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Analysis of Drainage Channel on Musi V Bridge, Gandus District, Palembang

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ABSTRACT

Musi V Bridge is one of the three bridges on the Kayu Agung–Palembang–Betung Toll Road. This bridge is the longest toll bridge in Indonesia and connects the cities of Palembang and Betung. It has a length of 1,684 km and a width of 17 m and is located in Gandus District, Pulokerto Village, Palembang City. Channel is one of the bridge constructions that functions to overcome flooding. This research aims to analyse the dimensions of pipe channels based on flood discharge to overcome inundation on bridge bodies. The analysis uses rainfall data from BMKG Station, Kertapati Station and SMB II Station. Data are processed using frequency analysis and suitability tests to obtain concentration times and hydrological discharge parameters. Data are then compared with the hydraulic discharge processed from the channel dimensional parameters. The evaluation results of the planning diameter are assumed to be 8 inches or 20.32 cm according to the guidelines, which state a minimum channel diameter of 200 mm or 20 cm and a minimum pipe installation slope of 2% for comfort. The results of the comparison of hydrological and hydraulic discharges show that all drainage channels are feasible.

1. Introduction

In urban areas, water infrastructure requires proper analysis to overcome inundation problems [1]. The progress of sustainable infrastructure development is a priority for the Indonesian government and it includes constructing bridges as a means of transportation on land that connects one region to another. The progress of bridge construction development also positively influences increasing economic growth and regional equity. However, considering that Indonesia is a country that is vulnerable to high rainfall, the planning of drainage systems on bridges needs to be designed to avoid puddles that interfere with motorist activities [2].

Musi V Bridge is located in the Gandus District of Palembang City. It is a bridge on the Kayu Agung–Palembang–Betung toll road and has two lanes in two directions and a length of 112 km. The bridge has a length of 1,684 km and the construction connects Palembang City and Betung [3].

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During the rainy season, excess water often becomes a problem for puddles in urban areas. To overcome this inundation problem, scholars should conduct hydrological analysis to determine the amount of flood discharge that is likely to inundate the location or catchment area. Blockages in the inlet or bars can cause flooding or puddles, which are usually present in a place [4]. They can also be caused by the size of the channel [5], which cannot accommodate planned discharge that could previously be predicted in advance by hydrological analysis in the area [6]. Hydroplaning conditions or slippery roads can cause accidents, either single or consecutive [7]. Inappropriate drainage system planning will also affect the sustainability of a bridge's construction [8] because puddles that occur can make the upper structural area of the bridge vulnerable to corrosion and increase the bridge maintenance costs [9]. Thus, infrastructure is expected to cause a country's progress because it can become an investment field turned into construction that harms the country with significant development costs [10].

Based on previous research that has been carried out, it is necessary to carry out an analysis to calculate the amount of discharge that can drain surface water on the bridge road body. Apart from that, calculating dimensions and choosing the right drainage channel material is very important to ensure that the pipe channel design is appropriate to the amount of water discharge that will be imposed on the bridge. This research aims to propose a drainage system design in the bridge area to anticipate future inundation or flooding problems. Channel capacity must be adjusted to the discharge based on the results of hydrological and hydraulic analysis so the required pipe-shaped channel dimensions can be determined [11-15].

2. Methodology

2.1 Research Location

This research focuses on the Musi V Bridge in Gandus District, Palembang City. This bridge, which has a length of 1,684 km and a width of 25.4 m, connects Palembang and Betung.

2.2 Stages of Research

Data processing was carried out using hydrological analysis, where rainfall data for the last 10 years were obtained from BMKG rainfall data from the South Sumatra Climatology Station at Kertapati Station and SMB II Station. Data were then processed to obtain a rational method.

The following components in hydrological analysis include:

i. Data on rainfall were obtained from the South Sumatra Climatology station at Kertapati station and SMB II station, the closest station to the Musi V Bridge area. Data were recorded daily from 2012 to 2021. Based on hydrology theory, the average rainfall for rainfall data from data sources from more than two stations should be analysed. In this study, average rain was used in algebraic method. Figure 1 shows the average rainfall data from two rain gauge stations:

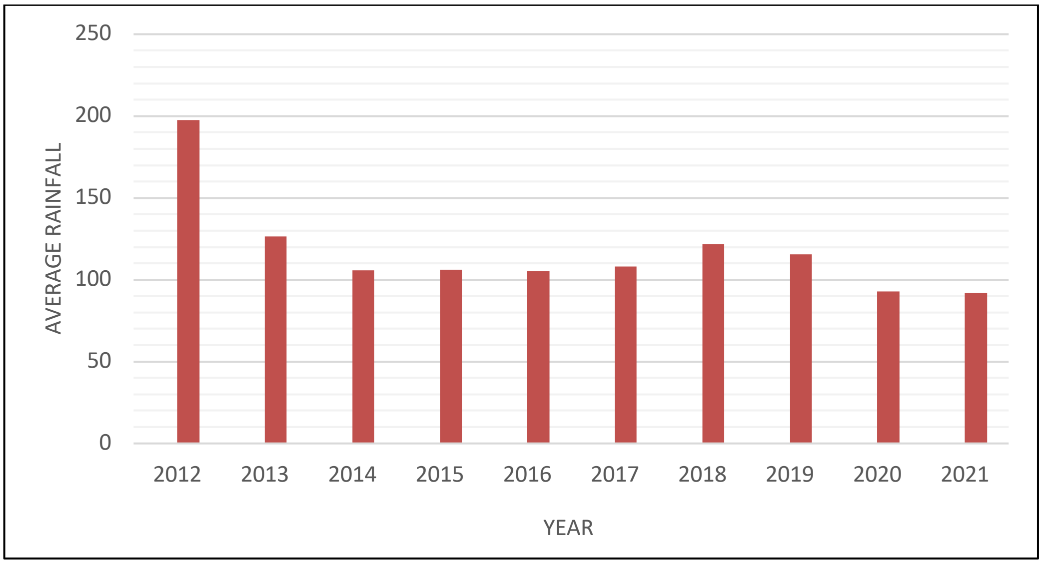

Fig. 1. Average rainfall from 2012 to 2021

i. Rainfall plan was determined by comparing the results of normal distribution, log-normal distribution, gumble distribution and log Pearson III distribution.
ii. Distribution suitability test was carried out using Chi-Square and Smirnov–Kolmogorov methods.
iii. Concentration–time (tc) was determined (tc) [16-18].
iv. Using the formula from Mononobe, we determined the rain intensity value
v. After all components were obtained, the discharge on the Musi V Bridge was calculated using the rational method [16-18].
vi. The following components in hydraulic analysis include:
    1. Calculation of water discharge in the circular cross-section of the pipe.
    2. Determination of the size of the drainage channel by using the circle area formula.

Hydrological and hydraulic analyses were carried out to obtain appropriate pipe channel dimensions and consider the slope of the pipe installation.

2.3 Hydrological Analysis

Hydrological analysis used rainfall data obtained from rain gauge stations close to the location in this research. Rain is an important part of hydrological analysis, especially when knowing the discharge plan in an area so that you can plan the right channel dimensions in the drainage system. Rainfall in a large area usually has different rainfall analyses, so hydrology cannot rely on data that only comes from one rain station. Therefore, an average rainfall value obtained from several rain stations is needed to obtain accurate hydrological analysis results.

In general, the return period used in designing bridge drainage channels is 10 years [19]. The return period is also used to calculate probability distributions. Probability distribution analysis is carried out to determine the suitable probability distribution to use so that it can be continued in the fit test calculations. This probability distribution analysis included normal, Gumbel, log-normal and log-person III distribution. To ensure that the probability distribution that will be used is acceptable, we performed a goodness-of-fit test by using Chi-Square test and Smirnov–Kolmogorov test [18]. The results were compared to obtain a suitable probability distribution that will be used in calculating the planned rainfall.

Concentration time channels rainwater from the farthest point until a certain point is seen in the drainage area. To simplify the calculation of concentration time, the formula invented by Kirby is used, namely:

$$T_c = 1{,}44.\ (nd\ \frac{L}{\sqrt{i}})^{0{,}467} \tag{1}$$

With :
L= Flow Length (m)
i= slope (m)
nd = Coefficient of roughness

Previous researchers calculated rainfall intensity by using the Mononobe formula, which yielded good results [20,21]. Rain Intensity is the accumulation of rain shown in the height of rain per unit of time, which depends on the duration of the rain and the frequency of its occurrence and obtained from analysis of rain data [17,18,20]. The calculation of rain intensity depends on existing data. The relationship between rain intensity and time often depends on local conditions. Based on this analysis, the calculation of the duration of rainfall intensity (I) is obtained based on the 'assumption' of centralised rain distribution for one day and is calculated based on the Mononobe equation:

$$I = \frac{R_{24}}{24} \cdot \left(\frac{24}{tc}\right)^{2/3} \tag{2}$$

In hydrological analysis, flood discharge calculations use a rational formula because it is easy to use. The planned flood discharge consists of three components, namely, runoff coefficient (C), rainfall intensity data (I) and water catchment area (A).

$$Q = 0{,}00278 \cdot C \cdot I \cdot A \tag{3}$$

With:
Q = Peak flood discharge (m^3)
C = Drainage coefficient
I = Rain intensity for a specific repeat period (mm/h)
A = Drainage area (Ha)

2.4 Hydraulics Analysis

Deck drains are pipes installed to channel runoff water gravitationally from the surface of the toll road to the edge channel under the bridge. PVC pipes should be used so that the diameter of the planned deck drain is typical [19,22,23]. Just like slope protection channels, the diameter of the deck drains pipe uses a reference to the discharge that will pass through these pipes, so to find out the hydraulic discharge or discharge that this channel can accommodate can be known using the equation:

$$Q = V \cdot A \tag{4}$$

where

Q= Flow Discharge (m^3 /s)
A= Cross-sectional Area (m^2)
V= Flow Speed (m/s)

2.5 Drainage System

The water disposal path used to avoid puddles in a place is a function of the drainage system so areas free from puddles or floods can be utilised optimally. Drainage can be classified based on how it is formed, the location of the building, its function and the construction system [24]. It will be explained as follows:

i. Based on the way it is formed.
   1. Natural Drainage occurs naturally without any help from humans.
   2. Artificial Drainage is deliberately made by humans to form a building of various shapes and materials, such as pipelines, culverts and so on.
ii. Based on the Building Location.
   1. Ground Surface Drainage is a drainage channel that functions to drain runoff water and is located above ground level.
   2. Drainage Below Ground Surface is a drainage system whose function is to channel runoff water and is located underground/embedded due to several special reasons.
iii. Based on Drainage Function.
   1. Single purpose functions to distribute only one type of wastewater, for example, draining rainwater when rain occurs.
   2. Multi-purpose functions to channel several types of runoff water, such as being used in turns or used simultaneously.
   3. Based on the building system

3. Results
3.1 Probability Distribution Analysis

Probability distribution analysis is carried out to determine the suitable probability distribution so that it can be continued in the calculation of the match test. Probability distribution analysis includes normal distribution, clump distribution, normal log distribution and Pearson III log distribution.

Table 1
Recapitulation of rainfall plans

Return Period Tr (Year)	Probability Distribution			
	Normal	Log-Normal	Gumbel	Log Pearson III
2	117,0950	108,998	111,071	107,1274
5	142,5637	131,411	149,171	130,8145
10	155,9044	150,377	173,131	151,9135
25	166,8196	180,513	201,069	184,935
50	179,2507	207,918	225,856	214,4866
100	187,7403	242,101	248,147	248,6962

3.2 Goodness of Fit Test

A goodness-of-fit test can be performed so calculations can continue. The match tests used are Chi-Square test and Smirnov–Kolmogorov Test. The results will be compared with each other to obtain a matching probability distribution, which will be used to calculate planned precipitation. The results of the compatibility tests can be recapitulated to obtain the probability distribution to be used.

Table 2
Compatibility test recapitulation

Distribution	Statistical Parameters	Chi-Square Test	Smirnov-Kolmogorov Test
Normal	Not Accepted	Not Accepted	Accepted
Log-Normal	Not Accepted	accepted	Accepted
Gumbel	Not Accepted	Not Accepted	Accepted
Log Pearson III	Accepted	Accepted	Not Accepted

In the statistical parameter test and Chi-square and Smirnov Kolmogorov fit tests, the probability distribution that can be used is Log-Normal distribution.

3.3 Hydrological Discharge

Hydrological analysis aims to determine the planned discharge used in drainage planning. The data that will be used in this analysis are rainfall data, which are used to calculate rain intensity, concentration time and planned discharge (Q hydrology). Data will be compared with the channel discharge resulting from hydraulic analysis (Q hydraulics) to obtain a final conclusion regarding the channel that will be evaluated. Based on the calculations, each inlet connected to the drainage pipe can accommodate the respective design discharge of 0.0095 m^3/s. Hydrological Q is calculated in other channels in the same way. The results of calculating total hydrological Q and hydrological Q per inlet in the Musi V Bridge area can be seen in the following table:

Table 3
Hydrological Q calculation results

CHANNEL	A (km^2)	I (mm/hour)	C	Q hydrology Total	Number of inlets	Q hydrology per inlet
ABT 1 – PS1	0,00008512	617,18	0,9	0,0131	2	0,0066
PS1 - PS2 to PS11 - P1	0,00008775	617,18	0,9	0,0136	2	0,0068
P1 - P2 to P9 - P10	0,000490815	617,18	0,9	0,0758	8	0,0095
P10 - P11 to P13 - P14I	0,0005031	617,18	0,9	0,0813	8	0,0102
P14I - P14II	0,00117	617,18	0,9	0,1807	8	0,0226
P14II - P14III	0,002106	617,18	0,9	0,3252	8	0,0407
P14III - P14IV	0,00117	617,18	0,9	0,1807	8	0,0226
P14IV - P15 to P25 - P26	0,0005031	617,18	0,9	0,0777	8	0,0097
P26 - P27 to PS21 - PS22	0,000490815	617,18	0,9	0,0758	8	0,0095
PS22 - ABT 2	0,00008775	617,18	0,9	0,0131	2	0,0066

3.4 Hydraulic Analysis

Hydraulic analysis calculates the hydraulic Q value or planned discharge that the drainage channel can accommodate. Several parameters that need to be known are the diameter, surface area, type and circumference of the pipelines as well as the hydraulic radius of the channel. According to the

Circular of the Minister of PUPR, No 23/SE/M/2015, drainage pipes on bridges must have a minimum diameter of 200 mm or 20 cm and be placed at a slope of at least 2% to avoid blockages caused by mud and rubbish piles. Pipe-shaped channel with a diameter according to the rules so that it is assumed to be 0.232 m (PVC 8”). The following calculations will be explained as follows:

Area of Circle (A) $= \frac{1}{4} \cdot \pi \cdot D$
Area of Circle (A) $= \frac{1}{4} \cdot 22/7 \cdot 0{,}232$
Area of Circle (A) $= 0{,}03244 \text{ m}^2$

Circumference of Circle (P) $= \pi \cdot D$
Circumference of Circle (P) $= 22/7 \times 0{,}232$
Circumference of Circle (P) $= 0{,}6386$ m
Hydraulic Radius (R) = A /P
Hydraulic Radius (R) = 0,03244/0,6386
Hydraulic Radius (R) = 0,0508

The next calculation is to find the v value or speed by using the Manning formula in a channel with a pipe Manning coefficient of 0.012. Slope data are required. The recapitulation of hydraulic discharge calculations can be seen in Table 4.

Table 4
Hydraulic Q calculation results

CHANNEL	Q hydrology per inlet	i	v	Q hydraulic	Q hydraulic > Q Hydrology
ABT 1 – PS1	0,0066	0,0201	1,620538	0,0526	APPROPRIAT
PS1 - PS2 to PS11 - P1	0,0068	0,0202	1,624564	0,0527	APPROPRIAT
P1 - P2 to P9 - P10	0,0095	0,0213	1,668211	0,0541	APPROPRIAT
P10 - P11 to P13 - P14I	0,0102	0,0225	1,714559	0,0556	APPROPRIAT
P14I - P14II	0,0226	0,0226	1,718365	0,0557	APPROPRIAT
P14II - P14III	0,0407	0,0227	1,722163	0,0559	APPROPRIAT
P14III - P14IV	0,0226	0,0227	1,722163	0,0559	APPROPRIAT
P14IV - P15 to P25 - P26	0,0097	0,0226	1,718365	0,0557	APPROPRIAT
P26 - P27 to PS21 - PS22	0,0095	0,0214	1,672123	0,0542	APPROPRIAT
PS22 - ABT 2	0,0066	0,0202	1,624564	0,0527	APPROPRIAT

The drainage pipe can accommodate Q hydrology per inlet for a return period of 10 years because the dimensions and slope of the evaluation results are large, with a diameter of 20.32 cm (PVC 8”) and a slope starting from 2.01%, which is by the Circular Letter of the Minister of PUPR, No 23/SE/M/2015. The comparison between hydrological Q per inlet > hydraulic Q, whose diameter and slope have been analysed, shows that the design meets the requirements and allows water pooling.

4. Conclusion

The hydrological analysis shows the planned discharge resulting from rainfall data processing has a rain intensity of 618.18 mm, the flow coefficient for the asphalt material area is 0.9 and each channel has different surface areas. The Total Hydrological Q is obtained, which is calculated per full slab on the abutment and pier. The channel pipe diameter is at least 20 cm and the pipe installation height is at least 2%. The calculation results show that hydraulic Q > hydrological Q per inlet, indicating that it is ‘appropriate’ for all channels to ensure that all channels are safe from blockages and flooding on bridges.

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