Design of The Prestressed Concrete Bridge Structure on The Leuwigajah Bridge

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ABSTRACT
The increasing volume of vehicles that passing on Mahar Martanegara Street has caused traffic jams at the Leuwigajah Bridge, Cimahi. Because it is not balanced with adequate road conditions and bridge characteristics (bottleneck). The solution from the West Java Provincial Government to overcome this problem is by building a new bridge adjacent to the existing bridge at the Purbaleunyi Toll Road crossing. The first steps of bridge design by mapping the existing bridge first using Infraworks software to produce a 3D visualization of the existing bridge. Then the design of the bridge structure using a prestressed concrete type PCI-Girder beam with a simple beam system. The results of the bridge structure design were visualized by 3D modeling in the existing conditions. The data used for the bridge design is the result of a location survey and technical data for the existing bridge which is used as a reference and comparison. The load and structure calculations on the bridge refer to SNI 1725: 2016 and RSNI T-12-2004 using Midas Civil software. The output is technical data of each structural component such as dimensions and reinforcement used, the type of prestressed beam used is PCI-Girder H210, the number of tendons, and the number of strands on the PCI-Girder, also 3D modeling at the Leuwigajah Bridge, Cimahi as visualization 3D of the bridge.

Keywords: *BIM, 3D modeling, prestressed concrete, bridge, structure*

1. INTRODUCTION

The traffic jam that often occurs on Mahar Martanegara Road in Cimahi City is due to the increasing number of people and the volume of vehicles every day. This condition is not compatible with adequate roads and because many logistical vehicles that violate traffic rules to cross the bridge at certain hours. The existing bridge which has limited capacity and the characteristics of the bridge is a bottleneck is one of the factors that cause the traffic jam, so there is often a long queue of vehicles on the bridge. Also, there is a fountain garden at the roundabout which is a new cause of the increased intensity of traffic jams on the road, that is because many people stop seeing the objects. The traffic jam at the Leuwigajah roundabout to Nanjung Road is very difficult to eliminate, especially during rush hour. Therefore in 2020, the solution from the government of West Java is to restore the function of the road as a provincial road on Mahar Martanegara Road by building a new bridge at the intersection of the freeway in Leuwigajah, Cimahi. Leuwigajah Bridge construction planning will be held in 2020 by the Office of Highways in West Java Province and will only conduct a tender process.

In general, a bridge is a construction that functions to connect two parts of a road that is divide by obstacles such as river flows, lakes, deep valleys, irrigation channels, railroads, and the road that not cross at the same level. Based on its materials, the bridge can be classified as a wood bridge, steel bridge, masonry bridge, bamboo bridge.

Reinforce concrete bridge and pre-stressed concrete bridge. The pre-stressed concrete bridge is one type of bridge with concrete containing steel cables material to providing initial stress to the concrete due to the character of the concrete which is unable to hold tensile forces. The materials used for this system are concrete and steel cable systems. The system consists of cables (wire, strand, bar), sleeves, and anchors (live anchors, dead anchors) [1]. There are two types of pre-stressing systems in pre-stressed concrete that is the pre-tension system and post-tension system. In the post-tensioning method, the tendons are pulled after the concrete has been cast. Before casting, a sleeve attached to the groove of the tendon. After the concrete is finished, the tendons are inserted into the concrete through the pipe tendons that were previously installed during casting [2]. Implementation of Building Information Modeling (BIM) in bridge design is to visualize the construction before it becomes a physical construction. BIM is not just software—rather, it is a process and software. Taking that one step further, we now see that successful BIM use requires three key factors: processes, technologies, and behaviors [3]. The use of 3D modeling aims to be more efficient because it does not obstruct traffic above and below the bridge and aims as a benchmark in the dimensional planning and layout of the bridge.

1.1 Calculations Of The Bridge

Loading and its combination used in bridge design based on SNI 1725-2016 Loading on Bridges [4]. The main reinforcement is calculated based on the distance from the outer compressive fibers to the center of gravity of the tensile reinforcement and to the compressive reinforcement which is determined by $d = h - p - \frac{1}{2}\, D_{re} - \emptyset_{shear\ re}$ and $d' = p + \frac{1}{2}\, D_{re} + \emptyset_{shear\ re}$. That h is the effective height and p is the width of the concrete cover. The reinforcement ratio is checked corresponding to $(\rho_{min} < \rho < \rho_{max})$ that minimum reinforcement ratio is determined by $\rho_{min} = \frac{\sqrt{fc'}}{4f_y}$ or $\rho_{min} = \frac{1,4}{f_y}$, maximum reinforcement ratio $\rho_{max} = 0,75 \times \frac{0,85 \times \beta_1 \times f_c' \times d}{f_y} \left(\frac{600}{600+f_y}\right) + \rho' \frac{fs'}{f_y}$ and $\rho - \rho' = (0,5 - 0,75)\rho_b$ for reinforcement ratio. Which fc' is the value of the compressive strength of the concrete (MPa), fy is the stress on the reinforcement which is calculated at the workload (MPa), β_1 is the compressive strength factor of the concrete, ρ is the ratio of the tensile stress of the reinforcement, ρ' is the ratio of the compressive reinforcement to the cross-sectional area concrete, and ρ_b is the ratio of reinforcement which provides a balanced stress condition. The area of compressive and pull reinforcement (As') and (As) can be defined as $M_u = \varphi\,[(A_s - A_s')\, f_y \left(d - \frac{a}{2}\right) + A_s'.f_y.(d - d')]$ and $A_s - A_s' = (\rho - \rho') \times b \times d$ concrete. For the pre-stressed concreate beam the area of reinforcement is defined as $A_s = 0.4\% \times \text{sectional area}$ [5].

Calculation due to bending shear is determined by the condition ϕVn ≥ Vu with the value of Vn is $V_n = V_c + V_s$, shear strength contributed by concrete (Vc) is $Vc = \frac{1}{6}\sqrt{f_c'} \times b \times d$ and controlled to sectional area of concrete component, and shear reinforcement needed corresponding to $Vu < \varphi\left(Vc + \frac{2}{3}\sqrt{f_c'} \times b \times d\right)$ and $Vu > \frac{1}{2}\,\varphi.Vc$ shear reinforcement is calculated by $Vs = \frac{Vu}{\varphi} - Vc$ and $Vs = \frac{Av \times f_y \times d}{s}$ formula, That φ is the reduction factor (0.7), Vs is shear strength of reinforcement beam, Vc is concrete shear strenght, and Av for shear reinforcement area. If the shear failure can occur locally (punch shear) around a support or centered load, the shear design strength shall be taken as φ Vn, where Vn is calculated according to $V_{no} = u.d\,(f_{cv} + 0{,}3.f_{pc})$ if the component does not have a shear head or $V_{no} = u.d\left(0{,}5.\sqrt{f_c'} + 0{,}3.f_{pc}\right) \leq 0{,}2\; u.d.f_c'$ if the component has a shear head. Which that fcv = $\frac{1}{6}\left(1 + \frac{2}{\beta_h}\right)\sqrt{f_c'} \leq 0{,}34\sqrt{f_c'}$, Mv is for the bending moment of the plan transferred from the concrete slab to the pedestal in the direction under review, β_h is for comparison between the longest dimension of the weighted effective area (Y) with the dimension X which is measured perpendicular to Y, and the effective length of the critical shear circumference (u). In diaphragm planning, it is necessary to check the high flexible structural components (high beams). Based on SNI 2847-2019 concerning Structural Requirements for Buildings, the provisions of high beams can be seen in the following equation $l_n \leq 4h$, with the information ln is the net span of the diaphragm and h is the diaphragm height. High beam shear strength (Vn) is defined using the equation of $V_s = \left[\frac{A_v}{s}\left(\frac{1+\frac{l_n}{d}}{12}\right) + \frac{A_{vh}}{s_2}\left(\frac{11-\frac{l_n}{d}}{12}\right)\right] f_y \text{ x } d$, where Av is the area of the shear reinforcement perpendicular to the tensile reinforcement for the spans distance s (mm^2), Av > 0,0025 x b x s_1 and Avh is the area of parallel shear reinforcement with tensile bending reinforcement in the distance s_2 (mm^2), Avh > 0,0025 x b x s_2.

For the pre-stressed concrete beam the longitudinal effect of stress inhibits the formation of shear damage. The vertical component of stress (Vp), concrete shear, concrete shear reinforcement, and shear reinforcement (Vcs) that withstand the shear force due to external loads V. To find the value V, the equation is V = V_{cs} + V_p. The distribution of shear stress τv on the concrete section is stated in the equation $\tau_v = \frac{V_{cs} \times Q}{I \times b}$ which I for the sectional Inertia. Shear stress in pre-stressed concrete consists of direct stress in the horizontal direction (fx) and in the vertical direction (fy). The value of the principal stress ft in relation to τv and fc in pre-stressed concrete is $f_t = \sqrt{\tau_v + (0{,}5f_c)^2 - (f_c)}$. The moment of cracking actually states the shear due to the load that works when the bending crack occurs with the stirrup distance (s), and it defined as $S = \frac{A_v f_y 3}{b_w}$. The concrete web shear strength is defined as $V_{cw} = V_c + V_p$ and $V_{cw} = b_w d\left(0{,}3\sqrt{f_c'} + 0{,}3f_c\right) + V_p$. From the two equations, the smallest value is taken. Shear strength contributed by shear reinforcement (Vs) is $V_s = \frac{V_u}{\varphi} - V_{cw}$ and the area of stirrup reinforcement (Av) is $A_v = \frac{75\sqrt{f'_c}\, b_w s}{1200 \times f_y}$. In torsional design, the factored torsional moment must be less than the torsional resistance of a prestressed concrete multiplied by the strength reduction factor (Tu ≤ ϕTn). Which the nominal torsional strength of the cross-section of the structural components is Tn =

Tc + Ts, Which Tc is concrete nominal torsional strength and Ts is nominal torsional strength contributed by torsional reinforcement. Torsional reinforcement is doesn't needed if $\frac{T_u}{\emptyset T_c} < 0,25$. If this equation is not correct, then the torsion reinforcement consisting of a closed section and a longitudinal reinforcement must be installed so that the following inequality $\frac{T_u}{\emptyset T_n} + \frac{V_u}{\emptyset V_n} \leq 1$ is correct. Concrete component minimum torsional strength (Tc) is defined as $T_c = 0{,}4\,\Sigma x^2 y\left(0{,}3\sqrt{f_c'}\right)\sqrt{1 + \frac{10 f_{pe}}{f_c'}}$ which fpe is compressive stress in concrete due to effective prestressing forces. The nominal torsional strength of the torsional reinforcement is determined by $T_s = f_y\left(\frac{A_{sw}}{s}\right) 2\, A_{ct}\, cot\theta_t$ which Asw is the area of reinforcement forming closed stirrups and Act is the concrete cross-sectional area. Minimum torsion reinforcement and longitudinal torsional reinforcement must meet the following conditions as $\frac{A_{sw}}{s} \geq 0{,}2\frac{y_1}{f_{y,t}}$ and $A_s \geq 0{,}2\frac{y_1\, u_t}{f_y}$ which y_1 is the biggest dimension for shear reinforcement and u_t is the perimeter of the polygon with its apex at the center of the longitudinal reinforcement.

The stability control of the abutment is calculated against rolling and sliding. Rolling control can be defined as $\frac{\Sigma M_V}{\Sigma M_H} > 1{,}5$ which Mv is moment resistance (kNm) and Mh is the rolling moment (kNm). The sliding control according to requirements of $\frac{\Sigma V\, x \tan\theta}{\Sigma H} > 1{,}1$. After stability control, there are two alternatives. First, construction is safe for stability, the dimensions of the abutment according to requirements and can be used. The construction is not safe for stability, it is necessary to change the dimensions of the abutment or replacing it with a deep foundation, to support to be safe against rolling, sliding, and bearing capacity.

1.1.1. Pre-stressed Beam Design

The initial pre-stress force (Pt) is determined by taking the smallest value between the following two equations $\frac{Pt}{A} + \frac{Pt\, x\, es}{Wa} - \frac{M}{Wa} = 0$ and $\frac{Pt}{A} + \frac{Pt\, x\, es}{Wb} - \frac{M}{Wb} = -0.6\, f'ci$ with M according to maximum beam moment and es is a tendon eccentricity. For the pre-stress force at jacking stage is determined by $Pj = \frac{Pt}{0.85}$ and $Pj = 0.8\, x\, Pb1\, x\, nt$, from that equation the specify of number tendon can be defined in $nt = \frac{t}{0.85\, x\, 0.8\, x\, Pb1}$ and number of strand in $ns = \frac{Pt}{0.85\, x\, 0.8\, x\, Pbs}$ by percentage of yield stress in $po = \frac{Pt}{0.85\, x\, ns\, x\, Pbs}\, x\, 100\%$, so that the prestress force that occurs due to jacking is $Pj = po\, x\, ns\, x\, Pbs$, which Pbs is a minimum breaking load of one strand and Pb1 is one tendon breaking load.

The trajectory of the tendon core in the pre-stress beam section is viewed every one meter. The calculation of the trajectory of the center tendon is based on the following equation $Y = 4\, x\, es\, x\, \frac{X}{L^2}\, x\, (L - X)$ with X is the support distance to the center length of beam and L is the length of pre-stress beam. Tendon layout can be defined using the equation of $Zi = Zi' - \left(4 \times xi \times \frac{X}{L^2} \times (L - X)\right)$ That Zi is the position of each tendon review, Zi' position of each tendon review on the span support, xi the difference between zi - zi'. The effective width of the concrete slab is taken from the smallest value of L / 5, 12 x ts, and the distance between longitudinal girder (s). The resistance moment on the beam can be determined by $W_a = \frac{I_x}{y_a}$ for upper side and $W_b = \frac{I_x}{y_b}$. Whereas in a composite beam, the moment of resistance is determined by $W_{ac} = \frac{I_c}{y_{ac}}$ for upper side of the beam slab, $W_{ac}' = \frac{I_c}{(y_{ac} - ts)}$ for the upper side of the composite beam, and $W_{bc} = \frac{I_c}{y_{bc}}$ for the lower side of the composite beam. That Ya and Yb is the center of gravity from the upper and lower of the cross-section, Yac and Ybc is the center gravity of composite beam from the upper and lower of the cross-section.

Allowable stress transfer pressure and stress services pressure can be defined as $\sigma_{ct} = 0{,}60 \times fci'$ and $\sigma_{cs} = 0{,}45 \times fc'$ that $fci' = 0{,}80 \times fc'$, tendon eccentricity calculated using the equation of $e_s = y_b - 125$. Upper fiber tension and lower fiber tension is defined as $f_a = -\frac{P_e}{A} + \frac{P_e \cdot e}{W_t} - \frac{M_{total}}{W_t}$ and $f_b = -\frac{P_e}{A} - \frac{P_e \cdot e}{W_b} + \frac{M_{total}}{W_b}$. The number of strands calculated based on UTS (*Ultimate Tensile Strength*) using the equation of $n_s = \frac{P_i}{80\%\, UTS}$. The pre-stress force will decrease during transfer (short term) or during service (long term). This reduction in pre-stress forces is caused by the anchor of the seat during the delivery of the force (slip) $ANC = \Delta fs = \frac{\Delta a}{L}\, .Es$, tendon friction effect of flection at the post-tensioning phase $FR = Pj\,(1 - e^{-\mu\alpha - KLx})$, shortening of concrete elasticity $ES = \frac{n \times P_{j(n)}}{Ac}$, concrete shrinkage $SH = \varepsilon_{SH} \times K_{sh} \times Es$ and tendon relaxation $RE = C[Kre - J(ES + SH + CR)]$.

Shear connector is a sliding connection between the floor plate and the girder beam and calculated according to horizontal shear tension due to force as $f_v = \frac{V_i \times S_x}{(b_v \times I_{xc})}$ which Vi for the force at the reviewable section, sx is the static moment of the area of the plate to the center of gravity of the composite section. The total area of the shear connector is defined by $A_{st} = n_x \times A_s$ which is ns is the number of the shear connector, and As is the Area of a unit of shear connector. A static moment of the cross-sectional area to the point of the composite section calculated by $S_x = b_{eff} \times h_o \times (y_{ac} - \frac{h_o}{2})$ which beff is the effective width of the slab, ho is slab thickness and Yac is the center gravity of the beam.

1.2. Related Works

This related work section presents an overview of the design and analysis of bridge with applying technology BIM for 3D Modeling. These days, the application of technology BIM in performing design and analysis of the bridge is effective and efficient as it can facilitate the work but requires you to understand and apply BIM role in the design and analysis of bridges.

Landge et al [6] describe the design and analysis of the I-girder bridge using STAAD- Pro software. The element structures 3D modeling is done in STAAD Pro with live load and dead load applied and the final stresses, deflection, etc.

Simey [7] provides an overview of bridge construction using 3D building information models during the implementation of the Röforsbron bridge project and how 3D modeling can be applied as planned into future bridge project implementation. To expedite and facilitate implementation, 2D images can be extracted directly from the model by all actors, so no need to manually create 2D sections.

Nazir and Malhotra [8] describe the pre-stressed girder element design based on the Morice-Little method using the IRC specification. In the Morice little method, the effective width is divided into eight segments and nine boundaries. The loading and deflection of these nine boundaries are calculated and the deflections are related to the mean deflection. This girder design using CSiBridge software which focuses on bridge analysis and can be developed on SAP 2000 software. This software allows the use of analytical techniques in a step-by-step process.

1.3. Our Contribution

This paper presents about the design of bridge structures based on previous research with exploring further the implementation of the technology BIM for 3D modeling. Meanwhile, several previous research focused on the analysis of bridge structure calculations using the software. Furthermore, in this paper the design of the pre-stressed concrete bridge structure on the Leuwigajah Bridge, Cimahi refers to the SNI-1725-2016 regulation as a reference standard for loading that works on bridge structures and RSNI T-12-2004 concerning Concrete Structural Planning for Bridges as a reference standard for calculating bridge structures. The implementation of BIM for 3D modeling on Leuwigajah bridge planning is used to streamline the data collection process and analysis of the bridge structure. The location of the existing bridge located at the crossroads of Toll Purbaleunyi cause topography measurement and investigation of the bridge with 3D modeling methods needed.

1.4. Paper Structure

The rest of the paper is organized as follows. Section 2 introduces the research method including the process undertaken, the results and discussion of bridge design. Finally, section 3 concludes the paper about the design and analysis of Leuwigajah Bridge by applying 3D modeling.

2. BACKGROUND

The goal of this research is to design and analyze pre-stressed concrete bridge on Leuwigajah Bridge by applying Building Information Modeling (BIM) in the research process. The steps of this research are shown in Figure 1. The location of the bridge is in the Nanjung Village, Nanjung / Leuwigajah District or on STA 127+788 Padalarang-Cileunyi Toll Road. The object of the case study is the Leuwigajah Bridge, which is planned to be built beside the existing Leuwigajah Bridge. This research will be planned for the overpass bridge with the design of a pre-stressed concrete bridge using PCI-Girder with a bridge span of 47 m and a width of 10 m.

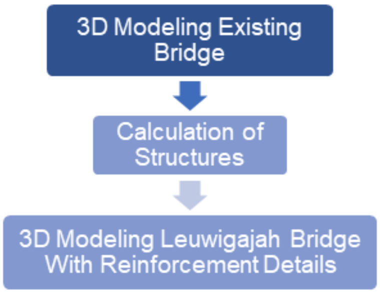

Figure 1 Steps of Leuwigajah Bridge Design

2.1. 3D Modeling in Infraworks Software

The location of the bridge at the overpass Purbaleunyi toll road causes the need for topographic measurements and bridge investigations using 3D modeling methods. Autodesk Infraworks software as a reference to design the dimensions and position of bridge structures and reduce collisions with existing bridges and other projects around the bridge. In modeling the bridge in Infraworks software, there are several steps as follows:

a. The use of satellite imagery in Infraworks software can be taken from the model builder by looking for the name of the area or region that will be used. Then, determined a satellite image capture area with a maximum area of 200 km^2.
b. After the satellite image is taken, digitizing the road alignment refers to the alignment of the road from the satellite image.

c. Placement and modeling of the existing bridge structure on the road alignment that crosses the Purbaleunyi toll road according to the required clearance length and height. Then get the dimension approach of the existing bridge as shown in Figure 2.

From the modeling results obtained several parameters that become references as secondary data in the design of the Leuwigajah Bridge. The data obtained are as follows:

a. Height of the Bridge : 724.654 m

b. Bridge Length : 47 m

c. Bridge Clearance : 5.2 m

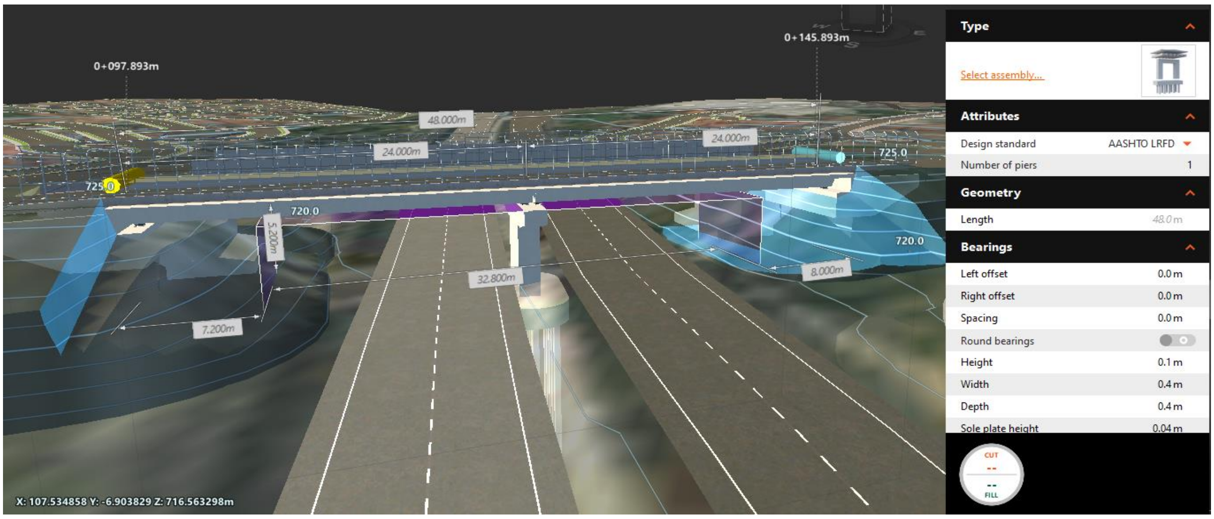

Figure 2 Existing Bridge Dimension Approach

2.2. Design of Structures

The calculation of bridge elements includes parapets, concrete slabs, girders, diaphragms, and abutments. The parapet dimensions used are based on SEM PUPR 07/SE/M/2015 about Guidelines for General Requirements for Bridge Planning [9]. Loading on the parapet consists of horizontal load and wind load. So that the ultimate moment is 96 kNm and the ultimate force is 80 kN. The calculation of parapet reinforcement is based on the design of doubly-reinforced beam and shear reinforcement with concrete compressive strength (fc') 25 MPa, tensile strength (fy) 350 MPa, the dimension of main reinforcement is D19-100, and the divided reinforcement used in the parapet is D13-250.

The type of concrete slab that works is a one-way slab with slab thickness is 200 mm, concrete compressive strength (fc') of 30 MPa and tensile strength (fy) of 350 MPa. Loading on the concrete slab is calculated using Midas Civil software using load combination based on SNI 1725:2016 and the ultimate moment diagram can be seen in Figure 3. Midas Civil software helps to analyze a bridge planning design and provides optimal and accurate analysis results. The calculation of concrete slab reinforcement is based on the design of doubly-reinforced beam and shear reinforcement. From the calculation of the number of reinforcement used in one layer every one meter of concrete slabs using 7 pieces with the main reinforcement diameter used is 16 mm and the distance between the bars is 140 mm (D16-140). The divided reinforcement on the concrete slabs is a flexible reinforcement parallel to traffic. Based on RSNI-T-12-2004, the determination of parallel bending reinforcement based on the proportion of the main reinforcement parallel to the traffic direction, from the calculation results obtained the divided reinforcement used is D13-200 mm. Because $V_u \leq \phi V_c$ (13655 N $\leq$ 97129.466 N) and $P_u \leq$

ϕP_n (263.250 kN $\leq$ 479.105 kN), the concrete slabs section do not require shear reinforcement because it can withstand the shear and shear forces of the punch. While from the calculation of divider reinforcement used is D13-200 mm.

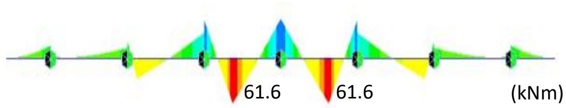

Figure 3 Ultimate Moment Diagram on Concrete Slab

The calculation of the girder is designed for a span of 47 m. The cross-sectional dimensions of the girder used are based on the PT WIKA Beton, precast concrete specification standard using PCI-Girder H-210 cm as shown in Figure 4 with concrete compressive strength (fc') of 60 MPa and the spacing between girders is 140 cm using the type of strands uncoated 7 wire super strands ASTM A-416 Grade 270.

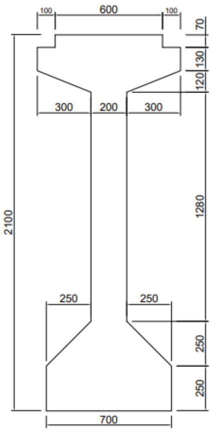

Figure 4 Dimensions of PCI-Girder

Loading on the PCI-girder is calculated using Midas Civil software using load combination based on SNI 1725:2016 with the result of the ultimate moment is 26507.63 kNm and diagram of the ultimate moment is shown in Figure 5.

Figure 5 Ultimate Moment Diagram on PCI-Girder

The methods for the analysis of PCI-Girder are as follows:

a. PCI-Girder cross-section analysis and composites cross-sectional analysis of PCI-Girder and concrete slab
b. Calculation of initial and final stress conditions
c. Calculation of the number of tendons and strands and calculation of tendon positions
d. Determines the tendon trajectory and the layout of each tendon and determine the dead and live anchors
e. Calculation loss of stress and calculation of stresses on the PCI-Girder section and the composite section
f. Bursting steel calculation
g. Calculation of reinforcement on the PCI-Girder and calculation of the shear connector

From the analysis, the number of tendons is 6 pieces with a total of strands of 110 pieces. The live anchor used VSL type Sc and dead anchor VSL type P and, tendon positions can be seen in Figure 6. The layout of each tendon is calculated from 0 m to 23.5 m, with the spacing every 1 m. so that the Y distance for each tendon can be known. The layout of each tendon is shown in Figure 7.

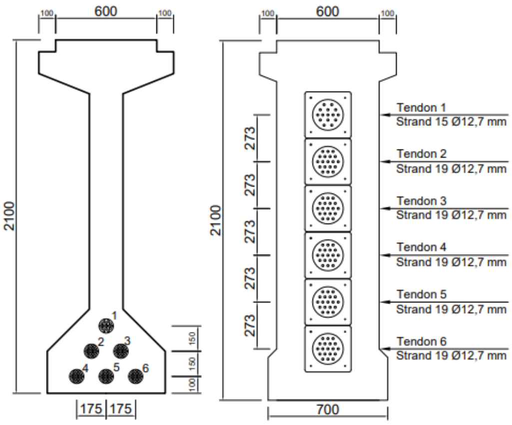

Figure 6 Positions of Tendon

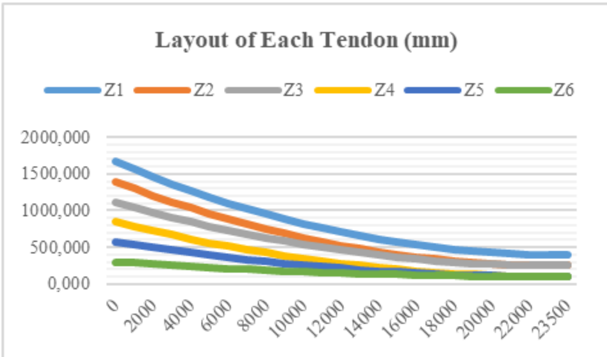

Figure 7 The Layout of Each Tendon

Loss of pre-stress on PCI-Girder is 25.059% and from the calculation of bending reinforcement in pre-stressed concrete beams, it is obtained that the main reinforcement used is 8D13 for the upper segment, 8D13 for the middle segment. and 10D13 for the lower segment. From the calculation of shear reinforcement obtained then the stirrup reinforcement D13-75 mm can be used. The calculation of diaphragm reinforcement is based on the design of doubly-reinforced beam and shear reinforcement (high beam) with concrete compressive strength (fc') of 30 MPa and tensile strength (fy) of 350 MPa. Based on Midas Civil, the ultimate moment is 18.088 kNm as shown in Figure 8.

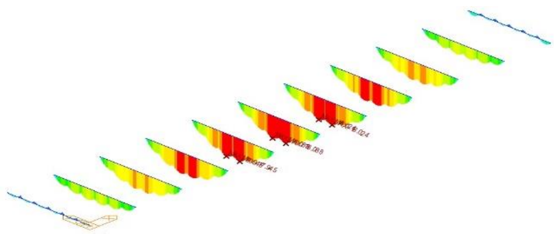

Figure 8 Ultimate Moment Diagram on Diaphragm

Based on the calculation of reinforcement, the required number of reinforcement is 5D16-60 and installed in 2 layers. From the calculation of high beam shear reinforcement, that obtained the shear reinforcement of a diaphragm is using D13-300 for the horizontal shear reinforcement and vertical shear reinforcement.

Abutment stability control is determined by rolling and sliding forces. Reinforcement in abutment is divided into several parts: upper back wall, lower back wall, breast wall, corbel, and wing wall with concrete compressive strength (fc') of 30 MPa and tensile strength (fy) of 350 MPa. The upper back wall is using D16-100 for main reinforcement, D13-100 for divided reinforcement, and D13-200 for shear reinforcement. The lower back wall is using D25-90 for main reinforcement, D19-100 for divided reinforcement, and D13-250 for shear reinforcement. Breast wall main reinforcement is using D32-90, and D16-400 for shear reinforcement. Corbel main reinforcement is using D22-100, D16-100 for divided reinforcement, and D13-250 for shear reinforcement. Wing wall main reinforcement using D22-100 and D16-200 for divided reinforcement.

2.3. 3D Modeling In Tekla Structures

Tekla Structures is 3D building information modeling (BIM) software used in the building industry and construction for steel and concrete detailing to create and manage data accurately and in detail, and can create 3D structural models without forgetting materials and complex structures [10]. Perform 3D modeling to visualize the bridge components on Tekla Structure software starting from the abutment, girders, diaphragms, concrete slab, and parapets. Some of the initial stages carried out are as follows:

a. Making the grid as a medium for determining the location of the bridge components and the distance between the bridge components. Making a grid by determining the distance between the x-axis, y-axis, and z-axis.

b. Bridge components are modeled according to the dimensions and materials used. Modeling of bridge components using tools on the concrete table.

c. Reinforcement modeling is carried out after the bridge component modeling is complete. At this step, the reinforcement is modeled on each of the typical bridge components and then copied to the other components.

d. Clash checking on bridge components aims to check collisions between components to ensure that the bridge component model and the calculation results of reinforcement can be applied without colliding with other components

e. 2D and 3D modeling outputs are cast unit drawings to make it easier to communicate the design results of structural components as shown in Figure 9.

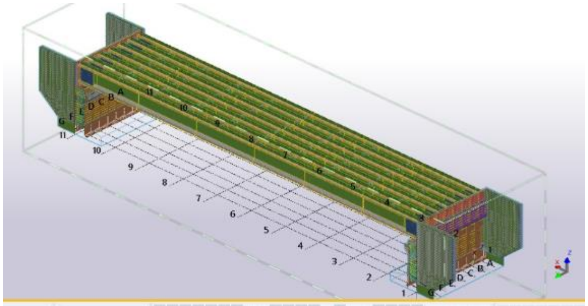

Figure 9 3D Modeling in Tekla Structures

3. CONCLUSION

Based on the design and analysis of the Leuwigajah Bridge with a span of 47 m and a width of 10 m using a PCI-Girder H210 with a pre-stressed concrete system, the results of the structural calculations obtained reinforcement that used and the spacing of each reinforcement. Also, from the calculation of the pre-stressed concrete girder, the required number of tendons is 6 and strands is 110 with the loss of pre-stressing 25.059%. The application of BIM technology with 3D modeling for the design and analysis of the Leuwigajah Bridge can be more effective and efficient because it can visualize a more accurate and realistic bridge design in the field and can detect crashes/errors early and prevent them from affecting the bridge design. The use of BIM in this bridge design can provide efficient project management results thereby reducing production costs. The result of the design of each component of the bridge can be visually modeled in 3D on the actual existing conditions of the area, so that can minimize their failures on the application of the design results. Leuwigajah Bridge 3D modeling using Tekla Structures software can provide detailed bridge components, detailed and precise reinforcement based on structural calculation data so that it can save time and costs as well as simplify the bridge design and work process in the field. 3D modeling of existing bridges and Leuwigajah bridges designed using Infraworks software to visualize the bridge in actual conditions in the field to provides a better understanding of what the finished bridge design will look like.

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