PHYSICAL MODEL APPROACH OF CRIB WALLS TO IMPROVE THE RIVER SLOPE STABILITY

Achmad Syarifudin
Indonesian Association of Hydraulic Engineers (HATHI) of South Sumatra;
Universitas Bina Darma
achmad.syarifudin@binadarma.ac.id

Asri Mulyadi
Palembang University
asrimulyadi@unpal.ac.id

Henggar Risa Destania
UIGM University
henggarrisa@UIGM.ac.id

Abstract

This study aims to determine the pattern of crib walls collapse at river bends and the effect of the slope angle of the crib walls not escaping the water as a crib walls 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 crib walls installation are varied. The crib walls 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 walls angle of 30° occurred in the fifth crib walls 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 walls occurs in the first grout, which is 0.012 at a relative speed (v/t) of 0.0042. At the angle of 60° crib walls, there is a maximum relative erosion depth (de_3/t) of 0.082 at a relative speed (v/t) of 0.006 on the third crib walls. The increasing of the relative velocity (v/t) the greater the value of the relative erosion depth (ds/t).

Keywords: **Crib walls; scale models; erosion and sedimentation; slope stability**

1. INTRODUCTION

In the 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 highwater discharge fluctuations and reduced river capacity (Paimin et al, 2012).

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 (Holdani Kurdi, 2019).

To determine the dimensionless number can be done by dimensional analysis (Holdani Kurdi, 2019). 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:

$= (M^{\alpha 1} L^{\beta 1} T^{\tau 1})k1 * (M^{\alpha 2} L^{\beta 2} T^{\tau 2})k2 * .... (M^{\alpha n} L^{\beta n} T^{\tau n})^{kn}$

$= [M (^{\alpha 1k1+ \alpha 2k2} +........ +^{\alpha nkn})]*[L^{\beta 1k1} + {}^{\beta 2k2}+....... +^{\beta nkn}]*[T^{\tau 1k1}+ 2\ {}^{k2} +......... +\tau n\ {}^{kn}]$ is a dimensionless number if:

$\alpha 1\ k1+ \alpha 2\ k2 +........+ \alpha n\ kn = 0$

$\beta 1\ k1 + \beta 2\ k2+....... + \beta n\ kn = 0$

$\tau 1\ k1 + \tau 2\ k2 +........+ \tau n\ kn = 0$

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 1,280 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 (Syarifudin, A et al, 2018).

2. RESEARCH METHODS

2.1. *Research sites*

This research was conducted in the Hydrology and Hydraulics laboratory of Bina Darma University Palembang as shown in Figure 1 (Syarifudin, A et al, 2019).

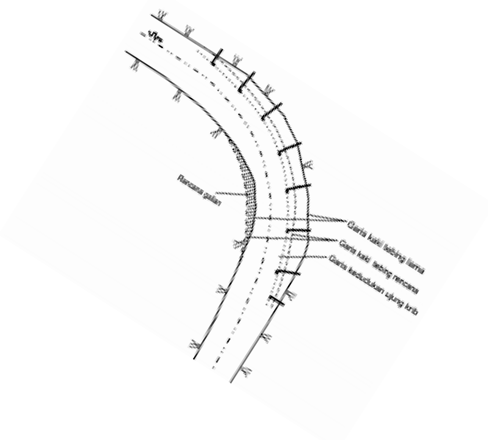

Figure 1: Crib walls design model (Syarifudin, A, 2020)

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 at Bina Darma University (Syarifudin, A, 2019).

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

2.4. Materials and Tools

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

Table 1 List of the 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 walls model	3, 5 and 7 unit	Simulation tool
4.	River bed materials	Sieve analysis result	Simulation material
5.	Water	Suitable for storage	Flow simulation

2.5. *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 (d_{50}) 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 walls models
- The sixth stage, conducted a trial with a running time of 60 minutes, with every 15 minutes good observations were made with 3 groin models, then 5 crib walls models and 7 groin models. Observations and recordings of erosion and sedimentation patterns were carried out in each scenario of the installation of the crib walls model.
- The seventh stage, discusses the results of observations that occur in the crib walls model and makes research conclusions and provides suggestions for further research by other studies.

3. RESULTS AND DISCUSSION

3.1. *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 crib walls 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:

$$\pi 1 = v/t \quad (1)$$
$$\pi 2 = de/t \quad (2)$$
$$\pi 3 = h/t \quad (3)$$
$$\pi 4 = t/2g \quad (4)$$

$(h/t) \times (t/2g) = 2gh = v$

$f\ (v/t\ ;\ de/t;\ v) = 0\ (v \approx 0)$

$(v/t) = f\ (de/t)$ focus on erosion around the cribs

3.2. *5 (five) crib walls models with an slope angle of 60°*

In conditions where there are 5 (five) crib walls at the bend of the river with a slope angle of 60 ° as shown in Figure 1.

Figure 2: The Placement of the crib walls with slope angle of 60°

Table 4 The Results of Analysis of the Scouring Depth at the Crib walls Slope Angle of 60°

		Non dimensional parameter					
V	(t)	V/t	de_1/t	de_2/t	de_3/t	de_4/t	de_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

3.3. *Simulation Results*

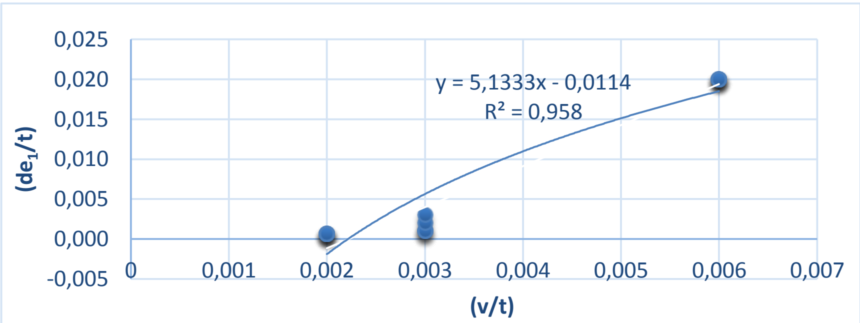

Figure 2: The relationship between (v/t) and (de_1/t) of the crib walls with slope angle of 60°

In Figure 2, If the time taken is 60 minutes, then the velocity v that occurs is 0.12 cm/sec, then with a velocity v of 0.12 cm/sec taken as a benchmark calculation, the amount of sedimentation that occurs is 0.648 cm or with a scale of 1:100 , then the amount of sedimentation is 64.8 cm in the model or 0.648 m in the prototype (site).
Then erosion begins to occur at a certain distance and increases to the maximum erosion depth at a relative velocity (de1/t) of 0.006, which is 0.02. Likewise, the erosion depth is 72 cm in the model or 0.72 m in the prototype (site).
The value of R^2 = 0.958 or R = 0.978 and this means that 97.8 percents there is a suitable value between the depth of erosion with the velocity parameter v and time t on the cribs placement with an angle of 60°.

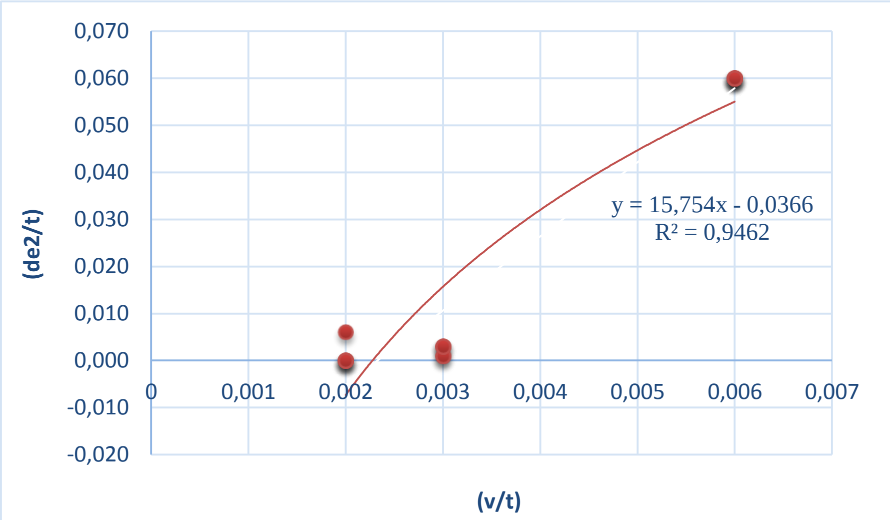

Figure 3: The relationship between (v/t) and (de_2/t) of the crib walls with slope angle of 60°

Almost the same as what happened in the second crib walls, as seen in Figure 3. It can be seen that the maximum relative erosion depth (de_2/t) is 0.06 at a relative velocity (v/t) of 0.006. and then the value of R^2 = 0.946 or R = 0.972, this means that 98.59 percents there is a suitable value between the depth of erosion with the velocity parameter v and time t on the cribs placement with an angle of 60°.

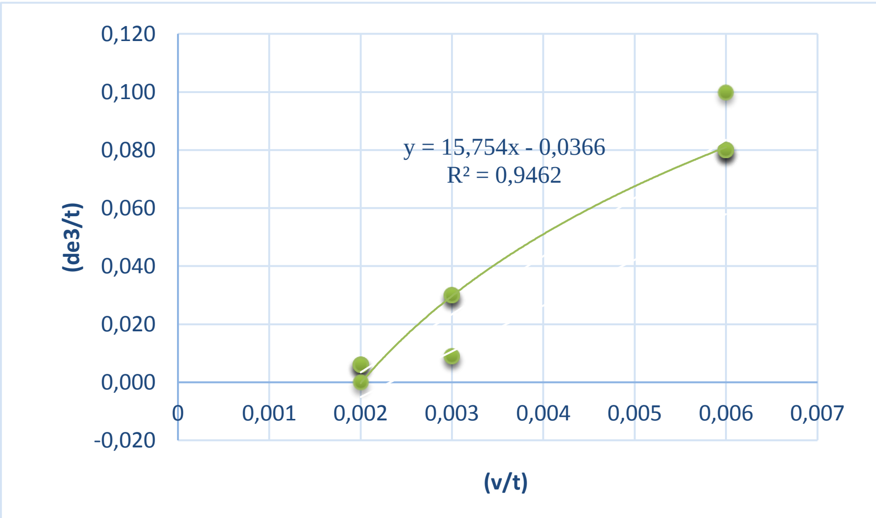

Figure 4: The relationship between (v/t) and (de_3/t) of the crib walls with slope angle of 60°

Figure 4. The third crib walls shows that the relative velocity (v/t) increases significantly in a straight line or linear trend, namely the greater the maximum relative depth value (de_3/t)max of 0.08.

The value of R^2 = 0.946 or R = 0.972, this means that 98.59 percents there is a suitable value between the depth of erosion with the velocity parameter v and time t on the groynes placement with an angle of 60°. The same like The relationship between (v/t) and (de_2/t) of the 60° cribs slope angle. (figure 5).

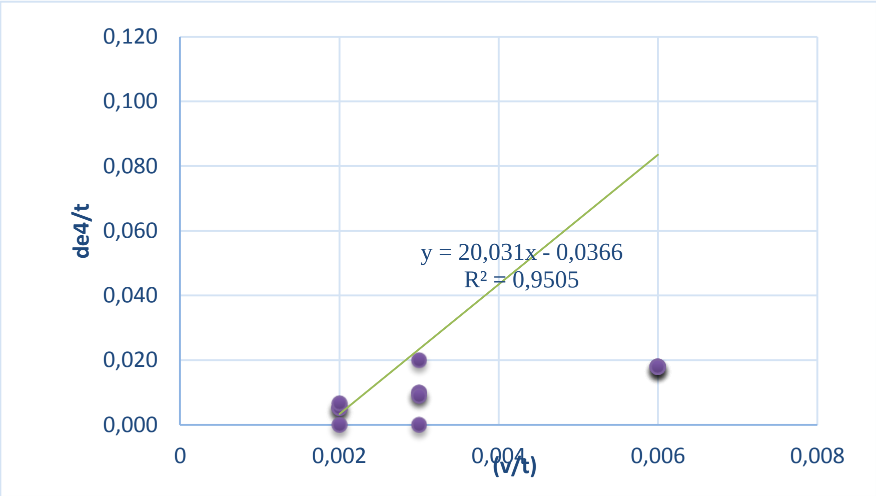

Figure 5: The relationship between (v/t) and (de_4/t) of the crib walls with slope angle of 60°

In contrast to the graph in figure 5. where the greater the relative velocity (v/t), the more it shows a decreasing trend in the relative depth of erosion (de_4/t).
This is because the longer the flow time (t), the velocity v will decrease and be stable and there is no increase in erosion at river bends.
The value of R^2 = 0.950 or R = 0.974, this means that 97.4 percents there is a suitable value between the depth of erosion with the velocity parameter v and time t on the cribs placement with an angle of 60°.

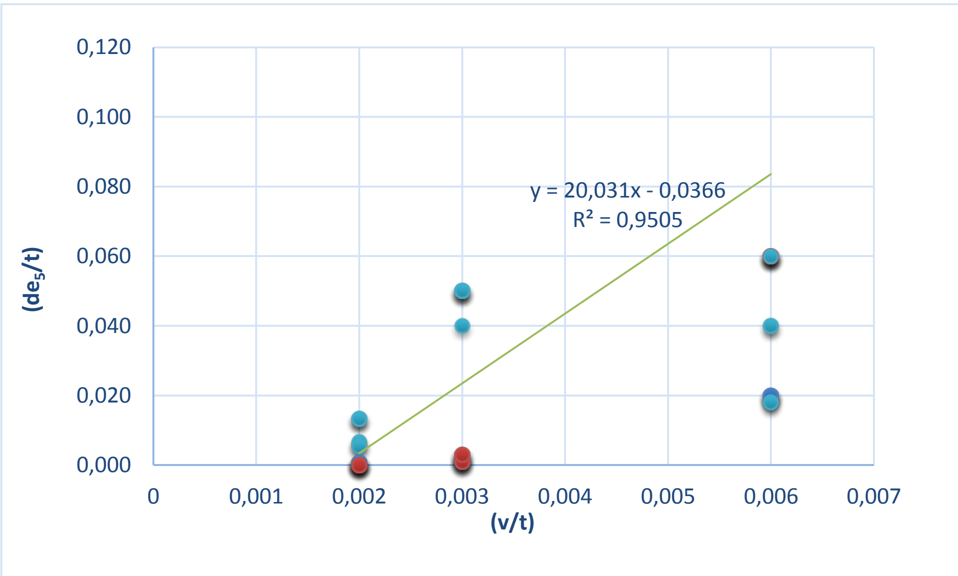

Figure 6: The relationship between (v/t) and (de_5/t) of the crib walls with slope angle of 60°

Figure 6 shows that there has been a maximum relative depth at the fourth crib walls (ds_4/t), namely at a relative velocity (v/t) of 0.004 with a maximum relative depth of erosion (de_5/t) of 0.06. After that, there was a decrease in the relative depth of erosion (de/t) proportional to the relative velocity (v/t) that occure.

It is the same with the value of $R^2 = 0.950$ or R = 0.974, this means that 97.4 percents there is a suitable value between the depth of erosion with the velocity parameter v and time t on the crib walls placement with an angle of 60^o.

4. CONCLUSION

At the slope angle of 60°, the maximum relative erosion depth (de/t) is 0.082 at a relative velocity (v/t) of 0.006 at the third crib walls. So, if the velocity is 1 m/sec with 1 hours, the **erosion** occurs 0,029 cm in the model or **2.90 m** (in site) with scale of 1:100 and with R = 0,974 or means that 97.4 percents there is a suitable value between the depth of erosion with the velocity parameter v and time t on the crib walls placement with an angle of 60^o.

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Biodata

Achmad Syarifudin is a Professor in Urban Drainage, Environmental and River Engineering at Bina Darma University with more than 25 years of professional experience as a consulting engineer, laboratory manager, researcher and lecturer. He is a recognized expert in Sustainable Urban DrainageSystem, Water Resources, River Engineering. His research has been funded by Ministry of education and culture, research and technology of the Republic of Indonesia. He has a long history of applied research and published in journal papers and publications in the last 3 years. Email: achmad.syarifudin@binadarma.ac.id