International Journal of Engineering and Science Applications
ISSN 2406-9833
IJEScA

Design of The New Upper Structure Comba Bridge in Jayapura Regency Using Prestressed Concrete

RA Wibowo[1], Irianto[2], DSS Mabui[1], M Wantoro[2]
[1]Civil Engineering Department, Faculty of Engineering Yapis Papua University, Indonesia
[2]Master of Engineering in Civil Engineering, Master's Program, Yapis Papua University, Indonesia
email: rezkyaprilyantowibowo@gmail.com

ABSTRACT

Comba Bridge is located in the main road of Jayapura Regency. This bridge has some damages due to the density of the traffic on the bridge. In order to increase the level of service, it is necessary to figure out the solution. One of the solution is designing a new bridge beside the old bridge. The aim is to design a new bridge using prestressed concrete girder as the main structure and figure out the general construction method for this bridge. Stressing method for the main structure is post tensioning method. The new bridge has two 25 meters spans. Designing includes secondary structure design and main structure design. The analysis result show that pedestrian barrier consists of two galvanized steel railing, H-profile steel column, concrete deck slab and pavement slab using reinforced concrete with 22 cm thickness. Main structure using Precast Concrete I Girder (PCI Girder) has 4500 kN initial prestressed force and 4 cables that consist of 7-wire strand super grade. Erection method of the girder using launcher machine.

Keywords: Prestressed concrete bridge, Post tensioning, PCI girder

1. INTRODUCTION

The Sentani Comba road in Jayapura Regency is where the Comba Bridge is located. The bridge experiences a significant volume of traffic due to its prime position along the main road in the Jayapura-Sentani region. In addition, as per the 2020 report by the Directorate General of Land Transportation, there has been a rise in the number of motorized vehicles across various modes of transportation in Papua Province, resulting in an overall increase of 10%. The bridge's functionality is affected by the dense traffic it faces, leading to deficiencies. The situation of congestion on a bridge can be extremely perilous. Bridges are intended for accommodating moving loads rather than stationary loads. The comfort level of road users, specifically highway bridges, is affected by the rise in vehicle volume.

In order to address this issue, a decision was made to opt for an alternative approach by constructing a fresh bridge adjacent to the existing one. The main structure of the new bridge will be planned using the post-tensioning method with Precast Concrete I Girder (PCI Girder). Dean [1] asserted that precast bridge beams ranging from 10 to 30 meters in length have been found to be more cost-effective in the United States when compared to the utilization of steel and reinforced concrete. Moreover, concrete material surpasses steel material in terms of corrosion resistance and maintenance ease.

2. LITERATURE REVIEW

A. Basic Bridge Planning

Planning a bridge, it is crucial to base the process on procedures that offer viable options for reaching a limit state throughout the bridge's entire design life. The construction of the bridge is believed to have been done in compliance with all the necessary requirements, and it is assumed that proper maintenance will be carried out to ensure its durability and longevity during its design life. The boundary conditions that need to be understood in the bridge planning process are:

1) Ultimate Limit State

   Ultimate actions that render a bridge unsafe are known as the triggers, and the bridge's response to these actions is referred to as the Ultimate Limit State.

2) Service Limit Conditions

   Serviceability Limit Condition is a permanent change in shape in the foundation material or in a local main supporting element, permanent damage due to corrosion, cracking or fatigue, vibration and flooding on the road network and land around the bridge as well as damage due to erosion in channel troughs, river banks. and road embankments.

B. Bridge Loading

The loads acting on the bridge under [2] include:

a. Fixed load
   1) Own weight
   2) Additional dead load/utility
   3) Effects of shrinkage and crawling
b. Traffic load
   1) Load column "D"
   2) Truck load "T"
   3) Dynamic Load Factor (FBD)
   4) Brake Style
   5) Loading for pedestrians
c. Environmental Action
   1) Wind Load
   2) Earthquake Effects

C. Concrete Prestressing

Prestressed concrete consists of high quality concrete material and prestressed steel tendons. In its implementation, there are two methods of applying concentric forces to prestressed concrete, namely pre-tensile and post-tensile systems. The way the pretensile system works is by applying prestressed force first to the steel tendon before the concrete is cast. As for the post-tensile method, the concrete is cast first, then the steel tendon is inserted in the hole that has been available in the concrete for further prestressing force to be applied.

D. Loss of Prestressing Force

In general, the loss of prestressing force can be explained as follows:

a. Immediate loss

This direct loss of prestressing force is caused by:

1. Elastic shortening of concrete

$$ICE : \frac{n..Ti}{Ac} \quad (1)$$

with:

ICE : loss of prestressing force
It : initial prestressing force
n : ratio of modulus of elasticity (*Es/Ec*)
Ice : modulus of elasticity of cable/prestressed steel
Ec : modulus of elasticity of concrete

2. Anchor slip

The measured slip on average reaches 2.5 mm in size. The magnitude of the total elongation of the tendon:

$$\Delta\ L : \frac{f_{pi}}{Es} L \quad (2)$$

Loss of prestressing force due to slip:

$ANC : \frac{S_{average}}{\Delta L}$ x 100 (3)

With :

ANC : loss of prestressing force due to armature slip

ΔL : Deformation of the Armature

FPI : Tension in tendons

ES : modulus of tendon elasticity

L : tendon length

Average : average price of armature slip

3. Wobble effect

$FPF : F1 \, . \, e^{-(\mu\alpha + KL)}$ (4)

With :

F1 : Starting Voltage

α : angle in tendon

μ : coefficient of shear

K : wobble coefficient

L : prestressed cable length

b. Long-term loss

1. Crawl

$CR : Kcr \dfrac{Es}{Ec} \, (fci - fcd)$ (5)

with

CR : Loss of prestress due to crawling

Kcr : Crawl coefficient, the magnitude of which:

Pre-tension : 2,0

Post-Tension : 1.6

Es :Modulus of elasticity of prestressed steel

Ec :Modulus of elasticity of concrete

Fci :Concrete Tension at Steel Position/Level prestressing shortly after force transfer Guessing.

FCD: Concrete stress at the center of weight tendons due to *dead load* (load dead).

2. Shrink

$SH : \varepsilon sh \, . \, Ksh. \, Is$ (6)

with

SH : Loss of tension in tendons due to concrete shrinkage

Es : Modulus of elasticity of prestressed steel

εsh : Effective shrinkage can be found from the following equation:

esh : $8{,}2 \times 10^{-6}\left(1 - 0{,}06\dfrac{V}{S}\right)(100 - RH)$

V : Concrete volume of a component of a prestressed concrete structure

S : Surface area of prestressed concrete structure components

RH : Relative air humidity

Ksh : Depreciation coefficient, the price is determined against the time between the end of casting and the moment of applying prestressed forces

3. Steel relaxation

$RE : C\,[\,Kre - J\,(\,SH + CR + ES\,)\,]$ (7)

with

RE : Stress loss due to relaxation of prestressed steel

C : The magnitude of the relaxation factor depends on the type of prestressed wire/steel.

Kre: Coefficient of relaxation, the price ranges from 41~138 N/mm2

A : Time factor, the price ranges from 0.05~0.15

SH : Voltage loss due to concrete shrinkage.

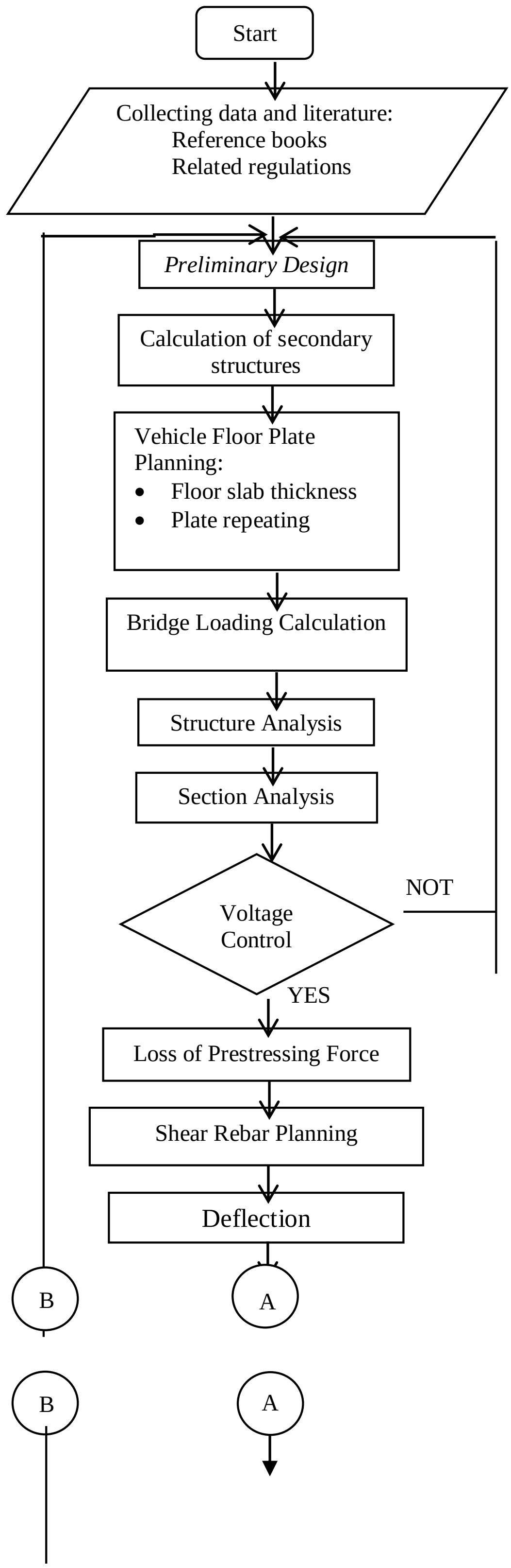
CR : Stress loss due to concrete *Creep*.

ES : Voltage loss due to elastic shortening.

3. RESEARCH METHODOLOGY

This research uses secondary data in the form of bridge geometry data. The first stage is the preliminary *design* to determine the initial dimensions of each structural element. Then the planning of the secondary structure of the bridge is carried out. Bridge loading based on [2]. From the results of the loading calculation, structural analysis is carried out to determine the inner force that works.

After that, the calculation of the initial prestressing force is carried out. Then control is carried out on the voltage that occurs in the cross section. For more details can be seen in the following flow chart:



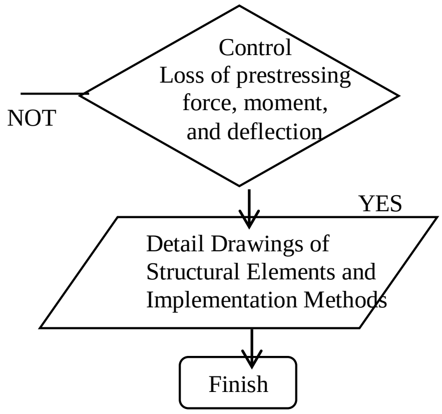


Figure 1. Final Project Work Flow Diagram

4. RESULTS AND DISCUSSION

A. Preliminary Design

Bridge Location	: River Sentani, Jayapura Regency
Bridge spans	: 2 x 25 m
Vehicle floor	: 2 lanes 1 way
Traffic lane width 2 x 3.5 m	
Curb width	: 2 x 1.5 m
Transverse width of the bridge	: (2 x 3.5) + (2 x 1.5) : 10 m

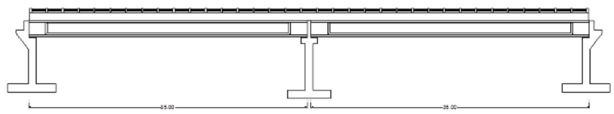


Figure 2. Bridge Side View

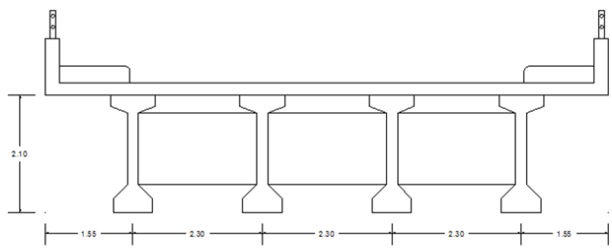


Figure 3. Cross Section of the Bridge

1) Prestressed Girder

Prestressed girders are planned using PCI Girders type H210 with a span of 25 m as many as 4 pieces.

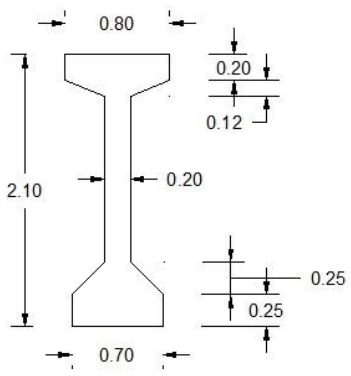


Figure 4. PCI Girder H210

2) Tendon

Table 1. Strand Properties

Type	Diameter (mm)	Area (mm2)	*fu* (MPa)	*Es* (MPa)
7-wire *strand super grade*	12,7	100	1860	195000

Source: Prestressed Concrete Structure Planning Manual For Bridges

3) Vehicle Floor Plates and Sidewalks

For the determination of the thickness of the floor slab of the vehicle should be planned on the basis of the minimum thickness *of ts* regulated in [3]. The thickness of the floor slab of the vehicle is planned to be 220 mm.

220 $\geq$ 200 mm... OK!

220 $\geq$ (100+40 *l*) mm

220 $\geq$ (100+40.2.3) mm

220 > 192 mm ... OK!

4) Diaphragm Beam

The diaphragm beam is a stiffener between prestressed girders. The cross-sectional dimensions of the diaphragm are 0.3 x 1.28 m. The length of the diaphragm is 2.10 m.

5) Backrest

The backrest is planned to consist of two backrest pipes with galvanized steel pipe material Ø 76.3 mm BJ-37, backrest posts with H steel profiles as high as 500 mm spaced 2 m apart, and reinforced concrete backrest walls with a thickness of 25 cm as high as 500 mm.

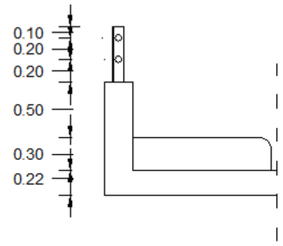


Figure 5. Cross Section Backrest and Sidewalk

6) Data Material

Table 2. Material Quality

Structural Elements	*fc'* (MPa)	*fy* Deform (MPa	*fy* sengkang (MPa)
PCI Girder	40	400	250
Floor Slab	30	300	
Sidewalk	30	250	
Diaphragm	30	300	250
Backrest wall	30	250	

B. Secondary Structure

1) Backrest

a. Backrest pipe

Retained load : 0.75 kN/m

: 76.48 kg/m

Distance between poles : 2 m

Backrest mast height : 1 m

Pipe dimensions : galvanized steel pipe Ø 76.3 mm BJ-37.

Technical data of pipe profiles:

Ø	: 7.63 cm	I :	43.7 cm^4
t	: 0.28 cm	F :	6,465 cm^2
W	: 11.5 cm^3	G:	5.08 kg/m

Factored load (qu) : 128.464 kg/m

$$M\max = \frac{1}{8}.q.l^2 = 64{,}232 \text{ kgm}$$

Voltage and Deflection Control

σijin : 1600 kg/cm2

Steel : 2.1 x 105 MPa

- Deflection Control

Deflectionclearance: $\frac{L}{300} = \frac{2000}{300} = 6{,}67$ mm

Deflection that occurs: $\frac{5.q.L^4}{384EI}$

2,916 mm < 6.67 mm... OK!

- Voltage Control

  The voltage that occurs in the backrest pipe is:

  $\frac{Mu}{W} \leq$ σijin

558.54 kg/cm2 < 1600 ... OK!

b. Backrest Posts and Backrest Walls

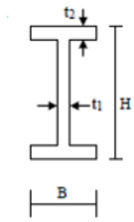


Figure 6. Backrest Pole Profile

The backrest post uses ST-37 steel profile with the following technical data:

B : 50 mm I : 187 cm4

H : 100 mm W : 37.5 cm3

T1 : 5 mm G : 9.3 kg/m

T2 : 7 mm

Profile height : 50 cm

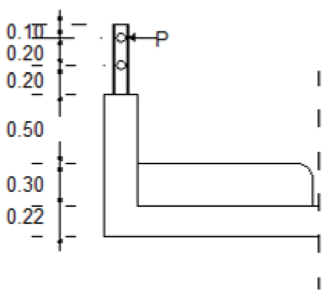


Figure 7. Backrest Loading

Load held by the backrest:

P : 152.96 kg, working in the horizontal direction at the end of the backrest pole.

So that the maximum moment that occurs,

Mu : 152,96 . 0,5

: 76.48 kgm

$\frac{76{,}48 \times 10^2}{37{,}5} \leq 1600$

203.95 kg/cm2 < 1600 kg/cm2 ... OK!

The moment that reaches the end of the sidewalk,

Mu : 152,96 . (0,9 + 0,3)

: 183.552 kgm

Mn : $\frac{Mu}{\phi}$: $\frac{183{,}552}{0{,}8}$: 229.44 kgm

Staple reinforcement,

$As = \rho.b.d$

: 11.2 cm 2 → used reinforcement ø12-100 (As : *11.31 cm2)*

Divider reinforcement,

As' : 0.2 . 11.31 : 2.262 cm2 → used reinforcement ø10-200 (*As* : 3.93 cm2)

2) Vehicle Floor Plates

Dead load (*Qu*) : 1,3 (5,28 + 2,26)

: 9,802 kNm

Muxt : $\frac{1}{10} Qu \,.\, L2$

: 5.185 kNm : 0.529 tm

Muxl : $\frac{1}{14}\ Qu \,.\, L2$

: 3.704 kNm : 0.378 tm

Muyl : $\frac{1}{3}\ Mxl$

: 1.225 kNm : 0.126 tm

C. The Burden of Life

The calculated live load is due to the load of the T load on the bridge floor. The distribution of load on the vehicle floor due to T-wheel load amounted to 11.25 tons (RSNI T-02 2005). Since the floor width of the bridge > 5.5 m, it is reviewed against two conditions:

a. Condition 1 (1 wheel in the center of the plate)

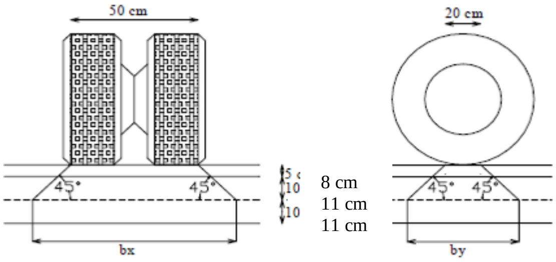


Figure 8. Load 1 wheel in the center of the plate

T : FBD $\dfrac{T}{tx.ty}$: 28.65 tons

Mx record : 0,16903 . 28,65 . 0,88 . 0,58

: 2,472 tm

My : 0,1099 . 28,65 . 0,88 . 0,58

: 1,607 tm

b. Condition 2 (2 wheels close together with a distance of 100 cm in the center of the plate)

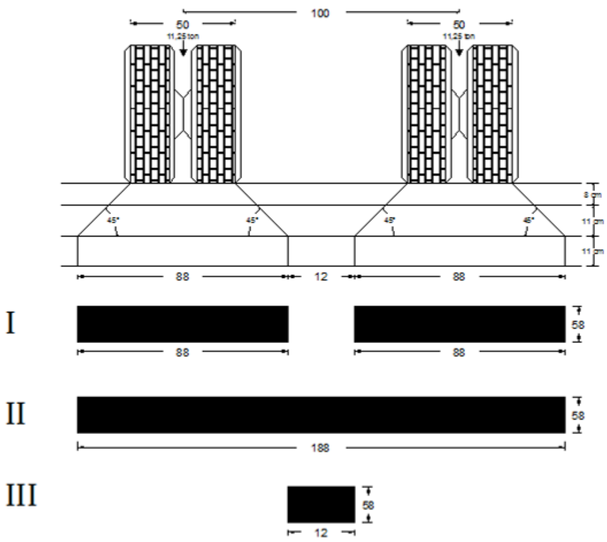


Figure 9. The load of 2 wheels is close together with a distance of 100 cm in the center of the plate

Mux : 1,8 . 2.472 : 4.4496 tm

Muy : 1,8 . 1,607 : 2,893 tm

Total moment

<u>Fulcrum moment</u>

Muxt : 0.529 + 4.4496 : 4.979 tm

<u>Field moments</u>

Muxl : 0.378 + 4.4496 : 4.823 tm

Muyl : 0.126 + 2.893 : 3.019 tm

The reinforcement of the plate pedestal uses D16-150 and the field plate X direction D16-150 and Y direction D16-250.

3) Diaphragm Beam

The diaphragm planning on this bridge uses *simple beam analysis*. Because the diaphragm only functions as a lock and stiffener between girders so that rolling does not occur and is not the main structure. The diaphragm is considered to stand alone, so the load held is only heavy on its own.

a) Imposition

WU : 1,3 . 921,6

: 1198.08 kg/m

MU : $\dfrac{1}{12}$. *WU . L2*

: 440.2944 kgm

b) Recurrence plan

d : 1209 mm

$As = \rho.b.d$

: 16.93 cm^2

used reinforcement 4 D22

c) Control against sliding

VU : $\dfrac{1}{2}$ *WU. L*

: 1257.984 kg

VC : $\frac{1}{6}\sqrt{fc'}b'h$

: 58642.83 kg

$VU < VC$, hence the practical sengkang ø10-200 is used

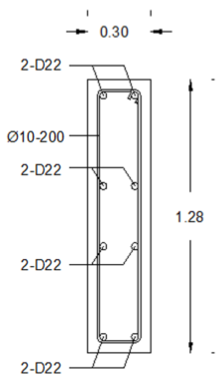


Figure 10. Diaphragm beam repeatability

D. Cross-sectional analysis of girders

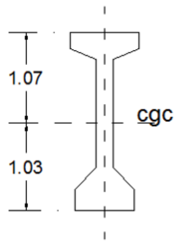


Figure 11. Cross Section Before Composite

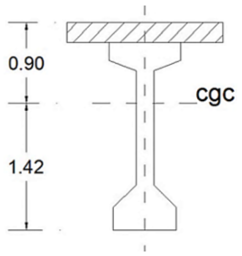


Figure 12. Composite Cross Section

Table 3. Cross-sectional Analysis

Before Composites		After Composite	
Ic	3,805 x 1011 mm4	Ick	2,417 x 1011 mm4
St	3,544 x 108 mm3	Stk	2,681 x 108 mm3
Sb	3,706 x 108 mm3	Sbk	1,704 x 108 mm3
Kt	469.91 mm	kt'	455.19 mm
Kb	491.39 mm	kb'	725.03 mm
Ec	33994.48 MPa		

E. Imposition

a. Own Weight Girder

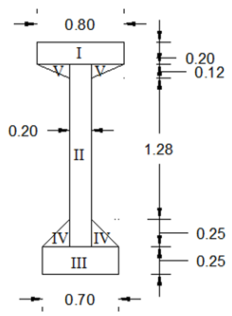


Figure 13. Prestressed Girder

Table 4. Girder Cross-section Calculation

Cross-section	p	h	A (m2)	V (m3)
I	0,8	0,2	0,16	5,6
II	0,2	1,85	0,37	12,95
III	0,7	0,25	0,175	6,125
IV	0,25	0,25	0,031	1,094
V	0,3	0,12	0,018	0,63
Sum			0,754	26,399

Specific gravity : 2500 kg/m3

Girder weight : 2500 . 0,754 . 25

: 1885.63 kg/m

b. Additional Dead Load

1) Vehicle Floor Plate Weight

: 1214.4 kg/m

2) Asphalt Weight

: 404.8 kg/m

3) Rainwater

: 115 kg/m

Total additional dead load : 1734.2 kg/m

c. Traffic Load

Load "D"

- Equally Divided Load (BTR)

L : 2 x 25 : 70 m

To L > 30 m, q : $9{,}0\left(0{,}5+\frac{15}{L}\right)$ kPa

: 6.43 kPa : 6.43 kN/m2

S : 2.3 m

LE : $\sqrt{L_{AV}.L_{MAX}}$: $\sqrt{35.35}$: 25 m

FBD for LE : 25 m is 40%.

BTR : q . S . FBD : 20.7 kN/m

- Line Load (BGT)

p : 49 kN/m

BGT : p . S . FBD : 157.78 kN

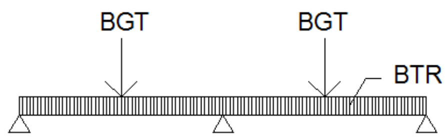


Figure 14. Live load configuration 1

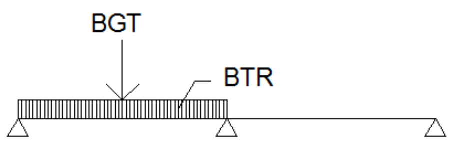


Figure 15. Live load configuration 2

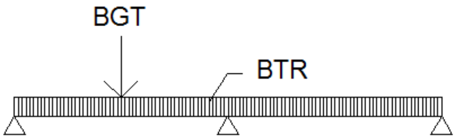


Figure 16. Live load configuration 3

Brake Load

The magnitude of brake force for a 25 m bridge span is 88.75 kN

Wind Load

TEW : 166.79 kN

Earthquake Load

W :

1192964,32 Kg

:

11929,64 Kn

C : 0.223 (Jayapura earthquake spectrum response)

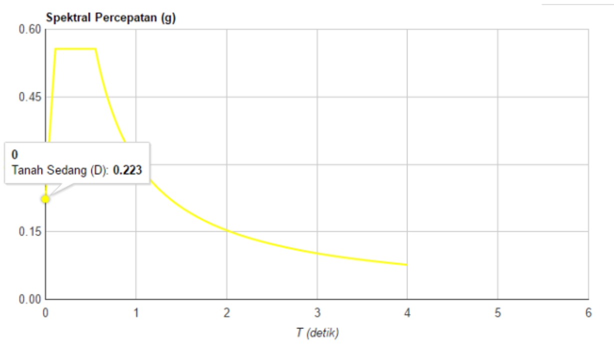


Figure 17. Jayapura's spectrum response to medium soils

S : 1.3225 (Table 33 RSNI T-02 2005)

I : 1.2 (Table 32RSNI T-02 2005)

TEQ : 0,223 . 1,3225 . 1,2 . 11929,64

: 4221.9 kN

F. *Structural Analysis*

Figure 18. Moments Due to Live Load Configuration 1

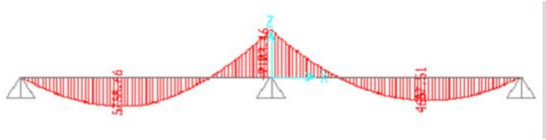


Figure 19. Moments Due to Live Load Configuration 2

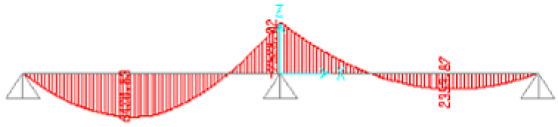


Figure 20. Moments Due to Live Load Configuration 3

Table 5. Recapitulation of Latitude Force Due to Vertical Load

Jarak (m)	*Vtotal* (kN) Konf. 1	Konf. 2	Konf. 3
0	-791,527	-851,244	-336,411
5	-509,401	-569,118	-232,911
10	-227,276	-286,992	-129,411
15	54,85	-4,867	-25,911
20	494,756	435,039	235,369
25	776,881	717,165	338,869
30	1059,007	999,29	442,369
35	1341,133	1281,416	545,869

G. *Prestressing Force Calculation*

Clearance voltage

1) When transferring

σpress ≤ -24 MPa

σtarik ≤ 1,581 MPa

2) When service loads

σpress ≤ -18 MPa

σtarik ≤ 3,162 MPa

Tendon eccentricity (*Eo*) : h – 200 mm – Ct

: 826.53 mm

Estimation based on stress conditions at transfer in the lower fiber to determine the initial prestressed force (*Pi*).

$$-\frac{P}{Ac}-\frac{P.e_0}{Sb}+\frac{M_G}{Sb}\leq 24 \text{ MPa}$$

$$-\frac{P}{754250}-\frac{P.826{,}53}{370633540{,}3}+\frac{(1{,}614x10^9)}{370633540{,}3}\leq -24$$

MPa

1.326 x 10-6 P + 2.23 x 10-6 P ≤ 24 + 4.255

$P \leq 7973847.019$ N

Used Pi : 4500000 N

Control of the voltage that occurs in the girder cross-section due to Pi : 4500000 N and EO : 826.53 mm.

1) When transferring

Top fiber,

$$-\frac{P}{Ac}+\frac{P.e_0}{Sb}-\frac{M_G}{Sb}\leq \sigma\text{tensile}$$

0.980 MPa ≤ 1.581 MPa ... OK!

Bottom fiber,

$$-\frac{P}{Ac}-\frac{P.e_0}{Sb}+\frac{M_G}{Sb}\leq \sigma\text{press}$$

-15,203 MPa ≤ -24 MPa ... OK!

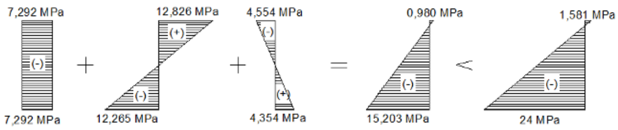


Figure 21. Diagram of voltage at the time of transfer

2) When service loads

Top fiber,

$$-\frac{Pe}{Ac}+\frac{Pe.e_0}{St}-\frac{M_G+M_{DL}}{St}-\frac{M_L}{St_k}\leq$$

σpress

-8,103 MPa ≤ -18 MPa ... OK!

Bottom fiber,

$$-\frac{Pe}{Ac}-\frac{Pe.e_0}{Sb}+\frac{M_G+M_{DL}}{Sb}+\frac{M_L}{Sb_k}\leq \sigma\text{press}$$

-1,757 MPa ≤ -3,162 MPa ... OK!

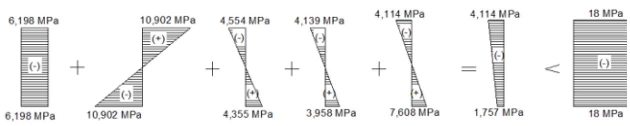


Figure 22. Stress diagram at the time of service load

H. Tendon Calculation

$$Aps : \frac{Pi}{fp_{eff}}$$

$$= \frac{Pi}{0{,}82\ fp_u} : 3606.08 \text{ mm2}$$

$$n_{Strand} : \frac{Aps}{Ap_1}$$

$$: \frac{3606{,}08}{100} : 36{,}061 \text{ pieces} \approx 38 \text{ pieces}$$

4 tendons are used, so there are 2 tendons with 10 strands *and 2 tendons with 9* strands.

Table 6. The position of each tendon

Distance (mm)	Tendon 1 (mm)	Tendon 2 (mm)	Tendon 3 (mm)	Tendon 4 (mm)
0	1400,000	1150,000	900,000	600,000
2500	1147,959	931,122	747,449	527,041
5000	934,694	745,918	618,367	465,306
7500	760,204	594,388	512,755	414,796
10000	624,490	476,531	430,612	375,510
12500	527,551	392,347	371,939	347,449
15000	469,388	341,837	336,725	330,612
17500	450,000	325,000	325,000	325,000

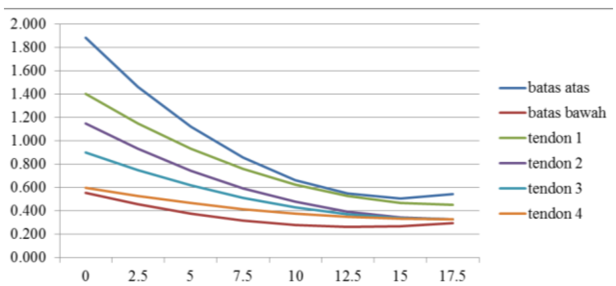


Figure 23. Tendon layout up to 1/2 span

I. Loss of Prestressing Force

1) Short-term

- Elastic shortening

Table 7. Loss of prestressing force due to elastic shortening

	Tendon 1	Tendon 2	Tendon 3	Tendon 4
nstrand	10	10	9	9

APS (mm2)	1000	1000	900	900
Ti (N)	457560 0	305040 0	137268 0	0
ES (MPa)	34.798	23.199	10.440	0

So that the loss of prestressing force due to average elastic shortening is as much as:

Es-Average : $\dfrac{34{,}798+23{,}199+10{,}44+0}{4}$

: 17,109 MPa

- Anchor Slip

ΔL : $\dfrac{f_{pi}}{E_s} L$

: 274.51 mm

ANC : $\dfrac{2{,}5}{274{,}51}$ x 100% : 0.91%

- Tendon friction

Table 8. Loss of prestress force due to tendon friction / *wobble effect*

	Tendon 1	Tendon 2	Tendon 3	Tendon 4
e (mm)	576,53	701,53	701,53	701,53
L (mm)	17500	17500	17500	17500
α (rad)	0,132	0,160	0,160	0,160
fpf (MPa)	593,60	550,20	550,20	550,20

2) Long-term

- Shrink

.SH : (8.2×10^{-6}) . (1-(0.06 . 4,704)) . (100-80) 0,8 . 19500

: 18.36 MPa

- Crawl

CR : 1,6 $\dfrac{195000}{33994{,}5}$ (12,912 – 5,95)

: 64.28 MPa

- Steel Relaxation

RE : 1,28 [120 – 0,15(18,36 + 64,28 + 17,109)]

: 105,037 MPa

3) Total Loss of prestressed force

Total loss : %ES + %CR + %SH + %RE

: 1,12% + 4,21% + 1,2% + 6,89%

: 13.43% < 20% ... OK!

J. Calculation of Shear Reinforcement

$$\frac{Vu}{\phi} > \frac{1}{2} Vc$$

1788176.93 > $\frac{1}{2}$ 0.4 $\sqrt{fc'}$ *Bw DP*

1788176.93 > 451573.25 ... Then body shear reinforcement is required.

The need for shear reinforcement

Vs : $\dfrac{Vu}{\phi} - Vc$

: 817884.5 N

Axle : $\dfrac{1}{4}$ π 102

: 78.5 mm2

Cross-sectional height control:

$$\frac{2}{3}\sqrt{fc'} b_w d_p$$

: $\dfrac{2}{3}\sqrt{40}\,200.1785$

: 1505244.2 N > *Vs*, then the cross section is sufficient

$\dfrac{Av}{s}$: $\dfrac{Aps.f_{pu}}{80.fy.d_p}\sqrt{\dfrac{d_p}{b_w}}$

: $\dfrac{3800}{80.250.1785}\sqrt{\dfrac{1785}{200}}$: 0.592 mm2/mm

s : $\dfrac{2.As}{0{,}592}$

: $\dfrac{2.78{,}5}{0{,}592}$

: 295.4 mm

Cheque:

$Vs \leq Vcmin$

817884.5 > 376311,042 ... then S/2 should be used

s/2 : 295,4 / 2

: 132.7 mm ≈ 130 mm

K. Deflection

δmax : L/800 : 43.75 mm ↓

Table 9. deflection

When Transfer		When Erect		Final Stage	
Consequences of Prestressed Forces	27.75 mm ↑	Consequences of Prestressed Forces	49.95 mm ↑	Consequences of Prestressed Forces	61.05 mm ↑
Due to girder's own weight	14.69 mm ↓	Due to girder's own weight	27.17 mm ↓	Due to girder's own weight	25.25 mm ↓
				Due to additional dead load	40.53 mm ↓
				Aftermath of BTR	16.12 mm ↓
				Due to centralized load	30.83 mm ↓

$\Delta Total$: 13.06 + 22.78 + 25.8 + 61.05 – 40.53 – 16.12 – 7.69

: 2.7 mm ↓ < δmax ... OK!

L. Moment Capacity Control

Dc : 40 mm Ns : 30 pieces

$As1$: $\frac{1}{4}\pi$ 132 : 132.67 mm2

Ast : 30 . 132.67 : 3979.95 mm2

Bt : 1741.72 mm

Composite prestressed moment arm,

dp : Ct + ts + e : 2120 mm

Pe : FPE . Aps

: 5795760 N

FPE ≥ 0.5 Fpu

1525,2 $\geq$ 930 ... OK!

$\frac{f_{py}}{f_{pu}}$: 0.85, so γp : 0.4

For fc' : 40 MPa, $\beta 1$: 0.77

ρp : $\frac{Aps}{Ac_k}$

: 0,33 %

ρc : 0

ρt : $\frac{Ast}{Ac_k}$

: 0,51%

ωt : $\rho_t \frac{fy}{fc'}$

: 0,051

$$Fps : Fpu\left[1-\frac{\gamma_p}{\beta_1}\left(\rho_p\frac{f_{pu}}{fc'}+\frac{d}{d_p}(\omega_t-\omega_c)\right)\right]$$

: 1662.33 MPa

ωp : $\rho_p \frac{f_{ps}}{fc'}$

: 0,1388

1) Stress width of the concrete block (assuming the neutral line is on the flange)

Tps : Fps . Aps

: 6316859.3 N

Ts : Ast . Fy

: 2334904 N

a : $\frac{Tps+Ts}{0,85\,fc'.b_t}$

: 146,099 mm < *Ts*, hence the assumption true.

2) Check maximum reinforcement

Based on *AASHTO 3rd Edition 2004, Sec 5.7.3.3,* the depth of reinforcement is effective in cross section, *de* :

$$De \quad : \frac{Aps.f_{ps}d_p + Ast.fy.d}{Aps.f_{ps} + Ast.fy}$$

: 2096.66 mm

$$c \quad : \frac{a}{\beta_1}$$

: 189.74 mm

$c/_{de}$: 0.09 < 0.42 ... OK!

3) Check the ultimate design moment

$$Mn \quad : Tps\left(dp - \frac{a}{2}\right) + Ast \;.\; Fy\left(d - \frac{a}{2}\right)$$

: 1750776183 Nmm

Mu : 6256.66 kNm : 6256.66 x 106 Nmm

ø Mn : 0,8 . 1750776183

: 14.007 x 106 Nmm

Mu ≤ *ø Mn*

6256.66 x 106 < 14.007 x 106 ... OK!

4) Check the minimum design moments necessary

Tensile stress cracking, *fr*

$Fr \quad : 0{,}7\ \sqrt{fc'}$

: 4,427 MPa

Cross-sectional crack moment, *Mcr*:

Mcr : (*Fr – fakt*) *Sbk* + *Mtotal*

: (4.427 – 1.76) 517740575.3 + 6.257 x 109

: 7639244795 Nmm

$$\frac{\phi Mn}{Mcr} \geq 1.2$$

1,833 > 1.2 ... OK!

M. Continuous Plate Connection Planning

The need for reinforcement in the fulcrum area is calculated based on the largest live load moment that occurs from each configuration of the live load previously described. The quality of steel used is BJTD 30.

1) Calculation of reinforcement needs

$$\rho min \;:\; \frac{1{,}0}{fy} = \frac{1{,}0}{300} = 0{,}0033$$

$$\rho max : 0{,}75.\left(\frac{0{,}85.30.0{,}85}{300}.\frac{600}{600+300}\right)$$

: 0,036

Mu : 213128740 Nmm

$$Rn \quad : \frac{213128740}{0{,}8.1000.170^2} : 9{,}22$$

$$\omega \quad : 0{,}85\ .\ \left(1 - \sqrt{1 - \frac{2{,}353.9{,}22}{30}}\right) : 0{,}403$$

ρhit : 0,403 $\frac{30}{300}$: 0.0403 > ρmax, then used ρmax

So that the basic reinforcement needs are obtained, namely:

Axle : 0,036 . 100 . 17

: 61.2 cm2

When D22 reinforcement is used, then:

$$s \quad : \frac{1/_4.\pi.22^2.1000}{6120} : 62.11 \text{ mm} \approx 60 \text{ mm}$$

For reinforcement, what is needed is 50% of the area of the main reinforcement. So that the need for reinforcement is obtained, namely:

Asbagi : 50% . 61,2

: 30.6 cm2

When D22 reinforcement is used, then:

$$S \;:\; : \frac{1/_4.\pi.22^2.1000}{3060}\ 124.22 \text{ mm} \approx 120 \text{ mm}$$

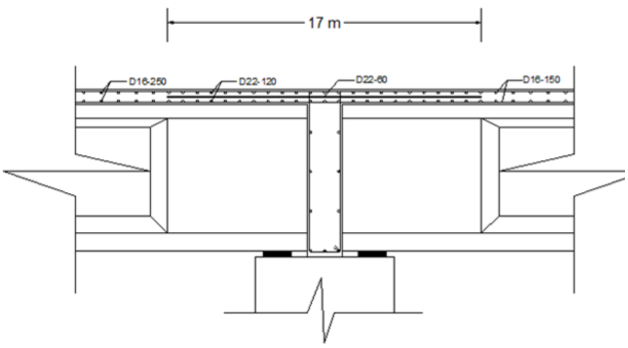


Figure 24. Continuous Plate Connection Details

N. Planning Elastomeric Bearings

Elastomeric used *Freyssinet Elastomeric Bearing* Type B 400 x 500

Sliding modulus, *G* : 1.2 MPa (BMS Table 8.1)

Bulk Modulus, B : 2000 MPa (BMS Table 8.1)

elastomeric length, *a* : 400 mm

elastomeric width, *b* : 500 mm

Thick blanket, *Tc* : 5 mm

Thick inner layer, *T1* : 12 mm

Steel plate thickness : 4 mm

Number of layers, *n* : 5 layers

Thick side covers, *TSC* : 2.5 mm

The total thickness of the elastomer, *t* : 89 mm

Vmax : 5778 kN

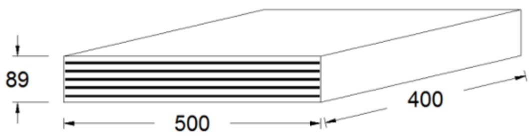


Figure 25. Elastomeric Pieces

Elastomeric Control:

1) Form factor

$$S : \frac{A}{P.t1}$$

with

A : bonded surface area

P : circumference of the bonded surface

T1 : effective thickness elastomer

For laying laminates $4 < S \leq 12$

$$S \ : \frac{400.500}{(400+500)2.12} : 11.1 < 12 \text{ ... OK!}$$

2) Average compressive voltage requirements

$$\frac{V}{A} \leq 15 \text{ MPa}$$

$$\frac{2773{,}97 \times 10^3}{400.500}$$

: 13.87 MPa < 15 MPa ... OK!

3) Laying stability requirements

$$\frac{V}{A_{efff}} \leq \frac{2.b.G.S}{3.t}$$

$$\frac{2773{,}97 \times 10^3}{390.490} \leq \frac{2.500.1{,}2.11{,}1}{3.89}$$

14.52 MPa < 49.89 MPa ... OK!

4) Requirements of laying detention

$H < 0.1$ ($V +$ 3 $Aeff$ x 10-3)

255.543 < 0.1 (2773.97 + 3 (390,490) x 10-3)

255.543 kN < 334.727 kN ... OK!

5) Minimum thickness requirement of steel plate

$$Ts > \frac{3.V.t_1}{A.fy}$$

$$4 \ > \frac{3.2773{,}97 \times 10^3.12}{500.400.260}$$

4 > 1.92 mm ... OK!

$Ts \geq 3$ mm

4 > 3 mm ... OK!

O. Methods of Implementing Girder Erection

In general, there are four stages in the method of implementing girder erection, namely:

1) Preparation
   a. Worksite preparation
   b. Procurement of girders
   c. Girder mobilization

d. Lowering girders from trailer trucks using cranes.

2) *Stressing*

This stage is the initial prestressing force application stage. Before the *jacking/stressing* process is carried out, the *strand* cable is cut as needed. Then the cable is manually inserted into the tendon sleeve (*duct*) according to the plan. Then at one end of the cable is installed a dead armature as a cable lock. On the other side of the cable is installed live armature. Upon completion, the rest of the cable is cut about 2-3 cm from the outer edge of the anchor.

3) *Grouting* and *Finishing*

The grouting process is carried out to fill the air cavity between the strand and duct and at the anchor hole with concrete mortar. This is done so that the tendon avoids corrosion, the bond between the tendon and concrete is stronger, and the stress that occurs can be evenly spread throughout the span.

Grouting is done with a machine that pumps concrete mortar through one side of the hole until the entire duct is fully filled. The anchor must also be covered with concrete mortar with a minimum thickness of 3 cm.

4) Erection Girder

This stage is the stage of transporting girder beams to the fulcrum location according to the plan. The erection process is done with one launcher. The girders are transported by boogie truck to the launcher location. Then the girder is placed on the crane on the launcher. After that, the prestressed girders began to be moved towards the fulcrum on the pillars and abutments of the bridge using a launcher.

5. CONCLUSION

Based on the results and discussion, the bridge design was obtained as follows:

The total length of the 70 m bridge is divided into two spans of 25 m each with a total width of 10 m. The main girder uses *Precast Concrete* I (PCI) Girder H210 with a span of 25 m Concrete. The main girder is planned as many as 4 pieces installed with a distance of 2.3 m. The backrest consists of two backrest pipes with galvanized steel pipe material Ø76.3 mm BJ-37, backrest posts with a steel profile H as high as 500 mm, and reinforced concrete backrest walls with a thickness of 25 cm as high as 500 mm. The floor slabs of vehicles and sidewalks use reinforced concrete with a thickness of 22 cm. The diaphragm uses reinforced concrete with a size of 30 x 128 cm. The main girder is prestressed concrete with *Pi*: 4500 kN and 38 *super grade 7-wire strands* spread in 4 tendons. The prestressing force loss that occurs is 13.43%. The total deflection that occurs is 2.7 mm ↓. The pedestal uses laminated elastomer from *Freyssinet* with a size of 400x500 as much as 5 layers. The continuous plate connection uses D22-60 main reinforcement and D22-120 reinforcement. The girder erection method uses the help of a *launcher tool.*

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