Modeling and Detailing Railway Bridge Structure Using Allplan Engineering

Wahyu Tamtomo Adi(✉), M. Adib Kurniawan, and Rochmad Basuki

Construction and Railway Technology, Indonesian Railway Polytechnic, Madiun, Indonesia
tamtomo@ppi.ac.id

Abstract. The railway bridge design and construction must precisely follow the technical standard due to the high impact load and small tolerance on the track component. Building Information Modeling (BIM) can provide the details and accuracy needed for a railway bridge's design and construction process. The purpose of this study is to use Allplan Engineering, a well-known BIM-based software, to perform three-dimensional modeling of the upper and lower structures of the bridge, model the reinforcement, detail the bar bending schedule of the bridge structures, and compare the results with shop drawings document. The objective is reached by creating a model from a shop drawing document of a case study of a double track 10.3 m width and 25 m length bridge at STA 2 + 168 of a 5.4 km railway project connecting Kedundang Station to New Yogyakarta International Airport (NYIA) Station. The model dimension and quantities results were compared with manual estimation from the shop drawing document. The quantity estimation comparison showed the same value for concrete volume and different values of steel bars reinforcement. The steel bars reinforcement volume for the whole structure generated from the Allplan Engineering 3D model was 1.36% below the manual calculation from the shop drawing document. These findings suggested that using BIM for railway bridge detailing can provide precise detail and efficiency rather than a manual estimation from 2D shop drawings.

Keywords: Railway Bridge · 3D Model · BIM · Allplan Engineering · Concrete Reinforcement

1 Introduction

The railway industry's construction sector has been rapidly developed with various railway infrastructure projects, as stated in the National Railway Masterplan. The target of developing railway networks and services by 2030 is to achieve a 10,524 km railway network in Java, Bali, Sumatra, Kalimantan, Sulawesi, and Papua [1]. In constructing the railway infrastructure, a railway bridge is an integral part that must be built when the railway line crosses the river or for an elevated railway. Railway bridges bear higher impact loads than highway structures. As the bridge supported the track structure, the combination of track and bridge movement should meet the tolerances in track standards, and the interaction should be considered in the design and detailing [2]. The construction

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must precisely follow the technical standard with tolerance in millimeters [3]. It needs to implement Building Information Modeling (BIM) to achieve the detail required for the design and construction of railway infrastructure, especially railway bridges [4, 5].

The construction industry worldwide has implemented BIM in various stages of construction in Architecture, Engineering, and Construction (AEC) fields. Building Information Modeling (BIM) is a system or technology that includes design, construction, and maintenance integrated with 3D modeling [6]. The application of BIM using various recently developed software is effective for planning, construction, maintenance, management, and demolition. The application of BIM to the construction industry in Indonesia is still the subject of various studies [7–9], which have developed over the past decade. However, the application of BIM to the construction of railway infrastructure, especially in the form of the railway bridge, has not been discussed in various studies.

One of the BIM software used to model the structure details and make rebar drawings automatically, as well as quantity estimation, was Allplan Engineering [10, 11]. It produced time efficiency and better quality for the shop drawing and as-built drawing production [12]. Therefore, the purpose of this study was to use Allplan Engineering to perform three-dimensional modeling of the upper and lower structures of the bridge, to model the reinforcement, to detail the bar bending schedule of the bridge structures, and to compare the results with shop drawings document.

2 Method

This study used a case study from a shop drawing document of a double track 10.3m width and 25m length Prestressed Concrete I (PCI) girder bridge at STA 2 + 168 of a 5.4 km railway project connecting Kedundang Station to New Yogyakarta International Airport (NYIA) Station. The whole project construction date was from 2019 until 2021. The modeling method used the shop drawing as the secondary data to create a 3D model of the bridge using Allplan Engineering 2020 with Allplan campus licensing. The modeling process followed two-dimensional drawing, three-dimensional drawing, reinforcement drawing, and producing a bar bending schedule report. The tolerance for the 3D model was in millimeters, and the model was validated by comparing the dimension and volume of each bridge component.

After the modeling process, the concrete and reinforcement detail quantities were obtained using two methods, manual estimation and BIM-based estimation. The conventional estimation of the concrete volume used the Average End Area Method, and length × width × height following the bridge component type was calculated using Microsoft Excel. The conventional estimation of rebar volume used Total Length × Unit weight × Number of Rebars. The BIM-based estimation used Allplan Engineering, which could automatically generate a report of Quantity Take Off to be exported to Excel, Word, and pdf after the model and reinforcement have been finished [11]. These results were analyzed by a comparative analysis of the quantity results from the software as primary data, with the 2D shop drawing obtained from the project as secondary data.

3 Results

3.1 Three-Dimensional Bridge Structure Modeling

The modeling of the bridge was started with two-dimensional modeling in Allplan Engineering using Menu Design [13]. In the menu, several Tabs provide the function for two-dimensional modeling, which includes Tabs for creating 3D lines, boxes, and other objects as needed to model the complete shape of one part of the bridge. The next step was three-dimensional modeling for a part of the bridge using the modeling Tab Menu. The modeling Tab had several menus for three-dimensional modelings, such as 3D surface to create a surface and extrude to create three-dimensional shapes from the two-dimensional drawings by providing the length of the span of the structural elements. Each structural bridge component, including bore-pile, pier, pile cap, pierhead, slab, PIC Girder, diaphragm, and barrier, was created as 3D models by the software. The result of the bridge's concrete model, as in Fig. 1, showed the isometric visualization of the structural bridge model.

The benefit of using Allplan for modeling the structure as a reliable BIM software was it showed the conflict in the design using collision control. In addition, the precision of each part of the structure model was checked using a layout editor menu to view the dimension of the model in the two-dimensional form. Figures 2 and 3 show a comparison of drawing results from the Allplan Engineering model layout and the shop drawing.

Figure 2 and Fig. 3 show the 2D drawing of the Pier, pile cap, pierhead, PCI girder, and barrier from the bridge section. These images show that Allplan Engineering can be used to illustrate the details of the bridge section as previously designed using Autocad. In addition, the details of drawing dimensions and object standards can be set to meet the required drawing standard. The track-top structure of the railway, as in Fig. 2, consisted of ballast, sleepers, and rail, which was not included in the model in Fig. 3 because the study focused only on the concrete detailing of the railway bridge.

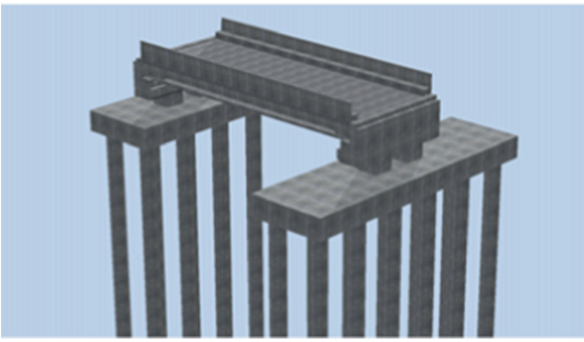


Fig. 1. 3D model of the bridge

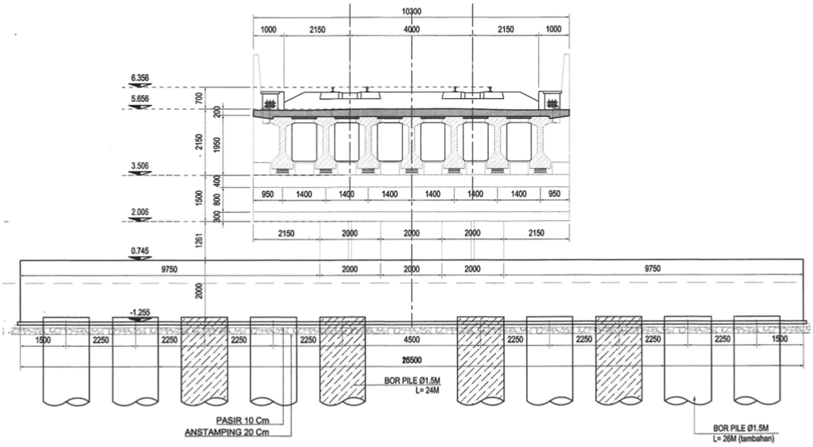


Fig. 2. Shop Drawing Layouts

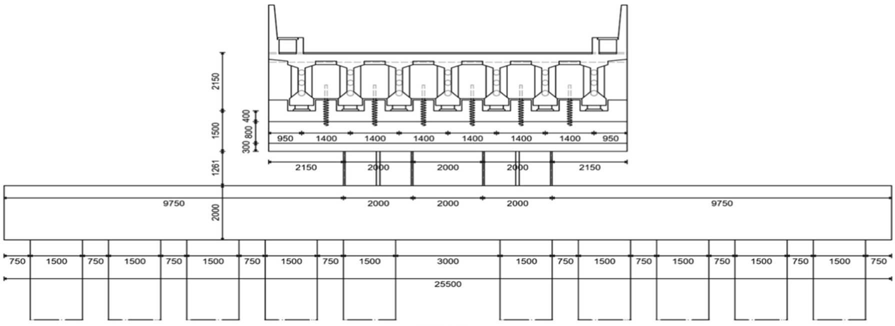


Fig. 3. Allplan Engineering Layout

3.2 Modeling of Concrete Reinforcement and Bar Bending Schedule

For modeling concrete reinforcement, Allpan Engineering provides a Reinforcement menu. The reinforcement can be defined in the bar shape menu, including the reinforcement type, length, diameter, concrete cover thickness, rebar overlapping, anchor details, etc. After the define the bar type, it can be placed in the 3D model of the concrete structure model that has been previously made with adjustments on rebar number and distance. The conflict of the rebar model can be checked from the Menu Collison Check. The reinforcement model varied in colour to distinguish each type of rebar on the bridge model (see Fig. 4).

Figure 4 shows the result of an isometric visualization of a 3D bridge model with each rebar created according to the shop drawing. In addition to three-dimensional results, Allplan Engineering steel reinforcement can be illustrated in two-dimensional shapes with the layout editor menu.

Figure 5 shows the layout of the concrete and reinforcement model using the layout editor menu. The reinforcement model varies in colour to distinguish each different type

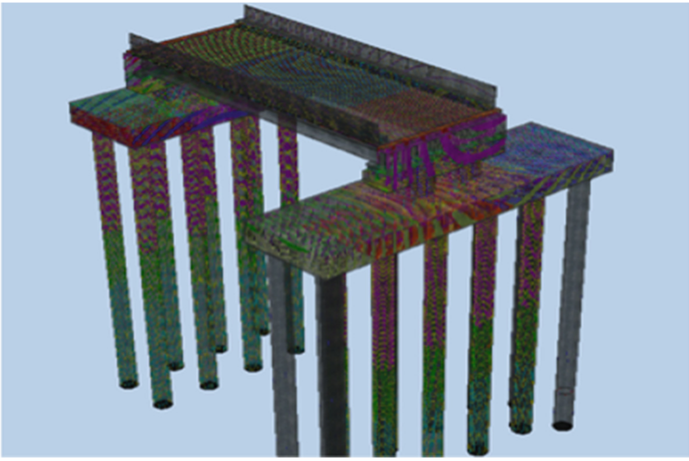


Fig. 4. Isometric Projection of Bridge Model and Reinforcement

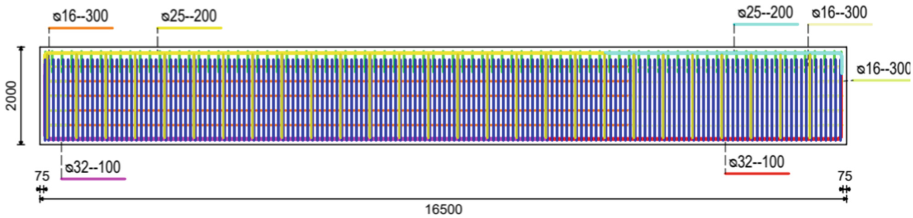


Fig. 5. Allplan Pilecap Reinforcement Layout

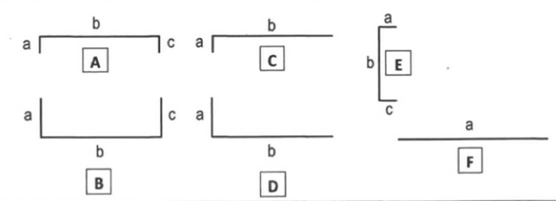
of rebar on the bridge model. The output from Allplan Engineering can be set to display all or some reinforcement models. It also provides a menu to create attributes needed for the rebar drawing. After the reinforcement is completed, the software can generate a Report of the bar bending schedule for all the reinforcement. On the reinforcement menu, select menu Bar Schedule – Bending shapes list. Figure 6 shows the bar bending schedule table (measurement in mm), compared to the shop drawing, as in Fig. 7 (measurement in cm).

Figure 6 shows that Allplan can provide a table with similar results as from manual estimation from the shop drawing compared to Fig. 7. The table results are shown in Figure because it consists of the illustration of each bar reinforcement. Although the model was created with the exact length dimensions, the shape of the reinforcement, and the type of bridge reinforcement, the total weight of rebar results showed slightly different results. The total weight of the steel bar reinforcement of the Pile Cap from the shop drawing was 23,393.88 kg and from the model was 22,444.66 kg. The difference occurred because the manual estimation from the shop drawing was not reduced by bend deduction from the steel bar geometry. In contrast, the BIM-based estimation calculated the volume based on the geometry of the 3D drawing.

Mark	Pcs	ø [mm]	Single length [m]	Dimensioned bending shape (not to scale)	Total length [m]	Mass [kg]
1	38	25	11.95	(11500) 500	454.10	1750.10
2	38	25	5.30	500 (4850)	201.40	776.20
3	83	25	8.25	7350 (500)	684.75	2639.03
4	74	32	11.94	1640 (10360)	883.26	5576.05
5	74	32	7.57	(5990) 1640	559.88	3534.55
6	164	25	10.71	(1730) 7350	1756.44	6769.32
7	10	16	12.00	(12000)	120.00	189.48
8	10	16	4.35	(4350)	43.50	68.69
9	10	16	8.29	(500) 7350	82.86	130.84
10	324	16	1.98	(150) 1730 (150)	639.90	1010.40
				Total mass [kg] :		22444.66

Fig. 6. Bar Bending Schedule Pilecap P29 Allplan

LIST OF REINFORCEMENT FOR PILE CAP P 29 (BH 05)



NO	DIA (mm)	DISTANCE (mm)	TYPE	DIMENSION (Cm) a	b	c	d	e	f	overlap	TOTAL LENGTH (m)	UNIT WEIGHT (Kg/M)	NUMBER	WEIGHT (Kg)	REMARKS
P29															
F1	25	200	C	50	1,150						12.00	3.853	38.00	1,756.97	
F1'	25	200	C	50	485					100.0	6.35	3.853	38.00	929.73	
F2	25	200	A	50	735	50					8.35	3.853	83.00	2,670.32	
F3	32	100	D	164	1,036						12.00	6.313	74.00	5,605.94	
F3	32	100	D	164	599					128	8.91	6.313	74.00	4,162.41	
F4	25	100	B	173	735	173					10.81	3.853	164.00	6,830.75	
F5	16	300	F	1,200							12.00	1.578	10.00	189.36	
F5	16	300	F	435						64	4.99	1.578	10.00	78.74	
F5	16	300	A	50	735	50					8.35	1.578	10.00	131.76	
F6	16	600	E	15.0	173.0	15.0					2.03	1.578	324.00	1,037.88	
													TOTAL	23,393.88 Kg	

Fig. 7. Bar Bending Schedule Pilecap P29 Shop Drawing

3.3 Concrete Bridge 3D Model and Reinforcement Volume Comparison

After the modeling stage, we can compare the results of the Allplan Engineering model with the information stated on the shop drawing document. Allplan Engineering provides menu create Reports for fast and accurate quantities based on the 3D model of the bridge. The Report consists of material, dimension, height, volume for each material, and total volume, which should be customized according to the requirement. The comparison of quantity estimation between the 3D model and the shop drawing document can be seen in Table 1.

Table 1 shows no difference between the total volume of Allplan Engineering and the total volume of manual calculations from the 2D shop drawing document. From

Table 1. Concrete Volume Comparison.

No.	Element	Volume (m^3)		Difference	
		Shop Drawing	**Allplan**	**m^3**	**%**
1	Pile cap P29	247.5	247.5	0	0
2	Pile cap P30	382.5	382.5	0	0
3	Pier P29	9.93	9.93	0	0
4	Pier P30	10.05	10.05	0	0
5	Pierhead P29	55,48	55,48	0	0
6	Pierhead P30	55,48	55,48	0	0
7	Barrier	21.29	21.29	0	0
8	Slab Barrier	2.05	2.05	0	0
9	Ballast Stopper	5.87	5.87	0	0
10	Floor Slabs	52.81	52.81	0	0
11	Deck Plate	8.4	8.4	0	0
12	Diaphragm Type D1	3.36	3.36	0	0
13	Type D2. Diaphragm	2.38	2.39	0	0
14	Pedestal 600X400	2.88	2.88	0	0
15	Pedestal 550X400	0.88	0.88	0	0
16	PCI Girder	129.84	129.84	0	0
17	Elastomeric Seat	0.25	0.25	0	0
18	Borepile L = 24M	339.29	339.3	0	0
19	Borepile L = 26M	367.57	367.57	0	0
20	Borepile L = 28M	395.84	395.84	0	0
Total Volume		2,093.64	2,093.64	0	0

these results, it can be concluded that using the software can help the engineer and contractor work efficiently on the quantity calculation of the concrete bridge. The concrete reinforcement quantity can be generated using the report menu. The reporting process of rebar detailing by Allplan makes the volume calculation of the concrete bridge steel bar reinforcement effective by using the menu generating the bar lists on the Report. The bar list consists of the mark, the number of rebars, dimension and bending shape illustration, length, total length, and the weight of each rebar reinforcement. The Report can be customized to meet the standards needed [14].

Table 2 shows that the steel reinforcement estimation volume from the shop drawing document is higher than the value automatically calculated by Allplan Engineering. Allplan Engineering volume for each bridge component shows a value of 0.72% up to 4.05%, smaller than the manual estimation from the shop drawing document. Although the rebar drawing model was created with the same diameter, length, and number as the

Table 2. Concrete Reinforcement Volume Comparison.

No.	Reinforcement	Volume (kg)		Difference	
		Shop Drawing	Allplan	Kg	%
1	Pile cap P29	23,393.88	22,444.64	949.24	4.05
2	Pile cap P30	40,806.91	40,510.53	296.38	0.72
3	Pier P29	10,182.12	10,025.69	156.43	1.53
4	Pier P30	10,224	10,067.86	156.14	1.52
5	Pierhead P29	12,035.01	11,780.15	254.86	2.11
6	Pierhead P30	12,035.01	11,802.78	232.23	1.92
7	barrier	2,783.14	2,709.03	74.11	2.66
8	Floor Slabs	9,241.78	8,997.58	244.2	2.64
9	Bearing Pad and Pin Move P29	617.04	602.07	14.97	2.42
10	Bearing Pad and Pin Fix P30	593.4	578.44	14.96	2.52
11	Borepile L = 24M	56,182.64	55,607.23	575.41	1.02
12	Borepile L = 26M	42,974.13	42,645.42	328.71	0.76
13	Borepile L = 28M	47,832.29	47,450.43	381.86	0.79
Total Volume	268,901.35	265,221.85	3,679.5	1.36	

shop drawing document, the total steel bar length formula for the automatic calculation using the software could not be checked. It is probably reduced by bend deduction from the steel bar geometry. This study shows the total steel bar reinforcement volume from the automatic calculation, on average, is 1.36% lower than the manual calculation.

The results are similar to the previous study [11, 15]. This research suggests the difference in the quantity of reinforcement between manual and Allplan estimation might be caused by differences in hook length, the amount of reinforcement, and the input method in which manual calculation used the length of steel rebar. In contrast, Allplan Engineering uses the thickness of the concrete cover as the estimate reference [11]. Other studies suggest the designing process using BIM-based software such as Allplan Engineering can provide better drawing quality and provide time efficiency of up to 43.82% compared to conventional design [12]. However, implementing BIM software in the design and construction process for railway bridges in Indonesia will also need investment for human resource enhancement.

4 Conclusion

Details and accurate 3D models of a concrete structure and its reinforcement from a railway bridge have been made using modeling and reinforcement menus from Allpan Engineering software. The quantity estimation comparison showed no difference in the concrete volume of the model and shop drawing estimation. The result from the steel bars reinforcement quantity of the model was 1,36% smaller than the value of the shop drawing document. The BIM-based application can provide efficiency for the design and construction process, especially for railway bridges where details and accurate design and construction are needed due to high impact load and small tolerance on the track component.

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