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Analysis Planning Upper Structure Bridge: A Case Barelang-2 Bridge, Batam

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ABSTRACT

A bridge is part of a highway or city road, which is part of a city or community development plan. Therefore, the function of a bridge is not determined by the bridge expert. The definition of a successful bridge or structure is safe, functional, affordable, and beautiful. The purpose of bridge planning in Barelang is to connect the road from the Batam road area, and towards the Galang road area to produce more efficient, and effective traffic. The purpose of bridge planning is to find out how the structural calculation of the strength of the planned bridge is a means of connecting the road area to other road areas and reducing traffic congestion on the road. This method is a direct review of the location to be studied with the aim of knowing the existing conditions at the location, and documenting all conditions at the research location, reviewing previous journals with similar research, as an overview of the author's calculations, and analysis in conducting the research to be planned. Based on calculations on the planning of the upper bridge structure, the loading value on the dead load is 0.88307 t / m, and the live load is 18.518 t/m. The author also performs planning calculations in vehicle floor mechanics where the dead load is obtained at 0.41535 t/m, and live load 6.4581 t/m. For implementation using reinforcement must be by the plan so that it becomes an efficient bridge and does not experience a lack of strength in the structure.

1. Introduction

A bridge is part of a highway or city road, which in turn is part of a city or community development plan. Highways are one of transport infrastructure for the movement of goods , and people from one place to another , and one of the infrastructure needed to support development right now[1]. Therefore, the function of a bridge is not determined by the bridge expert. The definition of a successful bridge or structure is safe, functional, affordable, and beautiful. This bringing comfort , and convenience to the community [2]. The increase in the number of construction projects has made construction projects one of the most influential industries with a significant effect on the economic growth of developing countries[3].

Indonesia is a country with various contours, from mountains to plains, and rivers. Indonesia is a country that has many islands. Transportation used to connect between islands of various kinds such as air transportation, sea transportation, and transportation. People find it difficult to access l, and transportation, so to facilitate l, and transportation it is necessary to build bridges. In Europe the situation is not much different. According to a report by the German Institute for Economic Research (DIW), around 46% of bridges, 41% of roads, and 20% of motorways in Germany need repair (Robby Caspeele, 2018).

The bridge is one component of l, and transportation infrastructure functions to overcome artificial natural obstacles/barriers. Therefore, in an area, bridges generally function as part/component and road network systems. As an essential ingredient of the infrastructure system in a room, bridges always

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need attention so that their performance and service life can be maintained as much as possible, at least as planned [4].

The bridge is a facility that is often and most needed in every region. The structure of the building consists of a lower structure and an upper structure. The upper structure consists of beams, plates, columns, and the roof, and the lower structure is the foundation [5]. Generally, a bridge is formed from a steel structure stretching between two areas, either connecting an island or as access to an area. Above the bridge structure, a road is also made to make it easier to access the bridge so that the driver who passes through it will feel comfortable and not difficult to access. Bridges are often found in areas in Indonesia. The government has the initiative to build a bridge with various models, especially in the archipelago, seeing that thousands of islands are spread out of Indonesia. As part of the upper structure selection process, it is essential to consider the superstructure where the load will be supported by the foundation, as well as the bearing capacity of the ground and the depth of the hard ground, which will affect the shape of the foundation. There are many types of foundations, and choosing one depends on the cost and execution time [6].

Coupled with topographical conditions in Indonesia, which are hilly and limited by rivers. This is what makes many bridges connect/cross access between the two regions. The construction of a bridge must be carried out following careful planning, and the type of bridge to be used must be by the conditions in the area. Starting from the materials used, essential parts in making bridges, and calculating the strength of the load that a bridge can withstand if the bridge is traversed by many vehicles.

Bridge planning in Barelang aims to connect the road from the Batam, Rempang, and Galang islands to produce more efficient and effective traffic. The purpose of bridge planning is to find out how the structural calculation of the strength of the planned bridge is a means of connecting the road area to other road areas and reducing traffic congestion on the road.

2. Literature Review

According to the American Association of State Highway and Transportation Officials (AASHTO) in (2019) a bridge is a structure designed to allow vehicles, pedestrians, or goods to pass through a cavity, such as a river, valley, or road, by supporting or suspending a load over it.

2.1 Definition Of Bridge

The bridge is a building structure with several elements and essential parts in its formation. Bridges are the most widely used structure in the world. Starting from the economic development of an area, providing convenience for the surrounding community in carrying out daily activities. In planning, and conducting a bridge, it has been regulated in the guidelines for rules adjusted by SNI 03-1725-1989 concerning guidelines for planning the loading of highway bridges. This guideline is undoubtedly a crucial thing and a benchmark in building a bridge so that the planning will be in accordance with established standards. In general, bridges have an upper structure, substructure, and foundation. The foundation is a significant work in civil engineering because it is this foundation that carries and retains a load that works on it, namely the upper construction [7]. The upper structure bears the burden of traffic vehicles that move on it—the load The load is channeled to the bridgehead, which must also be supported by the foundation. In some instances, with long spans, pillars are needed that support the load located between the ends of the bridgehead [8].

2.2 Bridge An upper Structure Construction

Bridge An upper structure construction is a bridge component consisting of elements that directly bear the traffic load and transmit it to the pillars or piers (Williams, 1937). The upper structure of a bridge

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typically consists of deck slabs, beams, and girders, which are supported by piers or abutments. Precast prestressed concrete double-tee (PPCDT) units have been widely used in upper bridge structures because of their high load-carrying capacity, ease of fabrication, and rapid construction. The PPCDT units are usually produced in a precast plant and transported to the bridge site for installation. Once installed, the units are connected by field-cast concrete closure pours to form a continuous deck slab. In recent years, PPCDT units have become more popular for short and medium-span bridges, and their behavior and design have been extensively studied [9].

2.3 Bridge Loadings

Loading from heavy vehicles contributes significantly to bridge damage. Loading is divided into two. There are dead and live loads. The dead load can be interpreted as the weight of all parts of the building with a fixed nature, including all additional factors, handling, machinery, and fixed equipment such as an integral part of a building. While the live load is the entire load arising from the occupancy or use of the building, including floor loads caused by moving objects, machinery, and equipment that are not an integral element of the building and can be changed throughout the life span [10]. In addition, the study also showed that factors such as vehicle height, wheelbase, and speed influence the level of damage to the bridge (Liu, 2019). Dead loads are static loads generated by the self-the weight of the structure, equipment, mechanical and electrical systems, and other elements that do not move (Tiwari, 2021). Permanent loads are generated by the bridge structure's self-the weight, including girders, cables, and concrete slabs (Y, 2020). Traffic loading classification into static, dynamic, periodic, and random loading (M. Lagos-Varas, 2019).

2.4 Basics Of Construction Calculation

Nominal Strength of Concrete in determining and planning a bridge, it is necessary to understand the nominal strength of the concrete to be used. The examples of strength possessed by concrete following the standard building rules No. 009 / BM / 2008 concerning the Planning of Reinforced Concrete Structures for Bridges are The compressive strength with prestressed concrete type at the age of 28 days, the value of concrete quality should not be below 20 Mpa, while the concrete quality for prestressed type is recommended to be at least 30 Mpa, Dance Strength The required provisions on tensile strength include that it can be taken at 0.33√(f'c) Mpa at the age of 28 days, with standardization treatment or calculated from probability results during the study. Flexural Tensile Strength The required provisions on tensile strength include 0.66√(f'c) Mpa at 28 days of age, with standardization treatment or calculated from the probability results during the study.

Based on the rules of the Construction and Building Manual No.009/BM/2008 entitled "Planning of Reinforced Concrete Structures for Bridges" in 2008 article 2.3.2, which contains concrete permit stresses consisting of Compressive allowable stress under service limit conditions Compressive allowable stress, σtk= 0.45̅ (for all load combinations). Compressive allowable stress at temporary load condition or prestress force transfer condition for prestressed concrete components Concrete section allowable compressive stress, σtk= 0.6̅ Where is the initial concrete compressive strength at the time of prestress force transfer? Tensile allowable stress at service limit state Permissible tensile stress of concrete section: Concrete without reinforcement: 0.15 √ MPa Fully prestressed concrete: 0.5 √ MPa. Tensile allowable stress at prestress force transfer condition for prestressed concrete components Allowable tensile stress at prestress force transfer: 0.25 √ (other than in place) 0.5 √ (in place).

Construction of T-beams on Bridges According to the 2008 "Planning of Reinforced Concrete Structures for Bridges" article 2.6.3, T-beams consist of T-beams, single T-beams, and double-reinforced T-beams. The abutment or bridgehead is one part of the bridge construction located at the ends of the bridge,

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which functions as a support for the building above it, and as a retainer for the *oprit* fill soil. The bridge construction is also equipped with wing construction to hold the soil perpendicularly from the road axle [11]. Pile foundation construction is one type of foundation used on bridges [12]. On this bridge, the type of foundation chosen is a pile foundation with a diameter of 300 mm. The loads received by the pile foundation are vertical load, foundation self-the weight, and pile foundation stability.

3. Method

The analysis in this report, in the form of analyzing a truss bridge construction, shows that in the upper structure of this bridge, there is a bridge with an upper frame, vehicle floor slab, cantilever plate, sidewalk design, Curb planning, and backrest pole design. Data collection is taken from primary and secondary data.

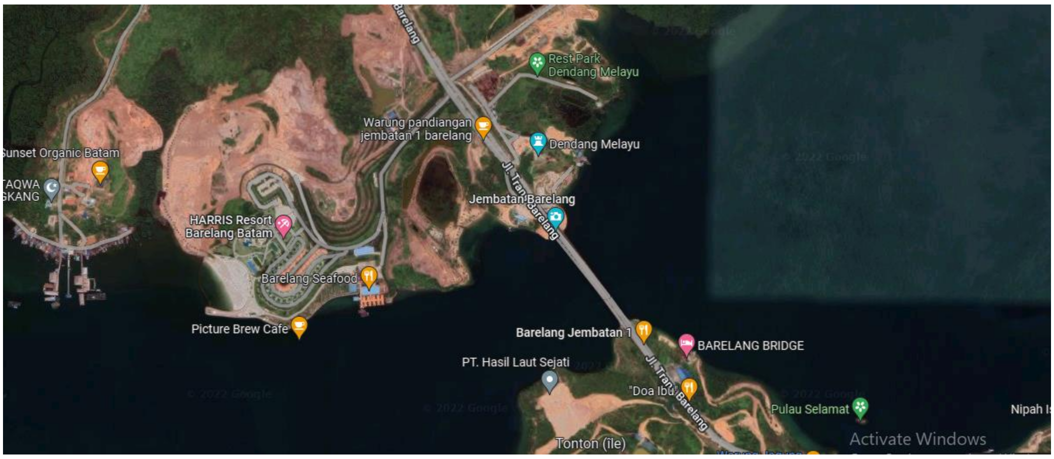

Figure 1. Map of Barelang-2 Bridge
(Source: Google Maps, 2023)

In collecting primary data, the authors carry out several stages so that this report follows the author's analysis based on facts in the field. The primary data collection techniques that the authors do include conducting a direct review of the location to be studied to know the conditions that exist at the site and documenting all conditions at the research location, as well as essential parts of the bridge as a reference for conducting research at that location. In secondary data collection, the author reviews previous journals with similar research to illustrate the author's calculations and analysis in conducting the research to be planned.

4. Result and Discussion

A good bridge is a bridge that has or has met the design criteria that form the basis of making a bridge. The bridge is planned to be easy to implement and provide benefits for traffic users following the plan's main points—first, the Strength and Stability of the Structure. The individual elements must have sufficient strength to withstand ULS (Ultimate Limit State) loads - the ultimate limit state and the structure must be stable under these loads. ULS loads are defined as loads with a 5% probability of being exceeded during the life of the design structure.

The second is Convenience and Security. Substructures and bridge foundations must remain in a serviceable condition at SLS (Serviceability Limit State) load - serviceability limit state. This means that the structure must not be subjected to cracking, deflection, or vibration so that the public becomes concerned, the bridge becomes unfit for use or significantly reduces service life. These effects are not examined for ULS (Ultimate Limit State) loads but for SLS (Serviceability Limit State) loads which are

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smaller and occur more frequently and are defined as loads with a 5% probability of being exceeded in one year.

The third is the ease of implementation and maintenance factor. The choice of plan should be easy to implement. Plans that are difficult to implement can lead to unexpected delays in the project and increased costs, so they should be avoided wherever possible. The fifth is the economic factor and budget availability. The cheapest plan is generally chosen according to funding and other plan points. Emphasis should be placed on the total life cost of the structure, which includes maintenance costs and not only on initial construction costs. The criteria design and planning can be seen in Table 1.

Table 1. Criteria and Planning Data

No.	Planning Data	Description
1.	Bridge span	= 15 m
2.	Payload	= Class I
3.	Bridge width	= Road width = 10 m
4.	Sidewalk width	= 1,5 m
5.	Traffic load	= Load Regulation no. 12
6.	1970 Highways Vehicle floor	= Concrete f'c 25 Mpa
7.	U39 steel (fy = 400 Mpa) Transverse beams	= Concrete f'c 25 Mpa
8.	U39 steel (fy = 400 Mpa) Longitudinal beams	= Concrete f'c 25 Mpa
9.	U39 steel (fy = 400 Mpa) Begel	=U24
10.	Profile steel quality	= B37
11.	The main beam size	= 40 x 120 cm
12.	Transverse beam spacing	= 3 m
13.	BJ of asphalt	= 2 t/m3
14.	BJ of concrete	= 2.4 t/m3
15.	Thickness of concrete slab	= 20 cm
16.	Thickness of pavement	= 5 cm
17.	Wheel load	= 10 tons

4.1 Vehicle Floor Planning

There are three specific gravity values, The specific Gravity of Water 1 t/m^3, The specific Gravity Of Asphalt 2 t/m^3, and The Specific Gravity Of Concrete 2 t/m^3. In vehicle floor planning to look for dead loads after obtaining the value of rainwater weight, asphalt weight, and the weight of the concrete slab, the qdl_1 value is 0.71 t/m, and the importance of curb, and backrest, the qdl_2 the value is 0.6034 t/m. According to the Minister of Public Works Decree No. 378/KPTS/1987 concerning Guidelines for Highway Bridge Planning article 4.1, the vehicle floor load is as follows qdl 0.88307 t/m.

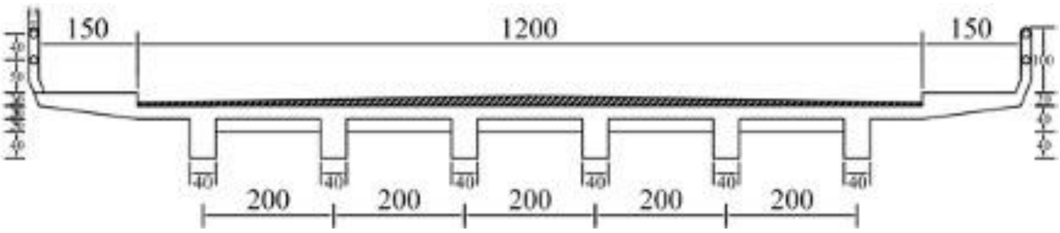

Figure 2. Vehicle Floor System

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The live load calculated on the vehicle floor is the T load (PPPJJR art. 1.2.3 Page. 5). Load T is a load that is a truck vehicle that has a double wheel load of 10 tons. The force distribution will be according to the 450 angles as follows, the ql 18,518 t/m value.

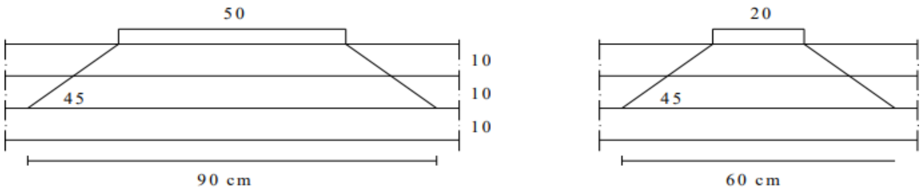

Figure 3. Wheel Loading Distribution

4.2 Vehicle Floor Mechanics Analysis

The floor plate is a one-way continuous plate following a moment (Article 13.2 Page 120)

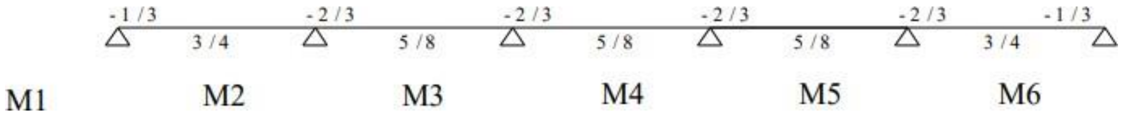

Figure 4. Vehicle Floor Distribution Coefficient

Mo is the moment that arises with the assumption of roller joint placement. The amount of Mo is sought as follows dead load, the value 0,41535 t/m. Live load Considering the loading conditions that may occur, the top moment of the loading condition is selected. Live loads have three states. There are conditions when one wheel is on the plate. The first condition is calculated and gets the Mmax value is 8,3331 tons. When two reels are on the scale, get the Mmax the discount is 9,42112 t/m.

The largest M11 is 9.4112 t/m, and Mo is 15,5562 t/m. So based on the moment coefficient, the following moments are obtained two a moment, first a moment of support, the value is M1 -5.1854 t/m, and the importance of M2 -10.3708 t/m is the same as the values of M3, M4, and M5. The last is to field a moment. The value of M12 is 11,6671 t/m same as the value of M56, and the importance of M23 is 9.7226 t/m same as the values of M34 and M45.

4.3 Vehicle Floor Reinforcement

Of vehicles, floor reinforcement is known as the value ρ min 0.0035, ρ b 0.0270, and ρ max 0.0155. So, based on the moment coefficient, the following moments are obtained two a moment, support reinforcement, and field a moment. Support Reinforcement from the data that has been processed, the value reinforcement splitter, according to the PBI article (9.1.3 Page 90), used D13 – 500 – As 399.6 mm2., and gets the value of ρneed<ρ max→ single reinforcement, used ρ=0,0111. Field Reinforcement from the data that has been processed, the value of The primary reinforcement according to PBI article (9.1.3 Page 90) is used D16 – 100 – As 2286 mm2. , and the the the value of ρneed>ρ max→\ used ρ=0,0185.

4.4 Cantilever Plate

The cantilever plate calculates the loads and reinforcement. The estimated load is divided into dead load and live load. Sidewalk reinforcement from the processed data dead load obtained gets qdl at 0,316 t/m. According to PPPJR Chapter III article 1.2.5.a. Page 10, the sidewalk construction must be calculated against a live load of 500 kg/m2. The value of q11 is 0,5 t/m, and qu is 1,1792 t/m. centralized load, the weight of the backrest pole, and iron 0,1214 t/m. According to the PBI article (9.1.3 Page 90), the

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reinforcement splitter used divider reinforcement D13 – 250 – 126 mm2, so ρneed $< \rho$ min ⟶ single reinforcement, used ρmin =0,0035.

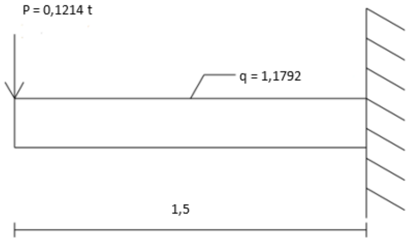

Figure 5. Sketch of The Cantilever Plate

4.5 Sidewalk Design

Sidewalk design calculates Sidewalk Loading, and sidewalk reinforcement. According to (7) the sidewalk width dimension is planned to be greater is 0.75 m [13]. Sidewalk loading consist of two loads, there are Dead Load, from the processed data obtained self the weight the value of 0,36 t/m, specimen the weight 0,15 t/m, and rainwater the weight 0,555 t/m. Live Load according to PPPJJR Chapter III article 1.2.5.a. page 10 it is required that sidewalk construction must be calculated against a live load of 500 kg/m2. Gets the value of qll = 1,466 t/m. According to PBI article 13.1.3.a page 192, Theoretical span (lt) 1,15 m, and Mu = 80,7827.104 Nmm. The table below is the calculation of Sidewalk Reinforcement. Field reinforcement from the data that has been processed, the value of dividing reinforcement according to PBI article (9.1.3 Page 90) The primary reinforcement used D13 – 300 -As 56 mm2 ρneed $< \rho$ min ⟶ single reinforcement, used ρmin =0,0035. Pedestal reinforcement from the data gets the value The primary support D13 – 300 – As 56 mm2 ρneed $< \rho$ min ⟶ single reinforcement, used ρmin =0,0035.

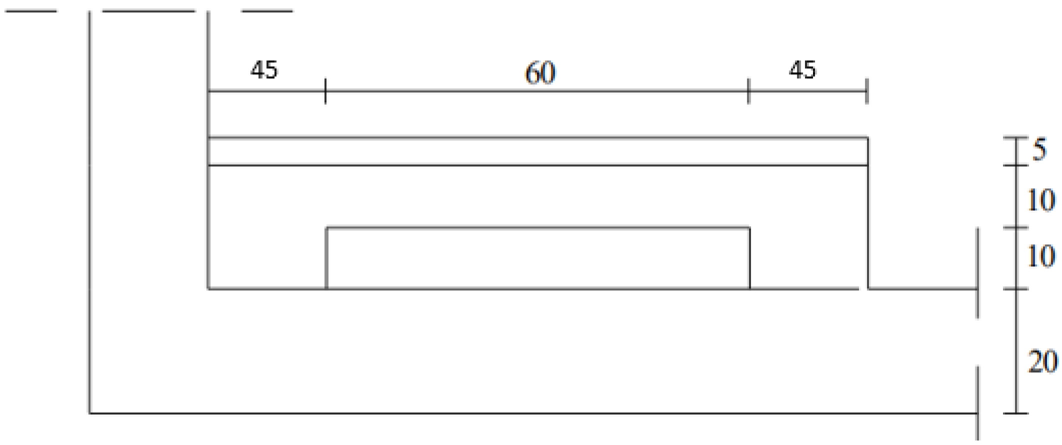

Figure 6. Sketch Sidewalk

4.6 Curb Planning

According to PPPJJR Chapter III article 1.2.5.b page 10, it is required that the Curbs located at the edges of the vehicle floor must be calculated to be able to withstand a horizontal load in the transverse direction of the bridge of 500 kg acting on the top of the Curb concerned at the height of 25 cm above the surface of the vehicle floor. The table below describes Curb reinforcement, and the figure below explains Curb planning and loading.

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Table 2. Curb Reinforcement

Unit	The the value
F'c	= 25 Mpa
h	= 200 mm
b	= 200 mm
$\beta 1$	= 18,8235
d	= 180 mm
d'	= 20 mm
ρ min	= 0,0035
ρ b	= 0,0271
ρ max	= 0,0203
Mn	= 1,25 x 106 N/mm
Rn	= 0,1929 N/mm
M	= 18,8235
Pneed	= 0,00048
As	= 126 mm2
Total reinforcement	= 2 pcs
Distance reinforcement	= 500 mm
The main reinforcement used= Ø13-100 → As = 126 mm2	
As	= 56 mm2
Total reinforcement	= 2 pcs
Distance reinforcement	= 500 mm
The main reinforcement used= Ø13-100 → As = 126 mm2	
ρneed < ρ min ⟶ single reinforcement, used ρmin =0,0035	

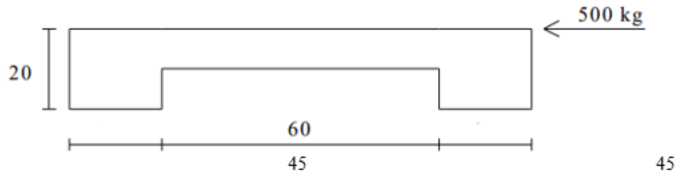

Figure 7. Curb Planning and Loading

4.7 Backrest Pole Design

According to PPPJJR Chapter III Article 1.2.5.c Page 10 requires that the stanchions at the edge of the pavement are calculated to withstand a horizontal load of 100 kg/m acting at the height of 90 cm above the pavement.

A horizontal force (H) of 100 kg acts along a 2-meter length (distance between stanchions) with a height (L) of 0.9 m above the pavement floor. From the steel construction profile table arranged by Ir. Morisco on pages 46 and 48, it is obtained that occurs 875,424 kg/cm2 <1400 kg/cm2. A moment Calculation on The Backrest Pole by Mu 40,5 x 104. Backrest Post Tensile Reinforcement Calculation gets ρneed < ρ min ⟶ single reinforcement, used ρmin =0,00583. Calculation Of Backrest Pile Shear Reinforcement: although no reinforcement was required in the calculation, Ø8 – 200 mm threaded reinforcement was provided for ease of implementation.

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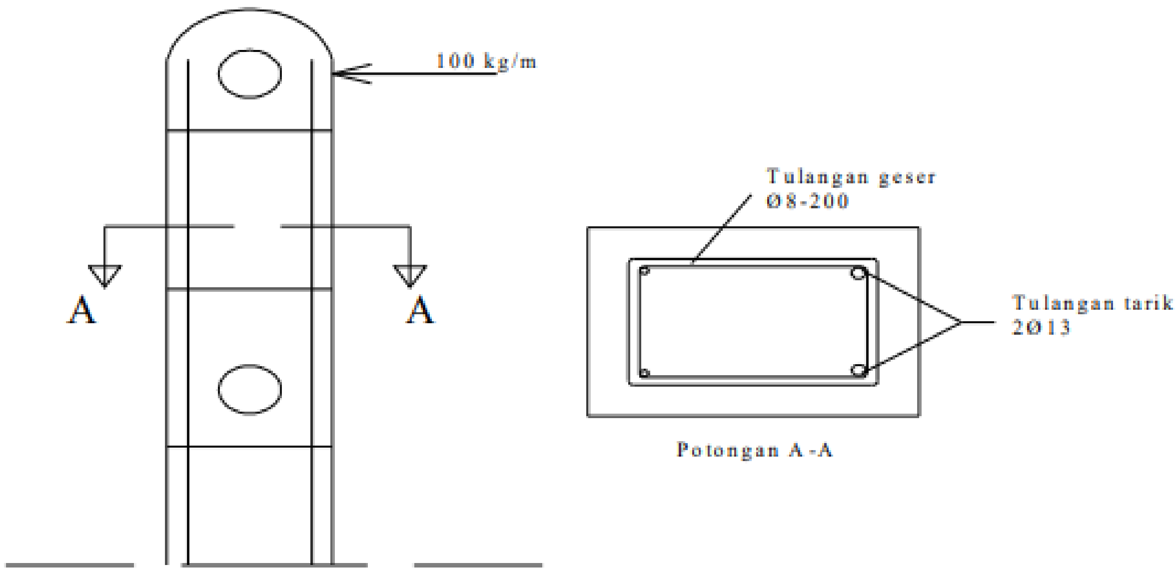

Figure 8. Sketch Of Backrest Reinforcement

Checking the distance between reinforcements 120-(2x20) -(2x13) -(2x13) ≥ 25 ……… ***PBI 1971*** 28 mm ≥ 25 mm ⟶ OK

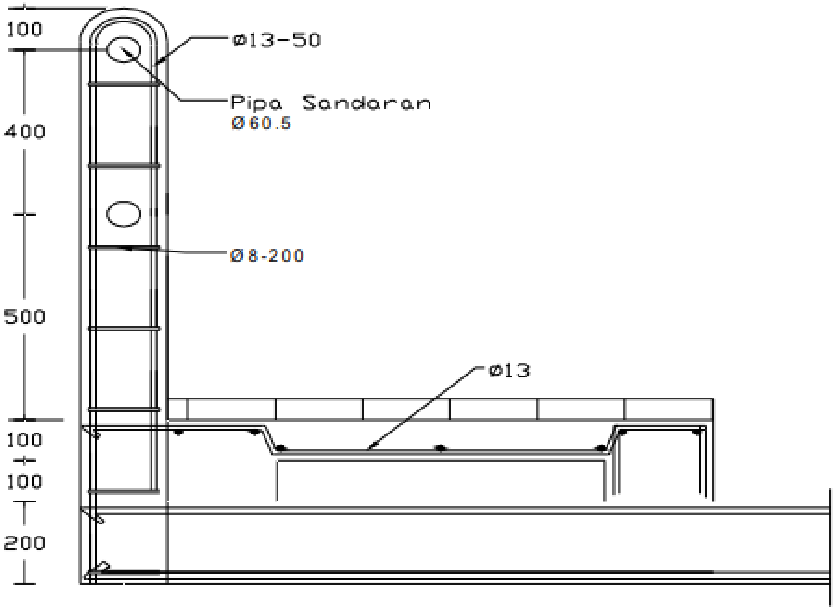

Figure 9. Reinforcement Sketches of Sidewalks, Curbs, and Stanchions

4.8 The main Girder Planning

The load analysis divided dead load, and live load, so from the processed data obtained qdl1, the value of 2,6154 t/m. P due to child beams (located per 4 m span, beam dimension 30/40) Pd1 = 0,3 x 0,4 x 2,0 x 2,4 = 0,576 ton. According to PPPJJR article 1.2.2.4.a. Page 6, the "D" load must be used to calculate girder strength. Load D is the arrangement of loads on each traffic lane consisting of a uniformly distributed load of "q" tons per meter length per lane and a line load of "P" tons per traffic lane. The stresses due to the line load P must be multiplied by the shock coefficient to consider the effect of vibrations and other dynamic products. At the same time, the uniform load q is not multiplied by the shock coefficient. The magnitude of the shock coefficient is determined under PPPJR article 1.3, page 10 gets the value of shock factor 1,307, and live loads per girder 11,406 t.

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4.9 Mechanical Analysis

1) Due Dead Loads

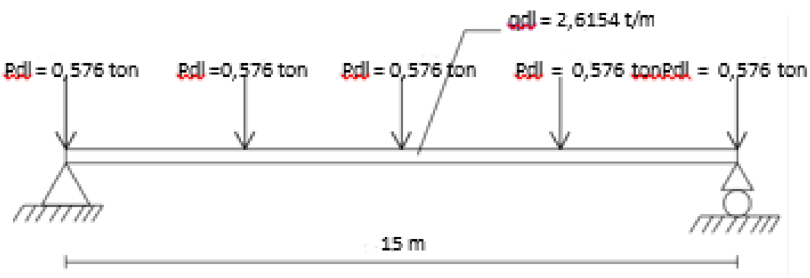

Figure 10. Loading Due *to* The main Girder Dead Load

2) Due Live Loads

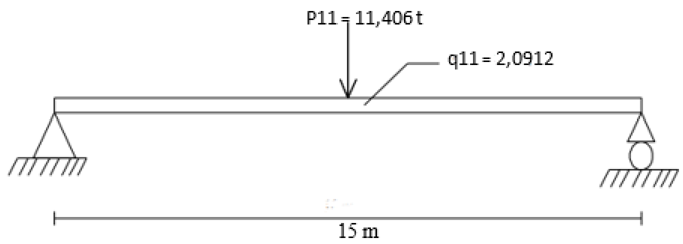

Figure 11. Loading Due To Live Load Of The main Girder

3) Due To Dead & Live Loads

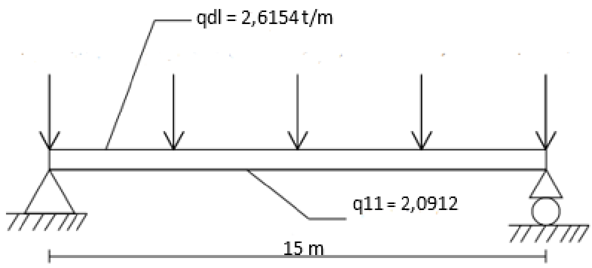

Figure 12. Loading Due To Live, and Girder Dead Load

4.10 Determination of moving live load location

There are three alternative, alternative 1 gets a moment the value is 3 tm. Alternative 2 gets a moment the value 42 tm, and the last alternative gets a moment the value is 61.89 tm. So, the maximum a moment is obtained in alternative 3 of 61.89 tm, which is the wheel load in the middle of the span. From the results obtained from girder reinforcement, which is ρ max 0.0203. Below is the cross-section, and bridge girder cross-section figures.

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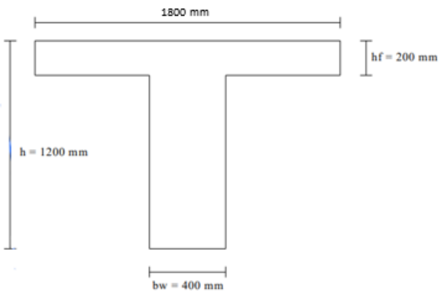

Figure 13. Cross – Section

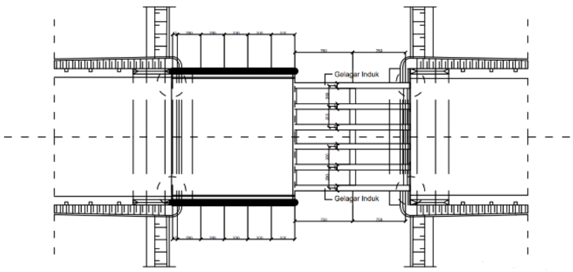

Figure 14. Bridge Girder Cross – Section

5. Conclusion

After planning the bridge calculation, the author can conclude several conclusions, including the following. The bridge is formed from a steel structure that stretches between two areas, either connecting an island or as access to an area. The bridge structure is also made a road to make it easier to access the bridge so that motorists who pass through it feel comfortable and do not feel difficult to access it. An upper structure of the bridge is part of the construction that receives direct loads, including the load on the bridge itself, dead loads, loads on vehicle traffic across the bridge, wind, and others. At the same time, the lower construction is part of the retaining wall construction caused by an upper construction load. Based on calculations for planning an upper bridge structure, the loading value on the dead load is 0.88307 t/m, and the live load is 18.518 t/m. The author also performs planning calculations in vehicle floor mechanics where the dead load is obtained: 0.41535 t/m and the live load is 6.4581 t/m. In planning the Curb reinforcement, the result of ρmax is 0.0203. From the conclusions obtained, the authors provide suggestions, among others, the reasonable regulations that are attempted to be the latest so that they always follow the development of the construction world. For implementation, reinforcement must be under the plan to become an efficient bridge and not experience a lack of strength in the structure. For readers who want to plan a bridge, reinforcement selection is critical regarding reinforcement size. There are not too many sizes using the size of iron on the market.

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