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Three-dimensional flow characteristics in a slit-type permeable spur dyke field

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This study is focused to enhance the effective use of permeable spur dyke. We considered very slender type permeable spur dyke (slit type) and assess their effectiveness in terms of flow properties by conducting fixed bed laboratory experiment and numerical simulation. This study indicates that deflecting type spur dykes showed better possibilities in case of deflecting the flow towards the bank. However, by using a staggered type of installation, the performance of any type of spur dyke field (attracting or deflecting) can be enhanced in terms of reduction of flow velocity within the spur dyke zone.

1. Introduction

Spur dykes, the structures made to direct the flowing water as well sediment, has already demonstrated their effectiveness as river training structures both in gravel bed and sand bed rivers. This type of structures also showed their efficiency in low altitude meandering rivers. But in case of a highly sediment-laden alluvial braided river, these types of structures are not always fully successful due to the dynamic characteristics of the river and instability of the structure itself. The presence of groyne/ spur dyke type of structures induce modification of flow by creating large-scale energetic flow features which cause fluctuations in flow velocity and pressure on bed resulting large scour hole, ultimately leads failure of the structure. Therefore, the understanding of flow around such structure is crucial for the optimum design of these type of structures.

In this study, we propose slit type (the width of the individual pile is very small compared to the channel width, the ration of channel width/pile width is 200) permeable spur dyke field to overcome the above-mentioned situation. And as the first step of research, we performed laboratory experiment and numerical simulation to understand the three-dimensional flow properties around this slit type permeable spur dyke.

Hence, the main objective of this research was to characterize the three-dimensional flow behaviours around a series of slit type spur dyke field. The specific objective was to find the optimum design of this type of spur dyke in terms of installation angle and position. We suppose the better understanding of flow phenomenon around this type of structure will be helpful for understanding the flow pattern of similar geometrical structure.

2. Methodology

In order to understand the flow property around slit type spur-dyke , experiments have been conducted under fixed bed condition in Ujigawa open Laboratory, Kyoto University. The experimental flume was 10m long with 0.8m width and having a longitudinal slope of 1/300. The details of the experimental setup us shown in Figure 1. A continuous discharge of 0.01m^3/s was supplied from the upstream end. The approach flow depth (D) and velocity (U) was 0.032m and 0.40m/s respectively. Six cases were considered depending on installation angle and individual pile position as described in Figure 1. Water depth and velocity were measured by ultrasonic depth sensor and L type electromagnetic velocity meter.

The numerical analysis was performed by using

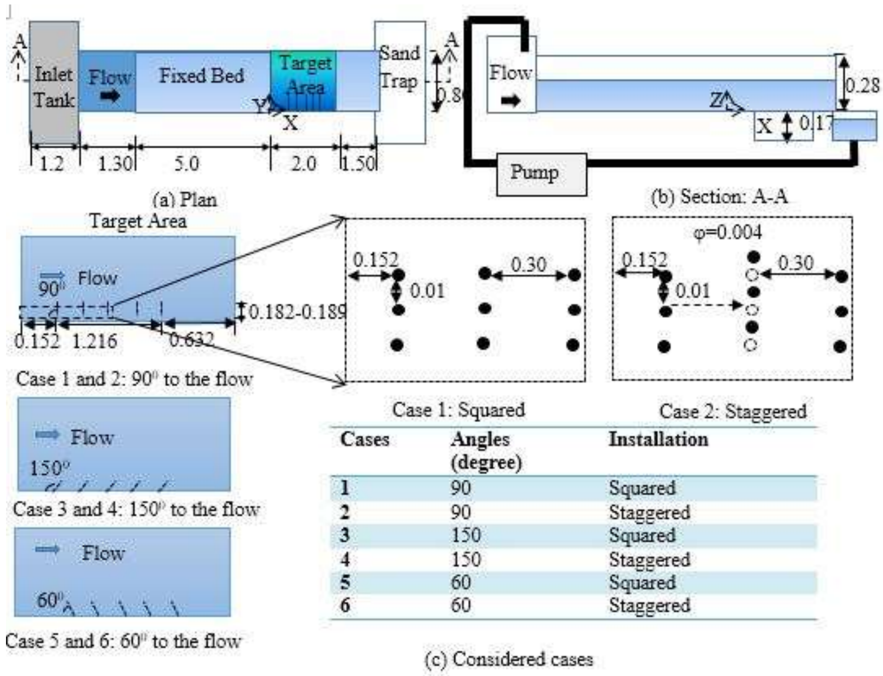

Figure 1: Details of experimental setup (All the dimensions are in meter)

interFoam solver (version 4.1) of the open source software code of OpenFOAM by solving RANS and continuity equations with $k-\omega$ SST model for turbulence closer. The volume of fluid (VOF) method was applied to capture the free surface flow.

3. Results

The experimental results showed that the average value of dimensionless water depth (d/D) for squared type arrangement of spur dyke such as case 1, case 3 and case 5 was 1.09, 0.39 and 0.43 respectively while for the staggered type of arrangement the values were 0.98, 0.43 and 0.64 for case 2, case 4 and case 6 respectively. The relative dam-up (the difference of water depth just upstream and downstream of spur dyke) was comparatively higher for the square type of spur dyke. The value increased 9%, 37%, 43% respectively for the square and staggered type of flow angle 90,150 and 60 degrees (Figure 2). The transverse flow velocity was higher in case 5 and 6 which represents the deflecting spur. The longitudinal velocity profiles revelled that for any alignment squared type of arrangement shows higher velocity within the spur dyke zone.

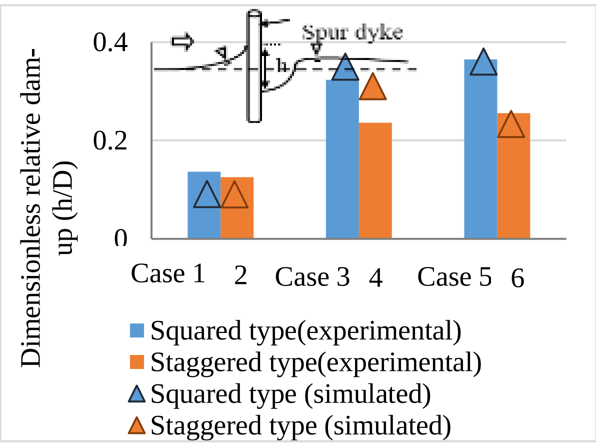

Figure 2: Dimensionless Dam-up of all cases

4. Conclusions

Using a series of very slender slit type spur dykes, the velocity can be lowered down more within the spur dyke zone by arranging the pile in a staggered way. The relative dam-up was higher in case of squared type spur dykes. It indicates higher velocity within the spur-dyke zone. This phenomenon can be used for desired sedimentation (faster/slower) within the spur dyke zone.