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DRAINAGE SYSTEM DESIGN OF THE LIGHT RAIL TRANSIT (LRT) ROAD RAWAMANGUN-PASAR PRAMUKA PHASE 1B STA 0+130 to 3+445

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ABSTRAK

Light Rapid Transit (LRT) adalah sistem transportasi publik modern dan efisien yang dibangun di permukaan tanah untuk mengurangi kemacetan lalu lintas dan menyediakan aksesibilitas tinggi. Salah satu komponen penting infrastruktur LRT adalah sistem drainase, yang berfungsi untuk mencegah genangan air di rel kereta api yang dapat membahayakan keselamatan dan merusak sistem kelistrikan. Proyek akhir ini berfokus pada perancangan jaringan drainase yang efektif untuk ruas jalan LRT antara Velodrome dan Pasar Pramuka Fase 1B, STA 0+130 hingga STA 3+445. Kajian ini meliputi analisis hidrologi dan hidrolika, meliputi perhitungan intensitas curah hujan, estimasi debit banjir rancangan dengan periode ulang 25 tahun, perancangan saluran drainase, dan perencanaan metode konstruksi. Penampang drainase yang diusulkan terdiri dari saluran U-Ditch dengan dimensi 0,5 × 0,5 m dan 0,8 × 0,8 m, serta gorong-gorong kotak pracetak berukuran 0,6 × 0,6 m dan 0,8 × 0,8 m. Desain ini mengacu pada standar teknis dan non-teknis. Total anggaran yang dibutuhkan untuk pembangunan sistem drainase ini diperkirakan sebesar Rp9,491,653,696.92. Sistem ini diharapkan dapat mengelola limpasan air hujan secara efektif dan menjamin keselamatan serta keandalan operasional jalur LRT.

Kata kunci: LRT, sistem drainase, debit banjir, U-Ditch, box culvert

ABSTRACT

Light Rapid Transit (LRT) is a modern and efficient public transportation system constructed at surface level to reduce traffic congestion and provide high accessibility. One of the critical components of LRT infrastructure is the drainage system, which serves to prevent water ponding on the rail tracks that could endanger safety and damage the electrical systems. This final project focuses on designing an effective drainage network for the LRT road segment between Velodrome and Pasar Pramuka Phase 1B, STA 0+130 to STA 3+445. The study includes hydrological and hydraulic analysis, covering rainfall intensity calculation, design flood discharge estimation with 25 years returns period, drainage channel design, and construction method planning. The proposed drainage cross-sections consist of U-Ditch channels with dimensions of 0.5 × 0.5 m and 0.8 × 0.8 m, as well as precast box culverts measuring 0.6 × 0.6 m and 0.8 × 0.8 m. This design refers to both technical and non-technical standards. The total estimated budget required for the construction of this drainage system is Rp9,491,653,696.92. The system is expected to manage stormwater runoff effectively and ensure the safety and operational reliability of the LRT route.

Keywords: *LRT, drainage system, flood discharge, U-Ditch, box culvert*

1. INTRODUCTION

Light Rapid Transit (LRT) is a modern mode of transportation constructed at ground level to reduce traffic congestion and improve public mobility. However, since the system operates using electrical power, a reliable drainage system is essential to prevent water ponding that may disrupt operations and pose safety risks. The construction project of the LRT corridor from Velodrome to Pasar Pramuka Phase 1B (STA 0+130 to STA 3+445) requires a well-designed drainage system to ensure that stormwater runoff can be managed effectively. This planning involves rainfall analysis, design flood discharge calculations, channel dimensioning, cost estimation, and construction methods. This study aims to design an efficient drainage system for the LRT that complies with technical standards to ensure optimal and sustainable functionality.

2. METHODOLOGY

Studi Area Map

The planning site is located along the area from Jalan Pemuda to Jalan Pramuka, situated in East Jakarta, DKI Jakarta Province. The length of the drainage channel in this study is approximately ±3,059 kilometers.

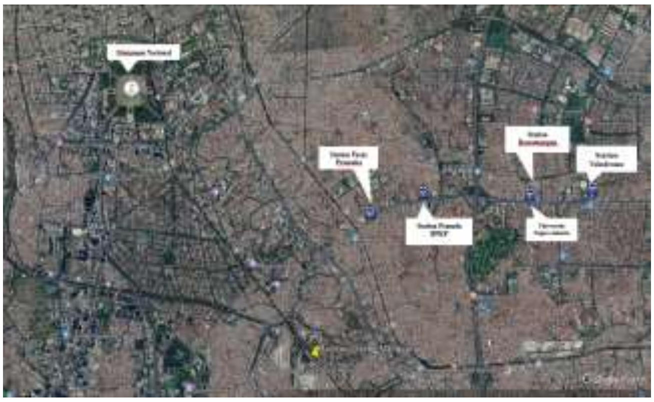

Figure 2.1 Location access map

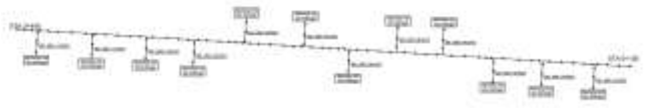

Figure 2.2 Result layout Sta.0+130 to 0+445

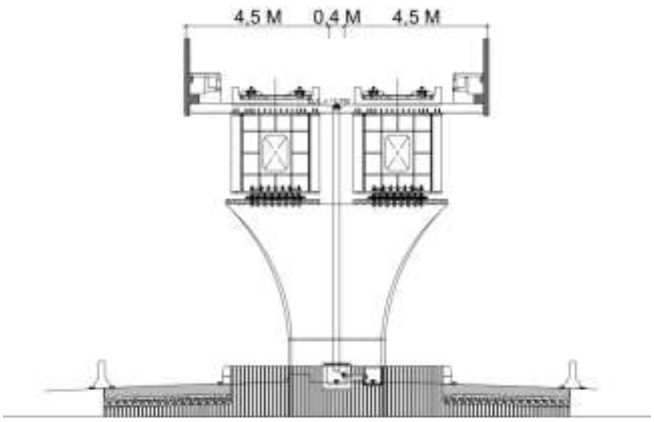

Figure 2.3 Cross section pier 4

Daily Rainfall Data

Rainfall data utilized in this analysis span the past ten years and were obtained from three rainfall stations in closest proximity to the study site: Manggarai, Pulo Gadung, and Istana Stations.

Consistency Test

Consistency testing was performed to assess the reliability and validity of the collected rainfall data. The data are deemed consistent when the recorded values correspond to the actual rainfall events observed on site. The testing procedure was conducted through the following steps:

a. Calculating the cumulative annual rainfall data
b. Calculating the average annual rainfall data
c. Applying the correction factor
d. Performing consistency testing for each year at the remaining rainfall stations.

Areal Rainfall

The areal rainfall was determined using an algebraic method based on the average total rainfall from nearby rain gauge stations. The following steps were followed in the calculation process:

$$d = \frac{1}{n}\ (d_1 +\ d_2 + \cdots + d_n) \qquad (1)$$

Description:

d = maximum regional rainfall per year (mm)
d_1, d_2. Dn = Maximum daily rainfall data
n = number of rain stations

Design Rainfall

Design rainfall is the result of an evaluation of the likelihood of rainfall with a specific intensity recurring over a certain period of time, encompassing both the frequency and duration of the rainfall event, as explained by Kamiana (2011). As a basis for the subsequent stages of analysis, it is necessary to calculate the coefficient of skewness (Cs), the coefficient of kurtosis (Ck), and the standard deviation (S) using the appropriate formulas:

$$Cs = \frac{n\sum(logxi - logx_{average})^3}{n-1)(n-2)s^4} \qquad (2)$$

$$Ck\ \frac{n^2\sum(logxi - logx_{average})^4}{n-1)(n-2)(n-3)s^4} \qquad (3)$$

$$S\sqrt{\frac{n\sum(logxi - logx_{rata-rata})^2}{n-1}} \qquad (4)$$

$$LogX_{design} =\ LogX_{average} + G.S_{Logx} \qquad (5)$$

Description:

Cs = coefficient skewness
Ck = coefficient of kurtosis
Xi = rain data
$\bar{X}$ = average value of rainfall data (mm/day)
S = standard deviation

Goodness-of-Fit Test

The goodness-of-fit test is essential to assess whether the selected distribution equation adequately represents the distribution being analyzed.

Kolmogorov–Smirnov Test

The Kolmogorov–Smirnov test is applied to assess the horizontal fit of the data. The procedure involves computing the difference ΔP = $P_{empiris} - P_{theoritis}$. If ΔP is less than the critical value (D_0), the distribution is considered to meet the goodness-of-fit criteria.

Chi-Square

The Chi-Square test is used to evaluate the goodness-of-fit of a selected distribution in representing the statistical data being examined. This testing process involves calculating the Chi-Square value (χ^2), which is determined using the following formula.

$$X^2 cal = \sum \frac{(d_{empiris} - d_{teoritis})^2}{d_{teoritis}} \quad \text{....................................... (6)}$$

Description:

X^2 = frequency of observation

$d_{empiris}$ = frequency of observation

$d_{teoritis}$ = theoretical frequency

Rainfall Intensity

Rainfall intensity is defined as the density of precipitation occurring within a given time interval, commonly expressed in units of millimeters per hour (mm/h) or centimeters per hour (cm/h).

$$I = \frac{R_{24}}{24} X \frac{24^{2/3}}{t} \quad \text{... (7)}$$

Description:

I = intensity of rain (mm/hour)

R24 = daily maximum rainfall (mm)

t = length of rain (hours)

Design Flood Discharge

The Rational Method is applied using an approach based on a composite runoff coefficient (C) or an average runoff coefficient, and the rainfall intensity is calculated based on the longest time of concentration (Suripin, 2004). The formula for calculating the design discharge using the Rational Method in metric units is as follows (Kamiana, 2011):

Q = 0.278 x I x A x C .... (8)

Description:

Q = Maximum flood discharge(m3/sec)

I = Average rainfall inten (mm/hour)

C = Flow Coefficient

A = Area of the drainage (km²)

Channel Discharge

The formula used for the calculation of channel discharge uses the continuity equation and the manning formula as follows:

Q =A.V..(9)

Description:

Qs = Channel discharge (m3/sec)

A = Channel cross-section area (m2)

V = Average flow velocity in the channel (m/sec)

Flow Velocity

The determination of water flow velocity in a channel can be calculated using the Manning equation, which is used to determine the design or initial velocity. The equation used is as follows:

$$V = \frac{1}{n} R^{2/3} S^{1/2} \quad \text{.. (10)}$$

$$R = \frac{A}{P} \quad \text{... (11)}$$

Description:

V = Average flow speed in the channel (m/sec)

n = Coefficient kekasaran Manning

R = Hydraulics radius (m)

S = Channel bed slope

A = Cross-section area (m2)

P = Wet perimeter (m)

Construction Method

The construction project execution method is a technical and procedural elaboration for transforming the design into a physical structure. This method reflects the application of engineering principles based on the interrelation between procurement documents, field technical and economic conditions, and the available resources, including the contractor's experience (Kanisius, 1996).

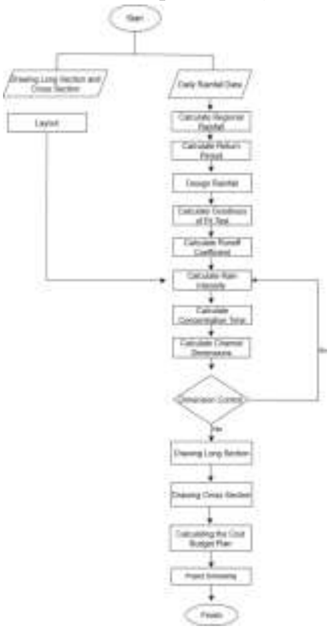

Figure 2.4. Research Flowchart

3. RESULTS AND DISCUSSION

Consistency Test

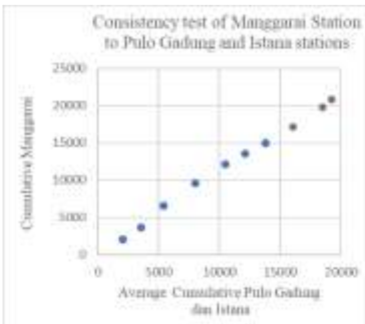

Figure 3. Graphic Consistency test of Manggarai Station to Pulo Gadung and Istana Stations

Calculating the correction factor derived from the computed M1 and M2 values for each station. For example: The correction value for the Manggarai station is: 0,937; Station

Pulo Gadung is 1,000; and Station Istana is 1,000. The data are then multiplied by the corresponding correction factor to obtain the adjusted (corrected) data.

Areal Rainfall

The following table presents the corrected average maximum rainfall values.

Table.1 Average Maximum Rainfall

Year	D
2015	272.00
2016	182.33
2017	159.33
2018	139.50
2019	118.33
2020	101.00
2021	99.33
2022	85.33
2023	82.07
2024	78.33

Design Rainfall

Based on the corrected average maximum rainfall data presented in the table above, the Log-Pearson Type III method was selected for the design rainfall calculation, as it was considered the most appropriate. Using a 10-year return period, the resulting maximum design rainfall is 272.00 mm/day.

Goodness-of-Fit Test

The distribution of annual rainfall data was analysed using two statistical methods the Smirnov-Kolmogorov test and the Chi-Square test, in order to assess its conformity to the Log Pearson Type III distribution.

In the Smirnov-Kolmogorov test**,** the maximum absolute deviation between the empirical and theoretical cumulative distributions (Δ Calculated) was found to be 0.14**,** while the critical values at the 5% and 1% significance levels were 0.41 and 0.49, respectively. Since Δ Calculated is less than both critical values, it can be concluded that the data follows the Log Pearson Type III distribution.

In the Chi-Square test, the calculated χ^2 value was 0.635. At a confidence level of 0.05 and with 10 years of rainfall data, the critical χ^2 value from the Chi-Square table was 14.067. Because the calculated χ^2 value is less than the tabulated value, it can be concluded that the distribution of the data is statistically acceptable.

Rainfall Intensity

In the rainfall intensity calculation, it is known the t =1 hour, resulting in a rainfall intensity of 0.00026 m/s based on the formula. This result is taken from the calculation example for Pier 2.

Design Flood Discharge

The Rational Method was used to calculate the design flood discharge, as shown in Equation (10). The total flood discharge for the right-side channel was found to be 0.1225 m^3/s, and for the left-side channel, it was also 0.1225 m^3/s.

Channel Dimensions

The slope of the existing channel is known, from which the actual discharge, flow velocity, and Froude number are calculated. For example, in a U-ditch channel with existing dimensions of b = 0.5 m and h = 0.5 m and a bed slope (S) of 0.006, the design discharge is 0.405 m^3/s, while the computed discharge is 0.45 m^3/s. Therefore, the channel discharge is considered safe.

From the calculation, the Froude number (Fr) is obtained as 0.815, where the criterion for drainage channels is $Fr \leq 1$. Therefore, based on the Froude number, the channel is considered safe.

From the flow velocity calculation, a velocity of V = 1.850 m/s is obtained. Given that the channel material is concrete, the allowable velocity ranges from vmin = 0.2 m/s to vmax = 3.00 m/s. Therefore, the flow velocity is still within the safe category.

The existing U-Ditch channel with dimensions of 0.5 m × 0.5 m and a bed slope of 0.006 is considered safe, as it can accommodate the design discharge of 0.405 m^3/s, while the calculated discharge is 0.45 m^3/s. The Froude number of 0.815 indicates subcritical flow, which complies with drainage channel criteria. The flow velocity of 1.850 m/s also falls within the permissible velocity range for concrete channels, which is between 0.2 and 3.0 m/s. Therefore, the channel can be classified as hydraulically safe.

In this planning, an additional building in the form of a control tank was also added as a means of maintaining and controlling the flow.

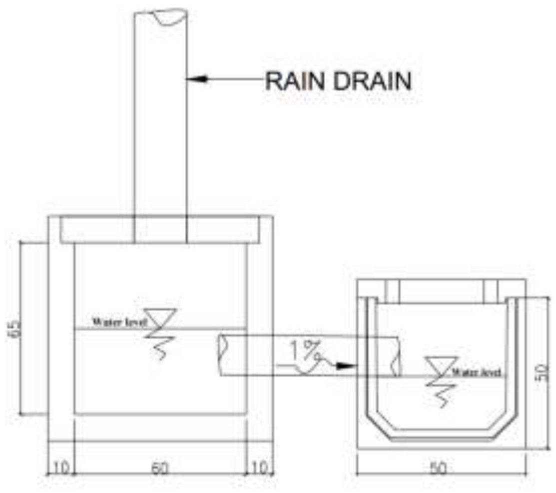

Figure 3.1 Control chamber Sta 0+130 to 3+260

CONSTRUCTIONS METHOD

Preliminary Works

Land Clearing: Removal of shrubs and obstructive materials to ensure the site is clean and ready for construction activities.

Bouw plank Installation: Installation of 5/7 cm timber and boards as reference guides for building layout measurements.

Mobilization: Mobilization of construction equipment and materials as specified in the equipment schedule.

Socialization: Safety awareness sessions carried out for workers and the surrounding community to ensure safe project implementation.

Drainage Channel Works

Earthworks

Excavation: Carried out with heavy machinery and jack hammers to break up hard or rocky ground conditions.

Backfilling: Suitable excavated material is reused as backfill in accordance with technical specifications.

Installation

Control Box: Excavation, casting of blinding layers (K-125), brick masonry installation, inlet-outlet pipe placement, 1:3 cement-sand plastering, and installation of precast iron cover.

U-Ditch (500x500x1200 mm & 800x800x1200 mm): Subgrade compaction, blinding layer casting (K-125), U-Ditch installation following design slope, mortar joint sealing, and installation of precast covers.

Box Culvert (600x600x1000 mm & 800x800x1000 mm): Installed using the same method as U-Ditch installation.

Pipe: Conveys runoff from viaduct surface to the drainage system, installed from Pier 3 to Pier 94, followed by leak testing upon completion.

Recapitulation of the Cost Estimate

Based on the calculated data, the Cost Estimate value is obtained as shown in the following table:

Tabel 3.2 Recapitulation of the Cost Estimate

No	Work Item	Volume	Unit	Unit Price	Total Cost
Preparation Works					
1	Land Clearing	4,118.16	m2	Rp18,531.70	Rp76,316,559.21
2	Bowplank Installation Works	1,162.04	m2	Rp450,000.00	Rp522,918,450.00
					Rp599,235,009.21
Pipe Installation					
1	Installation of 8" Diameter PVC Pipe,	1123.375	m	Rp3,084,208.74	Rp3,464,723,612.39
2	Roof Drain Installation	71	unit	Rp450,000.00	Rp31,950,000.00
					Rp3,464,723,612.39
Excavation Works					
1	Excavation Works for U-Ditch Channel	1,158.85	m3	Rp80,784.78	Rp93,617,552.49
2	Box Culvert Excavation Works	212.00	m3	Rp80,784.78	Rp17,126,373.57
3	Excavation for Control Chamber 60x60x65 cm	16.61	m3	Rp80,784.78	Rp1,342,158.35
4	Excavation for Control Chamber 85x85x150 cm	1300.5	m3	Rp80,784.78	Rp110,743,926.06
					Rp217,146,692.10
U-Ditch Channel Installation Works"					
1	U-Ditch 50x50x1200 mm Installation Works	348	m3	Rp1,057,003.37	Rp367,472,934.04
2	Soil Backfill	347.66	m3	Rp1,057,003.37	Rp367,472,934.04
					Rp4,409,675,208.42
Cross Drain Installation Works at 12 Points					
1	Installation of Box Culvert	76.32	m	Rp112,242.28	Rp8,566,330.81
2	Soil Backfill	21.2	m	Rp2,094,260.94	Rp44,398,332.03
Control Chamber Works					
1	Control Chamber 60 x 60 x 65	70	Unit	Rp1,167,683.64	Rp81,737,854.66
2	Control Chamber 85 x 85 x 150	12	unit	Rp4,910,058.16	Rp58,920,697.90
					Rp140,658,552.56
BUDGET PLAN					Rp8,884,403,737.51
BUDGET PLAN + PROFIT 10%					Rp9,772,844,111.27

CONCLUSION

Based on the results of the design flood discharge calculation for the Light Rail Transit (LRT) Road Rawamangun – Pasar Pramuka Phase 1B project, from Sta. 0+130 to Sta. 3+445, the final discharge is distributed across 12 outlet points, with a design rainfall intensity of 271.89 mm/day. A total of 1,123.375 meters or 188 pieces of 200 mm diameter PVC pipe are used to convey water vertically from the LRT road to the control chambers. The drainage channel design, covering a total length of 2.066 km from Sta. 0+300 to Sta.

3+680, utilizes precast U-Ditch elements. This planning consists of two types of U-Ditch and two types of Box to the flow capacity required at specific locations. Meanwhile, the Box Culvert also consists of two size types, namely 0.6 m × 0.6 m and 0.8 m × 0.8 m, which are applied to channel sections subjected to heavier traffic loads or thicker soil cover. The estimated budget required for the Light Rail Transit (LRT) Road Rawamangun – Pasar Pramuka Phase 1B project, from Sta. 0+130 to Sta. 3+445, is Rp. 9,491,653,696.92. Based on the results of the Drainage System Design for the Light Rail Transit (LRT) Road Rawamangun–Pasar Pramuka Phase 1B, Sta. 0+130 to 3+445, as outlined in the final report, it is recommended to install infiltration wells at each control chamber prior to the final discharge point in order to reduce the volume of runoff entering the existing manholes. In addition, it is recommended to install roof drain systems at intervals of 1 to 2 meters to improve water drainage and reduce the risk of water accumulation on the LRT roadway.

Culvert. The U-Ditch has two variations in size, namely 0.5 m × 0.5 m and 0.8 m × 0.8 m, which are selected according

REFERENCE

[1] Dyah Ayu Saraswati Mahariyani. (n.d.).

[2] *Data Proyek*. PT. Waskita Karya.

[3] Kamiana, I. M. (n.d.). *Teknik Perhitungan Debit Rencana Bangunan Air* (Edisi 2011). I Made Kamiana (Ed.).

[4] Dipohusodo, L. (1996). *Manajemen Proyek dan Konstruksi* (Jilid 1). Penerbit Kanisius.

[5] Karya, J., & Teknik Sipil. (2018). Perencanaan sistem drainase Jalan Tol Balikpapan–Samarinda Seksi 4. *Jurnal Teknik Sipil*, 7. Retrieved from http://ejournal-s1.undip.ac.id/

[6] Nugroho, J., Adityawan, M. B., Chaidar, A. N., & Suryadi, Y. (2023). Evaluation of drainage system of Light Rapid Transport (LRT) Depo – Kelapa Gading – Jakarta City. *Journal of Engineering and Technological Sciences, 55*(5), 600–612. https://doi.org/10.5614/j.eng.technol.sci.2023.55.5.9

[7] Suripin. (2004). *Sistem Drainase Perkotaan yang Berkelanjutan*. Magister Teknik Sipil.