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Analysis of Superbuilding Planning and Loading in Bridge Construction

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ABSTRACT

Bridges are a facility that is often and most needed in every region. Generally, a bridge is a structure formed from steel structures stretching between two areas, either connecting an island or as access to a location. Bridges are the most common and easy-to-find structures. In Indonesia, you can find many bridges, especially in every region. In general, bridges in Indonesia function as links between islands, which can help the economy of residents on the islands. Based on calculations in the structural planning of the upper bridge, the dead load loading value was 0.88307 t/m, and the live load was 18.518 t/m. Planning in vehicle floor mechanics where dead load is obtained: 0.41535 t/m and live load: 6.4581 t/m.

1. Introduction

Bridges are recognizable representations of human ingenuity that promote socioeconomic growth and connectivity across various terrains. Bridge planning involves a complex procedure combining engineering expertise, environmental awareness, and cultural sensitivity. Bridge planning traverses several terrains formed by multiple elements, including technology breakthroughs, physical limits, and socio-political dynamics, on a national and international level. [1]

Bridge planning is an international endeavour that crosses national boundaries and incorporates many innovations and problems. International bridge planning projects frequently feature state-of-the-art technology and interdisciplinary teamwork to achieve structural resilience and quality. Together, engineers, architects, and planners work across national boundaries, utilizing one another's specialities to create bridge designs that are both long-lasting and environmentally friendly. The global discourse on bridge planning is emphasized by factors like resilience to climate change, sustainable materials, and futuristic designs, which demonstrate a shared commitment to forming a sustainable future. [2]

International bridge planning projects also provide forums for capacity building and knowledge sharing, which promotes collaborations beyond infrastructure construction. Professionals in the field exchange creative solutions, lessons gained, and best practices through joint research projects, conferences, and workshops. This intellectual interchange benefits the area of bridge engineering and fosters international collaboration to address common problems and fortify diplomatic ties. [3]

On the other hand, bridge planning adopts a nuanced viewpoint within the national or local context, formed by distinct socioeconomic landscapes and cultural identities. For example, Indonesia's bridge planning incorporates contemporary engineering techniques and conventional knowledge. Engineers must consider local ecosystems and cultural sensitivities while designing bridges that cross water bodies of different widths and depths due to Indonesia's archipelagic terrain. Furthermore, there is a growing need for creative solutions that balance practicality, safety, and aesthetics due to population increase, fast urbanization, and infrastructure development. Furthermore, government policies, rules, and financing sources are entwined with national bridge planning initiatives in Indonesia to guarantee that infrastructure development aligns with national development priorities. The National Medium-Term Development Plan (RPJMN) and other government efforts demonstrating the Indonesian government's commitment to infrastructure development highlight the strategic significance of bridges in promoting economic growth and improving connectivity. Bridge planning in Indonesia seeks to close infrastructural gaps, advance equitable development, and raise the standard of living for Indonesians through concerted efforts amongst government agencies, private sector partners, and local communities. [4]

While international and national bridge planning has different contexts, several basic principles are always the same. Both situations emphasize the significance of careful design considerations, comprehensive feasibility studies, and reliable building techniques. Furthermore, the main objective of bridge planning, whether local or global, is to promote economic growth, increase connectivity, and raise community standards of living.

In summary, bridge design exemplifies human ingenuity and teamwork that embraces regional settings while overcoming geographic limitations. Bridge planning is a metaphor for our collaborative effort to bridge gaps and create pathways towards a sustainable future, helping us negotiate the complexity of our interconnected world. Bridge planning continues to connect communities and shape landscapes through a harmonic blending of local insights and global viewpoints, providing a lasting legacy for future generations. [5]

2. Literature Review

A bridge is a building structure that contains several important elements and parts in its formation. Bridges are the most widely used structures throughout the world [6]. It starts with developing an area's economy and providing convenience for local communities in daily activities. According to Wikipedia, a bridge is a structure made to cross ravines or obstacles such as rivers, railways, or highways. Meanwhile, the definition of a bridge, according to the PUPR Ministry, is that a bridge is a structure that needs to be planned well so that it can function optimally.

The regulatory guidelines adopted by SNI 03-1725-1989 regulate the planning and construction of bridges. These guidelines concern guidelines for planning the loading of highway bridges. This guideline is certainly a very important benchmark in building a bridge so that the plans that will be made will meet the standards that have been set.

2.1 Shapes and Types of Bridge

When planning to build a bridge, you need to pay attention to the shape and type of bridge that will be built later. This shape and type will later be adjusted to the conditions to be created [7]. Bridge types can be divided based on function, location, construction materials. and structure type.

2.2 Bridge Superstructure

The bridge's superstructure is a building that accommodates the loads caused by the traffic of people [8] and vehicles and then distributes it to the substructure. The following are the components of the superstructure of the bridge :

a. Slab
   The floor plate is a bridge component that distributes loads along the bridge's cross-section and span.
b. Main Girder
   The main girder is the main component that distributes loads longitudinally and is usually designed to resist deflection.
c. Secondary Girder
   Secondary girders consist of transverse and longitudinal girders. Transverse girders are ties between the main girders, designed to resist transverse deformation of the upper structural frame and help distribute part of the vertical load between them.

2.3 Bridge Loading

In conducting bridge research, we referred to SNI 1725:2016 loading for bridges. This standard sets provisions for loads and other forces used in the design of highway bridges, including pedestrian bridges and secondary construction attached to bridges. The above points must be used in planning all bridges, including span bridges whose main span is more than 200 m.

In the Highway Bridge Loading Planning Guidelines (PPJR, 1987), Department of Public Works, it is stated that to plan the loading of a bridge, you must pay attention to the following matters.

a. The primary load is the main load in stress calculations in every bridge design. What is included in the primary load is :
   - Dead Load
   - Live Load
   - Shock Load
   - Forces due to ground pressure.
b. Secondary loads are temporary loads that are always considered in stress calculations for every bridge design. What is included as a secondary load is :
   - Wind load.
   - Brake force and traction.
   - Forces resulting from earthquakes.
   - Friction force on moving supports.

3. Method

3.1 Analysis Object

This paper's analysis of a truss bridge construction shows that the upper structure of this bridge includes a longitudinal girder beam, diaphragm beam, and vehicle floor slab.

3.2 Data Collection

a. Primary Data

In collecting primary data, the author carried out several stages based on facts in the field. The primary data collection techniques that the author uses include:

- Conduct direct inspections of the location to be researched to find out the existing conditions.
- Document all existing conditions at the research location and important parts of the bridge as a reference for conducting research at that location.

b. Secondary Data

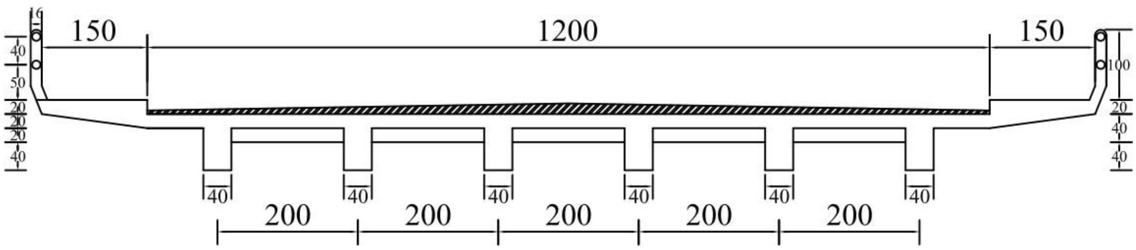
In collecting secondary data, the author reviewed previous journals with similar research to illustrate the calculations and analyses used in conducting the planned research.

4. Result and Discussion

4.1 Planning Data

Bridge span	= 15 m
Payload	= Class I
Bridge width	= Road width = 10 m
Sidewalk width	= 1.5 m
Traffic load	= Load Regulation no. 12 1970 Highways
Vehicle floor	= Concrete f'c 25 Mpa, Steel U39 (fy = 400 Mpa)
Cross beam	= Concrete f'c 25 Mpa, Steel U39 (fy = 400 Mpa)
Longitudinal beam	= Concrete f'c 25 Mpa, Steel U39 (fy = 400 Mpa)
Begel	= U24
Profile steel quality	= B37
Main beam size	= 40 x 120 cm
Transverse beam distance	= 3 m
BJ asphalt	= 2 t/m3
BJ concrete	= 2.4 t/m3
Concrete slab thickness	= 20 cm
Road pavement thickness	= 5 cm
Wheel load	= 10 tons

4.2 Vehicle floor planning



Picture 1 Floor Plan System
Source: Autocad

a. Load

Specific gravity of water: 1 t/m3

Specific gravity of asphalt: 2 t/m3

Specific gravity of concrete: 2,4 t/m3

1) Dead Load

- Weight of rainwater (3cm) = 0.03. 1. 1 = 0.03 t/m
- Weight of asphalt (10 cm thick) = 0.1. 1. 2 = 0.20 t/m
- Weight of concrete slab (20cm thick) = 0.2. 2. 2.4 = 0.48 t/m

qdl1 = 0.71 t/m

- Backing pipe weight (Ø60.5) = 2 . 1/4. π. 0.06052. 10 = 0.0574 t/m
- Weight of curb and backrest:
- Weight of rainwater (3 cm) = 0.03. 1 .1 = 0.0300 t/m
- Self weight of concrete slab = 0,2 . 1 . 2,4 – (1/2 x 0,2 x 1,5 x 2,4) = 0,36 t/m
- Weight of tiles and specs (5 cm) = 0,05 . 1 . 2,2 = 0,1100 t/m
- Weight of backrest pole and iron = 0,12 . 0,16 . 2,4 + 0,0574 = 0,1034 t/m

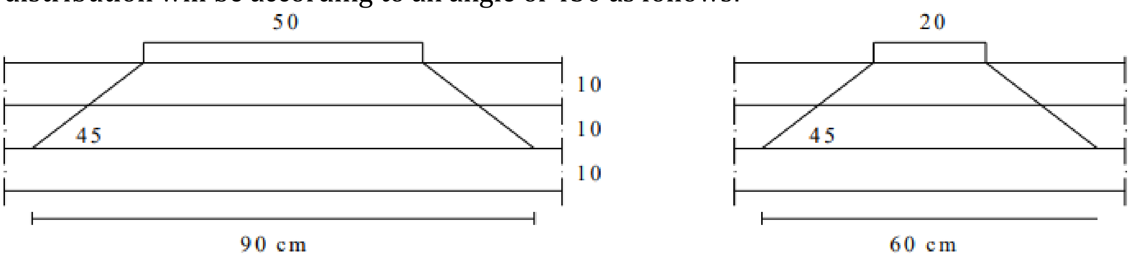
qdl2 = 0,6034 t/m

According to Minister of Public Works Decree No. 378/KPTS/1987 Concerning Highway Bridge Planning Guidelines article 4.1, the vehicle floor load is as follows :

Qdl = qdl1 + 1/L . 2qdl2
= 0,71 + 1/10 . (2. 0,6034)
= 0,88307 t/m

2) Live Load

The live load calculated on the vehicle floor is the T load (PPPJJR article 1.2.3 Page 5). The T load is the load that is a truck vehicle that has a double wheel load of 10 tons. The force distribution will be according to an angle of 450 as follows:



Picture 2. Wheel Loading Spread
Source: Autocad

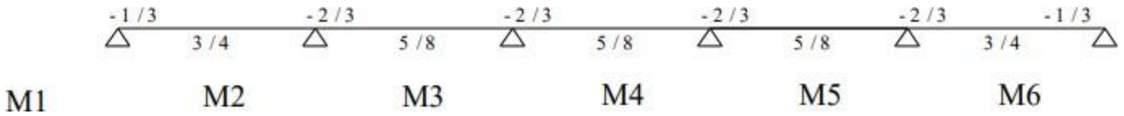
P = Force/area

= 10 / 0,9 x 0,6 = 18,518 t/m2 ql

= 18,518 . 1 = 18,518 t/m

b. Vehicle Floor Mechanics Analysis

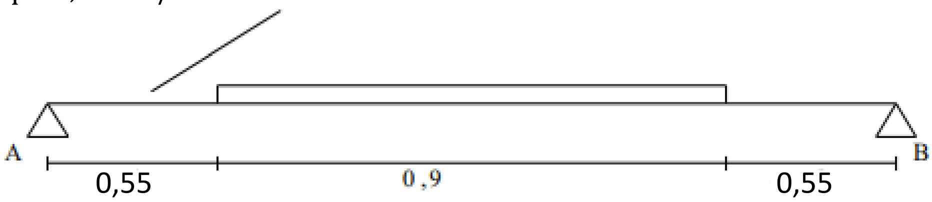
The floor plate is a one-way continuous plate with the following moment coefficient (article 13.2 Page 120)



Picture 3. Vehicle Floor Distribution Coefficient
Source: Autocad

Mo is the moment that arises when the roller joint is placed, the amount of Mo is found as follows :

1) Dead Load
   qdl = 0, 8307 t/m
   Mdl = 1/8 . 0,8307. 2.02
   = 0,41535 t/m
2) Live Load
   Judging from the loading conditions that may occur, the maximum moment is then selected from the loading conditions.
   a) Condition when 1 wheel is on the plate
      q = 0,8307 t/m



Picture 4. Condition when 1 wheel is on the plate
Source: Autocad

RA . 2,0 = (q . 0,9)(0,5 . 0,9 + 0,55)

RA . 2,0 = (18,518 . 0,9) (1)

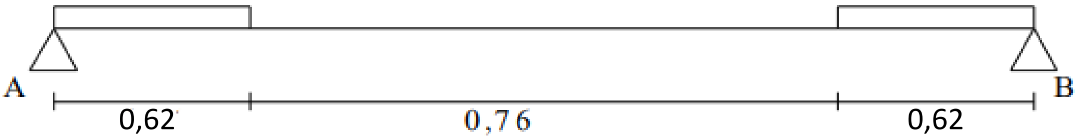
RA = 8,3331 ton

Mmax = RA . 1,0 – (q . 0,45) (0,5 . 0,45)

= 8,3331 . 1,0 – (18.518 . 0,45) (0,225)

= 6,4581 t/m

b) Condition when 2 wheels is on the plate



Picture 5. Condition when 2 wheels is on the plate
Source: Autocad

RA . 2,0 = (q . 0,62)(0,5 . 0,62) + (q . 0,42) (0,5 . 0.42 + 1,38)

RA . 2,0 = (18,518 . 0,42)(0,5 . 0,42) + (18,518 . 0,42)(1,59)

RA ≈ 14 tons

Mmax = RA . 1,0 – (q . 0,42)(0,5 . 0,42 + 0,38)

= 14 . 1,0 – (18,518 . 0,42)(0,59)

= 9,4112 t/m

Taken the largest M11, namely : 9,4112 t/m

Mo = 1,2 Mdl + 1,6 M11

= 1,2 . 0,41535 + 1,6 . 9,4112

= 15,5562 t/m

So based on the moment coefficient, the following moments are obtained :

- Support Moment

  M1 = M6 = -1/3 . 15,5562 = -5,1854 t/m

  M2 = M3 = M4 = M5 = -2/3 . 15,5383 = -10,3708 t/m

- Field Moment

  M12 = M56 = 3/4 . 15,5383 = 11,6671 t/m

  M23 = M34 = M45 = 5/8 . 15,5383 = 9,7226 t/m

c. Vehicle Floor Reinforcement

Used : f'c = 25 MPa ≤ 30 Mpa ⟶ $\beta = 0{,}85$

Quality of reinforcing steel U39 ⟶

Fy = 400 MPab = 1000 mm
d = 180 mm
h = 400 mm
d' = 20 mm

$\rho \min = \frac{1{,}4}{fy} = \frac{1{,}4}{400} = 0{,}0035$

$pb = \frac{0{,}85 \times \beta 1 x f'c}{fy} x \frac{600}{600+fy}$

$= \frac{0{,}85 \times 0{,}85x25}{400} x \frac{600}{600+400} = 0{,}0270$

ρ max $= 0{,}75 \text{ x pb}$

$= 0{,}75 \text{ x } 0{,}0270$

$= 0{,}0155$

1) Support Reinforcement

Mu $= 10{,}3708 \text{ t/m} = 10{,}3708.10^7$ Nmm

$$\text{Mn} = \frac{Mu}{\emptyset} = \frac{10{,}3708.10^7}{0{,}8} = 12{,}883.10^7 \text{N}/mm$$

$$\text{Rn} = \frac{Mu}{bd^2} = \frac{12{,}883.10^7}{1000.180^7} = 3{,}976 \text{ N}/mm^2$$

$$\text{m} = \frac{fy}{0{,}85\, f'c} = \frac{400}{0{,}85\ .25} = 18{,}8235$$

$$\rho \text{ perlu} = \frac{1}{m}\{1 - \sqrt{1 - \frac{2.m.Rn}{fy}}\}$$

$$= \frac{1}{18{,}8235}\{1 - \sqrt{1 - \frac{2.18{,}8235.3{,}976}{400}}\} = 0{,}0111$$

ρ perlu $< \rho$max → single reinforcement, used $\rho = 0{,}0111$

As $= \rho$ perlu . b . d

$= 0{,}0111.\ 1000.\ 180$

$= 1998 \text{ mm}^2$

Number of reinforcement (n) $= \dfrac{\text{As}}{0{,}25\ \pi\ 16^2} = 9{,}9372 \rightarrow 10$ pcs

Reinforcement distance $= \dfrac{100}{10} = 100$ mm

Main reinforcement used = D16 – 100 → As = 1998 mm^2. Divider reinforcement according to PBI article (.9.1.3 Page 90) : As = 20% . 1998 = 399,6 mm^2.

Number of reinforcement $= \dfrac{\text{As}}{0{,}25\ \pi\ 13^2} = 3{,}0105 \rightarrow 2$ pcs

Reinforcement distance $= \dfrac{\text{b}}{\text{n}} = \dfrac{1000}{2} = 500$ mm

Used dividing reinforcement = D13 – 500 → As 399,6 mm^2

2) Field Reinforcement

Mu $= 11{,}6537 \text{ t/m} = 11{,}6537.10^7$ N/mm

$$\text{Mn} = \frac{Mu}{\emptyset} = \frac{11{,}6537.10^7}{0{,}8} = 14{,}5671.10^7 Nmm$$

$$\text{Rn} = \frac{Mu}{bd^2} = \frac{14{,}5671.10^7}{1000.180^7} = 4{,}4960\ N/mm^2$$

$$\text{m} = \frac{fy}{0{,}8\, f'} = \frac{400}{85\ .25} = 18{,}8235$$

$$\rho \text{ perlu} = \frac{1}{m}\{1 - \sqrt{1 - \frac{2.m.Rn}{fy}}\} = 0{,}0127$$

ρ perlu $> \rho$min → used ρ perlu = 0,0185

$$\begin{aligned} As &= \rho min \,.\, b.\, D \\ &= 0{,}0127 \,.\, 1000.\, 180 \\ &= 2286 \text{ mm}^2 \end{aligned}$$

Number of reinforcement (n) $= \dfrac{As}{0{,}25\,\pi\,16} = 11{,}3696 \;\rightarrow 10$ pcs

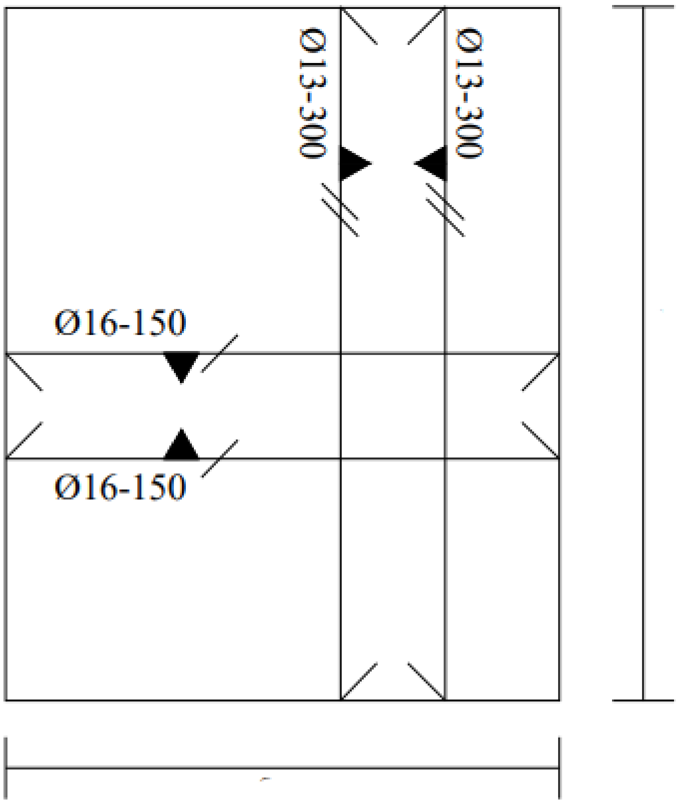
Reinforcement distance $= \dfrac{b}{n} = \dfrac{100}{10} = 100$ m

Main reinforcement is used = D16 – 100 → As =2286 mm^2. Divider reinforcement according to PBI article 9.1.3 Page 90 : As = 20%. 2286 = 457,2 mm^2.

Number of reinforcement $= \dfrac{As}{0{,}25\,\pi\,13^2} = 3{,}0105 \;\rightarrow 2$ pcs

Reinforcement distance $= \dfrac{b}{n} = \dfrac{1000}{2} = 500$ m

Divider reinforcement is used = D13 – 500 → As = 457,2 mm^2



Picture 6. Sketch of vehicle floor reinforcement
Source: Autocad

d. Cantilever Plate

1) Load

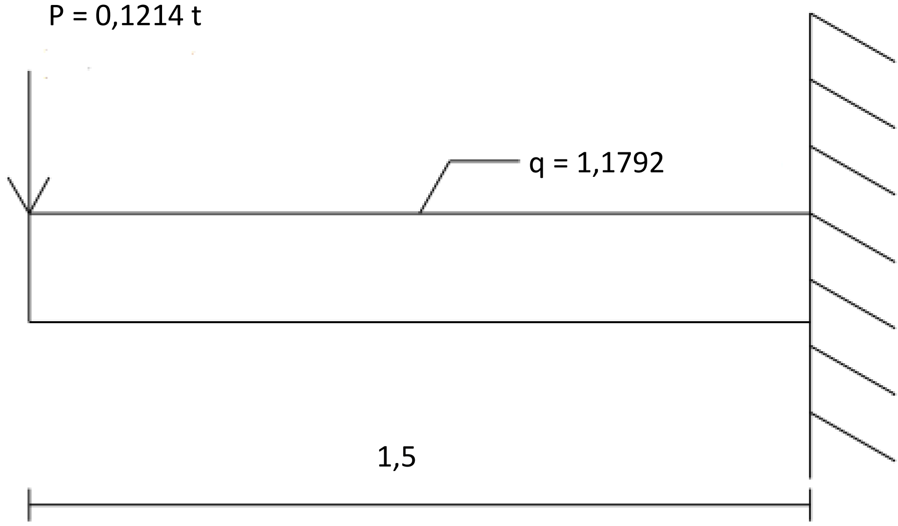
- Dead Load

Sidewalk Load

• Plate weight	= 0,2 . 1 . 2,4 – 0,1 . 1,1 . 2,4	= 0,216 t/m
• Tile weight and specs	= 0,05 . 1. 2	= 0,100 t/m
	qdl	= 0,316 t/m

- Live Load
  According to PPPJJR Chapter III article 1.2.5.a. Page 10 requires that sidewalk construction to consider a live load of 500 kg /m2.
  q11 = 500 . 1 = 500 kg/m = 0,5 t/m
  qu = 1,2 .qdl + 1,6 . q11 = 1,1792 t/m
  Centralized Load :
  Weight of backrest and iron posts = 0,1 . 0,16 . 2,4 . 1 + 0,0574 . 2 = 0,1214 t

2) Reinforment



Picture 7. Cantilever plate sketch
Source: Autocad

Used : f'c = 25 MPa > 30 MPa ⟶ $\beta = 0{,}85$
Quality of reinforcing steel U39 ⟶ = 400 MPa

b = 1000 mm d = 180 mm
h = 400 mm d' = 20 mm

ρ min = $\frac{1{,}4}{fy} = \frac{1{,}4}{400} = 0{,}0035$

pb = $\frac{0{,}85\ x\ \beta x f c}{fy} x\ \frac{600}{600+fy}$

$= \frac{0{,}85\ x\ 0{,}85 x 25}{400} x\ \frac{600}{600+400} = 0{,}0270$

ρ max = 0,75 x pb
= 0,75 x 0,0270
= 0,0202

Mu = 1/2 . qu . L^2 + P . L
= 1/2 . 1,1792 . $1{,}5^2$ + 0,1214 . 1,5
= 1,5087 t/m = 1,5087.10^7 N/mm

$$\text{Mn} = \frac{Mu}{\emptyset} = \frac{1{,}5087.10^7}{0{,}8} = 1{,}8858.\,10^7 \text{N}/mm$$

$$\text{Rn} = \frac{Mu}{bd^2} = \frac{1{,}8858.10^7}{1000.180^2} = 0{,}5820\ \text{N}/mm^2$$

$$\mathrm{m} = \frac{fy}{0{,}85\, f'c} = \frac{400}{0{,}85\ .25} = 18{,}8235$$

$$\rho\ \text{perlu} = \frac{1}{m}\{\ 1 - \sqrt{1 - \frac{2.m.Rn}{fy}}\ \}$$

$$= \frac{1}{18{,}8235}\{\ 1 - \sqrt{1 - \frac{2.18{,}8235.3{,}976}{400}}\ \} = 0{,}0047$$

ρ perlu $< \rho$ min → single reinforcement, used ρ min $= 0{,}0035$

As $= \rho$ min . b . d

$= 0{,}0035 . 1000, 180$

$= 630\ \mathrm{mm}^2$

$$\text{Number of reinforcement (n)} = \frac{\text{As}}{0{,}25\ \pi\ 16^2} = 3{,}1333\ \rightarrow 4\ \text{pcs}$$

$$\text{Reinforcement distance} = \frac{100}{4} = 250\ \text{mm}$$

Main reinforcement is used = D16 – 1250 → As 630 mm^{2}Divider reinforcement according to PBI article 9.1.3 Page 90 : As = 20% . 630 = 126 mm^2.

$$\text{Number of reinforcement} = \frac{\text{As}}{0{,}25\ \pi\ 13^2} = 0{,}9492\ \rightarrow 4\ \text{pcs}$$

$$\text{reinforcement distance} = \frac{1000}{4} = 250\ \text{mm}$$

Divider reinforcement is used = D13 – 250 → As 126 mm^2

6. Conclusion

A bridge is a significant structure, usually constructed from steel, designed to span between two areas, effectively connecting islands or regions to provide essential access. The construction of a bridge is not just about the main span but also involves the creation of a road to facilitate easy and comfortable passage for motorists. This road ensures that drivers and other users can access the bridge without difficulty, enhancing the overall usability of the structure. The design and calculation of the bridge's superstructure involve precise measurements to ensure its stability and safety. According to these calculations, the dead load, which is the bridge's weight, is determined to be 0.88307 tons per meter. In contrast, the live load, which accounts for the weight of vehicles and other traffic the bridge will support, is calculated to be 18.518 tons per meter.

Furthermore, in planning the mechanics of the vehicle floor, it is essential to account for dead and live loads. Here, the dead load is 0.41535 tons per meter, while the live load is 6.4581 tons per meter. These detailed calculations are crucial in the planning phase to ensure the bridge can withstand the various forces it will encounter over its lifespan. By addressing these load requirements, engineers can design a bridge that meets safety standards and provides reliable and long-lasting service to the community. Thus, a bridge is not merely a physical connection between two points; it is a meticulously engineered structure that embodies safety, convenience, and durability for all who use it.

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