (Government Complex): Uri is 45 km from Baramula and 105 km from Srinagar. It is approximately 55km from the epicenter. Uri was the first settlement where earthquake damage was pervasive, although it was by no means total. The damage in Uri can be divided into two categories - (1) damage to the government complex near the entrance to the town (Collector's Office, Medical Clinic, School, Army Base, and ancillary residential and office structures), and (2) damage to the private (mainly commercial) buildings in the market town.

The government complex was inaugurated in 1982 for the Jammu and Kashmir State Government. Many of the buildings in the government complex were destroyed or heavily damaged. The most conspicuous among these was the school - which was totally destroyed, leaving only the walls with the blackboards and one short section of the wall of the building standing. The walls of the school were of rubble stone and fired brick in cement-lime mortar, and the floors and roof were timber. There were no ties, and the joists and beams of the floors did not penetrate the walls. In the wreckage there was evidence that the structure had a concrete bond beam, which lay broken on the top of the pile. (It is unknown how much further demolition was carried out after the earthquake.) It appeared from the one section still standing that the joists ran parallel to the building, which meant that the long exterior walls may have been largely free standing without attachment to the floor system. [Figure 25]

Figure 25: Totally collapsed unreinforced masonry school building in Uri Government Complex.

Figure 26: Collapsed School buildings in Uri Government Complex.

Figure 27: Detail of rubble masonry construction of school building seen on left in Figure 26.

Two other smaller structures that were a part of the school were also destroyed. One was totally collapsed, with only the roof remaining intact resting on the fallen walls, and the other partially collapsed. Figures 26 & 27] These buildings lacked the kind of timber lacing found in traditional construction - and also used as we had seen in the house near to the Detha Mandir Temple [Figure 23 & 24], which had been constructed around the same time as this school. It appears also that most of the other government complex buildings were masonry with thin reinforced concrete floor slabs, rather than with timber joists and wooden floors. In this case, the flexible timber floors combined with the lack of ties and the short depth of the timber joists into the walls, as well as the complete lack of attachment of the floors to the walls parallel to the joists, may explain the complete collapse of this structure, while most of the other structures were only partially collapsed.

The standard form of construction in many of the other buildings in the government complex was (1) ground floor walls of rubble stone, (2) upper floor walls of brick, (3) floors of two-way RC slabs, (4) roofs of light timber covered with sheet metal. Some buildings had stone to the roof, and others had brick from the foundation to the roof. The brick walls generally fared better than the stone walls. A mosque near the school was also demolished so completely as to make it impossible to discern its original shape and configuration. It appeared to have been masonry with a reinforced concrete slab and wooden roof. Figure 28]

Figure 28: Collapsed Mosque in Uri Government complex.

Figure 29: Collapsed rubble stone upper story walls in Uri Government complex.

Figure 30: Brick building with rubble stone end walls in Uri Government complex.

The other structures in the complex surrounding the collapsed mosque were mostly residential structures. Those structures that were constructed of brick from the foundation up most often manifested damage at the ground story level in the form of diagonal tension "X" cracks. Some of these structures were close to collapse. In contrast to these buildings, those structures that had rubble stone construction extending to the top of the walls tended to collapse from the top down. There were several buildings that were still standing, but the stone walls had fallen away, leaving the roof held up by the interior partitions and the wooden window frames. None of these walls manifested diagonal tension cracks. Instead, the masonry appeared to have crumbled in place. From what could be seen in our short visit, there was no evidence of deliberate bonding of the walls either with stone bond courses, or by any other means, and the mortar was very poor or non-existent. The mortar appeared to have contained cement, but it appeared that the cement had failed to fully hydrate from premature drying out, as the mortar was brittle but the collapsed stones were largely clean and free of mortar. [Figures 29 & 30]

There were two structures in the complex that did surprisingly well, in light of the almost universal poor performance of the others. One of these, which was fortunately the medical clinic, was still in operation. [Figure 31] The other had formed a part of the clinic, but because of the collapse of the walls around its stair tower, it was out of operation. [Figure 32] Time limits prevented close examination of these facilities on the interior. From the exterior, however, it was evident that the functioning clinic was constructed entirely of brick with concrete floors, rather than with rubble stone at the ground floor level. It appeared to be of more recent vintage than the other structures in the complex, and of better construction. The smaller clinic building, which suffered the collapse of its stair tower walls, had stone at the ground floor level and brick above, but in this case, the stone walls remained intact, except where they extended out to form the base of the stair tower, where they collapsed.

Figure 31: This Medical Clinic in Uri Government complex was not significantly damage, and is still in use.

Figure 32: Adjacent annex to medical clinic was only slightly damaged except for the collapse of the walls of the stairway, which rendered it unusable.

Uri (Market Town): The remaining part of the site visit was spent in the commercial town of Uri. Because of the failing light and limit on time, this visit was limited to only about 20 minutes, so the examination of the buildings was brief.

What was notable was that in Uri, although the damage was heavy and pervasive, it was insufficient to shut down the normal life and business of the town. Many of the shops and offices were functioning, even in buildings that had sustained damage. [Figure 35] The kind of damage that had disrupted what would have been thought to be the more substantial buildings of the Government complex was rare in the market town. Walls were cracked and breached in some buildings, with some collapses, but most buildings were either totally of timber, or had Dhajji Dewari walls that remained intact. [Figure 36] Those buildings of rubble stone without timber lacing suffered similar failures to those in the government complex. In many of these, the stone was laid in mud mortar without bond courses. [Figure 33 & 37]

Figure 33 (left): State Bank Building collapsed in Uri.

Figure 34: Relief line for water, Uri.

Figure 35: In Uri, this and many other shops were open and in active use in wooden buildings, or even some partially damaged masonry buildings.

There were several reinforced concrete buildings that were under construction at the time of the earthquake, and these survived intact. In one instance, where the infill masonry was being installed, some of this infill fell over, but the frame remained standing undamaged (unless closer inspection, which I could not undertake in the time available, reveals cracks in the beam column joints). [Figure 38]

Figure 36: Intact Dhajji Dewari wall above collapsed rubble masonry wall.

Figure 37: Rubble masonry building with all walls collapsed but front where balcony and timber door frames held the stone together.

Figure 38: Reinforced Concrete structure under construction at time of earthquake. Undamaged, except for out-of-plane collapse of some infill masonry.

Conclusion:

From this one-day survey into the damage district in the Indian side of Kashmir, the following preliminary conclusions emerged.

(1) This earthquake seems to have had a similar profile in terms of its impact on buildings as the December 26, 2003 earthquake in Bam, Iran. In this case, as in that one, the area affected by major shaking was quite small, with the destructiveness of the shaking reducing quickly as one moves away from the epicenter. Uri was much less damaged than the towns that I did not see that were closer to the epicenter in both India and Pakistan.

(2) Also, like the Bam earthquake, the shaking near the epicenter appears to have been of a comparatively high frequency, with a very large vertical component. This would explain the extreme damage to the rubble stone walls, which for the most part collapsed in place, rather than being thrown over or developing diagonal tension cracks. Double wythe walls failed from the collapse of one or both wythes, in part from the outward pressure from the shaking down of their rubble cores. This can explain the frequent incidence where roofs were found to remain in place, supported by only the wood window frames after the stone walls had collapsed. Had the forces been from the side that caused that much damage, with so little left holding it up, the roofs would have been thrown over.

(3) Based on observations of examples that could be found in and near Uri, on the whole, timber lacing in masonry building construction has proved to substantially reduce the likelihood of collapse, and to leave buildings in a restorable condition that can also, in many instances, be safely occupied in a damaged state. The form of lacing to be found in Indian Kashmir is of two forms: horizontal runner beams in masonry bearing walls, known as "Taq" building system, and timber frames with masonry infill, known as Dhajji Dewari ("patch quilt wall" in ancient Persian). In the damage district of Uri, only the latter system can be found with any frequency, as it is a form of construction still in common use. Generally, despite the fact that the walls are very thin, with only one wythe of brick masonry infilling a light timber frame, these walls have survived well. There are even some dramatic examples where the unreinforced masonry walls below a top floor of Dhajji Dewari have fallen away, leaving the Dhajji Dewari walls hanging in space. (Dhajji Dewari is most commonly used in the upper floors of masonry buildings because it is light enough to avoid the overloading of the walls below.) It was apparent that the failure to use any of these measures in the government complex resulted in the extensive damage there, even though the buildings were far more substantial and costly than the typical building in the market town. Reports on the construction on the Pakistan side of the border, where damage was close to total, are that there was little evidence of similar timber-laced forms of construction.

(4) The absence of wall ties connecting the floors to the walls in almost every bearing wall masonry building was responsible for many of the collapses. In one masonry building in Uri with a rubble stone first floor, collapse was averted despite the widespread failure of the masonry walls probably because of the simple fact that the

joists penetrated the walls rather than simply resting in pockets. This secured the inner wythe of the walls from collapse by maintaining a downward force on it and keep it from overturning or collapsing in place.

(5) Damage on the softer soils of the Vale of Kashmir, some 35-40 km from Uri, was negligible. It is possible that in this case, the soft soils of the Vale further filtered out the higher frequency shaking that would have been more destructive to the short, stiff and brittle buildings found in that area, while the longer period shaking was enhanced - leading to the reports by the people of Baramula and Srinagar that the earthquake to them felt very strong. In the case of one oral report in Baramula, the respondent said he could not remain standing during the earthquake.

Figure 39: Men and boys in *ferren*, the traditional Kashmiri cloak in Dwer Village.

Figure 40: Young many warming his feet on the kongli, the traditional charcoal pot used for winter heating in Kashmir.

Figure 41: The kongli revealed from under the ferren. Despite relatively cold weather, many people wear only rubber flip flops for foot gear.

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