DAMAGE AND REHABILITATION IN AREAS AFFECTED BY THE OCTOBER 8, 2005 KASHMIR EARTHQUAKE, PAKISTAN*

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ABSTRACT: A massive devastating earthquake occurred in Kashmir on Oct. 8, 2005 at 8:50 (3:50UTC) local time of Pakistan. JSCE dispatched its first investigation/ technical support team of four civil engineers to the severely damaged areas in Pakistan by this earthquake during the period from Oct. 24 to 30, 2005 in a close cooperation with the Ministry of Foreign Affairs of Japan and Japan International Cooperation Agency (JICA). This report describes briefly findings obtained through the authors' reconnaissance, highlighting some issues for better rehabilitations.

Key Words: Kashmir earthquake, geotechnical issues, rehabilitations

INTRODUCTION

An intense earthquake (M 7.6) occurred in North Eastern Frontier Area of Pakistan (Epicenter: 34.493°N, 73.629E), about 90 km NNE of Islamabad at 8:28 local time, Oct. 8, 2005. The focal depth was reported to be 26 km (USGS). Earthquakes in the northern mountainous areas of Pakistan and adjacent parts of India and Afghanistan are the result of the movement of the Indian plate subducting north beneath the Eurasian plate at a rate of 40 mm/year (USGS), and. the area affected by this earthquake is a foreland of Hind-Kush ranges including the highest peaks in the world.

Japan Society of Civil Engineers (JSCE), with the approval of the Architectural Institute of Japan, is establishing a non-profit organization (NPO) to contribute to retrofitting and reconstructing of areas affected by natural disasters. Though it is still in progress, JSCE decided that it would dispatch a quick advance team to Pakistan (Oct 24-Oct. 31). The preliminary strategy of JSCE advance team was to make a first reconnaissance laying stress on the damage to dwellings, civil infrastructures etc, and then to discuss with experts from both Japan and Pakistan organizations about better tactics for future collaborations lucrative for both Pakistan and Japanese sides. The organizations include Japan International Cooperation Agency (JICA), Japan Bank for International Cooperation (JBIC), (Japan side) and National Highway Authority (NHA), University of Engineering and Technology, Lahore, etc.

This report outlines the findings obtained through the quick two-days survey and proposals to mitigate earthquake-inflicted losses. Some descriptions in this report are not fully evidenced yet, and therefore, some comments are not yet the conclusions reached after thorough discussions among the

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* Greater part of the report was taken from the Provisional JSCE Report by the authors [1].

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members. However, providing both Japan and Pakistan specialists and persons in charge with a rough-an-ready overview will be important for taking measures for the disaster relief and precautions against possible secondary disasters.

INTENSE SHAKE IN BALAKOT

A SE-NW trending fault system (including Murree and Muzafarabad faults) goes across Muzaffarabad and extends diagonally up to Balakot, while another fault system (including Panjal and Garhiharib faults) goes north up through the valley of River Kunhar. These two fault systems merge at around Balakot (Geological map of Garhi Habibullah Area, [2]), in such a way that valleys and mountain ridges take a sharp turn there. The topographical feature, thus, is similar to that we have in Akaishi Mountains, Japan **(Fig. 1)**, and we will not be able to regard the earthquake as something that cannot happen in Japan. According to Yani Najman [3], these two fault systems make up a wedge. This wedge cuts deep into high-raised mountains of red-purple shale (Balakot formation). Balakot is located at the wedge's northern apex.

There is a NW-SE trending long-bean-shaped hill at northwestern part of the city **(Figs. 3 & 4)**. The hill is independent among the other mountains surrounding the city, and about 700 m long, 300 in wide and 70-80 meters high. It has an asymmetric transverse cross-section (elevation) with a steep cliff on its NE side, and a gently dipping slope on the other SW side. One of the most spectacular aspects of the earthquake effect to Balakot was that almost all houses covering the SW-dipping gentle hillside were completely flattened **(Fig. 4)**. Seriously damaged area including this hillside seemingly extends belt-wise from NW to SE crossing River Kunhar. The contrast between the belt and other areas was clear **(Fig. 2)**.

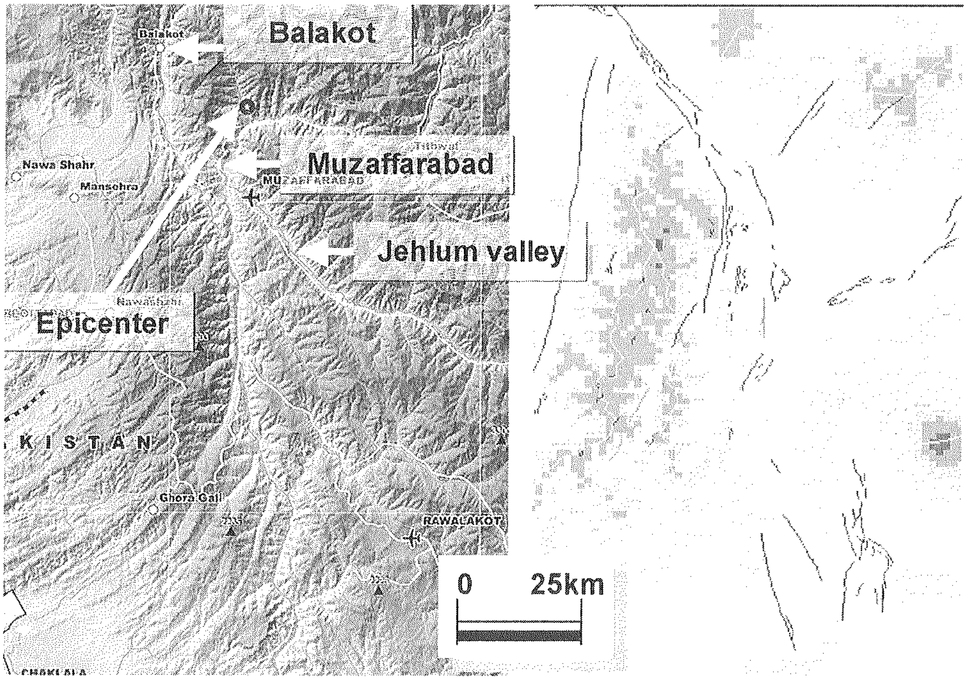

Fig. 1 Topographical Similarity between the affected areas in Pakistan (left) and Akaishi Mountains in Japan (right)

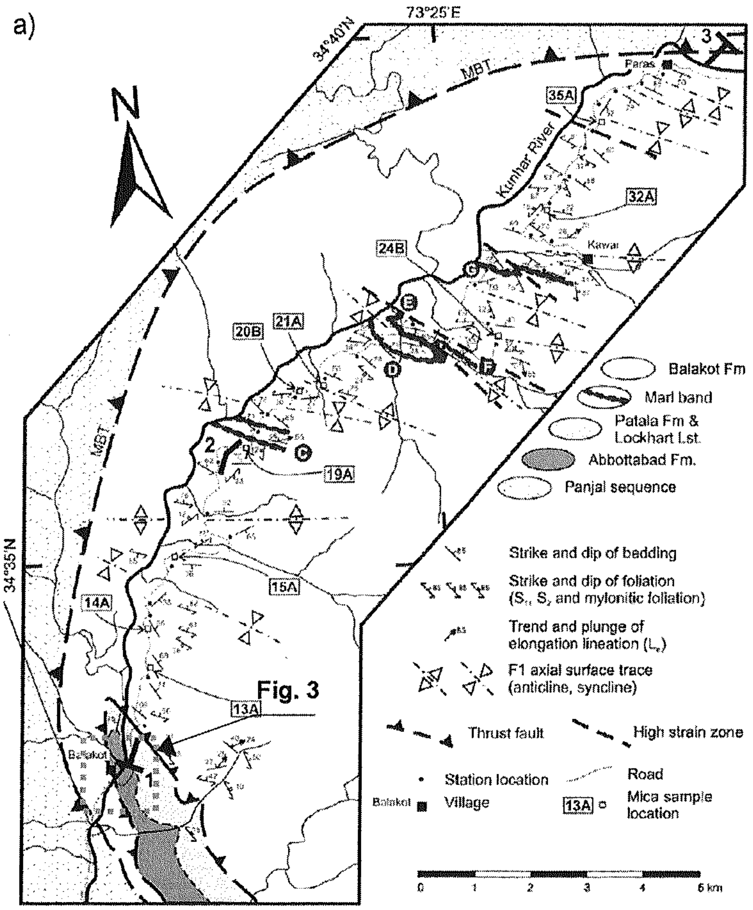

Fig. 2. Geological map of Kaghan Valley, Hazara-Kashmir Syntaxis, Pakistan (after Yani Najman [3])

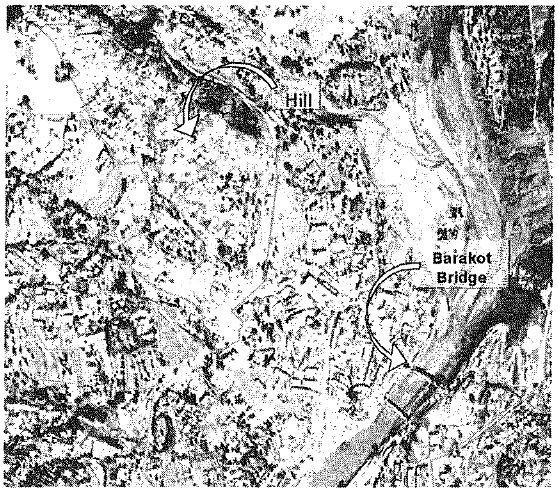

Fig.3. Satellite imagery of central Balakot from IKONOS (UNOSAT: http://unosat.web.cern.ch/unosat/asp/ [4])

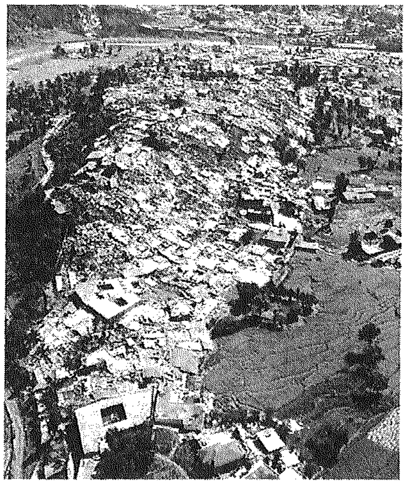

Fig. 4. Long-bean-shaped hill in Balakot: (Yahoo News Photo (Reuters [5]),

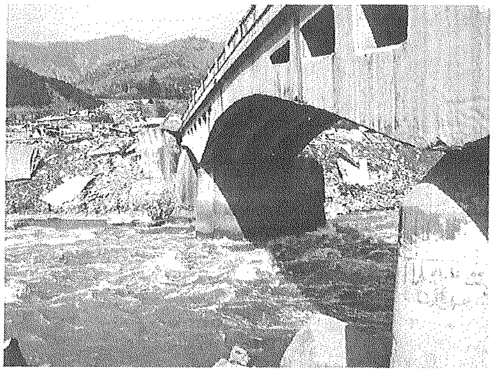

Fig. 5. Balakot bridge of National Route #15: The entire deck moved about 1m downstream side.

Fig. 6, Suspention bridge near Balakot bridge: The right tower was cut off and shifted towards downstream side.

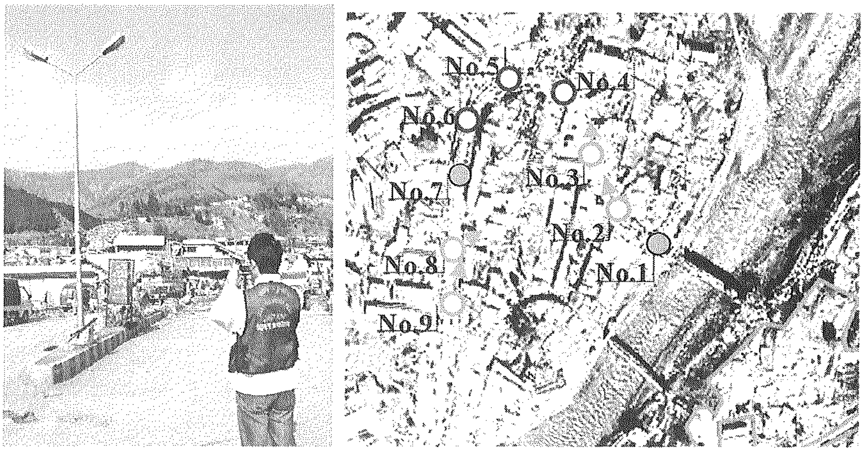

Fig. 7. Location and the inclination of the lampposts (● : sound, ○: shaky, ○→: bent). Arrows show the direction and the amount of the inclination (20degree=1cm). Imagery taken from UNOSAT website (http://unosat.web.cern.ch/unosat/asp/ [4])

There are two bridges within this belt, Balakot bridge of National Route #15 (3-span RC arch, Fig. 5) and a pedestrian suspension bridge about 100 m downstream side (**Fig. 6**). The entire deck of the Balakot bridge shifted over its two piers about 1m from north to south downstream side and a half meter towards the left abutment. The right masonry tower of the suspension bridge suffered a clear cut off at the level of 2m above the riverbed, and moved about 1m towards downstream side. Both clearly show that the shake there was very intense in NS direction, the direction in which the seismic soil wedge is pushed.

Measuring traces of strong ground motions remaining in structures, which are seen everywhere and have common features, will provide useful information for discussing shakes at particular areas. In our short preliminary investigation, only the direction of strong motion was estimated by measuring inclinations and directions of the inclined lampposts. We took total 9 lampposts lining Route #15 (**Fig. 7**). Two lampposts (1, 7) were standing almost upright and slightly damaged. Three lampposts (4, 5, 6) had screws broken at their base plates (22.5cm×22.5cm) and stood loose. Four lampposts (2, 3, 8, 9) were bent at their toes and inclined north. All these show that the ground motion was strong in NS direction.

Fig. 8. Terrace slope northeast of Balakot bridge

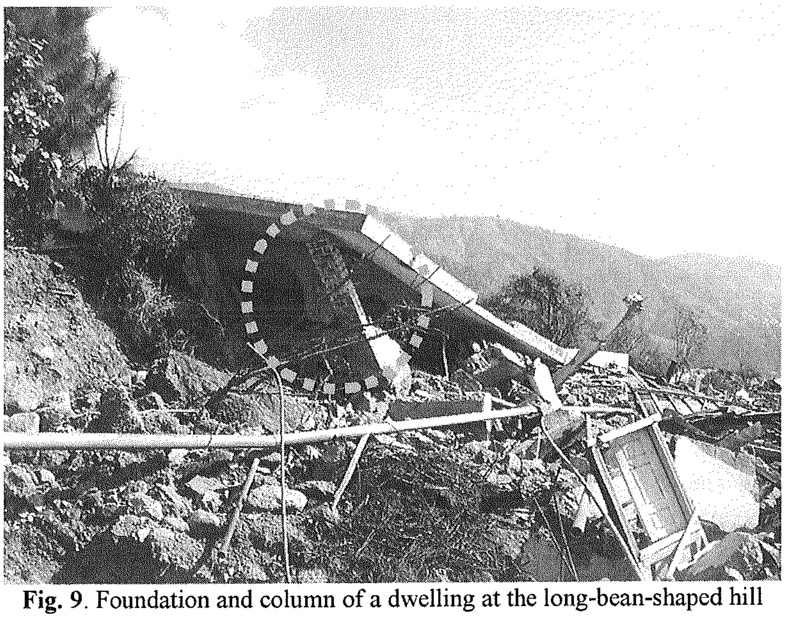

Fig. 9. Foundation and column of a dwelling at the long-bean-shaped hill

SOIL FOUNDATION PROBLEMS

Walls of structures are mostly made from cement sand blocks. Roofs are made from RC slabs. Almost complete collapses of these structures were often found on sloping grounds. These houses were attached to each other. When one house anywhere on the slope collapsed, it triggered the collapse of the others in domino-like manner and the result was the collapse of entire houses. Half-detached or completely detached houses also suffered cracking, but there were some narrowly escaped from complete collapse.

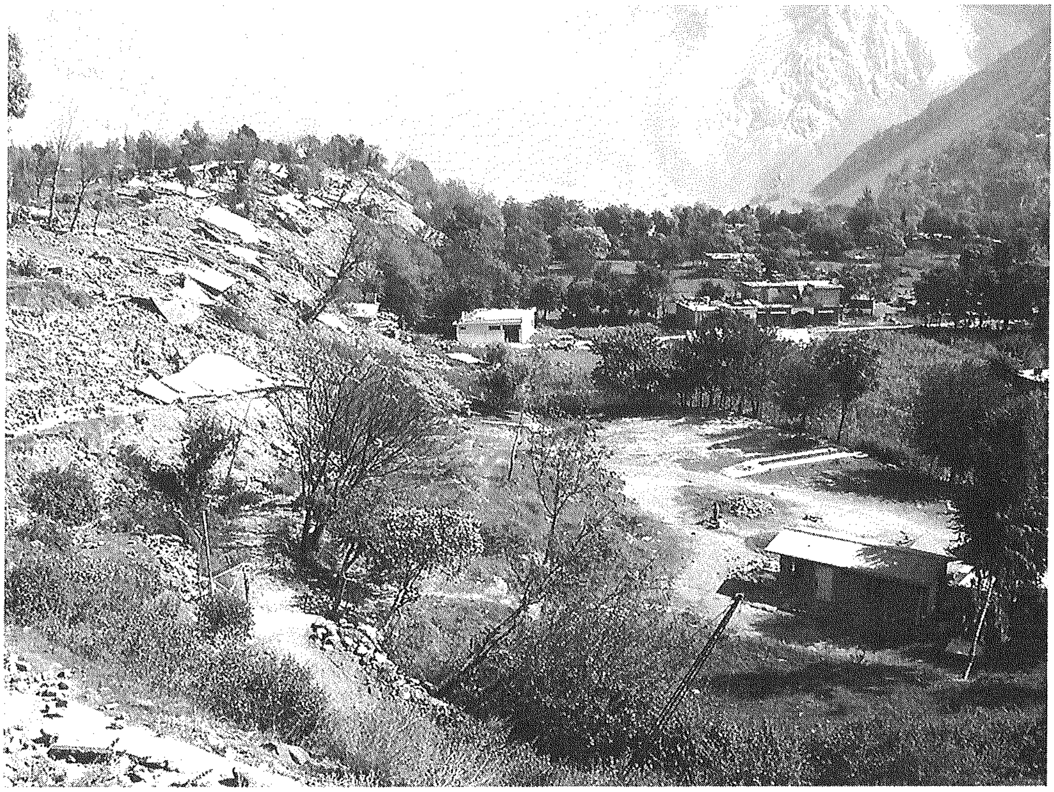

Fig. 10, Houses along terrace rim and those on flatland, north of Muzaffarabad

Hills and terraces near the northern end of Balakot basin are composed of either highly weathered sand rock or conglomerate of rounded to sub rounded boulders, cobbles, gravel, sand, silt, clay and other suspended matters that the glacier (or River Kunhar) have carried over centuries (See **Fig. 8**). They are heterogeneous in nature. Foundations of buildings on these terraces may have not been properly designed. **Fig. 9** shows a foundation found in the rubble covering up the entire slope of the abovementioned long-bean-shaped hill. The foundation was lying on the sandy slope surface with its column-foundation joint intact, indicating that the foundation didn't suffer any cracking but the foundation lost its soil support. A similar pattern of damage was also found in Muzaffarabad **(Fig. 10)**. Houses along the rim of the terrace were completely destroyed, while those on the flat land are seemingly standing upright. Soil cracks were visible along the rim.

LANDSLIDES

A white landslide belt extends straight from Muzaffarabad to Balakot. According to the Geological map (Geological Survey of Pakistan, 2004), this belt coincides with the Paleocene rock layer appearing directly above the Muzaffarabad fault. The rock is rich in limestone and calcareous shale, and they are noticeably weathered. A massive landslide occurred over about 1 km distance along the west mountainside rising northeast of Muzaffarabad. Cone-shaped piles of white/gray debris cover the mountainside (Fig. 11). These cones have roughly three different stripes of color (white, light gray and gray from the top to the toe) reflecting the effect of segregation. Since that slope was inaccessible, the angle of repose was estimated using a laser theodolite and satellite imageries of the area. The angles suggest possible travel distances of debris.

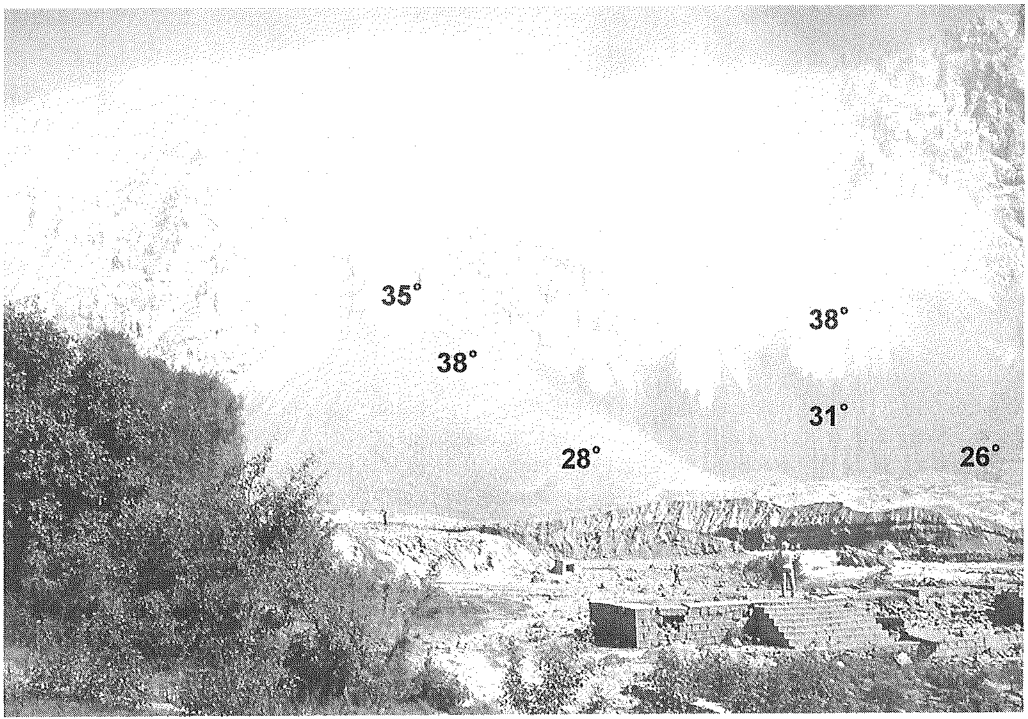

Fig. 11. Massive cliff failure (Muzaffarabad): Angles of repose were measured.

RECOMMENDATIONS

Soils, foundations and dwellings

1. There is a need to study engineering (physical) and geological features of soils and rocks of mountains existing in the affected areas for rational measures to stabilize slopes.
2. Where possible, two or more storey structures should be constructed on piles. Where not possible or difficult such as on slopes, shallow foundations can be used if they are properly designed to withstand/resist differential settlement. Providing a connecting beam on or slightly below the ground level can reduce the effect of the differential settlement.
3. Frame structure buildings consisting of RC columns, beams and slabs will be more resistant. Alternatively, if affordable, steel frame structures will definitely be more resistant.
4. If possible, houses on slopes should be kept detached from each other.

Roads and transportations

Short-term measures:

1. Satellite and/or aerial photographs will provide useful information about geotechnical hazards along major roads. Extracting high-risk points, quick and thorough investigations are to be conducted at these high-risk points.
2. Unstable soil/rock masses remaining above the road are to be removed. If impossible, a possible travel distance of landslide mass/debris is to be estimated. Existing debris deposits will give an important hint.
3. If road is to be constructed over debris deposits and/or landside masses, stabilize them. When a meandering river erodes the toe of a landslide mass, the toe must be protected by putting gabions etc.

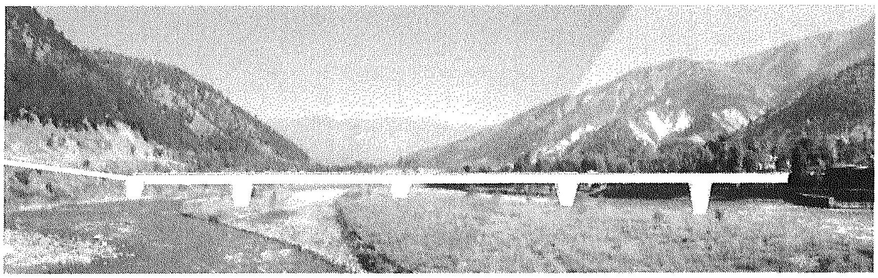

Fig. 12 Idea for enhancing redundancy by constructing bypass

Long-term measures:
Long-term measures will be expensive, but surely reduce the maintenance costs.
Connecting existing roads point-wise by constructing new bridges etc, a cost-effective bypass can be constructed allowing bi-directional traffic to be realized. One of candidate sites for Balakot can be approx. 4km south of the city (**Fig. 12**). Realizing a smooth traffic would make people to migrate easily, and new colonies will be formed.

Hierarchical operation for on-demand delivery

The reconnaissance team members observed refugees in both Balakot and Muzaffarabad making long lines for rations by the army, volunteers and/or NPOs (**Fig. 13**). At the same time, unnecessary goods had been thrown away (**Fig. 14**). This shows the mismatch between supplies and demands on the rescue goods. Also, the spontaneous delivery of the rescue goods made people stand in the line and waste time for the goods, which are possibly of no use. Relief goods have been dispatched from Islamabad to the damaged area mainly by small trucks. This results in a severe traffic jam. (On October 11, it took about 5hours from Mansehra to Muzaffarabad).

Here follows a proposal for hierarchical operation for on-demand delivery.

General rules
a) Urgent relief goods should be delivered within 24 hours
b) Operation center of the relief goods is to be set up. --- Big city without severe damage (can be far away from the damaged site)
c) Information sharing will be realized using wireless communication tools.
d) Relief goods without absolute urgency should be kept in satellite cities with slight damage and systematically delivered to the damaged area. (Spontaneous delivery is the worst.)

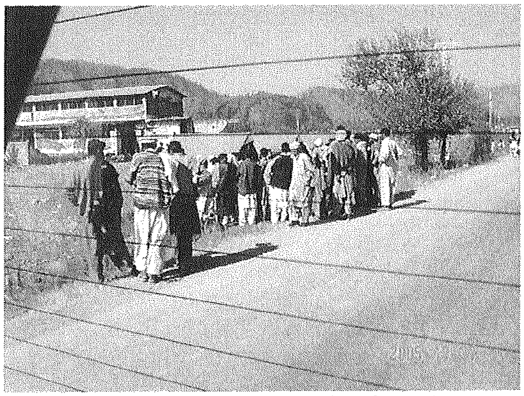

Fig. 13. Refugees gathering for ration

Fig. 14. Cloths thrown away

Typical procedure

1) ---(Operation Center)--- Roughly estimate the total amount of the urgent relief goods (drinking water, snacks, etc.) based on number of people in the severely damaged area.
2) ---(Operation Center→Damaged Area)--- Deliver urgent relief goods within 24 hours.
3) ---(Operation Center)--- All relief goods should be sent to the operation center first and the database of these goods should be built up.
4) ---(Damaged Area)--- When urgent relief goods are distributed, a database of people who came up to receive the goods should be built up. (photographs, names, number of people in a family, injury, etc.)
5) Establish communication: (damaged area) ⇔ (satellite cities) ⇔ (operation center) using i) mobile phones, ii)communication satellites, iii) ad-hoc wireless communications.
6) ---(Damaged Area)--- Collect information of needs of refugees and reflect it on the database
7) ---(Operation Center)--- Distribute relief goods to the satellite cities (using vehicles with large capacity) based on the needs on the database
8) ---(Satellite Cities→Damaged Area)--- Relief goods are sent systematically and regularly (using vehicles with small capacity and/or helicopters)

For rehabilitations in Jehlum Valley

Jehlums valley extends northwest to southeast from Muzaffarabad to the border (Line of Control) between Pakistan and India (**Fig. 1**). With gentler and longer mountain slopes on the eastern side of the valley, many small rivers have carried over centuries sands soils and other suspended matters, and eventually Jehlum river has been pushed against the western mountain side, and eroded deep the thick glacier time deposit there. This valley symbolizes the support of Japan for rehabilitation. The Japan International Cooperation Agency (JICA) is providing supports for retrofitting four major bridges in this valley. Japan Platform, a NGOs system realized through an equal partnership among NGOs, the business world and the Japan government, has been undertaking a project supporting Japan camp, a refugee camp in the valley.

Roads

Greater part of the Jhelum valley road is on the western side of the river. Slopes on the western side indicates the outcrops of intercalated shale and sandstone strata, and the strata dips about some 30 to 40 degrees towards the Jhelum river. Layers of shale and sandstone are jointed and rock mass of slopes is blocky. The joints were opened due to the shaking of the Oct. 8 Earthquake with water seeping through the discontinuity network (**Fig. 15**). Therefore, these blocks can be easily toppled and fall down the slope to the river blocking the road, or the entire surface rock mass can topple as a consistent body. Rerouting at some dangerous locations will be necessary for enhancing the redundancy.

Fig. 15. Blocky rock mass along western mountain side of Jehlum valley: Water is seeping through cracks

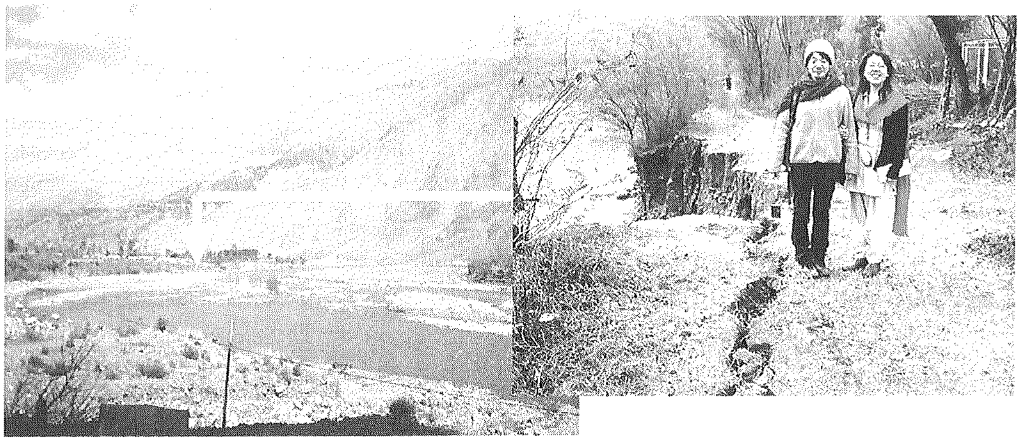

Fig. 16. Japan camp

Japan camp

A huge reddish slip surface of slope failure rises near the Japan camp on the other side of the Jhelum river (left in **Fig. 16**). A possible rockslide however may not be a serious threat to the camp, because strata of the rock seem to be dipping into the mountain, and only shallow surficial slope failures may occur. The water level of the Jhelum River will increase in snow-melting time, and the Oct. 8 earthquake triggered a massive landslide in Hattian. The landslide mass dammed a branch of Jhelum river and a considerable amount of water is now being trapped behind the soil mass posing a threat of flooding. Since the camp spreads over a 10m high terrace over the river, the camp will be hardly covered with water in a possible flood. However the river meanders around the camp and the southern rim of the terrace may collapse due to river erosion (right in **Fig. 16**). From the estimated properties of soil with inclusion of round boulders, it is desirable for refugees to stay at least 5 to 10m away from the rim of the slopes.

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REFERENCES

[1] Provisional report of the damage caused by Muzaffarabad earthquake of October 8, 2005, Pakistan, Advanced Body of the JSCE Reconnaissance Team, JSCE, http://www.jsce.or.jp/report/36/index.html, Oct., 2005.

[2] Geological map of Garhi Habibullah Area, District of Muzaffarabad, Geological Survey of

Pakistan, April, 2004

[3] Yani Najman, Malcolm Pringle, Laurent Godin, and Grahame Oliver: A reinterpretation of the Balakot Formation: Implications for the tectonics of the NW Himalaya, Pakistan, TECTONICS, 21(5), 1045, doi:10.1029/2001TC001337, 2002.

[4] UNOSAT, http://unosat.web.cern.ch/unosat/asp/.

[5] Yahoo News Photo (Reuters), http://news.yahoo.com/news?tmpl=story&u=/051009/ids_photos_wl/r2506774501.jpg