The effect of cribs slope angle on the erosion of the riverbank

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Abstract. A study laboratory experiment was carried out to determine the pattern of cribs collapse at river bends and the effect of the slope angle of the cribs not escaping the water as a cribs collapse control as well as sediment control in channels with various bend angles. The model was made in a channel 25 × 20 cm, a river length of 600 cm. Sediment distribution from fine sand that is not homogeneous and the flow is clear (clear water). The angle and distance of the cribs installation are varied. The cribs used in this experiment were 5 cribs with a tilt angle of 30° and 60°. Each treatment was observed with parameters related to erosion and sedimentation in the river bank bends, including velocity (v), time (t), depth of erosion (de), sedimentation (ds). The dimensional analysis method is used to see the relationship between dimensionless parameters with the Langhaar method. The results showed that the maximum relative sedimentation (ds5/t)max for the crib angle of 30° occurred in the fifth crib of 0.025 at a relative speed (v/t) of 0.06. While the maximum relative erosion depth (ds3/t)max for the tilt angle of 30° crib occurs in the first grout, which is 0.012 at a relative speed (v/t) of 0.0042. At the angle of 60° cribs, there is a maximum relative erosion depth (ds3/t) of 0.082 at a relative speed (v/t) of 0.006 on the third crib. The increasing of the relative velocity (v/t) the greater the value of the relative erosion depth (ds/t).

1. Introduction

In the current era of globalization, the development of urban areas is increasingly developing, the more problems that not only bring good effects but also have bad effects on natural and environmental conditions. The river is one of the aquatic ecosystems that is influenced by many factors, both in natural activities and human activities in the watershed. In the management of a watershed, it is necessary to pay attention to the water body of the watershed. Incorrect watershed management will have an impact on the sustainability of river water bodies, namely very high water discharge fluctuations and reduced river capacity. [1]

For physical modelling, it is usually done by reducing the various variables, namely by giving a scale (n) on each of these variables. Meanwhile, the scale of the various variables or parameters can be determined based on the relationship between the parameters expressed in dimensionless numbers, such as Reynold numbers, Froude numbers and so on. In addition to determining the relationship between scales, this dimensionless number can also be used to describe research results, thus the results of these studies can be generalized. [2]

To determine the dimensionless number can be done by dimensional analysis [2]. Dimensional analysis to determine the dimensionless number there are several ways, including by:

a. Basic echelon matrix
b. Buckingham (phi.theorem)
c. Rayleigh
d. Stepwise, dan
e. Langhaar

If the hydraulic phenomenon/event can be explained by n parameters Pi with i = 1,2, 3, ... , n and if the parameter is composed of m principal elements, then the product of dimensionless numbers that can be derived number (n-m). For hydraulic engineering purposes, there are usually 3 main elements, namely: mass (M), length (L), and time (T).

$j = P1^{k1} . P2^{k2} . P3^{k3} . . . . P$, where

jnkn = product of dimensionless numbers with j = 1, 2, 3

If Pi has dimension M, then the dimensions can be written as follows:

$= (M^{\alpha1} L^{\beta1} T^{\tau1})k1 * (M^{\alpha2} L^{\beta2} T^{\tau2})k2 * .... (M^{\alpha n} L^{\beta n} T^{\tau n})^{kn}$

$= [M\ (^{\alpha1k1+\ \alpha2k2}\ +........\ +^{\alpha nkn})]*[L^{\beta1k1}\ +\ ^{\beta2k2}+.......\ +^{\beta nkn}\ ]*[T^{\tau1k1}+\ 2\ ^{k2}\ +.........\ +\tau n\ ^{kn}]$ is a dimensionless number if:

$\alpha1\ k1+ \alpha2\ k2 +........+ \alpha n\ kn = 0$

$\beta1\ k1 + \beta2\ k2+....... + \beta n\ kn = 0$

$\tau1\ k1 + \tau2\ k2 +........+ \tau n\ kn = 0$

the coefficients αi, βi and τi can be known from the related Pi parameters.

In connection with this problem, in this study a laboratory experiment was carried out to determine the pattern of cliff collapse at river bends and the effect of laying non-permeable cribs as a control for cliff collapse as well as controlling sediment in a channel with a bend angle of 120°. Simulation of the installation of cribs was also carried out on variations in flow discharge at river bends. The model is made in a channel of 40 × 40 cm and the length of the river is 1280 cm and the length of the bend is 150 cm. Sediment of fine sand that is not homogeneous and flows in clear conditions (clear water). The angle and distance of the crib installation varies. [3]

2. Method

2.1. Research sites

This research was conducted in the Hydrology and Hydraulics laboratory of Bina Darma University Palembang as shown in Figure 1. [3]

Figure 1. River bend design model
(source: Syarifudin A, 2020)

2.2. Research Stages

The research stages are divided into two, namely:

- Physical research, which is carried out in laboratory experiments to observe and record existing phenomena.
- Hypothetical and analytical research, which was conducted to find the relationship and the variables that influence it.

2.3. Research Materials and Tools

The materials used in this study include:

- Sand with a diameter of 0.075 mm to 2.36 mm, is considered a sedimentary material which was previously analyzed by sieve to obtain a uniform grain diameter (ds) from river material.
- Water, as a medium for moving sedimentary material flows in the channel,

The tool used in this research is a hydraulics laboratory facility, Master of Civil Engineering, Postgraduate Program at Bina Darma University. [4]

The specifications of the tool are as follows:

River model with its turns:

- Wall material: made of ordinary mixed cement
- Effective length: 600 cm
- Width: 25 cm
- Depth: 20 cm

Measuring scour depth

- Meter, to measure the location of scour.
- Photo camera to take pictures during experiments
- Video recorder to record the execution of the experiment

3. Materials and Tools

The materials and tools used in this study are as shown in table 1 below.

Table 1. List of research tools and materials

No.	Tools name	Amount	Uses
1.	River scale model	1 set	A tool for writing data recording results
2.	Pump	1 unit	Assists the movement of flow in the model
3.	Crib model	3, 5 and 7 unit	Simulation tool
4.	River bed materials	Sieve analysis result	Simulation material
5.	Water	Suitable for storage	Flow simulation

3.1. Research Stages

In accordance with the research objectives, the following stages are required:

- The first stage is to collect references from journals, books, and other secondary data sources.
- The second stage, conducting a field orientation survey to obtain the current (existing) field conditions, taking photos of the field (site) so that it can be used as initial research data.
- The third stage is to design a river with a model scale from prototype to model with a maximum storage capacity of 1000 liters, consisting of 2 circulation tanks located upstream and downstream of the river model with dimensions of 500 cm long, 20 cm wide with a wall slope ratio of 1: 0.005.
- The fourth stage, conducting initial simulation trials to see the readiness of the river model and calibrating so that the model is in accordance with the conditions from prototype to model.

- The fifth stage is to test the model by placing the sediment base material from the sieve analysis by taking the average diameter (d50) with the assumption that the base material corresponds to that in the river prototype. Followed by the installation of the position of the crib model at the bend of the river with a certain distance of 5 crib models
- The sixth stage, conducted a trial with a running time of 60 minutes, with every 15 minutes good observations were made with 3 crib models, then 5 crib models and 7 crib models. Observations and recordings of erosion and sedimentation patterns were carried out in each scenario of the installation of the crib model.
- The seventh stage, discusses the results of observations that occur in the crib model and makes research conclusions and provides suggestions for further research by other studies.

4. Results and Discussion

4.1. Dimensional Analysis

Dimensional analysis in this study uses Langhaar's theorem, this theorem is considered more in line with current conditions and in accordance with research because the parameters are relatively few. The steps of dimensional analysis are as follows:

1. In the problem formulation it is stated that the parameters that affect the erosion around the groin include the angle of the groin slope (α), water depth (h), flow velocity (v), erosion depth (de), time (t) and acceleration gravity (g), and the density of water (ρ_w).
2. The parameters are grouped into:
   a. Dependent parameter: v
   b. Parameters changed during the experiment: ds, h, and t
   c. Other parameters: α , g, ρ_w
3. The prices of α1, β1 and γ1 are determined as shown in table 2 below:

Table 2. Determination of dimensional analysis

Group	1		2			3		Note
Parameter	**v**	**ds**	**h**	**t**	**α**	**ρ**	**g**	
M	0	0	0	0	0	1	0	α1
L	1	1	1	0	0	-3	1	β1
T	-1	0	0	1	0	0	-2	γ1
	k1	k2	k3	k4	k5	k6	k7	ki

Determination of dimensionless numbers as in table 3.

Table 3. Dimensionless numbers

ki	k1	k2	k3	k4	k5	k6	k7
Parameter	**v**	**d_s**	**h**	**t**	**α**	**ρ**	**g**
π1	1	0	0	-1	0	0	0
π2	0	1	0	-1	0	0	0
π3	0	0	1	-1	0	0	0
π4	0	0	0	1	0	0	-2

This results in the following dimensionless equation:

$$\pi 1 = v/t \quad (1)$$

$$\pi 2 = de/t \quad (2)$$

$$\pi 3 = h/t \quad (3)$$

$$\pi 4 = t/2g \quad (4)$$

(h/t) x (t/2g) = 2gh = v

f (v/t ; ds/t; v) = 0 (v ≈ 0)

(v/t) = f (ds/t) focus on erosion around the cribs

4.2. 5 (five) Krib models with a slope angle of 30°

In conditions where there are 5 (three) cribs at the bend of the river with a slope angle of 30 ° as shown in Figure 3. below

Figure 3. Placement of the 30° crib slope angle

Table 2. The results of the analysis of the depth of erosion at the crib slope angle of 30°

			Non-dimensional parameter				
v	**t**	**v/t**	**ds_1/t**	**ds_2/t**	**ds_3/t**	**ds_4/t**	**ds_5/t**
0.006	0.004	0.004	0.006	0.006	0.004	0.006	0.004
0.006	0.004	0.004	0.006	0.006	0.004	0.006	0.004
0.006	0.004	0.004	0.006	0.006	0.004	0.006	0.004
0.006	0.004	0.004	0.006	0.006	0.004	0.006	0.004
0.006	0.004	0.004	0.006	0.006	0.004	0.006	0.004
0.003	0.009	0.007	0.008	0.006	0.003	0.003	0.009
0.003	0.009	0.007	0.008	0.006	0.003	0.003	0.009
0.003	0.009	0.007	0.008	0.006	0.003	0.003	0.009
0.003	0.009	0.007	0.008	0.006	0.003	0.003	0.009
0.003	0.009	0.007	0.008	0.006	0.003	0.003	0.009
0.002	0.001	0.002	0.004	0.006	0.007	0.002	0.001
0.002	0.001	0.002	0.004	0.006	0.007	0.002	0.001
0.002	0.001	0.002	0.004	0.006	0.007	0.002	0.001
0.002	0.001	0.002	0.004	0.006	0.020	0.002	0.001
0.002	0.001	0.002	0.004	0.006	0.020	0.002	0.001

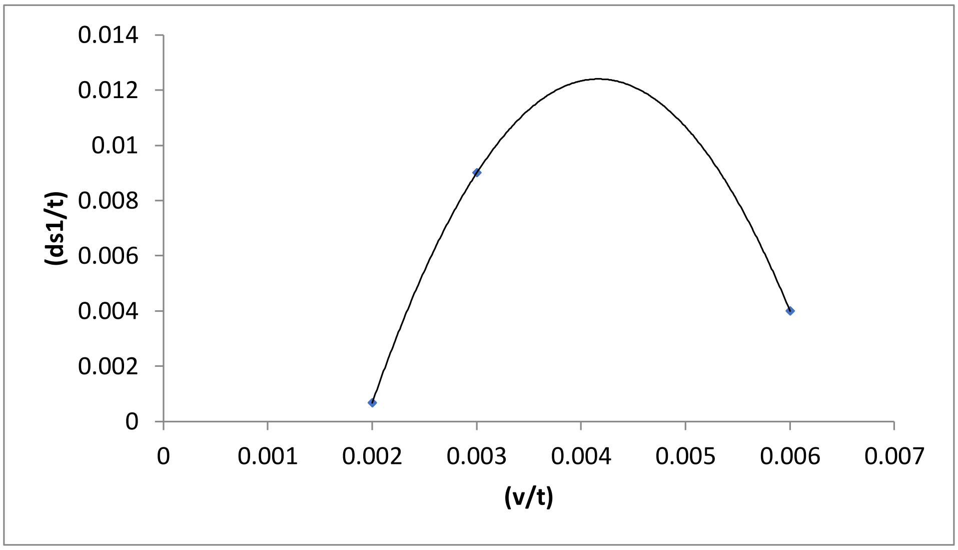

Figure 4. The relationship between (v/t) and (ds1/t) of the 30° crib slope angle

In Figure 4. it can be seen that in the first crib at the initial conditions there was a maximum relative erosion (ds1/t) of 0.012 at a relative velocity (v/t) of 0.0042.
This shows that the maximum relative velocity of 0.005 at the crib with a slope angle of 30° obtains a maximum erosion depth of 0.0125. After that the relative depth of erosion will continue to decrease along with the relative velocity that occurs in accordance with the principles of hydrodynamics of flow balance.

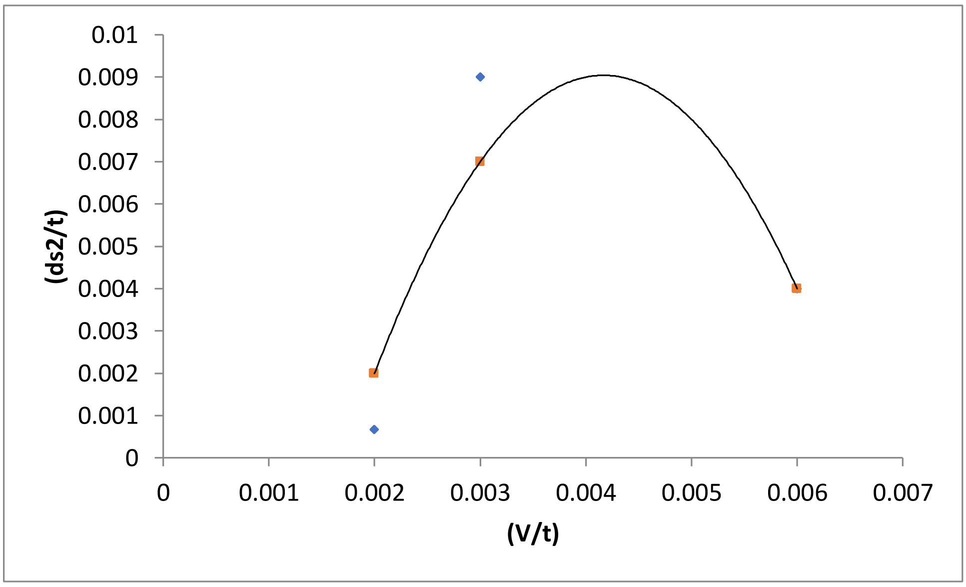

Figure 5. The relationship between (v/t) and (ds2/t) of the 30° crib slope angle

In Figure 5. it can be seen that in the second crib, there is a change in the maximum relative depth of erosion (ds2/t) which is 0.009 but the relative velocity (v/t) remains constant. This means that there has been a change in the relative depth in the second crib but the relative flow velocity (v/t) remains, different at the beginning of the flow movement in the first crib where the relative flow velocity produces relatively little erosion depth.

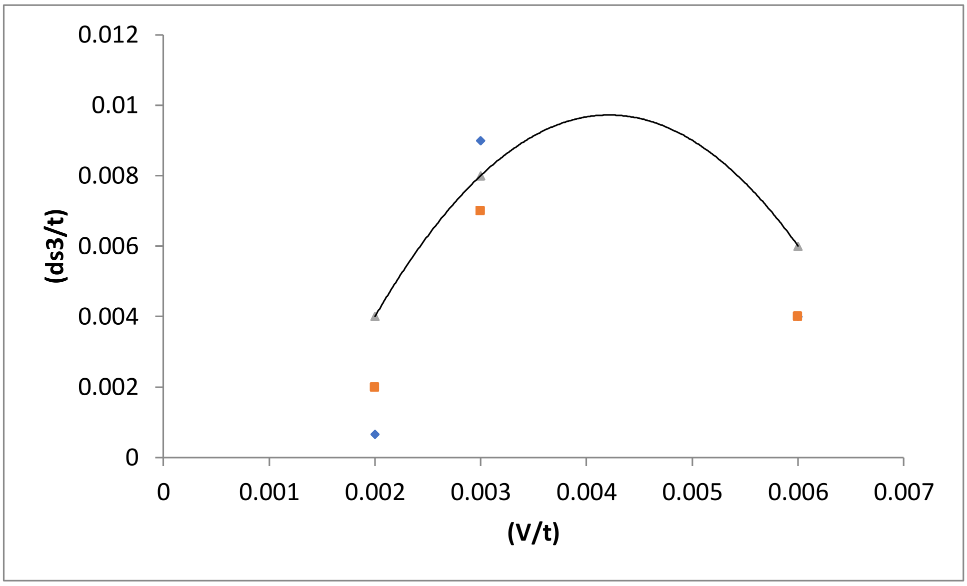

Figure 6. The relationship between (v/t) and (ds3/t) of the 30° crib slope angle

In Figure 6. it can be seen that in the third crib, there is a change in the maximum relative depth of erosion (ds3/t) which is 0.01 but the relative velocity (v/t) is 0.004. This means that there has been a change in the relative depth in the third crib but the relative flow velocity (v/t) remains, different at the beginning of the flow movement in the first crib where the relative flow velocity produces relatively little erosion depth.

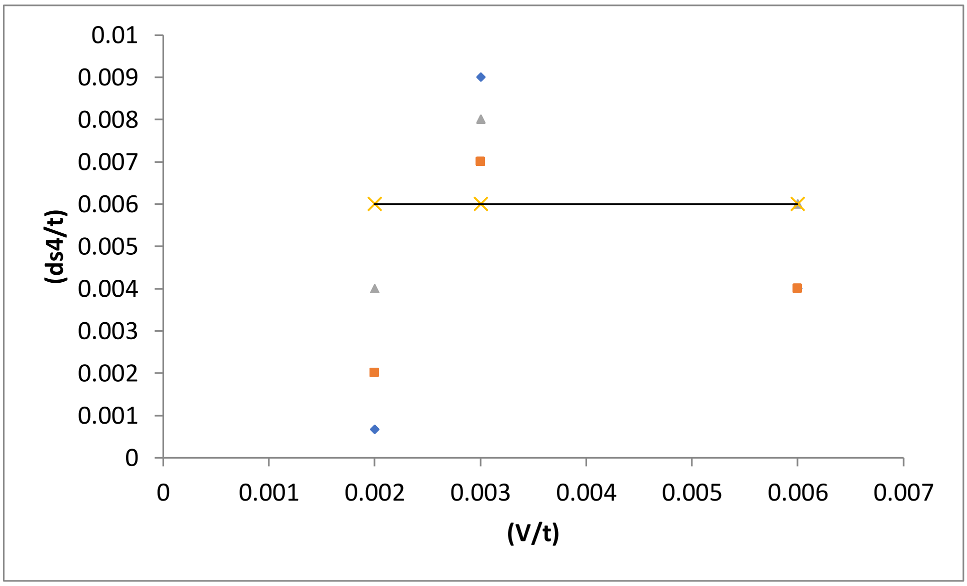

Figure 7. The relationship between (v/t) and (ds4/t) with a slope angle of 30°

In Figure 7. it can be seen that in the fourth crib there is no change in the increase in the maximum relative depth of erosion (ds4/t).

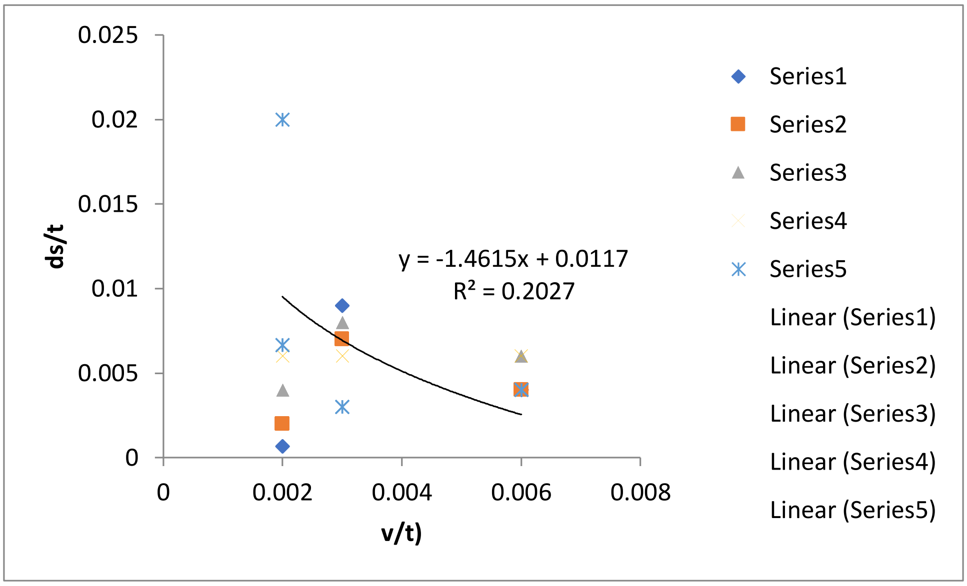

Figure 8. The relationship between (v/t) and (ds5/t) of the 30° crib slope angle

In Figure 8. it can be seen that in the fifth crib it is seen that there is a relatively more likely deposition (sedimentation) (dd/t) of 0.025 at a relative velocity (v/t) of 0.0045. In contrast to the fourth crib, there is no relative erosion (ds/t).

4.3. 5 (five) Krib models with an angle of 60°

In conditions where there are 5 (three) cribs at the bend of the river with a slope angle of 60 ° as shown in Figure 9.

Figure 9. Placement of the 60° crib slope angle

Table 3. The results of the analysis of the depth of erosion at the crib slope angle of 60°

Non dimensional parameter							
V	**(t)**	**V/t**	**ds_1/t**	**ds_2/t**	**ds_3/t**	**ds_4/t**	**ds_5/t**
0.03	5	0.006	0.020	0.060	0.080	0.018	0.018
0.03	5	0.006	0.020	0.060	0.080	0.018	0.018
0.03	5	0.006	0.020	0.060	0.080	0.018	0.040
0.03	5	0.006	0.020	0.060	0.080	0.018	0.040
0.03	5	0.006	0.020	0.060	0.100	0.018	0.060
0.03	10	0.003	0.001	0.001	0.009	0.010	0.040
0.03	10	0.003	0.001	0.001	0.009	0.010	0.050
0.03	10	0.003	0.001	0.003	0.030	0.009	0.050
0.03	10	0.003	0.002	0.003	0.030	0	0.050
0.03	10	0.003	0.003	0.003	0.030	0.020	0.050
0.03	15	0.002	0.001	0	0	0.000	0.007
0.03	15	0.002	0.001	0	0.006	0.005	0.013
0.03	15	0.002	0.001	0.006	0.006	0.005	0.013
0.03	15	0.002	0.001	0	0.006	0.005	0.013
0.03	15	0.002	0.001	0	0.006	0.007	0.005

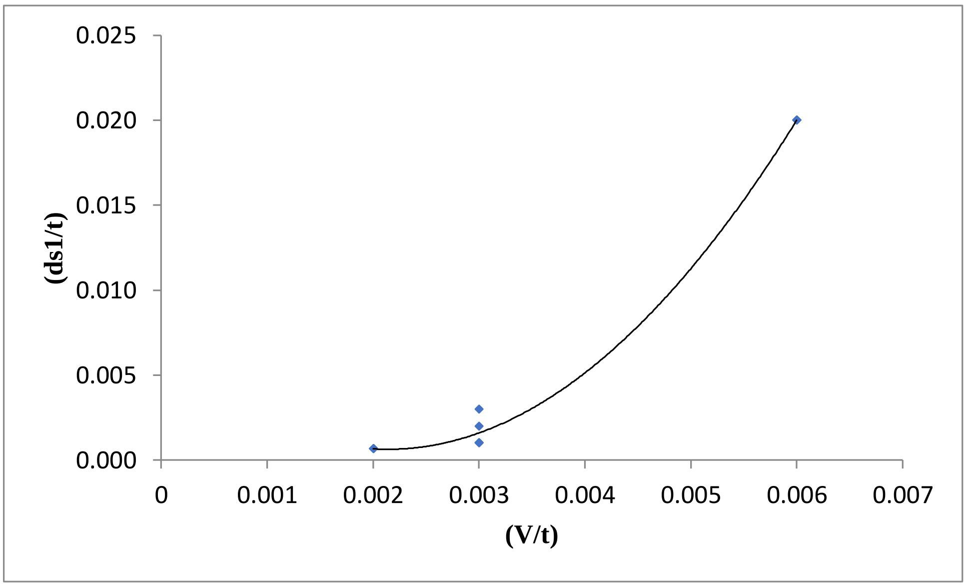

Figure 10. Graph of the relationship between (v/t) vs (ds1/t) of the 60° crib slope angle

It is different from the pattern that occurs in conditions such as those in Figures 4 to 8. In Figure 10, it can be seen that in the first crib, in the initial conditions, a relative deposition (ds1/t) of 0.0015 and a relative velocity (v/t) of 0.002.

Then erosion begins to occur at a certain distance and increases to the maximum erosion depth at a relative velocity (ds1/t) of 0.006, which is 0.02

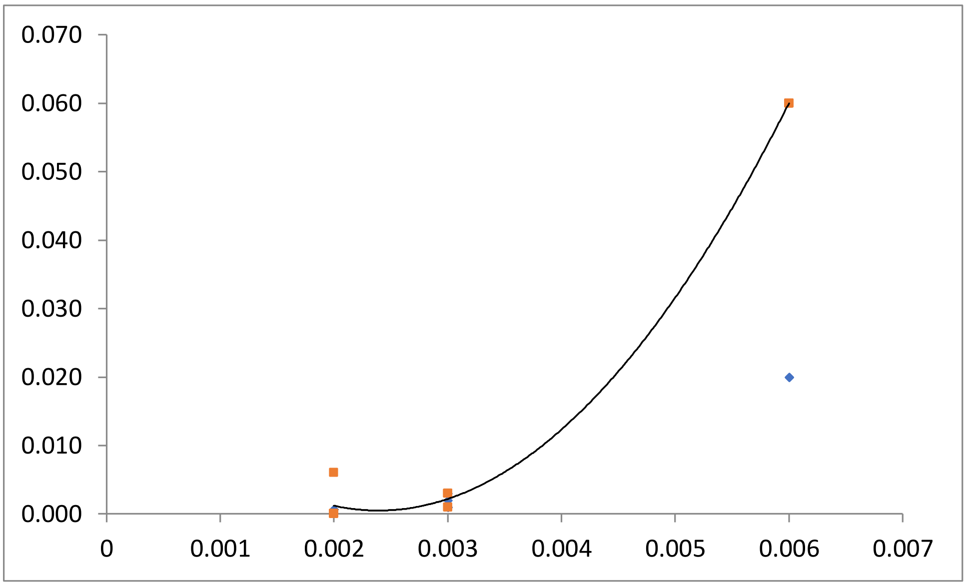

Figure 11. Graph of the relationship between (v/t) vs (ds2/t) of the 60° crib slope angle

Almost the same as what happened in the second crib, as seen in Figure 11. It can be seen that the maximum relative erosion depth (ds2/t) is 0.06 at a relative velocity (v/t) of 0.006.

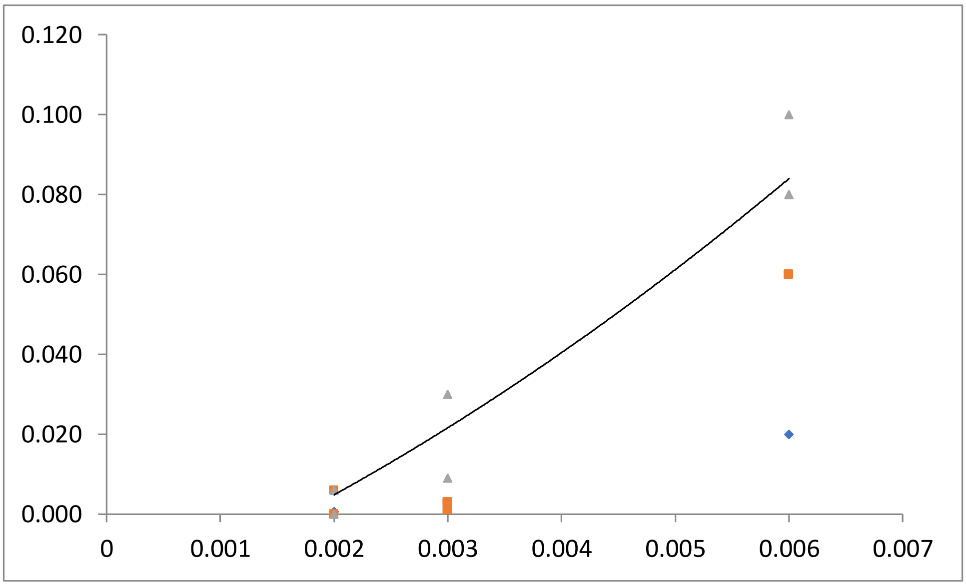

Figure 12. The relationship between (v/t) and (ds3/t) of the 60° crib slope angle

Figure 12. The third crib shows that the relative velocity (v/t) increases significantly in a straight line or linear trend, namely the greater the maximum relative depth value (ds3/t)max of 0.08.

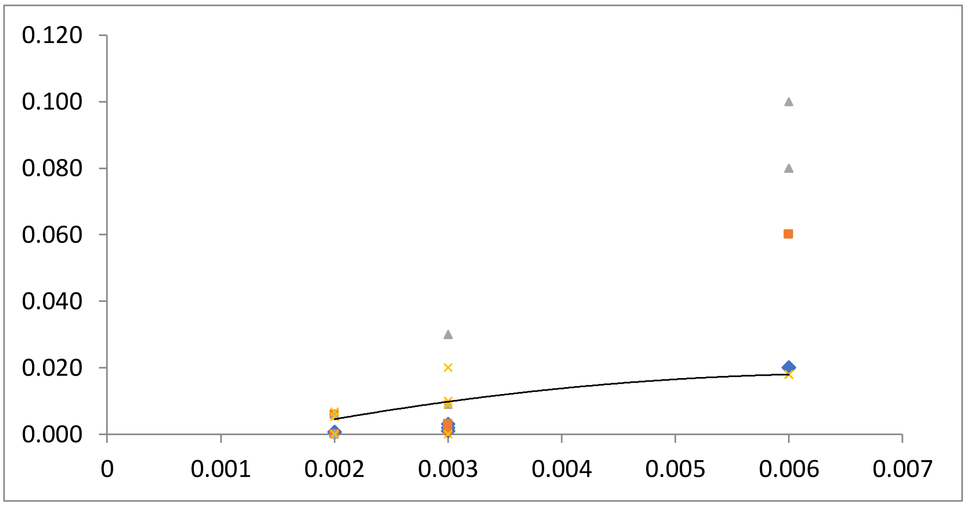

Figure 13. The relationship between (v/t) and (ds4/t) of the 60° crib slope angle

In contrast to the graph in Figure 13. where the greater the relative velocity (v/t), the more it shows a decreasing trend in the relative depth of erosion (ds4/t).
This is because the longer the flow time (t), the speed will decrease and be stable and there is no increase in erosion at river bends.

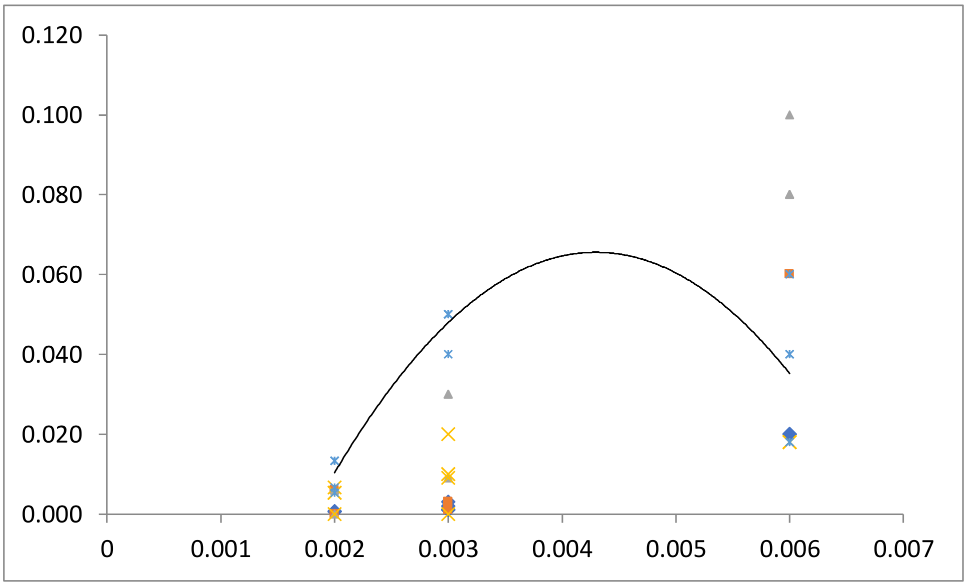

Figure 14. The relationship between (v/t) and (ds5/t) of the 60° crib slope angle

Figure 14 shows that there has been a maximum relative depth at the fourth crib (ds4/t), namely at a relative speed (v/t) of 0.004 with a maximum relative depth (ds4/t) of 0.06. After that, there was a decrease in the relative depth of erosion (ds/t) proportional to the relative velocity (v/t) that occurre.

5. Conclusion

The maximum relative sedimentation (ds5/t)max for the 30° crib slope angle occurs at the fifth crib of 0.025 at a relative velocity (v/t) of 0.06. While the maximum relative erosion depth (ds3/t)max for the 30° slope occurs at the first crib, which is 0.012 at a relative velocity (v/t) of 0.0042. At 60° crib slope, the maximum relative erosion depth (ds3/t) is 0.082 at a relative velocity (v/t) of 0.006 at the third crib. More greater of the relative velocity, occur the greater the depth of erosion.

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