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Trial construction of the reinforced river dike and its performance

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ABSTRACT: As a new application of the reinforced soil, a method called reinforced river dike is proposed. In order to establish a design and construction method for the proposed reinforced river dike, a real scale field construction and field monitoring were conducted at Shin-Sakai River in Gifu Prefecture, Japan. Many in situ measurements, which include the pore water pressure within the dike, the water level of the river, the deformation of the dike, and the flow speed of the river, were carried out to clarify the deformation mechanism of reinforced river dike. In the test embankment, some of the filling materials were drawn out in a large scale. Based on the observed data, the reason for the soil draw-out and the corresponding countermeasure are discussed in detail. During a heavy rain from Sept. 11 to 12, 2000, the test river dike with the reinforced soil was immersed with flood. Although the soil draw-out of the filling materials and the considerable deformation of the dike took place, it did not fail in whole. From this experience, the stability of the proposed reinforced river dike is confirmed.

1 INTRODUCTION

As a new application of the reinforced soil, a river dike embankment method with geo-grid reinforcement is proposed. There are some uncertainties in the design concept of the reinforced soils used in the river dike. Such factors as the limitation of the length of geo-grid reinforcement in rive dikes, the quality of filling material, the design the river-water flow speed, the resistance of the front unit against floating logs and boulders, and the plantation on the dike surface for preventing soil draw-out, should be investigated. The design of river dike is actually based on the sophisticated design concept, which provides insight into the failure mechanisms of the dike. The main possible failure mechanisms include: 1) overflowing, 2) piping, 3) sliding of dike slopes, 4) erosion of dike slopes, 5) soil draw-out from the dike, 6) squeezing, 7) seepage, etc.

The main purpose of this research is to establish a design and construction method for the newly proposed reinforced river dike by conducting a real scale field construction and field observation at Shin-Sakai River in Gifu Prefecture, Japan. The test dike has a length of 19.2 m and a height of 2 m with a steep gradient of 2:1. Within the 19.2 m length of the dike, the length of geo-grid, the back-filling materials, the surface-processing materials, and the material of dike wall were changed to investigate their characteristics against the aforementioned problems. Many in situ measurements, which include the pore water pressure within the dike, the water level of the river, the deformation of the dike, and the flow speed of the river, were also carried out to clarify the deformation mechanism of the reinforced river dike. The observed data are explained in detail along with the introduction of the structures of the reinforced river dike.

In the test site, various kinds of filling materials and protect net against the soil draw-out were used. Some of the filling materials were drawn out in a large scale. Based on the observed data, the reason for the soil draw-out and the corresponding countermeasure are discussed in detail.

A heavy rain that broke the local record of history occurred from September 11 to 12, 2000. During the rain, the test river dike with the reinforced soil was immersed with flood. Many measuring facilities flowed away and the top surface of the dike was severely eroded. Although the soil draw-out of the filling materials and the considerable deformation of the dike took place, it did not fail in whole. Based on the neighboring observed data including precipitation data and measurement of river water level changes, the damage process of the dike and its mechanism are explained in detail.

2 RESEARCH METHOD

A research group organized by Maeda Kosen Co. Ltd., Mitsui Chemicals Industrial Products. Ltd., Mitsubishi Chemical Functional Products Inc. Co. Ltd. and Gifu University is working on reinforced

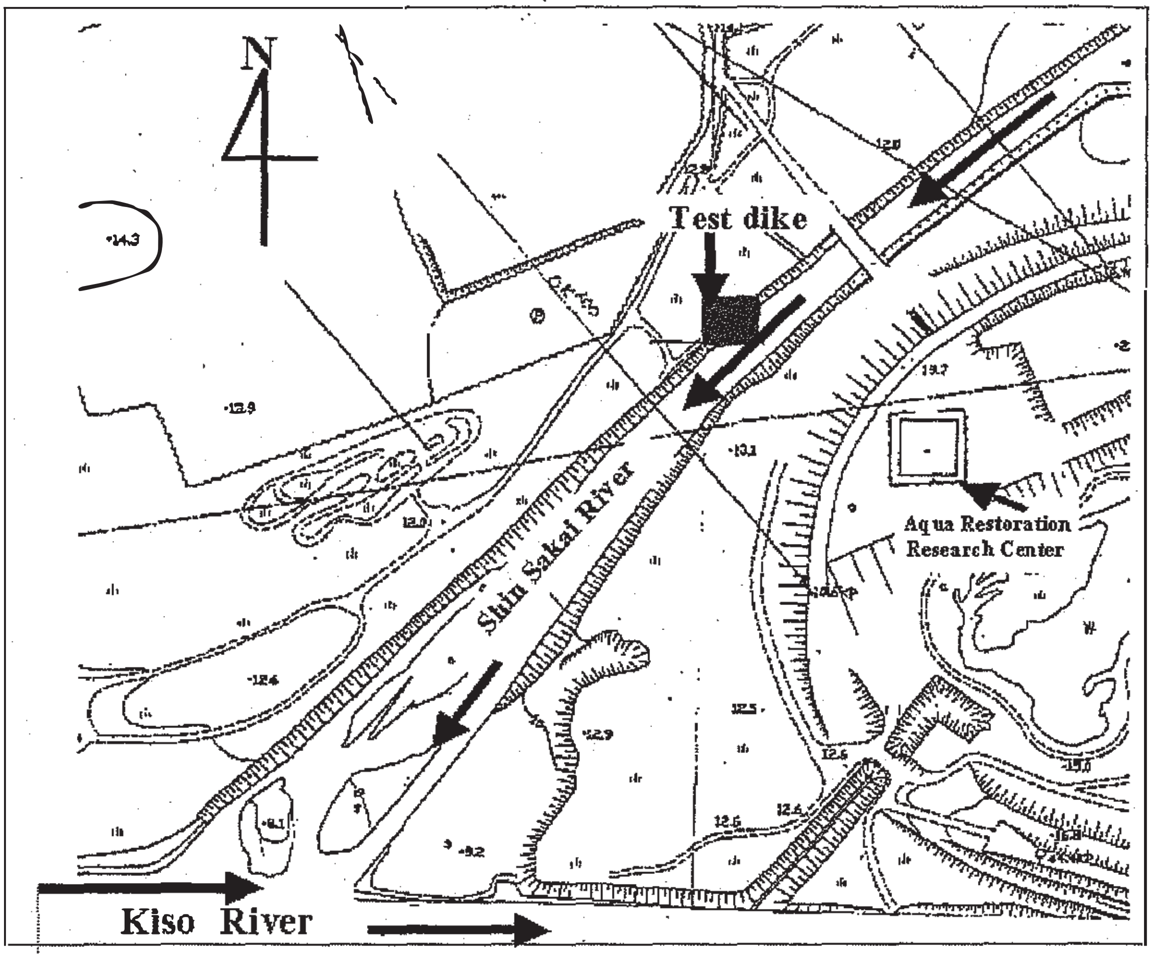

Figure 1. Location of the test river dike.

river dike. (Maeda(2000), Sawada et al.(2001)) In the research project, a real-scale test on the river dike with geo-grid reinforcement was conducted in Shin-Sakai River in Gifu Prefecture, Japan, in order to establish a reliable design and construction method for reinforced river dike, considering there-servation of natural environment. The trial river dike locates at the right bank of Shin-Sakai River with a gradient of 2:1. The location of the test dike is shown in Figure 1. The length of the test bank is 19.2 m and the height of the bank, from the normal water level to the top of the bank, is 2.0 m. It is divided into three sections. Sections A, B and C, are divided according to the different materials of geo-grid, the length and the pitch of the grid.

Figure 2 shows the overall view of the tested river. The river dike is embanked with 1.1 m in depth in Sections A and B and 1.5 m in Section C. The lengths of geo-grid are arranged in the same as the embanked depths in Sections A, B and C. The back-filled materials of the dike are sand above water lever and gravel beneath the water level. The tensile strength of the geo-grid is about 35 kPa. There is a metallic cover grid on the dike slope, taking a L-shaped structure whose gradient is the same as the

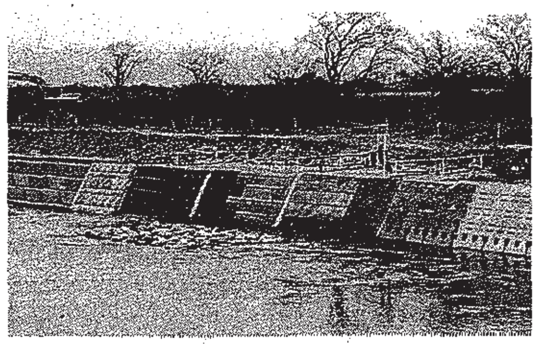

Figure 2. View of the tested river dike.

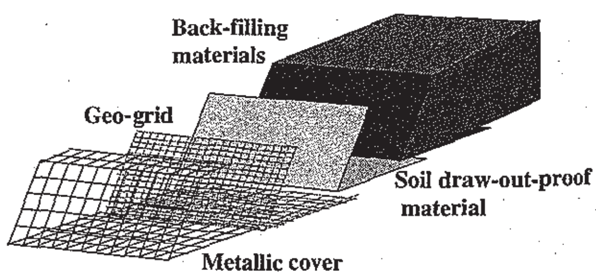

Figure 3. Construction of river dike embankment.

dike, that is, 2:1, as shown in Figure 3. Figure 3 shows the metallic cover, the geo-grid, the soil draw-out-proof material and the back-filling materials. In order to investigate the effectiveness of the coating used for the metallic cover, two kinds of coating, that is, electronic coating and PE (Polyethylene) coating are used. Because the main attention is paid to the deformation of the dike, various measuring instruments are installed to measure the deformation of the surface of the dike and the failure mechanism of the reinforced soil dike. Figure 4 shows the outlet of the measuring instruments and the dike composition.

3 MEASURING RESULTS AND DISCUSSION

The field measurements started on February 26, 2000. The measuring items are listed in Figure 4, which include the pore-water pressures in Sections A and B, water levels of the river at Sections A and C. The measurement stopped on September 12, 2000 due to a heavy rain during which the measuring instruments flowed away. From the observed data, which include the horizontal displacement of the dike, the pore-water pressures within the dike and water levels of the river and ground, it is found that those data are co-related to the change of the temperature to some extent. Therefore it is necessary to remove the influence of the temperature in processing the data. By adopting a filter which can remove the one-day-cycle change in temperature, the high-frequency variation existing in the observing data can be clearly removed, as shown in Figure 5.

From the observation, it is found that the deformation mainly occurred during the first three months, that is, from February to May.

After May, no remarkable deformation was observed. The deformation is considered to be the compression of the dike itself. As will be discussed later, the self-compression of the dike was finished around in September when the dike was fully immersed in water because of the flood caused by the heavy rain. The dike itself, however, did not fail anymore.

4 RESULT OF ELECTRO OPTICAL DISTANCE MESUREMENT AND ITS ANALYSIS

The deformation of the reinforced river dike was also measured with electro optical distance technique on April 6, May 18, July 4 and November 6, 2000. The deformations of reinforced soils and concrete-retaining sheets were measured by using bar-shaped targets inserted in the dike.

From the measured horizontal displacement of Section A, it is recognized that the dike tends to move towards the river. The reason is that the newly constructed dike is not stable and easy to be affected by the water flow of the river and the underground water within the dike. Furthermore, settlement was also observed in Section A. The horizontal displacement and the settlement in Sections B and C are not so large as compared to those in Section A. Similar results are also obtained from the measurements with usual measuring instruments.

5 SOIL DRAW-OUT FROM THE DIKE

Since the beginning of the measurement in April, the water level experienced several big changes that resulted in a maximum value of several 10 cm of

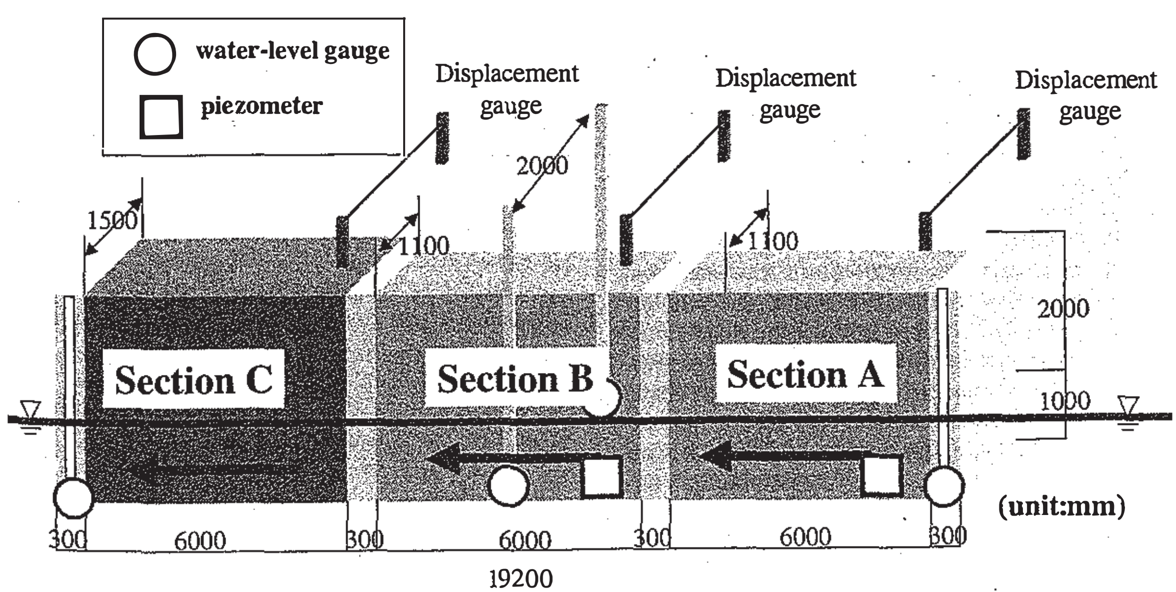

Figure 4. Position of measuring machine and outline of facility.

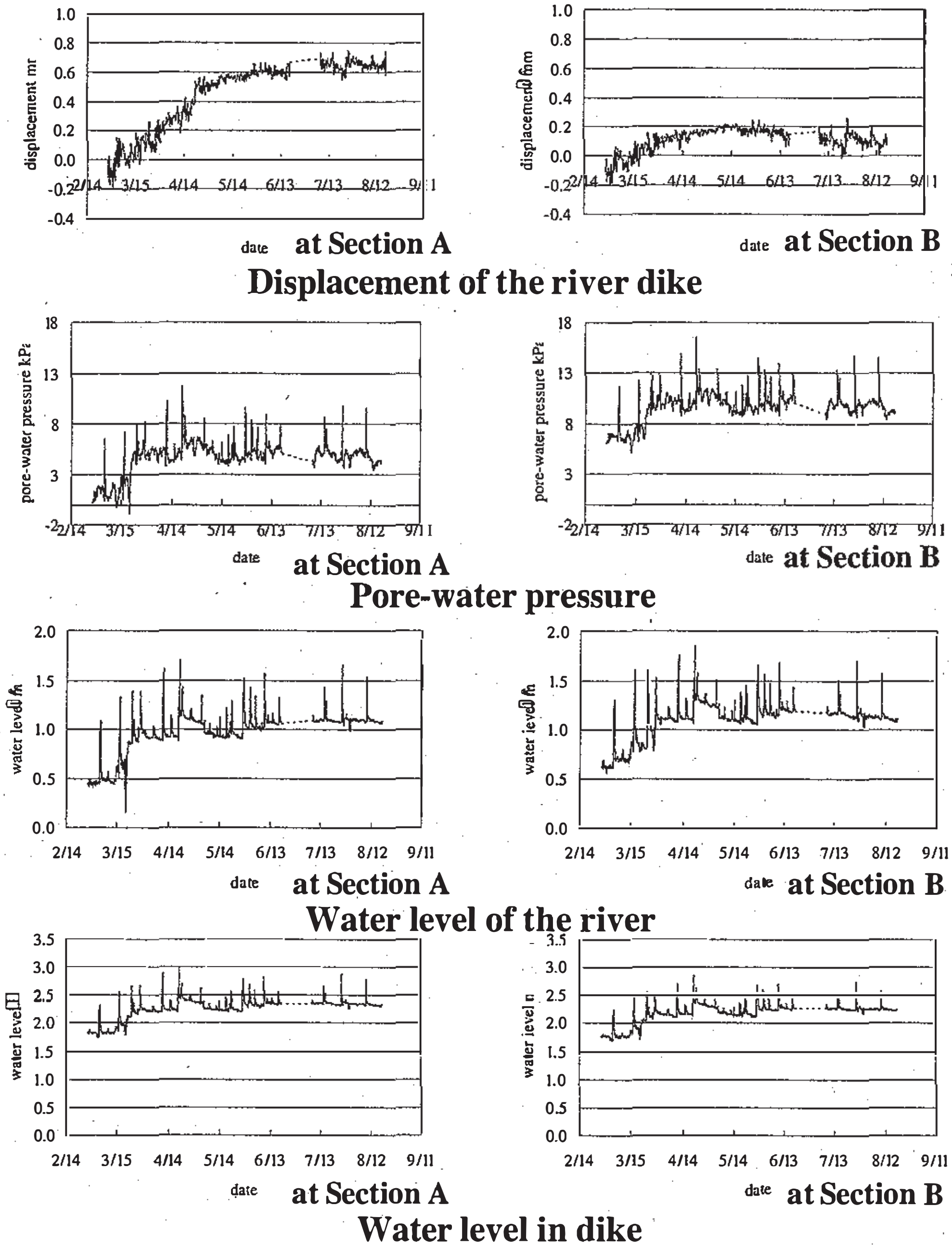

Figure 5. Results of various measurements of the river dike.

draw-out of filling materials from the slope surface of the dike. In order to investigate the situation of the draw-out, a frame with 10×10 cm grid was laid on the dike surface and the depth of the draw-out at every cross was measured by inserting a bar perpendicularly to the frame. It is found that serious draw-out occurred at the downstream side of concrete retaining sheets. The maximum values of the draw-out at Sections A, B and C are 55 cm, 45 cm and 65 cm, respectively. Figure 6 shows the distribution of the draw-out in each section. The reason why such a phenomenon occurred is that the resistances of the concrete retaining sheets and the dike surface are quite different and consequently a turbulent flow happened at the downstream side of the sheet, resulting in the draw-out. Especially in Section A where a larger draw-out occurred as compared to the other two sections, the pipe was installed for setting up the measuring instrument at the concrete retaining sheet, which results in a large turbulent flow. In other wards, if any extruded part of a structure exists, a turbulent flow will happen behind the extruded part, resulting in the draw-out of the materials.

Meanwhile, at the boundaries between different cover materials of the surface, a relatively larger draw-out was also observed. The reason is thought

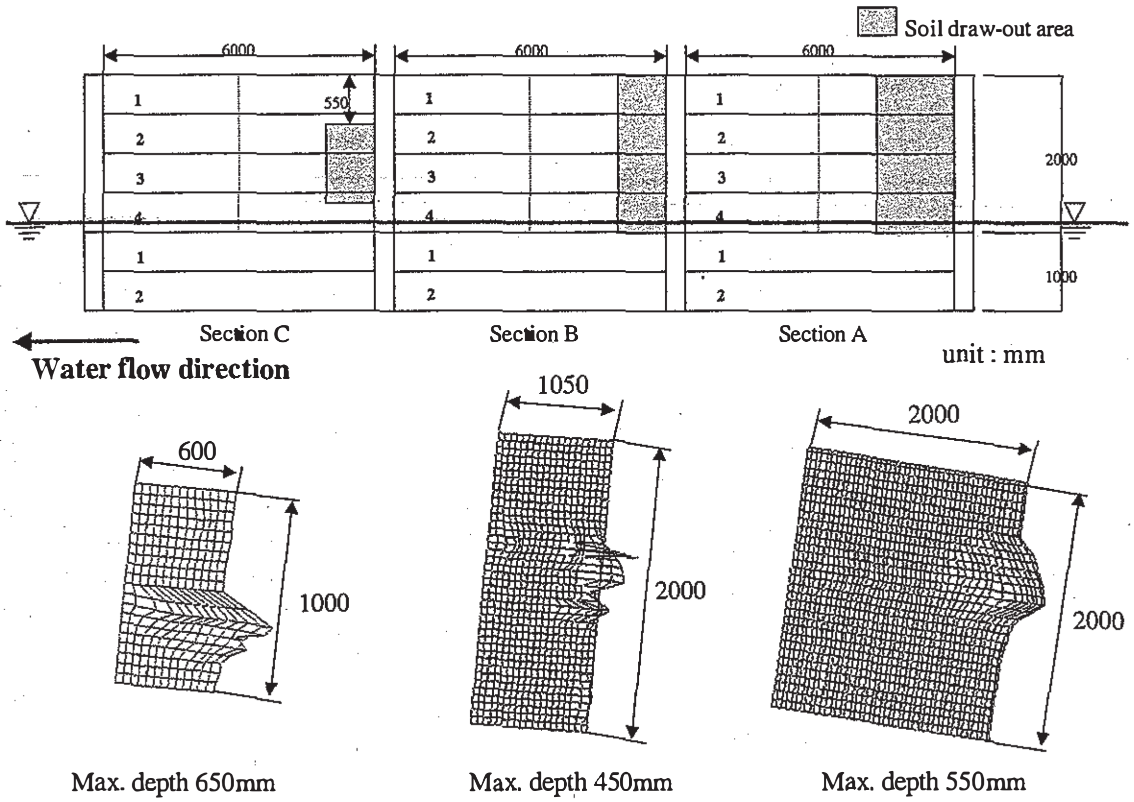

Figure 6. Soil draw-out areas at each section and depth of cavity.

to be that the boundaries are easy to be eroded by the flowing water and become the origin of the draw-out.

During the observation, it is found that the draw-out at the second and third layers was most serious. The explanation of the phenomenon can be given clearly, that is, when the water level of the river increases due to flood, water flowed deeply into the reinforced soils through these two layers boundary. After the flood went away, the water within the soils flowed out and took away the soils.

6 DAMAGE DUE TO HEAVY RAIN

A serious flood due to a heavy rain happened from September 9 to 12, 2000. Because of the flood, the test site was also overflowed, the data logger flowed away and the top of the reinforced soil dike was eroded. Figure 7 shows the eroded top surface of the river dike at Sections A, B and C. The draw-out on the slope surface of the dike wall was also observed. The dike itself, however, was not destroyed and the retaining ability and endurance of the dike are remained in work. Figure 8 shows the situation of the dike one day after the flood. It is known from the figure that the water level was still very high, only 1 m below the top of the dike although the highest flood had passed one day before.

From the erosion of the top of the dike due to the flood, it is understood that in designing a reinforced soil dike, the erosion caused by flood should be considered. In present study, concrete retaining sheets are installed in the dike with each 6 m interval. Therefore, even if the retaining ability and endurance of the dike are confirmed during the flood caused by the heavy rain, it is still needed to confirm whether the retaining ability and endurance of a dike is still kept after a serious flood if the concrete retaining sheets are not installed.

7 PLAN OF REBUILDING NEW DIKE

Based on the damage of the first trial river dike, the construction of a geo-grid reinforced river dike is newly planned. In the planning of rebuilding, different checking items are proposed for each sections, for instance, the soil draw-out will be checked in Section A; the total safety of the embankment will be checked in Section B; the retaining effect of the surface coating will be checked in Section C. Of course, in the present case, suitable instruments will be installed on different sections according to their measuring items, based on which careful discussion will be done to find the weak points of the reinforced river dike which acts as a retaining structure of a river. Furthermore, as aforementioned, concrete

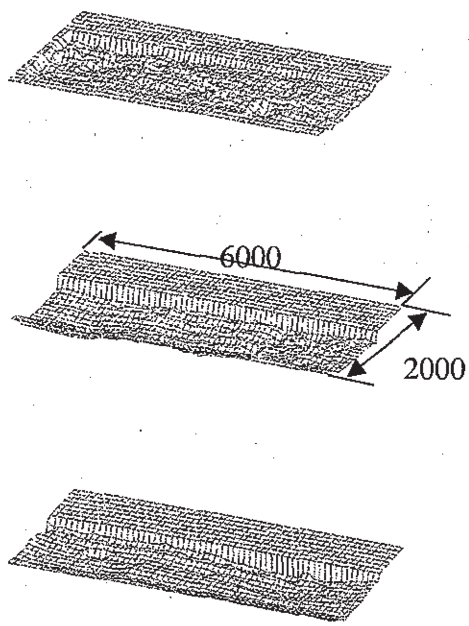

Figure 7. Eroded top surface on each section.

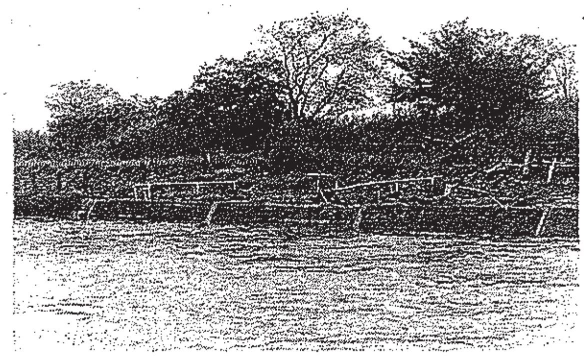

Figure 8. Situation of the dike one day after the flood.

retaining sheets will not installed at the boundaries between different sections this time because it will enhance the strength of a dike. It will be installed only at the beginning and ending sides of the test area.

In constructing a new river dike, the old one will be destroyed and removed. Therefore, it is a good chance to investigate the intact state of the old dike. A failure test will be conducted on the dike to investigate the mechanical behavior of the dike. In the failure test, a dead weight will be loaded on the top of the dike to simulate a possible external force that acts on the reinforced river dike. It is expected that by these field tests, it will be easy for us to design and construct a reinforced soil dike in the future.

8 CONCLUSIONS

In this study, a geo-grid reinforced river dike was proposed. In order to investigate the real behavior of the proposed river dike, a real scale field test was conducted. From this study, the following conclusions are derived.

1) From the observation and various kind of measurement, it is found that the deformation mainly occurred during the first three months that is from February to May 2000.
2) Because of the change in the water level of the river during site investigation term, it is found that serious soil draw-out occurred at the downstream side of concrete retaining sheets.
3) A serious flood due to a heavy rain happened from September 9 to 12, 2000. Because of the flood, the test site was overflowed and the top of the reinforced soil dike was eroded. The dike itself, however, was not destroyed and the retaining ability and endurance of the dike are remained in work.
4) In constructing a new river dike, a failure test will be conducted on the dike to investigate the mechanical behavior of the dike. From the results of failure tests, it will be easy for us to design and construct a reinforced soil dike in the future.

9 ACKNOWLEDGEMENT

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