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Research paper

Experimental Study on River Meander Planform Pattern

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Abstract

River meander basically related with one of the main catastrophe in real scenario such as flood. The number of research on river meander characteristics and process is quite small. Therefore, the study on river meander and its characteristics by using a physical model is one of the methods to enhance the knowledge on it. The main purposes for current study are to determine the characteristics of meandering river and to investigate the lateral movement of the river meander channel bank. The scope of study includes execution of desk study and developing a physical model of river meander by using sand channel in order to understand the behaviors of meandering river. All of the parameters and calculations are investigated through the experimental works. Based on the experimental works, the explanation on the river meander characteristics and planform lateral movement due to the process of erosion and deposition are achieved. Erosion and deposition process give an increment to the initial channel width with respect to the angle of direction β and flow rate Q. As a conclusion, this study can give a plenty of information that can act as references to gain more understanding on the river meander planform pattern.

Keywords: *River Meander; Physical Model; Lateral Movement; Planform Pattern; Sand Bed Channel*

1. Introduction

Over the years, rivers had been significantly important as they act as water resources, provide food for the other animals, transportation, and also defensive barrier. A certain river grows as they collect water from tributaries along the course and eventually flow into a larger of water body such as ocean. The major objective of river is as source of water supply. In Malaysia, it can be certainly founded that the main townships and early settlements are situated either at the river banks or estuaries. The result is that the river floodplains consistently occupied by settlements and industry. Hence, this makes flood control and the control of bank erosion and meander mitigation is essentially importance.

Floods are one of the main catastrophes and commonly occur at any reach of a river due to different circumstances. This problem arises because the water flows overflow the banks and encroach into the river basins. The overflow may occur in upstream, estuary and middle area. Hence, the river corridor usually flooded where the river is allowed to erode its banks when the flow is ensuring to be in natural state. However, the problem arises when there is uncontrolled bank erosion that may affect the river navigability due to free meandering. Due to this problem, the study and knowledge of bank erosion and deposition is essential along with meander formation as it is important for the design of such corridors [1].

Rivers do not flow in a straight pattern as anyone can think. There are three types of river flow pattern which is straight, meandering and braided river somewhere along its length [2, 3]. There are a lot of chances for a river to divert its direction in nature for instance the local distortion in bonding medium where the fallen trees and placement of boulders that blocking the river from a straight course [4]. Some of researchers make a conclusion that meander pattern of river flow is transformed initiate from straight channel stage due to cutoff toward braiding and being dispersed flow over the whole width [5]. Meandering of the river basically lean on many factors of surrounding relief, features of the breeds forming its valley in nature [6]. Therefore, it is important to understand the hydraulic and hydrology of waterways thus includes the characteristics of the river itself in order to sustain the river condition.

For this study purposes, meandering river pattern have been chosen to investigate the characteristics and processes of its channel. In order to identify the characteristics and formation stage in meandering channel, a preliminary study and experimental works is carried out to study and investigate on this meander channel.

2. Experimental Setup

The experimental works consist of developing meandering river with sand bed channel. The related observation during the experimental works such as lateral movement on the channel width through different flow rate magnitude. Direct removal of bank material by the water flow (fluvial entrainment) and bank failure due to geomechanical instability are also been investigated. The physical model setup was conducted in an open channel flume with effective length of 1910 mm, 850 mm wide and 600 mm deep as shown in Figure 1. In order to represent a meandering fine bed river, the main channel and river meander channel flood-plain was prepared with uniform river sand (D_{50} = 0.58 mm) with 60 mm depth.

In order to execute the experimental works, first, the channel bed was compacted with sand to replicate the river channel. Then, the channel was saturated with water to enhance the compaction. The sand bed was flattened using a wide sand scraper. By using the meter ruler attached on the upper of sand bed channel, the thickness of the sand can be measured in order to achieve the same level and thickness. After sand bed have been flattened and levelled, an initial main channel of river meander shape was formed by trowels with 30 mm thickness and 100 mm width respectively.

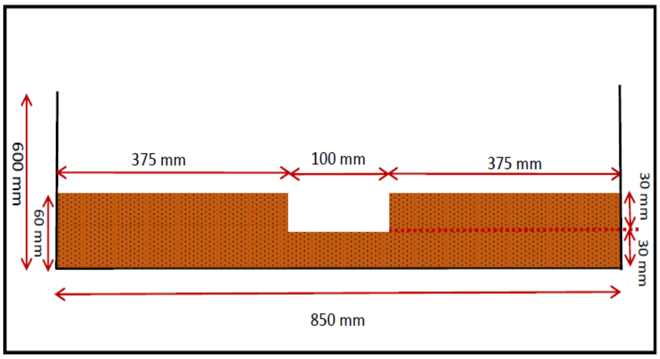

Fig. 1: The cross section of sand bed river meander channel.

The regulation of flow by means a rectangular shape weir constructed across the upstream from the point of discharge. The purpose of putting the weir is to ensure uniform flow and reducing the turbulence at the point of entry into the test length. The discharge flowing in the channel is determined first by calculating the velocity while the valve is controlled for the water inlet into the channel. Water circulated through the pipe with centrifugal pumps. Apart from that, a camera was used above water surface for measuring the surface flow field and recording channel morphology. Considering that the camera could not shoot widely, the channel planform is taken by just 2 m from the channel.
Features and details of the river meander channel that have been considered in this experimentation are shown in Table 1. The main meander channel shape is rectangular with dimension of 0.1 m width and 0.03 m depth respectively. Three different meanders with different angle of direction β had been constructed which are M_1 for 60 degree, M_2 for 80 degree and M_3 for 90 degree. According [7], the class type of river is depending on the sinuosity index K that calculated from the ratio of the meander length M, to meander wavelength L_m. Sinuosity index K of each meander river channel constructed in this study are proved more than 1.5 which is meandering form type [2, 8]. A summary of sinuosity index, SI according to [9] is shown in Table 2. Then, each river meander channel was run with three different flow rate of 0.12 L/s, 0.21 L/s and 0.36 L/s for five hours duration accordingly.

Table 1: River meander features for experimental setup

River Meander Features						
	Wave-length L_m, m	Length M, m	Amplitude A, m	Radius R, m	Angle β, deg	Sinuosity, K
M_1	1.020	1.840	0.720	0.2	60	1.804
M_2	1.275	2.015	0.910	0.2	80	1.580
M_3	0.950	1.850	0.832	0.2	90	1.950

Table 2: Sinuous index (SI)

SI	Class type
< 1.05	Straight
1.05-1.3	Sinuous
1.3-1.5	Moderate meandering
>1.5	Meandering form

3. Results and Discussion

The planform changes of the physical river meander model have been observed throughout the experiments. The results then were analysed based on the relationship between the discharge of the water flow Q and the angle of direction β.

3.1. Meander Planform Changes

Meander planform changes are observed and explained by parts which are due to angle of direction β, flow rate Q and channel lateral movement W'. Figure 2 shows the channel condition of each turning angle on different angle of direction β and flow rate, Q respectively. The main observation in Figure 2 is the bigger the angle of direction β of the channel, the higher chances of river meander to be changed. It also shows that the higher the water flow rate, the higher the velocity of water that lead to the higher chances of changes in meander channel pattern too. The reason is due to water flow that comes from inlet that erodes the channel bank. The bigger turning angle will lead to more erosion at the water inlet hence, giving more changes on the river meander planform pattern.

3.2. Lateral Movement

Lateral movement W' of meander channel is influenced by an erosion and deposition of the sand channel. Erosion of the sand channel commonly occurs at the outer bank while deposition of materials which is sand occurs at the inner bank as shown in Figure 3. The erosion and deposition were observed occur at every channel despite in different angle of direction β and flow rate Q respectively. Most channels that undergo this process will lead to lateral displacement of the channel which result the increment of the width channel [10]. Based on the Figure 3, it is proved that erosion occur at the outer bank. Meanwhile, sediment being transported to sedimentation location that located at the inner bank.
Figure 4 shows the lateral movement of the meander channel for each angle of direction β in selected flow rate Q which is 0.36 L/s. Based on observation of Figure 4, the incremental of the width channel observed due to erosion of bank channel were not more than 0.1 m. The difference between the initial and after five hours experiment run for the angle of direction β is 60 degree was 0.105 m while for angle of direction β is 80 degree was 0.11 m. In the other hand, the difference between initial and after channel for angle of direction β is 90 degree was 0.18 m. From these differences, the highest difference in incremental width is meander channel with angle of direction β is 90 degree while the lowest difference in incremental width is meander channel with angle of direction β is 60 degree.

 Q = 0.12 L/s	 Q = 0.12 L/s	 Q = 0.12 L/s
 Q = 0.21 L/s	 Q = 0.21 L/s	 Q = 0.21 L/s
 Q = 0.36 L/s	 Q = 0.36 L/s	 Q = 0.36 L/s
M_1(60 degree)	M_2 (80 degree)	M_3 (90 degree)

Fig.2: Meander river channel of different angle of direction β and flow rate Q

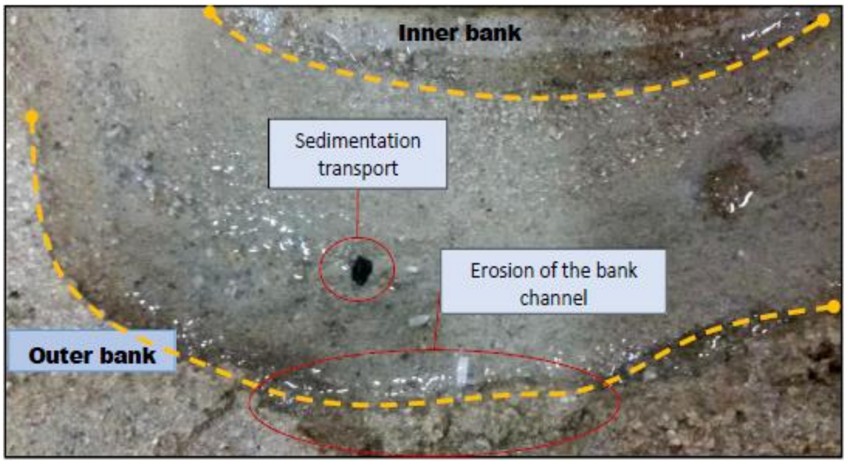

Fig. 3: Erosion at the bank channel of M_3 with angle of direction β is 90 degree

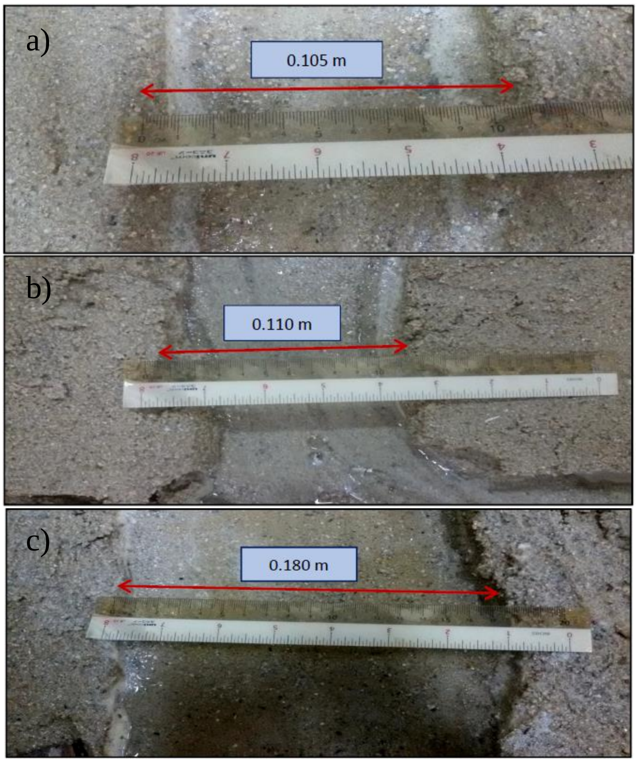

Fig. 4: Lateral movement *W*' when flow rate *Q* is 0.36 L/s at (a) β is 60 degree, (b) β is 80 degree and (c) β is 90 degree

4. Conclusion

The study of meander channel enhances the understanding on the characteristics and process of natural river. The outcome from this study can be stated as river meander planform pattern development is a slow process that takes times to developed properly. The water flow behavior is among the factors that influence the development since it has unpredictable water flow. In addition, lateral displacement occur during the experimental works is due to the erosion and deposition process. The erosion of the channel occurs at the outer bank meanwhile, the deposition of the materials such as sand grain developed at the inner bank of the channel. Erosion and deposition process give an increment to the initial channel width. Further work may consider the full scale of the physical river model with high technical equipment for more accurate result. River morphology modeling also needed as it allocates a framework which can analyze and test how river history develops over periods. It provides with a means of evaluating hypotheses, predicting change, and most importantly, challenging current ideas about the behavior of rivers.

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