Report on the Large-Scale Landslide at Mt. Bawakaraeng in Sulawesi

JICA Urgent Survey Group
on the Large-Scale Landslide
at Mt. Bawakaraeng

1. Introduction

Makassar (formerly Ujung Pandang) with a population of 1.2 million is a major city located at the downstream of the Jeneberang River. It is prosperous as the gateway to the Island of Sulawesi in Indonesia.

In the midstream area (about 35 km upstream of Makassar) of the Jeneberang River, the multipurpose Bilibili Dam (total storage capacity: 380 million m^3; completion of the dam body: 1999) has been completed to provide benefits to Makassar in flood control, irrigation, and water supply. The current landslide at Mt. Bawakaraeng occurred at the uppermost point of the Jeneberang River about 40 km upstream of the Bilibili Dam. Earth and debris from the landslide buried the valley along the river, causing devastating damage to Lengkese Village (The killed: 10; the missing: 22; damage to houses: 10; damage to public buildings: 1 (school); damage to livestock: 635 (cattle); damage to farmland: 1,500 ha; evacuees: 6,335 at the peak). There is also a concern about the potential effect on the Bilibili Dam, which is an important public structure in this area.

A landslide of this scale was the first experience to Indonesian authorities. Apprehending the potential effect on the Bilibili Dam as well as the occurrence of a secondary disaster, the Indonesian Government sent an official request of technical support (dated April 13, 2004) to the Japanese Government so that urgent measures can be taken. The request mainly consisted of the following three matters.

(1) Dispatch of JICA Sabo (erosion and sediment control) experts to investigate into the behavior of sediment.

(2) Support to the ISDM*[1] project (urgent survey before the next rainy season, technical advice, strengthening of organizations)

(3) Support to urgent measures and permanent measures, including their implementation

In response to this request, the JICA Sabo survey group consisting of five short-term experts was sent to the disaster site in Indonesia from June 20 through 29, 2004. This report presents an overview of the results of survey which was conducted together with long-term experts working on the ISDM project.

○ Members of the survey group

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ISDM*[1] Integrated Sediment-related Disaster Management

Figure - 1

2. Large-scale landslide at Mt. Bawakaraeng

Around 13:30 on March 26, 2004, the inner side of the caldera wall at Mt. Bawakaraeng (elevation: 2,830 m) collapsed on a large-scale in the Province of South Sulawesi on Sulawesi Island in the Republic of Indonesia. An enormous amount of earth and debris ran down the slope and then accumulated for as long as 7 km along the valley. Two collapse areas are found at the source section of the landslide: one is a collapse with a width of 500 m that occurred near Mt. Bawakaraeng (Collapse A); the other is a huge collapse at the ridge of Mt. Sarongan, which occurred in a horseshoe shape for a horizontal length of about 1,300 m (Collapse B). The relative height of the failure slope in both collapses is about 700 m.

From visual observation, it is presumed that the thickness of failed bedrock in Collapse A was approximately 150 m. In the case of Collapse B, considering from the fact that the summit of Mt. Sarongan before the landslide was situated inside the caldera with a horizontal length of 400 m, it is inferred that the thickness of failed bedrock was about 400 m at the largest, and about 200 m on average (the average value is a little larger than that of Collapse A). From this, the amount of collapsed soil is estimated to be approximately 53 million m^3 in Collapse A and about 182 million m^3 in Collapse B, amounting to 235 million m^3 in total.

It is observed that an estimated 5 million m^3 of soil mass, partly covered with vegetation, presumed to have fallen from the source section still remains in the center of the failure slope of Collapse B. This soil mass may lead to a secondary collapse if the lower end of it is eroded and made unstable.

Photo-1

Figure-2

3. Mechanism of landslide and possibility of further failure

The direct cause of this landslide has not yet been identified. There was no conspicuous rainfall on the days preceding the landslide. The cumulative rainfall from March 1 to March 26, on which day the landslide was set off, was 34 mm. Also, the occurrence of an earthquake is not confirmed.

As the mechanical factor contributed to the landslide, three factors can be cited: a large relative height of the side wall of the caldera; fragility of the bedrock of the side wall; and susceptibility to erosion of the accumulated sediment inside the caldera. The weak resistibility to erosion of accumulated sediment induced the riverbed degradation of the Jeneberang River that flows inside the caldera, making the relative height of the side wall of the caldera larger and removing talus accumulation at the foot section. As a result of this phenomenon, the shear force working on the foot of the side wall increased gradually, enabling the development of a slip surface over a long time, which contributed to the occurrence of landslide substantially. As to the failure mode, judging from the fact that the collapsed sediment passed over the ridge having a relative height of 200 m existing in the caldera, it is considered that the landslide movement was not the toppling type in which the head section of a soil mass overturns largely, but the falling of a soil mass with buckling-like rotation after the bedrock had failed at the bottom of the slope.

Collapsed sediment moved down the slope in the fluid state and accumulated for a length of about 7 km and a width of 500～800 m along the valley. Within the caldera, collapsed sediment flowed down and accumulated rather linearly along the Jeneberang

River. Outside the caldara, collapsed soil also flowed down along the river, with part of it running onto the terrace right below south of Panaikang Village. One of villagers who heard the rumbling sound of the landslide remembers the time when it occurred and the time when the sediment reached around the terrace. He says the time lag was just three minutes. As the distance from the collapsed point to the terrace area is about 6 km on the topographical map, the flow velocity is calculated as 33 m/s. Because the flow is not always straightforward, the flow velocity could be around 30 m/s, which is still a very high speed. In view of the fact that sediment stuck to the slope surface above the accumulated plane when it bumped against the hillside, and that the surface of the sediment immediately after its accumulation was still quite hot (hearing from local people), it is known that the collapsed sediment flowed down as a debris flow while engulfing air.

A pool of water is formed at several locations within the caldera and at both ends of the accumulation area. The biggest of them, about 200 m wide and 300 m long, is located within the caldera.

The rock slope where the landslide occurred has not yet stabilized, with separation and fall of small-sized rock masses occurring constantly. It is judged that fallen rocks and debris are forming a talus around the foot of the slope surface. Also, unsteady rock masses that did not fall and those that fell from the upper ridge but did not fall further, are found on the slope. Therefore, it is still dangerous to come near the foot of the slope. According to local people, a difference in the ground level accompanying a large crevice existed around the ridge even before the occurrence of the landslide. From these situations at the site, the possibility of further collapse cannot be ignored.

4. State of sediment discharge

Nearly three months have passed since the landslide occurred on March 26 this year. In Indonesia, the dry season continues from March to October. The total rainfall during the three-month period observed at Malino, a rain gauge point closest to the failure site, was 388 mm, with no major rains. Even the rainfall exceeding a daily rainfall of 30 mm occurred only three times. However, the collapsed soil accumulated on the upstream of the Jeneberang River has already been eroded for 50～150 m in width and for 30～80 m in depth, forming a valley-like topography (Photo-2), and the erosion is considered to advance further. In addition, as this erosion valley is zigzag-shaped planarly, it will be severely eroded by a debris flow if a large-scale flooding occurs. Therefore, it is judged that a large amount of sediment discharge will be unavoidable when the rainy season comes in November.

It is estimated that the amount of sediment discharge up to mid-June, 2004 was approximately 14 million m^3 from the visual observation and a topographical map reading of the erosion valley. In the case of a sediment movement like the current case that occurred as a result of a large-scale collapse, sediment discharge is considered to decrease exponential-functionally as times passes. However, a continuous survey is needed.

Photo-2

5. State of river course in the downstream

Six sabo facilities are situated along the river course of the Jeneberang River between the collapsed site and the Bilibili Dam, but they are all filled up with sediment. Especially, a large amount of sediment is temporarily accumulated at a sabo facility, 400 m wide, located at the downstream of the confluence point with the Malino River as well as in the river course above this facility. This indicates that a sediment control function and a river course adjustment function of the sabo facility are duly performed. The sediment overly accumulated in the river course is now being eroded (Photo-3), but no major indication of sedimentation is visible at the lower end of the reservoir of the Bilibili Dam. However, the Bilibili Dam that had been clear with blue water is now turbid with suspended sediment.

Photo-3

6. Planning of urgent measures

The sediment generated at the collapsed site on Mt. Bawakaraeng is forecasted to move out in about five years from now. It is feared that the discharge of this sediment will have serious effect on houses, agricultural land, public facilities, not to mention the serious degradation of functions of the Bilibili Dam which is indispensable for the development of the Province of South Sulawesi. To cope with this situation, the survey group has proposed a plan for implementing urgently-needed measures (an urgent measure plan) for a period of five years from 2004 to 2008.

As the time is very limited until the rainy season comes in November, the executable structural measure (hard measure) in this period is the removal of sediment that has been accumulated above six sabo facilities along the river course in the section between the collapsed site and the Bilibili Dam. As the mid- to long-term measures, repair of damaged sabo facilities (Photo-4), rise of sabo dams, and construction of new sabo dams, are considered. It is also necessary to take measures to prevent the failure of a large pool of water located in the caldera, but it must be commenced after sufficiently confirming the safety of work, because there is a possibility that part of the caldera wall may fail.

As the urgent non-structural measures (soft measure), rather than the introduction of highly advanced equipment, the following measures are considered appropriate: the development of a visual observation system making use of human resources; telemetering of a rain gage presently installed at Panaikang; and the establishment of a communication system to convey information to local people and NGOs by way of provincial and prefectural governments and others.

As the mid- to long-term measures, it is necessary to install rain gages not only at Panaikang but also around the caldera, to strengthen a warning and evacuation system, and to carry out a detail survey for identifying villages and houses having a small relative height to the riverbed in the downstream of the Jeneberang River.

Photo-4

7. Concluding Remarks

When our urgent sabo survey team visited Sulawesi for the survey of possible countermeasures against a large-scale landslide at Mt. Bawakaraeng, we had an opportunity to meet with Vice Governor of the South Sulawesi Province, Governor of Gowa Prefecture, and people of the Jeneberang Sabo Community (Komunitas Sabo Jeneberang). Through this opportunity, we felt keenly that local authorities have a deep concern over the effect on the Bilibili Dam due to the current landslide, and that local people are waiting for the earliest possible recovery and restoration as well as having a large expectation towards the technical support from Japan in the field of sabo (erosion and sediment control). The meeting with the Governor of Gowa Prefecture was reported in the local newspaper "South Sulawesi".

We would like to express our sincere thanks to the cordial support and cooperation during our field survey extended from the Provincial Government of South Sulawesi, Gowa Prefectural Government, Jeneberang River Project Office, Indonesia STC (sabo

technical center), Dr. Agnes at Hasanuddin University, and others. We truly hope that the proposed urgent measure plan will be implemented as early as possible so that the safety of the people and revitalization of the affected area are ensured very soon.

Photo-5

Photo-6

Figure-1 Mt. Bawakaraeng in Indonesia

Photo-1 Collapsed area seen from the ridge of caldera on the east side

Figure-2 Large-scale landslide at Mt. Bawakaraeng and the accumulated area of unstable sediment

Photo-2 Erosion at the accumulated area of collapsed sediment (sediment was accumulated after going over the plateau (Panaikang) in the back of photo)

Photo-3 Sediment accumulated in the river course.

Photo-4 Sabo facility damaged by flooding

Photo-5 The inauguration ceremony of the Komunitas Sabo Jeneberang (Jeneberang Sabo Community) being held by local people. Persons up to the fifth from the left are the members of the JICA sabo survey group.)

Photo-6 Visit of the JICA sabo survey group was reported in the local newspaper. (The JICA group paid a visit of respect to the Governor of Gowa Prefecture in the disaster-affected area.)