Conference Paper, Published Version

Tonegawa, Akihiro; Yoshitake, Hiroki; Yasuda, Hiroyasu; Hoshino, Tsuyoshi

Effects of Arranging Training Dikes on the Formation of Central Sandbars

Verfügbar unter/Available at: https://hdl.handle.net/20.500.11970/108494

Vorgeschlagene Zitierweise/Suggested citation:
Tonegawa, Akihiro; Yoshitake, Hiroki; Yasuda, Hiroyasu; Hoshino, Tsuyoshi (2016): Effects of Arranging Training Dikes on the Formation of Central Sandbars. In: Yu, Pao-Shan; Lo, Wie-Cheng (Hg.): ICHE 2016. Proceedings of the 12th International Conference on Hydroscience & Engineering, November 6-10, 2016, Tainan, Taiwan. Tainan: NCKU.

Effects of Arranging Training Dikes on the Formation of Central Sandbars

Akihiro Tonegawa, Hiroki Yoshitake, Hiroyasu Yasuda, Tsuyoshi Hoshino
Niigata University
Niigata, Japan

ABSTRACT

Vegetation in rivers has become problematic in Japan. All countermeasures so far have been palliative. Therefore, radical countermeasures must be taken to solve this problem. In this study, we focused on the beds with variable channel width and changed straight-channel planar shape by arranging their structures. Consequently, we demonstrate that it is possible to control bed formation by arranging their structures.

KEY WORDS: Training Dikes; Arrangement; Alternate bars; Central bars; Vegetation; Planar shape; Variable-width channel

INTRODUCTION

All of Japan's rivers are overgrown with vegetation such as trees and shrubs; this causes unsafe water flow during a flood. As a countermeasure, trees are being cut down and river channels and sandbars are being excavated. However, each countermeasure has been suboptimal; the removal and subsequent regrowth of trees and the backfilling of excavation points cause economic burden. From the viewpoint of sustainability, we argue that natural forces can help overcome these issues.

One of the reasons why for promoting vegetation growth in rivers is the formation of alternating sandbars, which is a meso-scale bed configurations that forms the main topography of a river. Alternating sandbars tend to concentrate the water route, thereby forming a motionless region conducive for deposition. Because of these characteristics, comparable height differences exist at the point of intersection. This results in a decrease in flood frequency and turnover rate of river bed materials during a flood. However, the multiple water routes and comparable height differences of sandbars usually do not intersect and thereby promote vegetation inside the river. This causes flooding and recirculation of the bed materials. Therefore, most of the rivers with central sandbars are not covered with glowing tress. The planar shape of the river enables variable channel width, which becomes narrower along the direction of the flow.

Laura and Wu researched the effects of variable channel width bed formation and showed wavelength and amplitude of width variation in planar shape. Although these studies have helped elucidate the factors that form beds in channels with variable width, sin-generated-curve flumes have been used historically because of the difficulty in directly applying a sin-generated-curve shape to a straight-channel shape during construction.

Herein, we apply a simple variable-width shape to a straight channel. We conducted moving bed experiments to research the effect of the channel planar shape on bed formation in order to approximate the planar shape of straight flumes to the geometric shape imitated by the variable-width channel. In the cross direction, water flow is concentrated and then diverted around structures; this causes a disturbance. Consequently, this behavior promotes bed formations that are different from straight-channel bed formations. In this study, we define the cross-direction structure width and distance between the centers of the two structures as amplitude and wavelength, respectively, and elucidate the relationship between bed formations and the planar shape of the channel.

MOVING BED WATER EXPERIMENT

Arranging the structures of both banks approximates the planar shape of the straight channel of the variable-width flume. Additionally, we aim to understand the relationship between the structure and bed formation. Initially, bed experiments were conducted under hydraulic conditions to form alternating sandbars without structures. Next, moving-bed experiments were conducted to determine the fundamental characteristics of the effects of arranging structures by arranging the structural pairs. Also, for reference, two half-wave-length sand bars formed when there were no structures or a pair of structures. Two arrangement spans were established between both structural centers, and moving-bed experiments were conducted by arranging three pairs of structures. Changes in the planar shape are expressed by changing the width and span of the arrangement as a parameter of the planar shape and by focusing on the characteristic of the bed forms formed by each planar shape.

Experimental Setup

The experiment was conducted in a 1000 cm long , 30 cm wide, and 1/160 gradient open-channel flume. Silicate sand, which had an average particle size of 0.76 mm, was used as the bed material and was spread onto the flume bed at a thickness of 5 cm. During the experiments with no structures, alternating sandbars were formed and a stationary discharge of 0.85 l/s was supplied from upstream of the flume. Using the diagram of Kuroki and Kishi, the aspect ratio and Shield's number were initially set to generate an alternating sandbar.

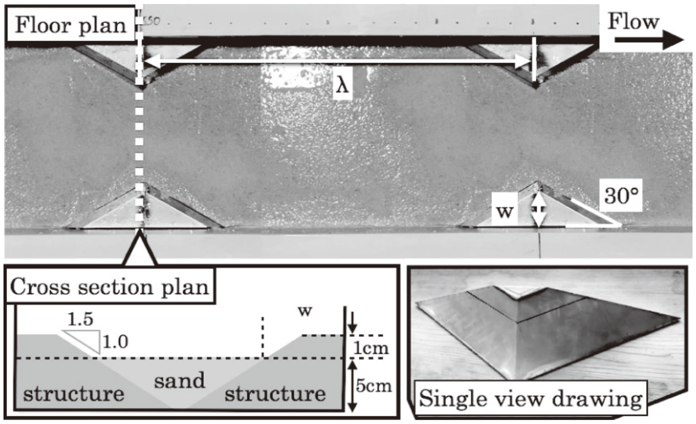

Fig. 1 Various factors of structure and arrangement pattern

Table 1 Experiment Cases

Case	Number of pairs	w (cm)	λ (cm)
0	0	-	-
1-1	1	3.0	-
1-2	1	5.0	-
1-3	1	7.0	-
2-1	3	3.0	100
2-2	3	5.0	
2-3	3	7.0	
3-1	3	3.0	200
3-2	3	5.0	
3-3	3	7.0	

Various Structural Characteristics

Figure 1 shows various factors of the truncated trigonal pyramid shape, which approximates a straight flume to a variable-width channel and arrangement. The structure and side wall angle were 30°. The width of the initial sand-surface structure was defined as “ w”; three widths— 3 cm, 5 cm, and 7 cm— were used. During the trial experiment using a straight wall, there was large local scour around the structures, and the floor of the flume appeared. Therefore, a slope with a gradient ranging from 1 to 1.5 was applied to the structure (6 cm in height) in order to reduce the effect of the scour around the structures. The structure was designed as such that only 1 cm of the height of the structure appears from above after spreading sand onto the flume bed at a thickness 5 cm after arranging the structures.

Arrangement Pattern

Structures were arranged in both banks, and the approximate geometric shape of the straight flume was used to imitate the variable-width flume. When arranging multiple pairs of structures, structures are arranged such that they span the centers of both the paired structures. This span is defined as “ λ ”. For “ λ ”, we used two sandbar wavelengths and conducted moving-bed experiments without structures and with a pair of structures as a reference. The arrangement spans used were 100 cm and 200 cm. Details of the experimental conditions are shown in table 1.

Experimental Procedure

At 1-h intervals, we drained and took pictures of the flume and continued the experiment until the alternating bars settled down, which happened at approximately six hours into the experiment. At first, we conducted moving-bed experiments without structures (case 0) and confirmed the formation of alternate bars. We arranged one or three pairs of structures of both banks and approximated the flume planar shape to the variable-width channel in order to confirm the effect of the variable-width channel on the formation of bed forms Cases 1-1 to 3-3 refer to the arrangement of one or three pairs of structures of both banks. In cases 1-1 to 3-3, the frequency at which the sandbars developed was fast. However, the time for the sandbars to settle down was short. The water and bed elevation around the pair of structures were measured using the moving optical cutting method developed by Hoshino and Yasuda. The measurement ranged in the longitudinal direction between 588 cm and 668 cm from the upstream end. The cross-direction measurement ranged from -12 cm to 12 cm from the center of the flume.

EXPERIMENTAL RESULT

No Structural Arrangement (Case 0)

Figure 2 depicts the results obtained in case 0 at 2, 4, and 6 hours from the start of the experiment. The formation of alternating sandbars was confirmed on the basis of the alternating sedimentation formed in the longitudinal direction. Additionally, motionless sand bars were confirmed from the fact that the sedimentation rate decreased with time. Half wavelength of sandbars was about 170 cm.

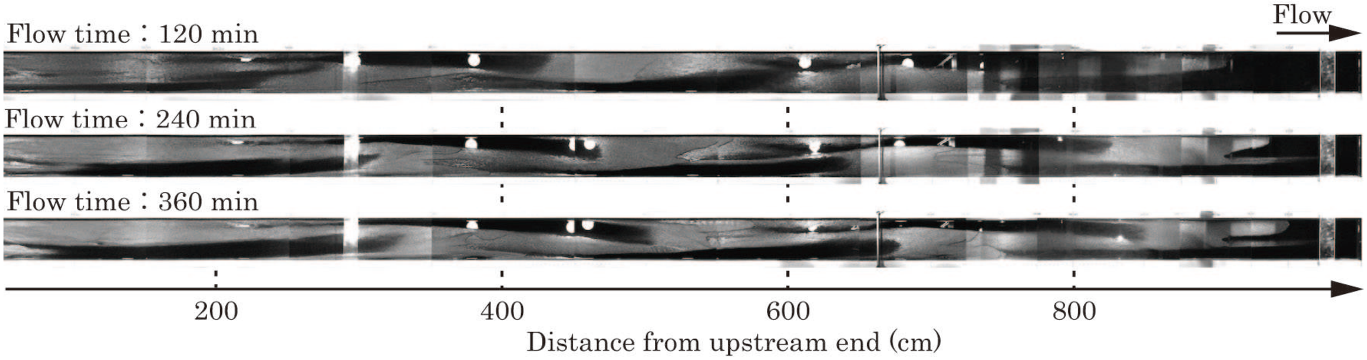

Fig. 2 Experiment result case 0

*

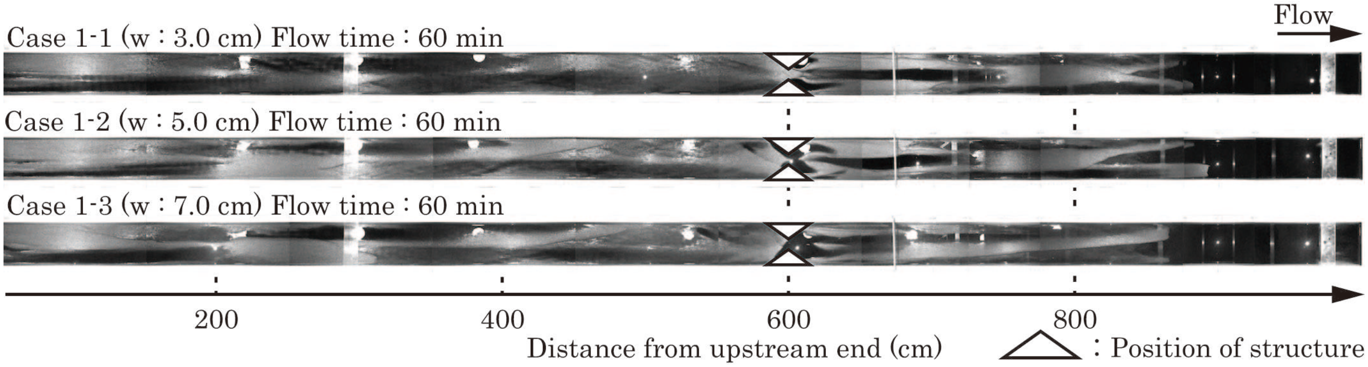

Fig. 3 Experiment result cases 1-1 to 1-3

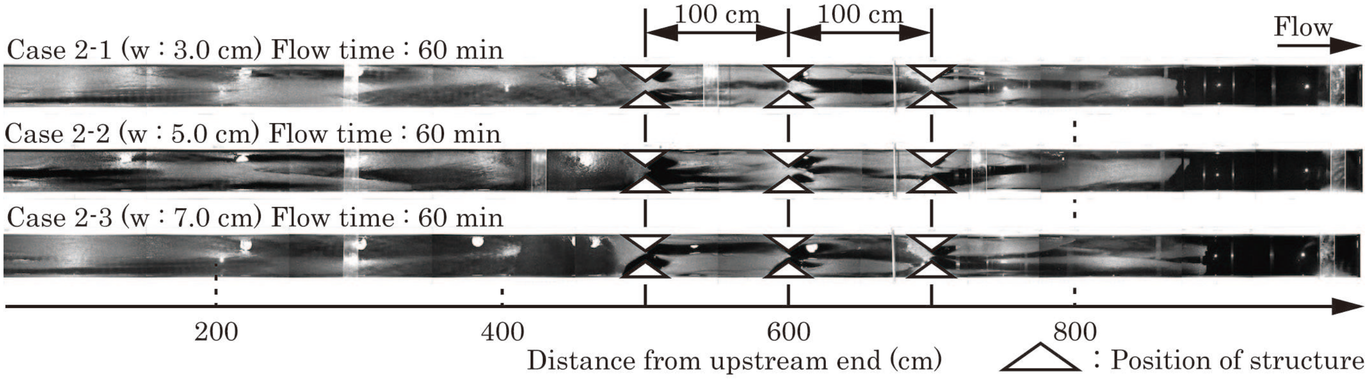

Fig. 4 Experiment result cases 2-1 to 2-3

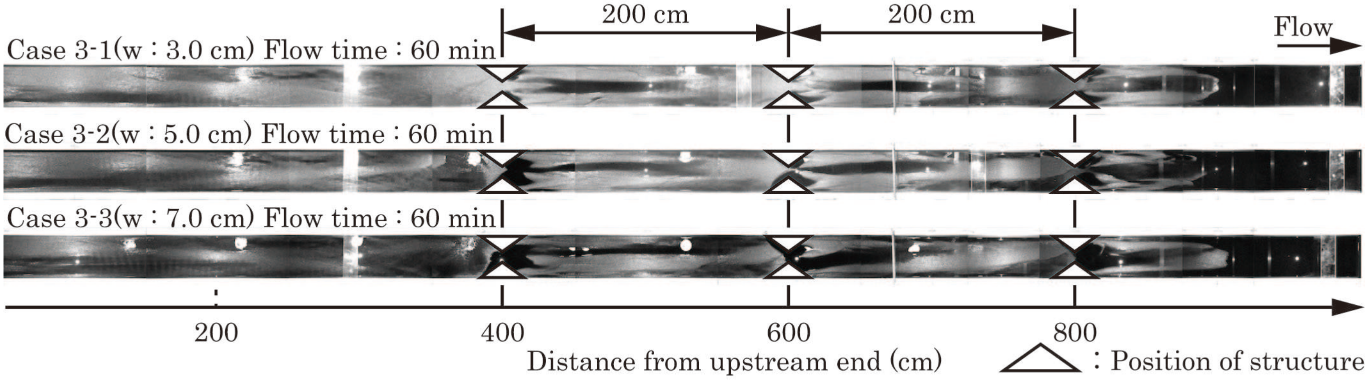

Fig. 5 Experiment result cases 3-1 to 3-3

One Structural Arrangement Pair (Cases 1-1 to 1-3)

Figure 3 depicts the results obtained in cases 1-1 to 1-3. Alternating sandbars were found to form upstream from the pair of structures as well as downstream Water flow was concentrated at the center of the flume; this resulted in the deposition of bed materials and formation sandbars in both banks. Furthermore, the main water route was divided by the formation of central sandbars in the downstream direction; this resulted in the formation of sandbars along both banks. Regarding the formation of central bars, we could visually observe that central bars formed by advancing to center and crossing the sandbars formed in both banks. If the length from the center of the structures to the front of the central bars is assumed as one wave-length, the half wave-length was approximately 120 cm.

Three Structural Arrangement Pairs (Cases 2-1 to 3-3)

Arrangement span 100 cm (cases 2-1 to 2-3)

Figure 4 depicts the results obtained in cases 2-1 to 2-3. Similar to the situation in cases 1-1 to 1-3, water flow was concentrated along the center of the flume; this resulted in the formation of sandbars and deposition of bed materials along both banks. Although central bars were not formed between both of structures in the longitudinal direction, central bars formations were confirmed in the downstream direction for the structures arranged on the most downstream side.

*

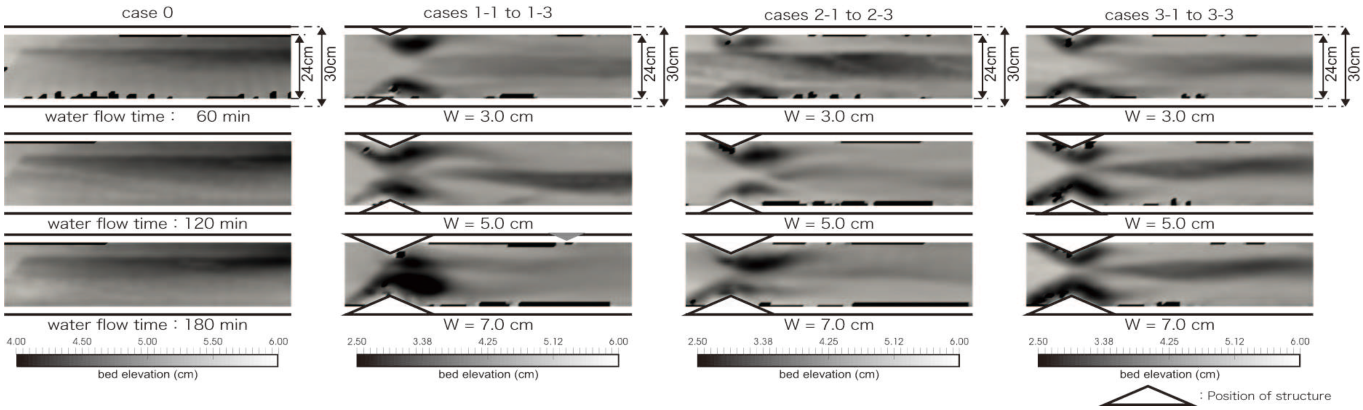

Fig. 6 Bed elevation measured by Moving Optical Catting Method

Arrangement span 200 cm (cases 3-1 to 3-3)

Figure 5 depicts the results obtained in cases 3-1 to 3-3. Similar to the situation in cases 1-1 to 1-3, water flow was concentrated along the center of the flume; this resulted in the formation of sandbars and deposition of bed materials along both banks. In addition, central bar formation was confirmed for both structures in the longitudinal direction.

Effect of Local Scouring Around the Structure

Table 2 shows the minimum bed elevation around the structures in each case (1-1 to 3-3) in order to show the effect of local scouring. As shown in table 2, the minimum bed elevation in cases 2-1 to 2-3 (arrangement span of 100 cm) was higher than that in the other cases (1-1 to 1-3 and 3-1 to 3-3). The effect of scouring in cases 2-1 to 2-3 was the smallest. We hypothesize that the arrangement of multiple structures in short spans leads to a reduction in the velocity of water flow and thereby reduces the effect of local scouring around the structures.

Table 2 Minimum bed elevation (cm)

Width of structure	Cases 1-1 to 1-3	Cases 2-1to2-3	Cases 3-1to3-3
3cm	2.29	2.93	2.76
5cm	2.38	2.53	2.13
7cm	1.02	2.45	2.21

DISCUSSION

In cases 1-1 to 1-3, structural phenomena such as scouring, sandbar formation in both banks, concentrated flow to the center of the flume, central sandbar formation, and the reformation of alternating sandbars occurred in order from upstream. According to Fig. 2, we hypothesized that outward water flow is distinguishable from the center of the pair of structures to 150 cm downstream; this leads to sandbar formation along the sidewalls. Consequently, we hypothesized that outward water flow weakens beyond 150 cm from the center of the structural pairs, and the central sandbars form by advancing to the center and crossing the sandbars formed in both banks. The reformation of alternating sandbars was confirmed at 250 cm downstream from a pair of structures. It has been suggested that the area over which structures influence bed formation is limited. When structural effects increase over long sections, structural pairs must be arranged at regular intervals. The range over which structures affect bed formation is limited. Therefore, alternating sandbars formed out this range.

In the three-pairs structural arrangement (cases 2-1 to 3-3), alternating sandbar formation between both structures in the longitudinal direction was not confirmed between both structures. It is effective to arrange three pairs of structures continuously in cases of maintain. In the three-pairs arrangement, there was a common point over which water flow was concentrated to the center of the flume. Central bars only formed when the arrangement span was 200 cm because the arrangement span was shorter than 150 cm; this eliminated outward water flow. Furthermore, when the arrangement span was longer than 150 cm, inward water flow was enabled and central bars formed. However, in cases 3-1 to 3-3, central bars existed between both structures in the longitudinal direction.

CONCLUSION

In order to approximate the planar shape of a straight flume to the geometric shape imitated by the variable-width channel, we hypothesize that adjusting the arrangement span will make it possible to control bed formation and reduce the effects of local scouring. We hypothesize that one construction method is effective for arranging multiple pairs of structures in both banks and for changing the planar shape of the channel.

REFERENCES

Hoshino, T. and Yasuda, H. (2016). 3D measurement of water and bed surface profiles during formation of sand-waves with moving optical cutting method: Annual journal of Hydraulic Engineering, JSCE, Vol 70, No 4, pp.I883-I888, 2016

Kuroki, M. and Kishi, T. (1984). Regime criteria on bars and alluvial straight channels: Journal of JSCE, Vol. 342, pp.87-96, 1984

Wu, F. C. and Yeh, T. H. (2005). Forced bars induced by channel width: Implications for incipient bifurcation, J. Geophys 110, F02009, doi:10.1029/004JF000160.

Laura, D. B. and Ninio, Y. (1995). River Bed Response to Channel Width Variation: Theory And Experiments