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Volume and Cutting Optimization of Reinforcing Steel in Construction of a Satpol PP Building Project

Quini Athaya Putri*, Fajar Sri Handayani, Setiono

Civil Engineering Study Program, Faculty of Engineering, Sebelas Maret University

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*Correspondence: Quini Athaya Putri
Email: quiniathaya@student.uns.ac.id

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Abstract: The world of construction is very dependent on technology, especially in the era of the industrial revolution which demands efficiency and competitiveness. The use of BIM (Building Information Modeling) technology supported by Autodesk Revit software enables more effective and efficient project planning and implementation. One application of BIM is in planning reinforcing steel requirements. To overcome material waste which often occurs due to less than optimal cutting of reinforcing steel, material management with a bar bending schedule and the use of BIM is an important solution. In the Satpol PP Building Construction Project in Bantul Regency by PT Quinad Bahana Indonesia, this new method with software was applied to correct cutting of reinforcing steel, reduce waste and increase construction efficiency. This research method includes data collection, 3D BIM modeling, comparing work volume using Autodesk Revit and conventional. After getting the reinforcing steel volume from the Autodesk Revit software, continue by entering the volume data into the BIM to obtain optimal reinforcing steel cutting patterns. The research results show that the use of Autodesk Revit software for column and beam work results in an overall difference of 11%. The volume resulting from Revit quantity take-off is less than manual analysis. Based on waste level calculations, the average value of waste level is 0.97%. This proves that the BIM is effective in reducing material waste on construction projects. Apart from reducing material waste, the BIM is also able to optimize reinforcing steel cuts.

Keywords: Autodesk Revit, Construction Management, Reinforcement Volume

Introduction

BIM is a technology, process, and a policy that enables the construction process to be collaborative and integrated in a digital model. This technology facilitates the development of design and construction documentation such as drawings, procurement details, and other interrelated specifications (Lien, 2023; P. Liu, 2023). One of the uses of BIM in construction is the use of Autodesk Revit software. Autodesk Revit provides modeling and collaborate data with scheduling, cost estimation, building sustainability, and facility management directly, thus speeding up project planning time (Putri, 2023; Zimmert, 2023).

Autodesk Revit can provide reinforcing steel volume output more effectively and efficiently. The use of BIM improves the quality work with detail, accuracy, and minimal rework (Tsakanika, 2022; Walraven, 2021). In terms of time, volume calculation is faster without manual calculation. The resulting volume is also lower than conventional methods, reducing the remaining steel material in construction projects. Collaboration between Autodesk Revit software and BIM can optimize the need for reinforcing steel to reduce wasted materials. To prevent waste, systematic and effective material management is required. Reinforcing steel management can be done with a bar bending schedule, which calculates the number, shape, and remaining pieces of steel reinforcement (J. Liu, 2020).

Bar bending schedule work is carried out by several methods to optimize reinforcement in the field (Pozo, 2020). One method is manual distribution. In addition, the bar bending schedule calculation can also be done with BIM , which makes it easy to control steel material waste (Din, 2020). This software provides optimal results for steel cutting, so that material use becomes more effective and efficient. This research aims to calculate the difference in the volume of reinforcing steel using conventional methods and Building Information Modeling (BIM) methods. Another objective is to show the effect of applying BIM in reducing material waste.

Methodology

This research uses a quantitative method with a case study that discusses the volume calculation and optimization of steel cutting of reinforcing columns and beams using the BIM method. The project used as the object is the Satpol PP Building Construction Project located in Bantul Regional Government Office Complex II, East Ring Manding St., Trirenggo, Bantul, Yogyakarta. This project has a building area of 984 m2. The data used in this research includes primary data in the form of shop drawings, as well as outlie specifications and technical specifications, while the secondary data includes previous articles and journals related to this research. The first step in this research is to remodel the building. The remodeling of Satpol PP Building Construction Project uses Autodesk Revit software to produce quantity take off in the form of reinforcing steel volume. The output will then be integrated into BIM to optimize the cutting of reinforcing steel in the project.

The research flow chart contains the stages of the research process from beginning to end which are presented in a concise manner. The flow char can be seen in Figure 1.

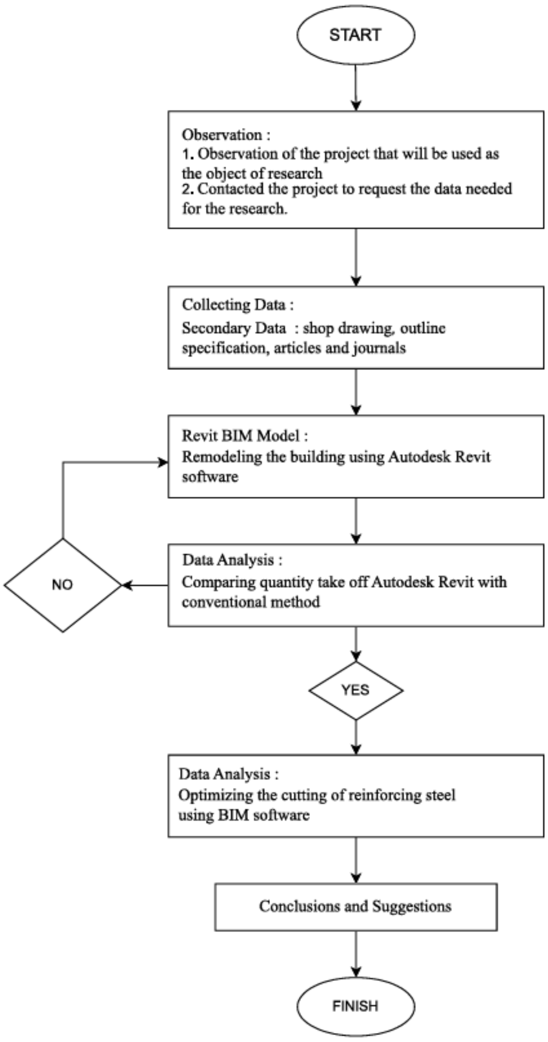

Figure 1. Flow Chart of Research Implementation

Result and Discussion

From building modeling using Autodesk Revit software, the volume of reinforcing steel required for column and beam structural work is obtained. Based on the results, it can be summarized in the following tabel:

Table 1. Recapitulation of Revit Method Volume Results

Structural Works	Total Lengths (mm)			Total Volume (cm2)
	6	10	16	
1st Floor Joist		1.045.501	1.133.747	299.220,7
1st Floor Main Beam		2.171.422	2.628.499	675.850,69
Structural Sloof		1.302.269	1.392.977	368.892,21
Practical Sloof	450.796	299.663		31.565,02
1st Floor Practical Column	444.462	912.060		74.827,97
1st Floor Structural Column		912.351	1.823.923	426.821,3

2nd Floor Main Beam		1.938.835	2.552.773	644.298,61
2nd Floor Joist		597.343	601.246	161.722,32
2nd Floor Practical Column	308.527	611.600		50.417,49
2nd Floor Structural Column		744.997	1.159.200	282.973,68

Table 2. Comparison of Conventional and Revit Work Volume

Structural Work	Quantity Take-off (m)		Difference (%)
	Conventional	Revit	
1st Floor Joist			
Main Rebar D16	1.279,82	1.133.747	16
Stirrups 10	894,21	1045,501	7
1st Floor Main Beam			
Main Rebar D16	2.587,94	2.628.499	1
Stirrups 10	1.848,55	2.171.422	43
Structural Sloof			
Main Rebar D16	1.653,09	1.392.977	2
Stirrups 10	1.212,08	1.302.269	17
Practical Sloof			
Main Rebar D10	301,33	299.663	11
Stirrups 6	786,00	450.796	17
1st Floor Practical Column			
Main Rebar D10	960,03	912.060	9
Stirrups 6	395,28	444.462	3
1st Floor Structural Column			
Main Rebar D16	1.669,36	1.823.923	5
Stirrups 10	882,45	912.351	12
2nd Floor Main Beam			
Main Rebar D16	2.628,00	2.552.773	3
Stirrups 10	1.904,77	1.938.835	2
2nd Floor Joist			
Main Rebar D16	744,00	601.246	19
Stirrups 10	475,90	597.343	26
2nd Floor Practical Column			
Main Rebar D10	705,66	611.600	0
Stirrups 6	292,78	308.527	2
2nd Floor Structural Column			
Main Rebar D16	1.162,35	1.159.200	19
Stirrups 10	727,30	744.997	5
Average			11

Based on the table above, it can be seen that there is a difference in the quantity take off of column and beam work using conventional methods and Revit. The overall average

difference in quantity take off between the conventional method and Revit is 11%. Overall, the quantity take off generated by Revit is less than the manual volume calculation. After obtaining the volume of reinforcing steel for column and beam structure work, the data will then be entered into BIM. The output of this research is the optimal cutting pattern of reinforcing steel and statistical data containing the total length of steel uses, the length of material that can be reused, and the length of material that cannot be reused.
The results of trial and error optimization calculations are presented in the following table:

Table 3. Statistical Data on the Cutting Results of Reinforcing Steel of the 1st Floor Joist

Parameter	Diameter (m)	
	10	16
Total length used	1.054,716	1.133,737
Reused material	9,88	12,435
Waste material (<5mm)	24,404	5,828

Table 4. Statistical Data of Cutting Results of Reinforcing Steel of the 1st Floor Main Beam

Parameter	Diameter (m)	
	10	16
Total length used	2.712,001	2.628,416
Reused material	209,047	37,226
Waste material (<5mm)	4,832	21,679

Table 5. Statistical Data of Cutting Results of Sloof Structure Reinforcing Steel

Parameter	Diameter (m)	
	10	16
Total length used	1.302,84	1.392,984
Reused material	0	299,77
Waste material (<5mm)	26,44	7,842

Table 6. Statistical Data on the Cutting Results of Practical Sloof Reinforcing Steel

Parameter	Diameter (m)	
	10	16
Total length used	450,88	299,652
Reused material	3,78	0
Waste material (<5mm)	13,34	0,348

Table 7. Statistical Data of Cutting Results of Reinforcing Steel of the 1st Floor Practical Column

Parameter	Diameter (m)	
	10	16
Total length used	443,775	912,06
Reused material	0	213,84
Waste material (<5mm)	4,005	2,1

Table 8. Statistical Data of Cutting Results of Reinforcing Steel of the 1st Floor Structural Column

Parameter	Diameter (m)	
	10	16

Total length used	912,6	1.823,648
Reused material	101,88	336,159
Waste material (<5mm)	0	4,374

Table 9. Statistical Data of Cutting Results of Reinforcing Steel of the 2nd Floor Main Beam

Parameter	Diameter (m)	
	10	**16**
Total length used	1.939,36	2.552,749
Reused material	199,88	32,642
Waste material (<5mm)	0	36,217

Table 10. Statistical Data of Cutting Results of Reinforcing Steel of the 2nd Floor Joist

Parameter	Diameter (m)	
	10	**16**
Total length used	597,54	607,249
Reused material	0	100,692
Waste material (<5mm)	2,46	0,326

Table 11. Statistical Data of Cutting Results of Reinforcing Steel of the 2nd Practical Column

Parameter	Diameter (m)	
	10	**16**
Total length used	308,05	611,6
Reused material	1,325	96,4
Waste material (<5mm)	2,625	0

Table 12. Statistical Data of Cutting Results of Reinforcing Steel of the 2nd Floor Structural Column

Parameter	Diameter (m)	
	10	**16**
Total length used	745,2	1159,2
Reused material	82,8	184,8
Waste material (<5mm)	0	0

From the statistical data table from BIM, the waste level value can be calculated. Waste level is the amount of material that cannot be reused or wasted during the construction process. The waste level value can be calculated using the formula:

$$\textbf{Waste Level} = \frac{\textbf{Waste Volume}}{\textbf{Requirements Volume}}$$

By using this formula, the percentage of waste level in the required reinforcing steel pieces can be obtained. The following is a recapitulation table of the waste level obtained:

Table 13. Recapitulation of Waste Level Results

Diameter (mm)	Total Length Used (m)	Waste Material (m)	Waste Level
16	11.297,983	76,266	0,675%
10	10.547,569	60,584	0,574%

6	1.202,705	19,97	1,660%
	Average		0,970%

Based on the table above, the average waste level value is 0,97%. This shows that BIM is able to reduce material waste in construction projects. In addition to reducing material waste, this software can also optimize reinforcing steel cuts. Thus, BIM can be used to plan construction projects effectively and efficiently.

In the Results section, summarize the collected data and the analysis performed on those data relevant to the issue that is to follow. The Results should be clear and concise. It should be written objectively and factually, and without expressing personal opinion. It includes numbers, tables, and figures (e.g., charts and graphs). Number tables and figures consecutively in accordance with their appearance in the text.

Conclusion

The average difference in the volume of reinforcing steel using conventional methods and Building Information Modeling (BIM) in beam and column work is 11%. Overall, the volume generated from Revit's quantity take off is less than using manual analysis. Based on the waste level analysis using BIM, the average waste level value is 0,97%. This shows that BIM is effective in reducing material waste in construction work.

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