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Laboratory Study of Bed Variation due to the Installation of Spur Dykes with Different Head Shapes

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Synopsis

Based on the shapes of the spur dykes in the plan, different kinds of spur dykes can be recognized: “Straight shape or I-type”, “T-type”, “L-type” and etc. So far a good number of works have been devoted to the study of the “straight” shape spur dykes, mainly aimed at investigating the flow structures around them. On the other hand, there are some limited researches and knowledge about the study of sediment transport around spur dykes with different shapes of head, especially when they are arranged in a series. In this study, the bed variation around two types of spur dykes with different shapes of head was investigated using experimental works. The equilibrium of bed variation in both spur dykes was shown and the differences and similarities of the pattern of scour hole were investigated.

Keywords: Spur Dyke, Groyne, Sediment Transport, Bed Variation, T-type, I-type

1. Introduction

Spur dyke is one of the main transverse hydraulic structures installed in the streams to prevent the bank erosion and improve navigation routes in rivers. Recently it is also used to provide better environment for the stream species which are in need of a diverse bed with various range of hydrodynamic, topographic and biologic conditions in rivers.

Based on the shapes of the spur dykes in the plan, different kinds of spur dykes can be recognized: “Straight shape or I-type”, “T-type”, “L-type” and etc. Spur dykes are rarely installed individually in the streams, but usually in series.

So far the considerable works have been dedicated to the study of the “single straight” shape spur dykes, mainly aimed at investigating the flow structures around them. On the other hand, there are some limited researches and knowledge about the study of sediment transport around spur dykes with different shapes of head, especially when they are arranged in a series. In 1964, Linder et al conducted a set of experiments to find the optimum combination of a series of L-shape spur dykes in a left bank of a reach of Missouri River in the U.S. In 2009, Vaghefi and Ghodsian studied flow field scouring around a single T-shape spur dyke in a 90 degree bend. In 2010, Kadota et. al. conducted a series of experiments in which they studied hydrodynamic of flow around an individual T and L- shape spur dykes.

To sum up, so far the researches about spur dykes have mainly focused on the study of straight spur dykes and even in the few researches about other shapes of spur dykes, the most cases were individual spur dyke (not series). In other word, there is still an extensive debate on how to optimize the spur dyke shape and their spacing in a series of spur dykes in order to increase their functionality specifically when it is needed to design nature-friendly spur dykes and to improve the bio-diversity of living environment of riverine biota and fauna by applying this kind of hydraulic structures inside the streams.

In this study, the formation of scour hole around two types of spur dykes with different shapes of head was investigated using experimental works. Two case studies were considered: a simple series of straight spur dykes and a simple series of spur dykes with T-head shape. The equilibrium of bed variation in both spur dykes was shown and the differences and similarities of the pattern of scour hole were investigated. Finally, an in-depth discussion about the formation of the scour hole and the deposition area around these types of spur dykes was studied in order to evaluate the performance of the special geometrical features of T-head shape spur dykes (its wing) to the formation and extension of scour hole toward the downstream.

The importance of this study can be highlighted regarding the fact that controlling bank erosion, better navigation and/or improving biodiversity are being directly affected by the shapes of these structures and accordingly on the basis of the primary objectives of the application of spur dykes, using a series of T-type would be an advantage compared to common designs.

2. Laboratory experiments

The experiments were done in a straight flume with of Ujigawa Open Laboratory, Disaster Prevention Research Institute, Kyoto University, Japan with 12.0m-long, 0.8m-wide and 0.28m-deep. Figure 1 shows a schematic view of the flume. The bottom and the sidewall of the flume were made of metal sheets with smooth roughness. The length (L) of spur dykes was 0.01m and they were installed in a recession area of channel with sand, located 5 meter from upstream of the channel.

A calibrated V-notch weir, fitted at the inlet of the flume, was used to measure the inflow discharge. The equipments for the measurements are fixed on the carriage which can move through the flume in the longitudinal direction. The spur dykes used during the experiments were made by Plexiglas plates with 1cm thickness.

Table 1 shows hydraulic conditions used for each different case in the experiments

3. Experimental procedure

Each experimental case was carried out for 4 hours, which is the time necessary to reach the dynamic equilibrium condition based on previous test experiments. Measurement of discharge was done by a V-notch weir and a point gauge. The water surface level for each hydraulic condition was regulated by a steel gate positioned at the downstream end of experimental flume. The deformed bed levels in the movable bed area were measured using a laser displacement sensor (Model: LK-2500) after the flume was completely drained out.

4. Results and discussions

Figure 2 shows the bed deformation of the series of spur dykes with T-head shapes and I-head shape with different opening length (1L, 2L, 3L, and 5L, in which L is the length of the groyne). In T-head spur dykes, the opening ration is from the downstream tip of one spur dyke to the most upstream tip of the next sour dyke in the series. Comparing the different open ratio between these

Table 1 hydraulic conditions used for each different case in the experiments

Flow Condition	
Discharge (Q) (m3/s)	0.0200
Channel Slope	1/800
Channel width (B) (cm)	80.00
Flow depth (hw) (m)	0.067
Flow Velocity (m/s)	0.37
Shear Velocity (u*) (m/s)	0.028
Sediment No	3.00
Sediment (d50) (mm)	1.78
sg	1.18
Sediment Density (g/cm3)	2.65
B/hw	11.94
Re	25000
Fr	0.20
u*/u*c	0.86

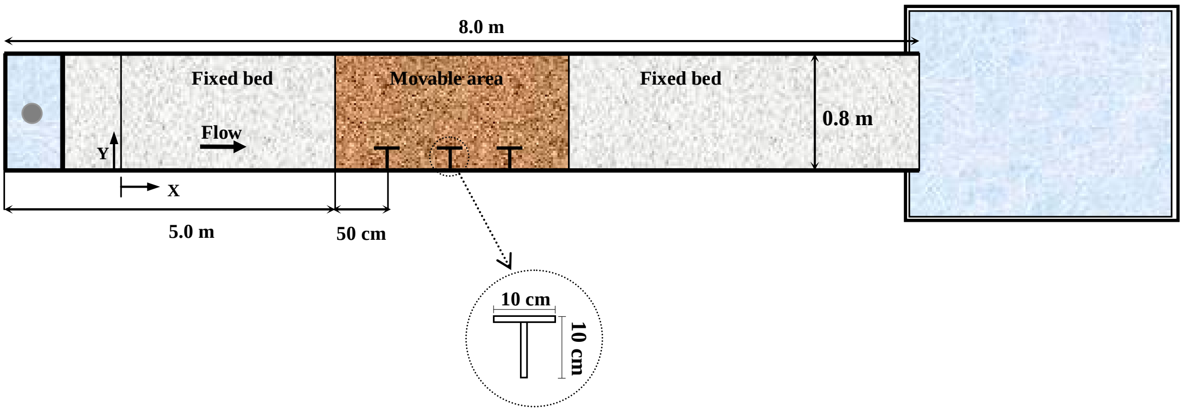

Figure 1. Schematic view of the experimental set up

two head shapes, firstly shows the considerable effect of the head shape on the bed changes.

In all Opening Ratio (OR), the overall pattern of the bed is different. In OR=1 and 2, in the series of T-head shape spur dykes , the presence of the wing of the spur dykes, made a sort of uniform pattern alongside of the embayments. While in I-type the changes has been formed right away from the banks of the channel. In OL=1, in the first embayment of the groyne a very limited point bar has been formed. By arising the OL to 2, this point bar has started to moved to upstream and near the center of the embayment. By increasing the OL to 3 and form, but the location of this point bar has been fixed and instead, the volume and dimensions of it has been started to expanding. This trend in I-type, but has a significant different. Comparing different OL in I-shape head shows a lag in similar behavior compared to the series of T-shape spur dykes. In other words, While in T-shape spur dykes, the formation of point bar in the first embayment was started from OL=1 and then moved to the upstream at OL=2 and expanding from OL=3, in I-shape spur dyke this trend has been observed from OL=2 (instead of OL=1). The first implication of this difference, highlight the less effect of the opening spaces in the interface of embayment and main channel on the formation of channel bed inside the embayment. Simply speaking, regardless of opening spaces in the interface of embayment and main channel, the distance between the boy of spur dyke has particular and clear affect on the pattern of bed changes in the series. Comparing the second embayment in these two different series, but shows the crucial rule of the head shape on the pattern of the bed inside and in front of embayments. In T-head spur dykes, before OL=3, there is no significant changes inside the embayment and it is just after OL=3 in which a visible point bar was formed between second and third spur dyke. While in I-type, the formation of point bar was started from OL=1. The third embayment in the series of spur dyke can be considered as a region in which there was enough length after the first spur dyke in series to form a uniform flow in front of the embayments. In this particular embayment, in T-head spur dykes, till OL=3 the presence of the wing caused the uniform area alongside the embayment. It was just after OL=3 (OL=5), in which by increasing the OL, the flow had enough spaced to intrude to the embayment and the wings of the spur dykes were not able to prevent the formation of the point bar. In I-shape spur dykes, this trend is somehow similar but with a lag in OL.

The first result of this comparison highlights the particular rule of the wing in the control of sediment transport in the first and second embayments. These two embayments are those one in which the uniformity of flow has not still been formed. On the contrary, in the third embayment in which there was enough length for the uniformity of the flow after the installation of the first spur dykes in the upstream, this rule was sort of faded.

In OL=5, but since the spaces between spur dykes was too high, so that the effect of the head shape has been rather local, the general pattern of the bed changes inside the embayments and alongside the interface between the embayments

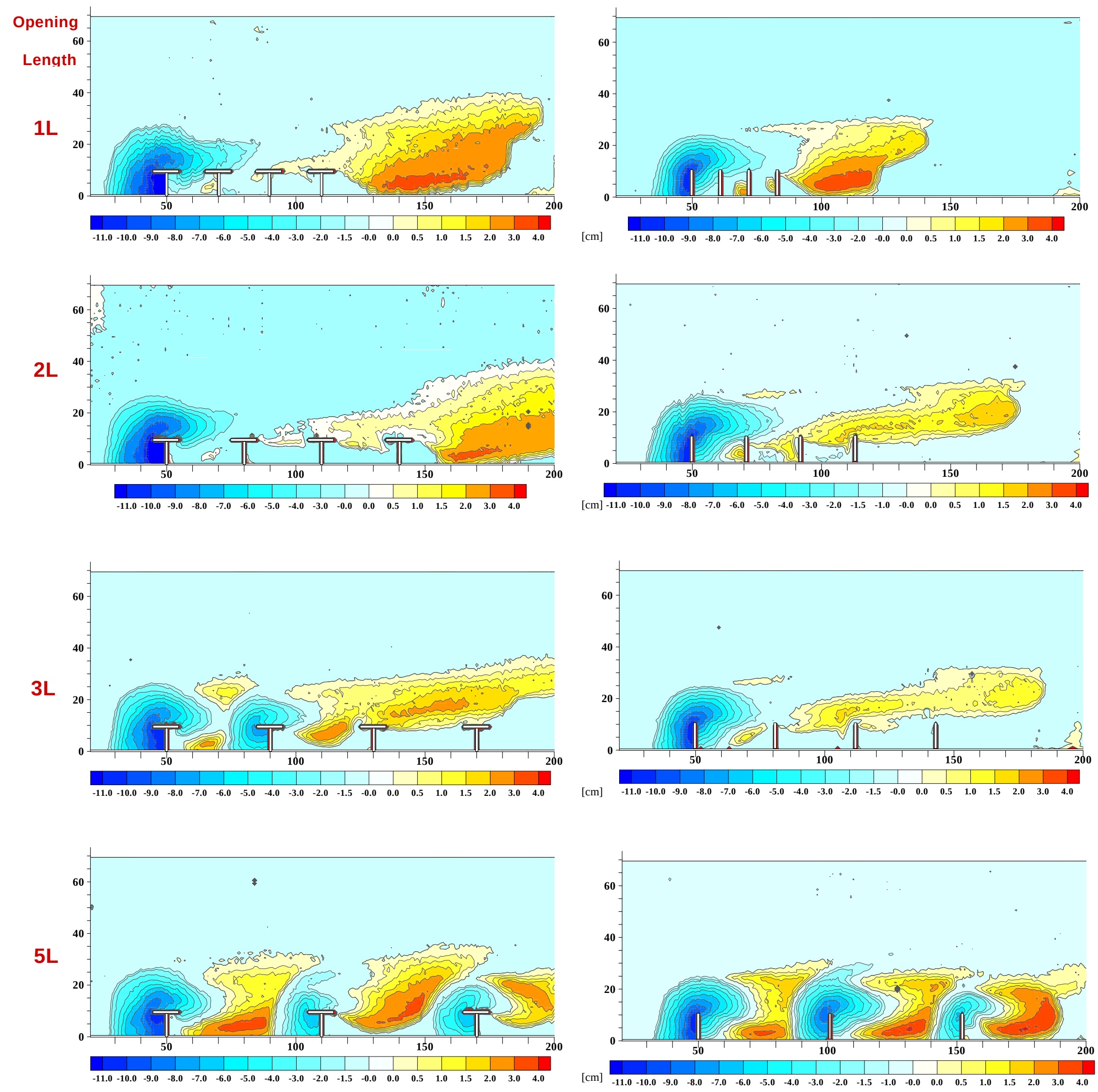

Figure 2 Bed changes in the series of spur dyke with different shapes and different opening length (OL)
Right: I-shape head spur dykes Left: T-shape head spur dykes

and main channel is rather similar in T-type and I-type.

5. Conclusions

In this paper, it was tried to compare the effect of head shapes of spur dykes on the general pattern of bed changes inside the embayments and alongside the interface between the embayments and main channel. It was shown that till the OL=5, the presence of the wing in T-shape spur dyke has significant effect, specifically in the first and second embayments. In third embayment in the series, the rule of the wing was rather less and was to form a uniform pattern alongside the interfaces of the embayment and main channel. In OL greater than 3, since the flow has enough space to intrude to the embayment completely, the rule of head shape on the general pattern of bed variation inside the embayment was rather local and limited.

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