II-28 FIELD OBSERVATION ON LOCAL SCOUR AROUND BRIDGE PIERS AT SHIMANTO RIVER

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1. INTRODUCTION

Bridge scour is a natural phenomenon that occurs when river morphology is changed or when an alluvial channel is partially obstructed, mainly as a result of human impact on the environment. Because of its influence on the design of the bridge and its foundations, scour has been discussed widely. It can be classified such as general scour, contraction scour, and local scour. The first case occurs independent of the existence of the bridge. The second and the third arise as a consequence of the bridge foundations (piers and abutments), which cause changes in the flow pattern accelerating the flow and inducing the formation of vortices at the rear of the structures when the flow approaches it. As a result, the shear stress distribution around the foundation increases, what leads to a scour process. Local scour has, as the main characteristic, the occurrence of a scour hole upstream of the foundation. Basically, there are two conditions to local scour: clear-water, and live-bed scour. Clear-water occurs when the material of the riverbed upstream of the foundation does not move, but the vortices resultant of the existence of the structure lift and drag the material at the pier base. As for live-bed scour both the material upstream of the foundation and at their base is forced to move (Breusers and Raudkivi, 1991). Therefore, the more is known about scour the better a countermeasure can be provided. In this paper, a scour process that has been developing at the piers of the Shimanto River Bridge (on Shikoku Island, Japan) is analyzed and discussed through a survey carried out at the site, and through previous record. In addition, an approach for prediction of scour depth is presented.

2. SHIMANTO RIVER ENVIRONMENT AND BRIDGE

The Shimanto River is the longest river on Shikoku Island, Japan. It has about 300 tributaries and flows down about 1,200 m from the south flank of the Mt. Irazu, in Ehime Prefecture (height of 1,336m) to the Pacific Ocean at the Tosa Bay in Kochi Prefecture. The drainage basin area of Shimanto River is 2,270 km^2, of which 90% is located on mountain region (Fig. 1). As a mountain river, it slopes steep, has a sand-gravel bed, and a wide range of grain size, suitable for the development of a clear-water scour process when a obstruction is installed on its way (Simons and Senturk, 1992). The climate surrounding Shimanto River is warm and the area has become a rainy zone due to typhoons. The area around the bridge has been flooded almost every year causing damage and human losses. The annual mean rainfall is around 2,700 mm, which exceeds the nationwide mean 1,800 mm. The annual mean flow is equal to 125.00 m^3/s, but varies according to the years. When the total annual rainfall is around the average, the mean discharge is equal to 43 m^3/s, but during the dry season it reaches 23 m^3/s.

Shimanto River Bridge

The Shimanto Bridge is a pillared truss iron bridge located in Nakamura City, at 9.5 km upstream the estuary and is used as a road, linking two sides of the city. It is 700 m in length and is underlain by 13 cylindrical shaped concrete group piers (eight are thick and are located inside the main river channel, five are thin). From the left side bank they are named as P1 to P13. The span between each pile is about 55 m. The piers are formed by joining two cylindrical piers at their base and at their top.

Figure 1. Shimanto River drainage basin.

3. FIELD WORKS

In order to find out the actual conditions of the Shimanto River bridge foundations, an investigation was carried out on July 17th, 2001. At first, the conditions of each pier foundation was verified, what showed that most of them have been partially unearthed, creating a wide hole at the rear, right, and left sides of the piers. In addition, the piers sediment mounts were also found downstream. In fact, a continuos process of degradation and agradation, as displayed on Fig. 2, has affected the area around the bridge.

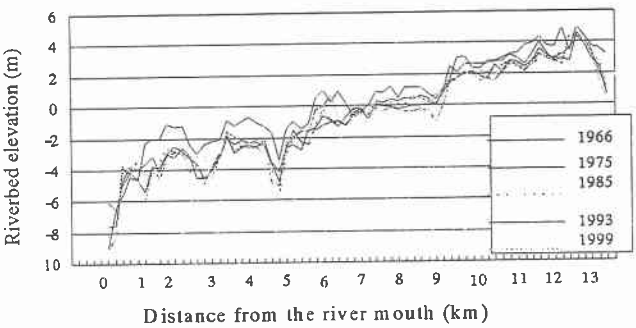

Figure 2. River bed elevation from the river mouth.

In order to determine countermeasures against the scour process, some data such as width and shape of pier, size of the bed material, and sediment size distribution were collected. At first, shape and size of the piers were measured. Then, in order to do sediment grading some boring were accomplished. Of these, one hole was dug 20 m upstream the centerline of piers 4 and 5 (P4, P5) and one downstream of the center line (Fig. 3).

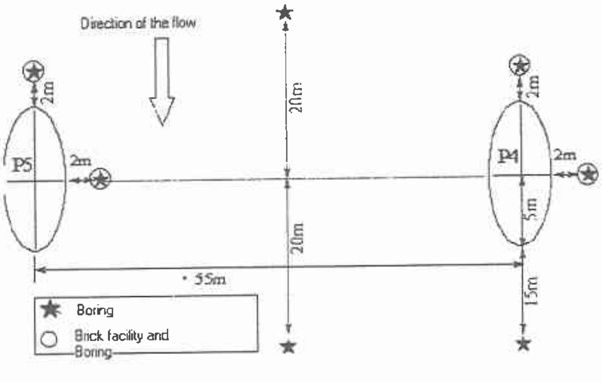

Figure 3. Location of the borings

The sediment particle of the boring was collected from two different layers of the riverbed in which larger particles such as graves varying in size from 10 to 20 cm were encountered crating an armoring layer. It arises as a result of the degradation and aggradation process. In previous measurement, a deep hole in between piers 6 and 7 (P6, P7) was discovered. In this work, an observation was conducted by using a robot, equipped with a video camera and other apparatuses for measurement enabling us to draw the shape of the scour hole and to measure the depth of its. Based on these and previous data a cross sectional shape of the riverbed at the site was depicted (Fig. 4). Although the hole has reached a deep stage, almost 10 m at the deepest point, the film from the robot showed that the foundations of P6 and P7 are up to now, out of risk.

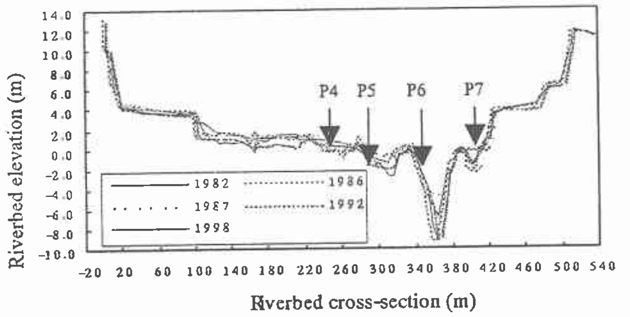

Figure 4. Riverbeds cross-section at 9.5km upstream of river mouth.

Because of the process of settling down of the suspended sediment inside the scour hole after flooding, scour hole depth is an information very difficult to be measured. In order to overcome this problem, a new approach for determining the scour depth was attempted through the installation of numbered bricks in the holes at the rear and left side of piers P4 and P5 (Fig. 4). The bricks have a fixed dimension, therefore, whenever floods occur washing away the bricks at the foundation, one may know the real depth of the hole by the number of bricks that were lifted-up. This technique proved to be valuable on September 14^{th}, 2001 when a flood occurred and submerged an entire area of river. An inspection on the following day showed that no signal of scour was seen around P4. On the other hand, a scour hole depth of 40 cm deep was found at upstream of P5, having the water flow washed away one of the bricks. Considering that it was a small scale-flooding event, a large-scale would scour much more.

4. CONCLUSION

In summary, a survey carried out at the piers of Shimanto River Bridge showed that most of the pier foundations have been seriously scoured along the time. The eroded sediment formed layers of different sizes and shape, mostly gravel type. A deep hole in between two of the existent piers is putting in risk the whole structure of the bridge. Finally, the brick facility has proved to be a promise toll for predicting scour hole depth.

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