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INFLUENCE OF BAMBOO DEBRIS ACCUMULATION FORMED BY CULVERT BRIDGES ON BACKWATER RISE DURING FLASH FLOOD

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ABSTRACT: Bambooplants appear to cover the sorrounding environment on the edge of River in Lombok to alleviate many environmentalproblems such as river bank erosion. Despite its usefull, side erosion along the upstream river during a heavy rain 2017 in Lombok island, West Nusa Tenggara. This phenomenon was drifted a significant amount of sediment and bamboo. Unfortunately, there are many culvert bridges installed in the river. The transported bamboo accumulated at thebridges and then overflowed the banks at several sections. The accumulation or jam also caused backwater rise. There are two types of culvert bridges in the river. One is a pipe culvert bridge and the other is box culvert bridge. This condition due to the accumulation at a bridge from the view of river engineering becomes a vital factor in flood problems. A series of experimental study was performedin Hydraulic Laboratory of University of Muhammadiyah Mataram in order to investigate the formation of bamboo debris accumulation formed by the two different types of culvert bridges. The small size of bamboo and model of culvert bridges were tested. The released of bamboo pieces were trapped by the model bridges and formed bamboo debris accumulation. These experimental results reveal that the bamboo debris accumulations contribute to backwater rise. The backwater rise and loss coefficients increase slowly with the volume of bamboo pieces trapped by a culvert bridge**.** A procedure of predicting backwater rise was proposed.

Keywords: Debris, Flash Flood, Accumulation, Culvert Bridge

1. INTRODUCTION

Side erosionand landslide along the upstream river reach, triggered by heavy rain in Lombok 2017 contribute the production of sediment and bamboo debris. This disaster caused the transport of bamboo debris and sediment in Jerowaru River. Some pieceswas trapped by obstructions in river and othercould be transported downstream by flash flood. There are two different types of bridges as obstructions during the flood. One is Kelambu Bridge as a circle culvert bridge. The other is Jerowaru Bridge as a box culvert bridge.The accumulation or jam at the bridge caused reduction in the waterway capacity, blockage of a river, increase in lateral forces and backwater rise. The accumulation become an important issue in Indonesia where large density of inhabitans lie at the vicinity of river.

Many different approaches have been proposed to solve the issue [1-10]. Fields investigations into woody debris jams formed by some obstacles during the 2012Yabe river flood were carried out by [5,6]. The obstacles were bridges and riparian trees in the river and houses on the flood plain. The dependence of volume of woody debris jam on the shaded area of obstacles clearly pointed out. Diehl [1] proposed the most possibility bridges with one pier in the channel to trap wood debris during flood event. The probability of wood debris accumulation at bridge decks can be depend on Froude number and the characteristics of bridge [9]. The jam blocked the channel and produced backwater rise [3,9]. However, much work on the problem of backwater rise due to the accumulation has been carried out, yet there are still some critical issue. The purpose of the present paper is to investigate influence of theaccumulation of bamboo debrison backwater rise.

2. THE MATERIAL AND EXPERIMENTAL METHOD

2.1 Hydraulic Models

The experimental study was carried out using a rectangular flume as shown in Fig.1. The flume was 0.30 m wide and 12.00 m long. Our experimental set up bears a close resemblance to the one proposed by [7,8].

The flume slope was set at 1/100 vertical to horizontal. The flume bed divided into two parts: movable and immovable parts. The movable flume bed was composed of sediment grains with specific weight = 2.67 and d_{50}=0.8 mm. The immovable bed part was roughened by the same materials as the movable bed materials.

Two types of culvert bridges wereperformed as obstructionsand placed on the immovable bed part 2.5 m distant from the end of downstream. Pieces of small natural bamboo were used as a model piece. The apparatus for dropping the bamboo pieces on the flow surface was installed at the station 5 m upstream from the model bridge. Inflow flow rate per unit width was about q=100cm^2/s at the end of upstream.

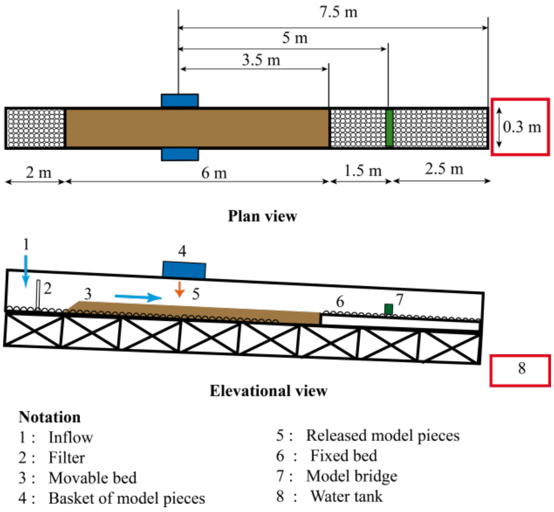

Fig.1 A flume for experimental study

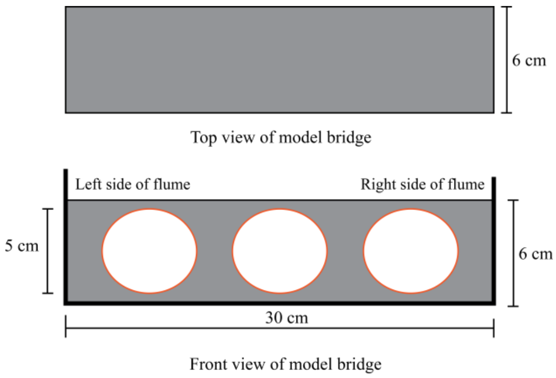

Fig.2 Model of pipe culvert bridge

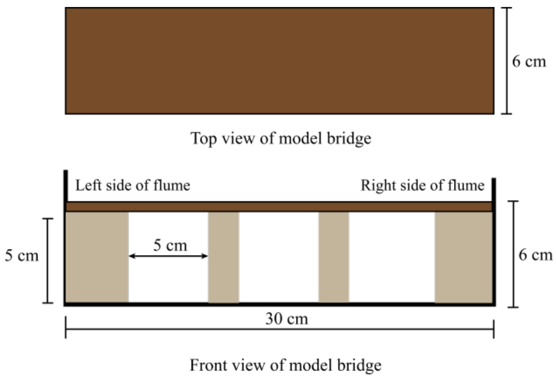

Fig.3 Model of box culvert bridge

2.2 Model of Bridges

Two types of culvert bridges were used as an obstruction and placed on the fixed bed part 2.5 m distant from the end of downstream. Fig. 2 presents apipe culvert bridge and Fig.3 shows a box culvert bridge. The bridge type was based on Kelambu and Jerowaru Bridge, Respectively. Its reduced size of the prototypes was 1/140. River slope was 1/100 near the model bridges.

2.3 Model of Bamboo Debris

The model debris was simulated by small pieces of natural bamboo; Its diameter was D= 2.0 or 3.0 mm and its length was from L = 3 cm till L = 11cm. The dry densityof model bamboo debris was 0.65 g/cm^3. Prior to a test, the pieces were soaked in water for 15 minutes and then were put in a few baskets on the right-left side oftheflume. The bamboo pieces released on the flow surface by openning the upstream wall of the basket. Fig.4 shows the oblique view of the basket and Fig.5 presents model of bamboo debris.

Fig.4 Box of release pieces

Fig.5 Model of bamboo debris

2.4 Procedure of Experiment

The procedure of experimental is in line with a variation of that used by [8]. Water flowed from the upstream of flume. The water flow conveyed sediment to downstream along the flume bed. However, under this condition less sediment transported.

Bamboo pieces in the box were released on the flow surface after the mixture flow becomes steady and uniform flow. It around 2 minutes after the front flow reached the downstream end of flume. The congested bamboo pieces moved to the model bridge in the flume. Detained bamboo debris formed a jam at the pipe culvert bridge (Fig.6 and Fig.7) and at the box culvert bridge (Fig.8 and Fig.9). A few containers were placed at the downstream end of flume for measuring discharge.

There are three video cameras that put on the flume to investigate the behavior of bamboo pieces at the model bridge. One video camera was on the top of the flume. The others video cameras were ion the left-hand site of flume.

A point gauge was located along the length of the flume to measure the height of water above flume bed. The height of water was measured during the accumulation of bamboo debris at the model bridges and without the model bridge Therefore, backwater rise includes the effect of accumulationsat model bridges in the first stage and that of without bridge in the second stage. The number of bamboo pieces trapped and accumulated at the model bridge was counted after the experimental runs.

Table 1 provides the experimental condition where eight runs were performed for every model bridge. The total number of pieces and discharge are from 135 to 450 and around 100 cm^2/s, respectively. The duration of each run was around 20 minutes.

Table 1 The Number and length of bamboo pieces

Run	Length of pieces (cm) / released pieces								
	11	10	9	8	7	6	5	4	3
1	50	50	50	50	50	50	50	50	50
2	45	45	45	45	45	45	45	45	45
3	40	40	40	40	40	40	40	40	40
4	35	35	35	35	35	35	35	35	35
5	30	30	30	30	30	30	30	30	30
6	25	25	25	25	25	25	25	25	25
7	20	20	20	20	20	20	20	20	20
8	15	15	15	15	15	15	15	15	15

Fig.6 Front view of piece accumulation at the pipe culvert bridge

Fig.7 Top view of piece accumulation at the pipe culvert bridge

Fig.8 Back view of piece accumulation at box culvert bridge

Fig.9 Top view of trapped pieces at box culvert bridge

3. EXPERIMENTAL RESULTS AND DISCCUSSION

3.1 Bamboo Debris Accumulation

Field survey in the inundation area (Fig.10 and Fig.11) and a series of flume experiment were carried out in order to explore the formation of bamboo debris deposition. Bamboo debris conveyed by the floods was to be deposited on riverside slope or flood plain and where the debris hits an obstacle. Our field surveys show that there are two types of the situation of bamboo debris at deposition site; one is the rest of individual bamboo pieces on riverside slope or floodplain and the other is the formation of bamboo debris accumulation.

Fig.10 The area of field survey

Fig.11 Inundated house near the pipe culvert bridge

Our experimental study only focused on the formation of bamboo debris accumulation. Two different types of culvert bridges were used. The accumulation of bamboo debris at the model bridges can determine by anumber of released bamboo pieces as shown in Fig.12 and Fig.13.

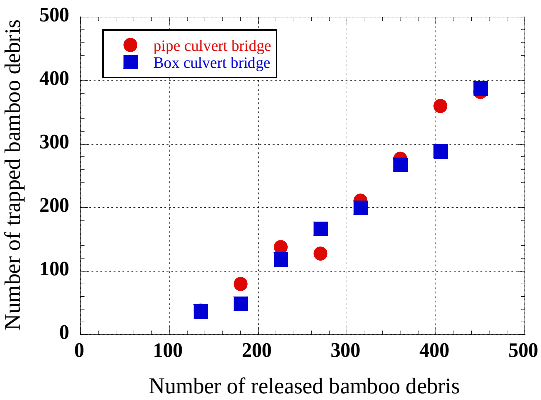

Fig.12 Relationship between released pieces and trapped pieces

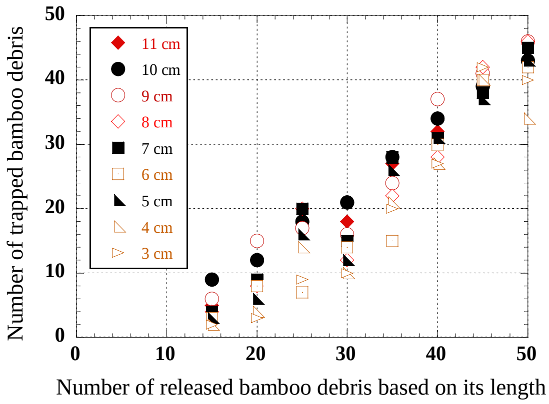

Fig.13 Relationship between released pieces based its length and trapped pieces at pipe culvert bridge

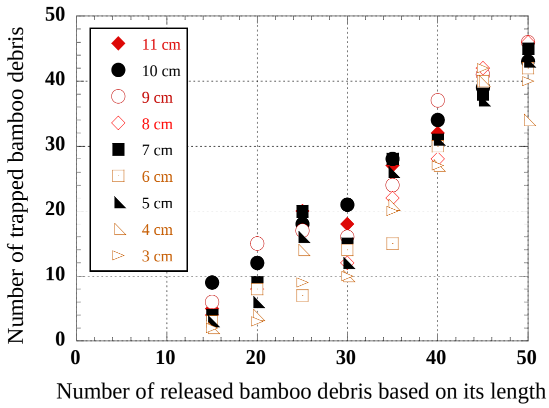

Fig.14 Relationship between released pieces based on its length and trapped pieces at box culvert bridge

3.2 Backwater Rise and Loss Coefficient

Every water surface is approximately same at around x=30 cm in downstream of the model bridge and at around x = 5 cm from the upstream of the model bridge. Backwater rise due to the accumulations at the model bridge is significantlylarge as shown in Fig.14 and Fig.15.The downstream water depth with accumulation is approximately equal to the normal depth. For convenience, the normal depth and velocity can be used as a reference value.

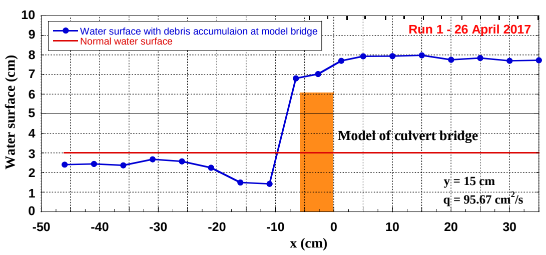

Fig.15 Water surface due to accumulated pieces at the pipe culvert bridge

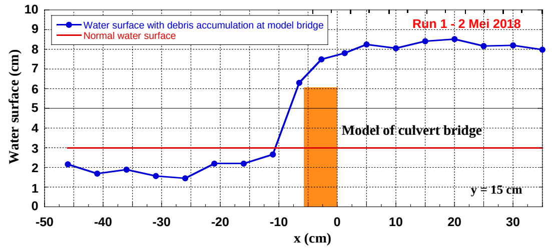

Fig.16 Water surface due to accumulated pieces at the box culvert bridge.

In order to identify backwater rise and loss coefficient, the following equations were used.

$$\Delta h_{ud}^{j} = h_u^j - h_d^j \quad (1)$$

$$\Delta h_{ud}^{n} = h_u^n - h_d^n \quad (2)$$

$$f_d^j = \Delta E_{ud}^j / ((v_d^j)^2 / 2g) \quad (3)$$

where

$$\Delta E_{ud}^j = \left\{ \frac{(v_u^j)^2}{2g} + h_d^j \right\} - \left\{ \frac{(v_d^j)^2}{2g} + h_d^j \right\} \quad (4)$$

$$v_u^j = \frac{q}{h_u^j} \quad (5)$$

$$v_d^j = \frac{q}{h_d^j} \quad (6)$$

Whereh^j_u = upstream water depth with accumulation, h^n_u = upstream water depth without accumulation, h^j_d = downstream water depth with accumulation, h^n_d = downstream water depth without accumulation,h^j_u = upstream water depth with jam, f^j_d = loss coefficient, E^j_{ud} = energy, v^j_d = downstream velocity with accumulation and v^j_u = upstream velocity with accumulation.

The equations of backwater rise and loss coefficientswere proposed in [8] were used. Eq. (1) is equation to predict backwater rise in each run. Eq. (3) is equation to assess loss coefficient. Changes in backwater rise were compared by a number of traped pieces. The backwater rise grows slowly with the volume of trapped pieces as shown in Fig.17. Then, as can be seen from Fig.18, loss coefficients increase slowly with the volume of trapped pieces. An empirical equation from the relationship between shaded area of obstruction and apparent volume of accumulation [6,7] were used to predict the volume of accumulation. The equation as follow

$$V_{wd} = CA_o^{\alpha} \quad (7)$$

Whereα = 3/2 and C = 2,5

Based on the results and the empirical equation, a procedure of estimation of backwater rise due to bamboo debris accumulation at a culvert bridge was proposed (Fig.19). In addition, the procedure could be applied to predict backwater rise from loss coefficient and hydraulic condition.

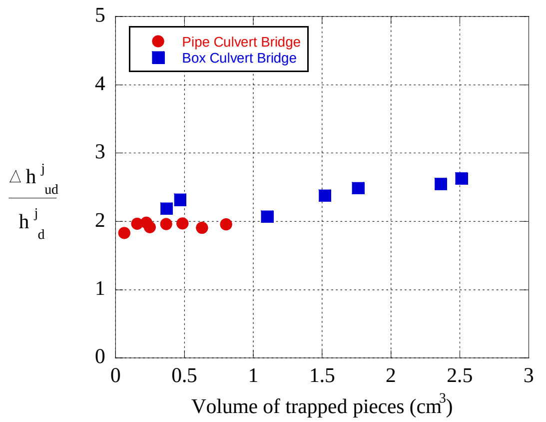

Fig.17 Relationship between backwater rise and volume of trapped pieces

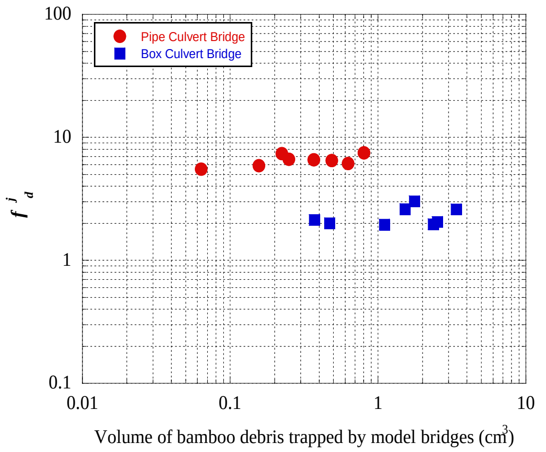

Fig.18 Relationship between loss coefficient and volume of trapped pieces

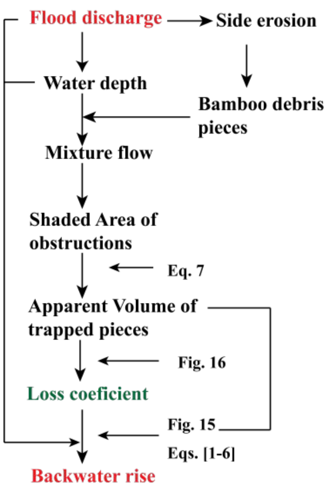

Fig.19 A flow chart for predicting backwater rise

4. CONCLUSION

The results obtained in this paper show that trapped bamboo debris increases significantly with the number of released pieces for pipe culvert bridge and box culvert bridge. However, the backwater rise and loss coefficients grow slowly with the volume of trapped bamboo debris at the two types of culvert bridge. Our work clearly has some limitations. Nevertheless,the result of our study could be useful for flood disaster prevention. Further experimental investigations are need to carry out to establish the results.

5. ACKNOWLEDGMENTS

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