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PLANNING MODIFICATION OF STEEL ARCH BRIDGE ON CIMANUK BRIDGE TOMO DISTRICT SUMEDANG REGENCY CIREBON-BANDUNG HIGHWAY

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ABSTRACT

One of the businesses that supports transportation is the construction of Bridge infrastructure. In improving and supporting transportation facilities, the condition of the bridge must be in good condition. The Cimanuk Bridge which originally used the Steel Box Girder & Steel I Girder structure with a pillar in the middle of the span, the structure will be modified into An Arch Steel Bridge without pillars. Cimanuk Bridge is ± 100 m long, including a long-span bridge so that it can use An Arch Steel Bridge Structure. [1] SNI 1726:2019 about Seismic analysis for design It uses the equivalent static. Analysis method based on SNI 1729: 2020 about Specification for structural steel building. And SNI 1725:2016 about Loading for bridges. The methode of structural analysis performed using SAP2000 version 22 software. The structural calculation process includes the determination of the structural system, load analysis, structural modeling, internal force analysis, reinforcement calculation, and examination of structural element requirements. The result show main structure profile using Double WF 700x550x40x45, Longitudinal Girder WF 500x200x10x16, Transverse Girder WF 1200x500x20x28, Tie Beam BOX 1000x1000x50, Wind Bracing using Square/Box.

Keyword: *Arch Steel Bridge; Cimanuk Bridge; Steel Structure; SNI 1729:2019; SNI 1725:2016.*

1. INTRODUCTION

In the planning of the duplication of the Cimanuk Bridge, this bridge is planned with a total span of 96.95 meters with a width of 13.4 meters with 2 spans, namely span I of 71.15 meters using Steel Box Girder and span II of 25.8 meters using Steel I Girder, with a foundation structure using pile foundation. The structure will be modified into a Pillarless Arched Steel Bridge. This modification planning is motivated by three things, the Cimanuk Bridge has a length of ± 100 m including a long span bridge so that it can use the Arched Steel Bridge Structure, in addition, in the planning of the bridge duplication, 1 pillar was made between 2 bridge spans, the pillar will affect the cross-sectional area of the Cimanuk river so that in this planning the structure of the Cimanuk Bridge without pillars will be modified. The advantage of a steel arch structure bridge is that it can transfer the load received by the bridge vehicle floor to the abutment which keeps both sides of the bridge from moving sideways when holding the load due to its own weight and traffic load, each arch part receives compressive force so that the arch bridge must consist of material that is resistant to compressive force. By using the arch method, it is possible to bridge long spans without pillars, which will not interfere with river flow, thus reducing the risk of structural failure due to erosion of the lower layers of the pillars.

Using steel material because steel has high ductility properties. Steel bars that receive high tensile stress will experience quite large strains before collapse occurs. Steel material is a material that is strong against tensile forces and weak against compressive forces, but the compressive force that can be borne

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E-ISSN : 2621-3966

is very closely related to the slenderness of the Profile.

Based on the explanation above, this planning will produce a design plan for a curved steel bridge according to field conditions referring to SNI 1725: 2016, SNI 1726 : 2019 and SNI 1729 : 2020 planning the upper and lower structures of the curved steel frame bridge construction.

2. LITERATURE REVIEW

Arched steel bridges have a number of advantages in terms of load transfer and structural stability, but there are also some important aspects that need to be considered. One of the main advantages of this bridge is its ability to transfer loads from the bridge deck to the abutments, maintaining the lateral stability of both sides of the bridge while supporting the loads from its own weight and traffic [1]. In an arched bridge structure, each arch member is subjected to compressive forces, and this requires the use of materials with good compressive resistance[2] . In addition to vertical loads, arched steel bridges are designed to perform well under dynamic load conditions such as vibrations and earthquakes. The high strength and ductility of steel make it a good choice for areas with high seismic demands, where the bridge can function properly and remain safe.

Designing an arched steel bridge requires special attention to several important aspects to ensure the safety, performance, and efficiency of the structure. The following are some aspects that must be considered in designing an arched steel bridge:

1. Load and Structural Strength Analysis: A key aspect of bridge design is proper analysis of the loads to be carried, including dead loads (the weight of the structure itself) and live loads (traffic and environmental factors). The design must be able to distribute these loads efficiently, taking into account the compressive forces imposed by the arch and the limitations of the materials used. Appropriate engineering materials, such as the use of high-strength steel, must be applied to meet these load requirements. [3], [4]
2. Dynamics and Response to Vibration: Arched steel bridges are often exposed to changing load dynamics, including vibrations due to traffic and wind conditions. Therefore, dynamic analysis is important to study the behavior of the structure in overcoming vibration responses. This includes numerical simulations and field testing to evaluate the impact of vibrations and other factors that may affect the performance of the bridge during its operational life [5], [6]
3. Seismic Design: For bridges located in earthquake-prone areas, the implementation of appropriate seismic design must be considered. Seismic design will help ensure the stability of the bridge in resisting dynamic forces generated during an earthquake [7]. Good adapters, reinforcements, and lateral force control are key in designing bridges in earthquake-prone areas [8].
4. Environmental and Material Factors: The design must also take into account material properties, including resistance to corrosion and environmental influences. The use of materials suitable for the local climate can extend the life of the bridge, while protection techniques from environmental elements, such as anti-corrosion paint, can improve the durability of the structure [9], [10]
5. Design Flexibility and Connectivity: Bridge designs must accommodate potential future modifications, especially if there are changes in traffic demand or integration with surrounding infrastructure, this includes considerations for accessibility and safety of pedestrians and vehicular users [11].
6. Aesthetics and Integration with the Environment: In addition to technical aspects, bridges must be designed with aesthetic considerations to harmonize with the surrounding environment. Landmark bridges not only function as transportation structures but also enhance the visual value of the area [12],[13] .
7. Structural Health Monitoring (SHM): Implementation of a structural health monitoring system for periodic maintenance and evaluation of bridge conditions is essential. This can help detect damage or reduction in bearing capacity early on, so that necessary maintenance actions can be taken [8],[14].

Overall, the planning of an arched steel bridge involves a combination of technical analysis, appropriate

P-ISSN : 2598-1277
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material selection, aesthetic considerations, and a plan for seismic load control. Success in planning this bridge will ensure its function and safety during its long operational life.

3. RESEARCH METHOD

3.1. General Technical Data

- Bridge Type: Composite Steel Frame Bridge
- Bridge Length: 96.95Meter
- Bridge Width: 34.1 Meters
- Track Width: 13.4 m
- Girder: span 70m steel box girder; Span 25m Steel I Girder
- Foundation Type: Bored Pile
- Foundation depth: 21 Meters
- Foundation diameter: 1 Meter

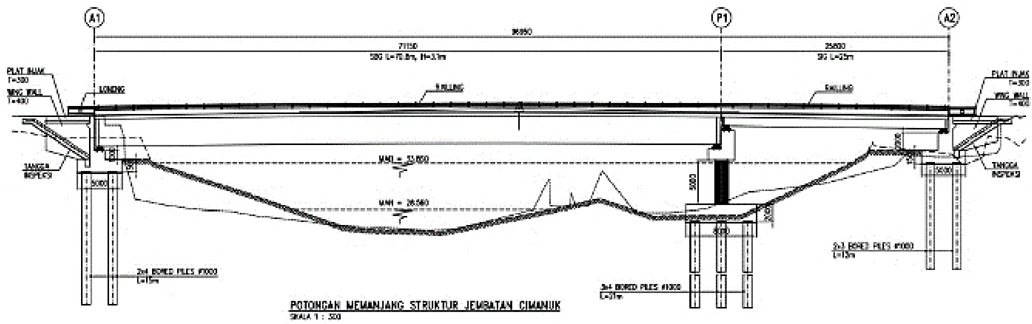

Figure 1. Cimanuk Bridge

3.2. Data Bridge Modification Plan

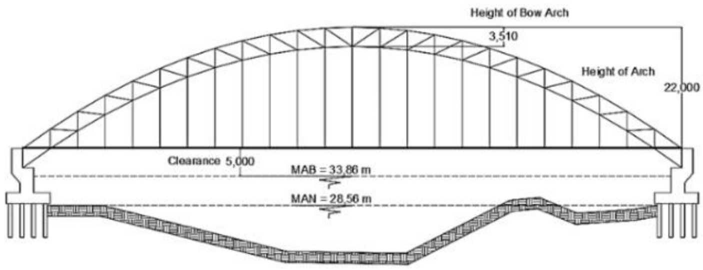

Figure 2 . Front View Modification Plan

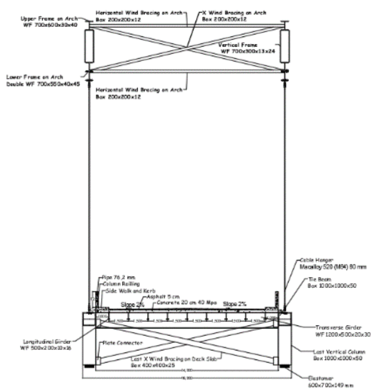

Figure 3. Cross Section Modification Bridge

 P-ISSN : 2598-1277
E-ISSN : 2621-3966

The planning stages of the arch bridge on the Cimanuk Bridge are data collection which includes That is the data obtained by directly reviewing the Cimanuk bridge construction project on the Cirebon-Bandung Highway, Tomo District, Sumedang Regency which is the object of research. The primary data needed for this study include: Field Technical Data such as bridge spans, pillar height, Cone Penetrometer Test and Soil Penetrometer Test. Working drawings for comparison materials from the initial design that the author will redesign to be research material. The next stage is the design layout for preliminary design calculations, after that calculating the upper structure of the bridge according to SNI 1725: 2016 and SNI 1729 : 2020 [15] [16] [17]and modeling the structure in SAP 2000. The planning of the lower structure is carried out after the analysis control of the SAP 2000 calculation of the strength and stability of the structure . The final stage of planning is drawing the results of the plan and calculating the budget plan.

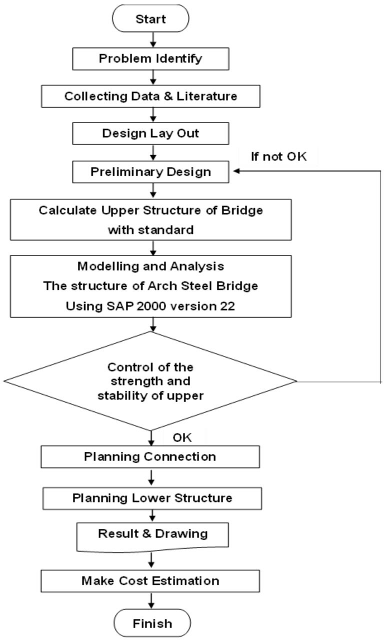

Figure 4 . Research Flow

3.3. Research Location

The location data of the Cimanuk Bridge is on the Cirebon-Bandung Highway, Tomo District, Sumedang Regency which crosses over the Cimanuk River.

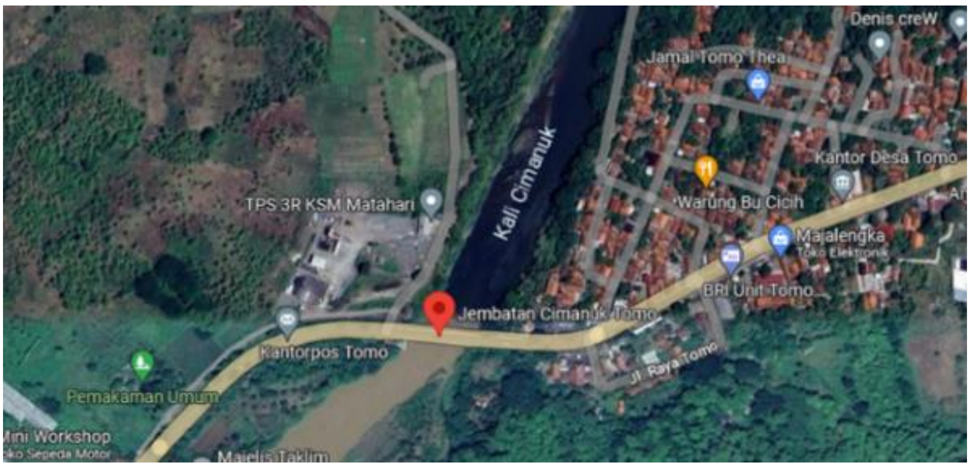

Figure 5. Research Location

P-ISSN : 2598-1277
E-ISSN : 2621-3966

4. RESULT AND DISCUSSION

4.1. Arch Geometry

High of arch = 22 m. The length = 120 m. Bow heigh t=3,51m. Width of bridge =14 m

4.2. Deck Slab and Railing Planning

Distance between Transverse girders 5 meter. Distance between Longitudinal girders (b1) = 1,5 meter. According to SNI 1725-2016 about thickness slab. Main reinforcement D16-150, Shrinkage reinforcement D10-200, Concrete 200 mm and Asphalt 50 mm.

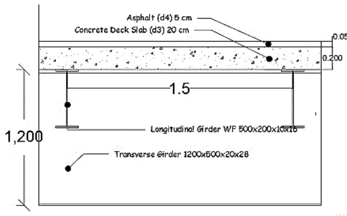

Figure 6 . Detail of Deck Slab

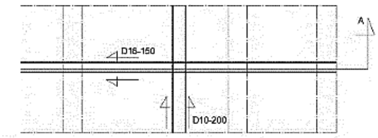

Figure 7. Deck Slab ReinLongitudinal section

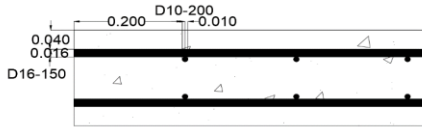

Figure 8. Cross Section Deck Slab

Ø pipe railing = 3 inch = 76,2 mm
Column Railing = 200x200x1200 mm
Ø Main Reinforcement Installed **3 Ø 12**
Shear Reinforcement: **Ø 10-150 mm**

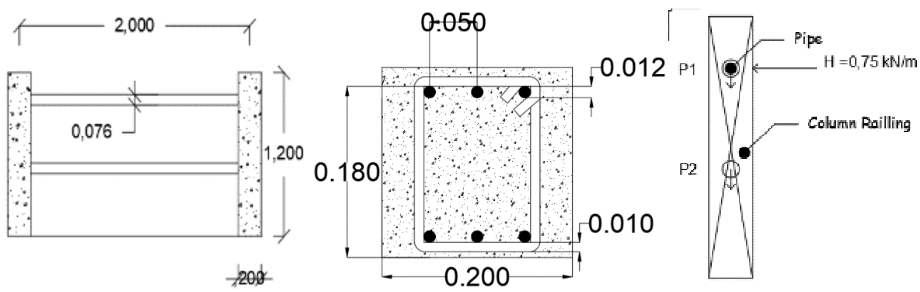

Figure 9. Detail of Railing

4.3. Sidewalk and Kerb

- **Kerb**

Main reinforcement used **d12-150**
Shrinkage rein: **d8-150** fc'= 35 Mpa

- **Sidewalk**

Main reinforcement used d12-15
So, used reinforcement d10-250 fc'= 35 Mpa

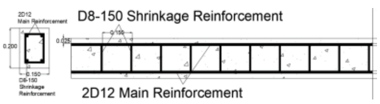

Figure 10. Longitudinal Section Kerb Reinforcement

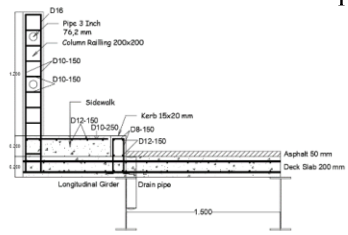

Figure 11. Cross Section Kerb

4.4. Main Structure

- **Longitudinal and transverse girder**

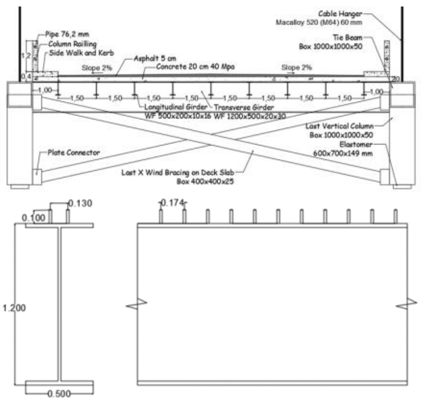

Figure 12. Cross Section Girder

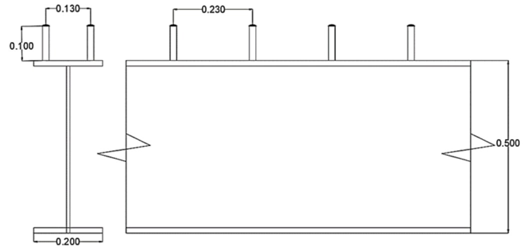

Figure 13. Longitudinal girder & Transverse Girder

Planning longitudinal girder use steel profile **WF 500x200x10x16 BJ50**
The Shear Connector installed in 2 rows there are 213 pcs. The distance is 230 mm
Planning Transverse Girder using steel profile **WF 1200x500x20x30 BJ50**
The Shear Connector is installed in 2 rows there are 86 pcs. The distance is 174 mm

- **Recapitulation of Analysis Main Structure**

Tabel 1. Recapitulation of Analysis Main Structure

No	Frame	Pu		ØPn		Pu	ØPn
		Tensile (Kg)	Compressive (Kg)	Tensile (Kg)	Compressive (Kg)	Control	Control
1	Tie Beam	15105347	-22838571	66618750	69104077,7	OK	OK
2	Last vertical column	2260993,89	-1437871,04	66618750	7011000,0	OK	OK
3	Vertical Frame S2& 3	352800,3	-535665,3	648656,3	540635,6	OK	OK
4	Diagonal Frame S2	323437,3	-197426,2	648656,3	379897,7	OK	OK
5	Diagonal Frame S3	197963,8	-114016,9	648656,3	418493,4	OK	OK
6	Upper Frame S1	377510,49	-235839,75	2804702,0	2267397,5	OK	OK
7	Upper Frame S2	1154516,3	-726746,8	2804702,0	2405657,4	OK	OK
8	Lower Frame	255662,4	-2020557,7	2804702,0	2267397,5	OK	OK
9	Upper Frame S3	193191,4	-505533,9	1833102,6	1744527,9	OK	OK
10	Diagonal Frame S1	499869,6	-338192,3	1833102,6	1738736,0	OK	OK
11	Vertical Frame S 1	352800,3	-535665,3	1833102,6	1835928,3	OK	OK

Source: Result Analysis

- **Recapitulation of Analysis Secondary Structure**

Tabel 2. Recapitulation of Analysis Secondary Structure

No	Frame	Pu		ØPn		Pu	ØPn
		Tensile (Kg)	Compressive (Kg)	Tensile (Kg)	Compressive (Kg)	Control	Control
1	Bracing on Deck Slab	250516,60	-205255,70	1246248,75	525951,19	OK	OK
2	Last X Wind Bracing on Deck Slab	206336,40	-310499,70	1246248,75	560430,82	OK	OK
3	X Wind Bracing on Arch Frame	7168,00	-8601,60	311670,24	36368,35	OK	OK
4	Wind Bracing on Arch Frame	31539,20	-28672,00	312081,75	139867,44	OK	OK
5	Horizontal Wind Bracing on Arch Frame	20070,40	-20070,40	311670,24	38833,32	OK	OK
6	Last Vertical Portal Column on Bridge	553204,50	-162164,20	1252732,13	1081806,97	OK	OK
7	Last Horizontal Portal	490590,00	-118100,00	1297539,45	758889,90	OK	OK
8	Cable Hanger	158529,99		172700,00		OK	

Source: Result Analysis

P-ISSN : 2598-1277
E-ISSN : 2621-3966

4.5. Cable Hanger

The hanging cable used is Macalloy 520 (M64) type, Carbon steel with a diameter of 60 mm.

4.6. Main Structure Connection

- **Longitudinal to Transverse Girder**

Type Bolt : A325 M16
The distance between bolts 60 mm
The distance bolt to joint edge 60 mm

Connector L-Plate : 90x90x7
Length L-Plate : 300 mm

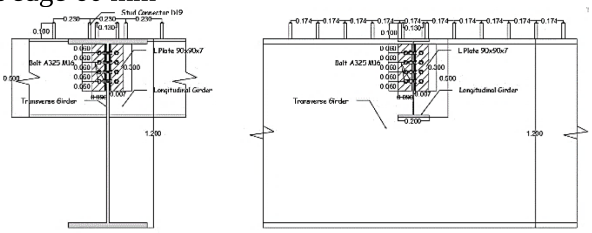

Figure 14. Detail Bolt Connection Longitudinal to Transverse Girder

- **Transverse Girder to Tie Beam**

Type Bolt : A325 M30
The distance between bolts 100mm
The distance bolt to joint edge 80 mm

Connector L-Plate :150x150x20
Length L-Plate : 560 mm

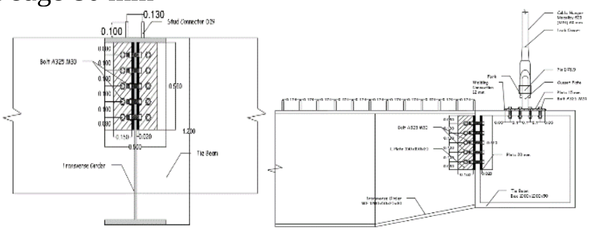

Figure 15. Detail Bolt Connection Transverse Girder to Tie Beam

- **Connection bolts tie beam to tie beam**

Type Bolt : A325 M36
The distance between bolts 150mm
The distancebolt to joint edge 100mm
Connector Plate: 60 mm

Height Plate : 800 mm
Length Plate : 1600 mm

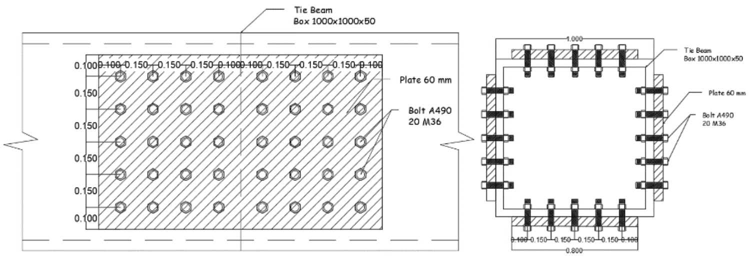

Figure 16. Connection bolts tie beam to tie beam

- **Cable Hanger to Tie Beam**

Gusset Thickness :153 Mpa
Plate Thickness : 30
Ø pin : 78,5
Type Bolt : A325 M24
The distance between bolts : 100mm

The distance bolt to joint edge 50 mm
Connector Plate: 15 mm
Height Plate : 400 mm
Length Plate : 600 mm

 P-ISSN : 2598-1277
E-ISSN : 2621-3966

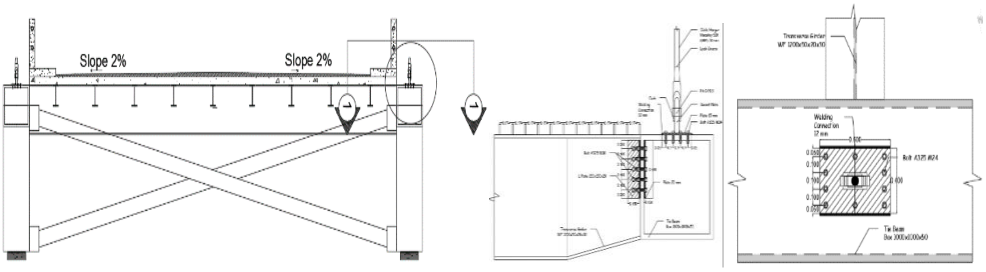

Figure 18. Detail Connection bolts cable hanger to tie beam

- **Lower Frame, Diagonal Frame, Vertical Frame Segment 3**

Type Bolt : A490 M36
The distance between bolts 110mm
The distance Bolt to joint edge 75 mm
Connector Plate: 15 mm

Figure 19. Detail Connection bolts Lower Frame, Diagonal Frame, Vertical Frame S3

4.7. Bracing Connections

- **Wind Bracing on Arch to Horizontal Bracing on Arch**

Type Bolt : A490 M30
The distance between bolts 100 mm
Distance bolt to joint edge 100 mm
Connector L-Plate: 200x200x20 mm
Type Plate : 50 mm

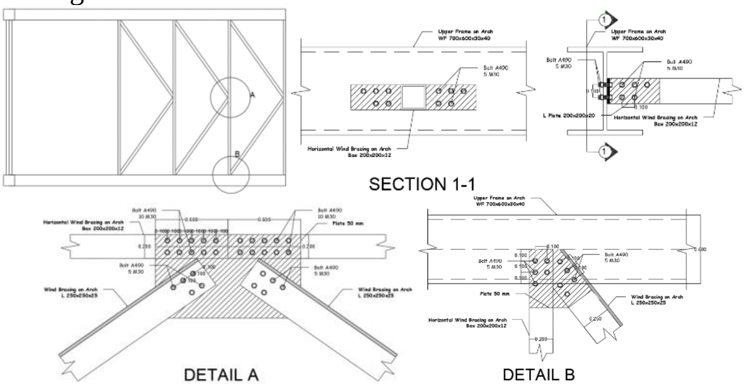

Figure 20. Detail Connection Bolts Wind Bracing on arch to Horizontal Bracing on Arch

- **X Deck Slab Bracing**

Type Bolt : A490 M36
The distance between bolts 120 mm
The distance bolt to joint edge 60 mm
Connector L-Plate :200x200x25 mm
Connector Plate : 50 mm

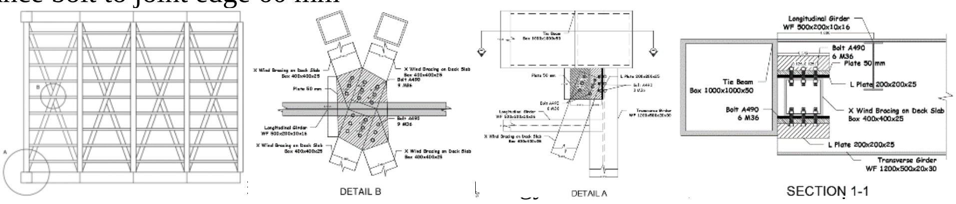

Figure 21. Connection Bolts X Deck Slab Bracing

P-ISSN : 2598-1277
E-ISSN : 2621-3966

- **Wind Bracing on Arch**

Type Bolt : A490 M24
The distance between bolts 100 mm
The distance bolt to joint edge 50 mm
Connector Plate: 20 mm

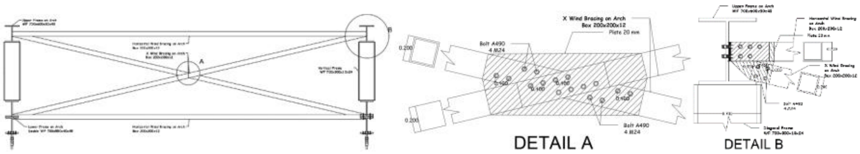

Figure 22. Connection BOLTS X Wind Bracing on Arch

- **X Last Bracing on Deck Slab**

Type Bolt : A490 M36
The distance between bolts 120 mm
The distance bolt to joint edge 60 mm
Connector Plate: 50 mm
Connector L-Plate :250x250x25 mm

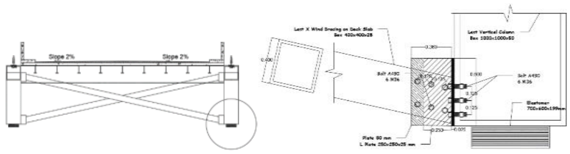

Figure 23 Connection BOLTS X Wind Bracing on Arch

- **Recapitulation of Analysis Main Structure Connection**

Tabel 3. Recapitulation of Analysis Main Structure Connection

Frame	**Vu**	**ØVn**	**Check**
Longitudinal Girder to Transverse Girder	22943,6	495495	OK
Transverse Girder to Longitudinal Girder	22943,6	38461,5	OK
Transverse Girder to Tie Beam	47024,2	202950	OK
Tie Beam-Tie Beam	1463871,5	1841400	OK
Cable Hanger	158529,99	235971,08	OK
BB, BD, BV	1931914	1106859600	OK

- **Recapitulation of analysis Secondary Structure Connection**

Tabel 4. Recapitulation of analysis Secondary Structure Connection

	Vu	**ØVn**	**Check**
Wind Bracing on arch to horizontal bracing on arch	126157	168750	OK
Wind Bracing on arch to horizontal bracing on arch	126157	168750	OK
X Deck Slab Bracing to Transverse girder	213911	222750	OK
X Deck Slab Bracing to Tie beam	213911	222750	OK
X Arch Bracing	53635	102960	OK
X Last Bracing on Deck Slab	445766	539550	OK

Elastomer

Laying length (a) = 600 mm
Laying width (b) = 700 mm
Elastomer layer thick (te) =16 mm
Thick rubber inner layer (t1) = 11 mm
Thick steel plates (ts) = 5 mm
Number of steel plates (n) = 10 layer
Top cover thickness (tc) = 25 mm
Side cover thickness (tsc) = 10 mm
Area of rubber(Ar) = 394400 mm2

 P-ISSN : 2598-1277
E-ISSN : 2621-3966

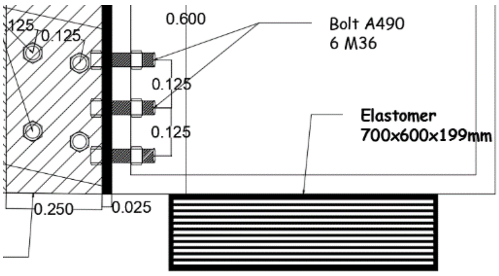

Figure 24. Detail of Elastomer Bearing Pad

5. CONCLUSION

From the various controls and calculations that have been carried out, conclusions that can be drawn from planning this final project include:

1. The cross section of the bridge consists of 12 meters of vehicle floor and 2 x 1 meter as a sidewalk. The number of vehicle lanes is 2 lanes 1 way (2/1 UD). The arc focal height is 22 meters.
2. The planning of the vehicle floor slab is a 40 MPa concrete slab with a thickness of 20 cm and covered with asphalt with a thickness of 5 cm.
3. The results of planning girders and wind ties are as follows:
   - Longitudinal Girder : WF 500x200x10x16
   - Transverse Girder : WF 1200x500x20x28
   - Tie Beam : BOX 1000x1000x50
   - X Wind Bracing Deck Slab : BOX 400x400x25
   - Last X Wind Bracing on Deck Slab : BOX 400x400x25
   - Wind Bracing on Arch : L 250x250x25
   - X Wind Bracing on Arch : BOX 400x400x25
   - Horizontal Wind Bracing on Arch : BOX 200x200x12
   - Last Horizontal Portal : BOX 500x500x25
   - Last Vertical Portal : BOX 500x500x19
   - Last Vertical Column : BOX 1000x1000x50
4. The hanging cable used is Macalloy 520 (M64) type, Carbon steel with a diameter of 60 mm and Minimum Break Load is 1727 Kn.
5. The results of planning the main frame profile are as follows:

   Segment I
   Upper Arch Frame : Double WF 700x550x40x45
   Diagonal Frame : WF 700x600x30x40
   Vertical Frame : WF 700x600x30x40
   Lower Arch Frame : Double WF 700x550x40x45

   Segment II
   Upper Arch Frame : Double WF 700x550x40x45
   Diagonal Frame : WF 700x300x13x24
   Vertical Frame : WF 700x300x13x24
   Lower Arch Frame : Double WF 700x550x40x45

   Segment III
   Upper Arch Frame :WF 700x600x30x40
   Diagonal Frame : WF 700x300x13x24
   Vertical Frame : WF 700x300x13x24
   Lower Arch Frame : Double WF 700x550x40x45
6. The placement used is a product of freyssinet with a specification of 600x700 mm thickness 149 mm

P-ISSN : 2598-1277
E-ISSN : 2621-3966

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1. Due to the possibility of the changes of the soil data, then it is necessary to keep checking the updates of soil data test. The results will according on the real field condition, which means the final result will be dynamical depend on the last soil test data.
2. In arc bridge design calculation it is recommended to use MIDAS CIVIL or CSI Bridge software rather than SAP2000. Because in MIDAS CIVIL or CSI Bridge software it is more specific in calculating bridges so that the results are found better.

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