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Evaluation of Rebar Waste Rate Calculation Model Utilizing Building Information Modelling Function: High Rise Building Case Study

Ryan Faza Prasetyo[1], Rama Adjie Darmawan[2], Danny Triputra Setiamanah[3]
Faculty of Civil Engineering[1,2,3]
Universitas Trisakti, Jakarta, Indonesia[1,2]
Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia[3]
e-mail corresponding: ryan@trisakti.ac.id[1]

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Abstract

The process that has the potential to generate construction waste is a construction operational process so that in this process it is necessary to make efforts to carry out waste control in real-time as a form of effort by the construction industry to play a role in suppressing waste production. Building Information Modelling is one of the supporting tools for project productivity whose function can be used to evaluate the level of construction waste, especially rebar waste which is one of the source materials for construction waste. The purpose of this study is to test the modeling of the calculation of the rebar waste rate utilizing the function of the Building Information Modelling so that it can be used as an alternative tool for evaluating the level of waste in real-time. The calculation modeling obtained from previous research was successfully tested on a case study of a high-rise building project and obtained the rebar waste rate at a certain time in accordance with the progress of work in the project site. From this research, it can be concluded that the calculation modeling can be carried out on high-rise building projects.

Keywords: *Rebar Waste Rate, Building Information Modelling, High-Rise Building*

1. Introduction

Construction industry are one of the industrial sectors contributed in waste creation globally. Waste creation led to environment contamination, so the effort for doing construction waste management need to be escalate [1].

At present efforts to carry out waste management occur in the construction operational phase. Several tools for predicting the amount of construction waste have been used to help reduce the creation of construction waste in the design phase, but alternative tools used for the decision-making process are still lacking [2].

The construction operational phase is a phase that is no less important than the design phase, because the emergence of additional creation of construction waste is very likely to occur in this phase. Five main causes were found during the construction phase which led to an increase in construction waste: poor site placement management, poor supervision, lack of worker experience, poor planning and poor job scheduling [3].

Other studies also concluded that several factors contribute to the creation of construction waste in the construction phase: frequent changes to the design, errors in making detailed designs and construction drawings, uneconomical fabrication of material forms, lack of knowledge about construction waste, purchasing materials that do not meet specifications. and improper storage of materials resulting in material damage and work failure [1].

To be able to suppress the creation of construction waste in the construction operational phase, tools are needed to assist decision making that can periodically evaluate and predict the level of waste creation. A construction waste management strategy can work well if it is supported by the presence of information and data that can describe the level of waste production properly. [4] [5] . For this reason, it is important to calculate the level of waste creation in the construction operational phase which can be monitored regularly so that it can become the basis for decision making in planning the implementation method, material purchasing and supervision methods so as to reduce the creation level of construction waste.

In the construction operational phase, high productivity is required in evaluation and planning work, so that the application of technology is very important to increase productivity. Building Information Modeling (Building Information Modelling) is a technology that is currently being used frequently in the construction industry. The main function of Building Information Modelling is a visualization tool and considered as an interactive tool that can dramatically increase productivity in the construction management process, from creation of construction drawings, management of execution time, calculation of implementation costs, and integrated information exchange between cloud-based project stakeholder [6].

Building Information Modelling can massively contribute to increasing project design productivity, estimation and visualization of building characteristics. The work volume calculation function is obtained from the Building Information Modelling-based quantity take off software which can minimize the traditional volume calculation process which ineffective in terms of time [7]. Building Information Modelling also proven to be effectively applied to the process of calculating the quantity of work volume during the construction operational process during the pandemic because of its advantages of being able to access and work both in the project office and from outside the project office [8].

Several studies have been conducted related to the calculation of rebar waste rate. Pertiwi et al (2019) analyze the wastage level in a high rise building project located in Kabupaten Badung, Indonesia. They calculate waste rate at certain point of project progress by dividing all rebar volume that already worked with the volume of rebar that stated in Bill of Quantity. They found overall wastage level of rebar at 12,78% at current point of structural progress. In that research the wastage level carried out are too high because the calculation did not consider another factor such as fabricated rebar and rebar at the warehouse [9].

Novita et al (2020) calculate rebar waste rate optimization in Infrastructure project type with Linear Program Method. In that research they consider the rebar planning volume and existing rebar waste which not used in any structural works to formulate optimized rebar form so they can minimize wastage level. This method focuses on planning process in construction and they did not perform recalculation after formulate optimized form of rebar [10].

Another research about rebar waste rate analysis performed by Mahapatni et al (2022) in a school building construction as a case study. To obtained rebar waste rate they consider data provided by project logistics where they provide updated data of rebar volume that already used and rebar volume that still in warehouse. In this research they use Cutting Optimization Pro Software and Microsoft Excel to evaluate the rebar waste rate. Software utilization performed in this research [11].

To evaluate rebar waste rate, we need to calculate rebar volume in Bill of Quantity, rebar volume in warehouse stock and rebar volume that already worked. If that volume provided through traditional quantification methods it can consume 50%-80% estimator’s time.[14] Building Information Modelling can reduce this because engineer are able to extract measurement and material quantities straight from models at every process of building modelling. [7] [12].

In this study the calculation model that will be tested is the calculation of the rebar waste rate. Rebar is a source of construction waste-producing material. 6 out of 9 projects indicated reinforcing steel had a high level of waste production [4] [13] It is hoped that with the integration

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between the use of Building Information Modelling and calculation model of waste creation, it is possible to obtain the calculation and evaluation of the creation level of construction waste in quick and efficient way in every certain point of structural progress.

2. Research Method

The method used in this study is to simulate the calculation of rebar waste rate in high-rise building projects at a certain point of progress value by integrating modeling calculations from previous studies with the Building Information Modelling function to obtain periodic and real-time volume calculations. Before modeling the calculation of rebar waste rate, modeling is first carried out in the Building Information Modelling software to determine the overall volume of reinforcing steel and the volume of reinforcing steel at a certain progress [14]. The Building Information Modelling software used to obtain reinforcement calculations is Glodon Cubicost. For the Building Information Modelling modeling process flow to determine the overall volume of work, it can be seen from Figure 1, while for the Building Information Modelling modeling process flow to determine the volume of work at a certain progress, it can be seen in Figure 2.

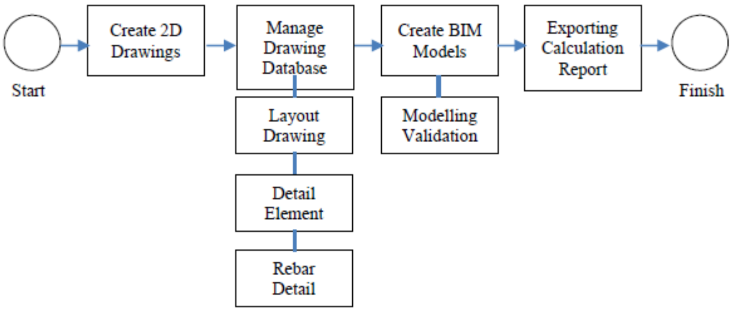

Figure 1. Process Flow Building Information Modelling Modelling to determine the overall volume of work (Prasetyo, 2021)

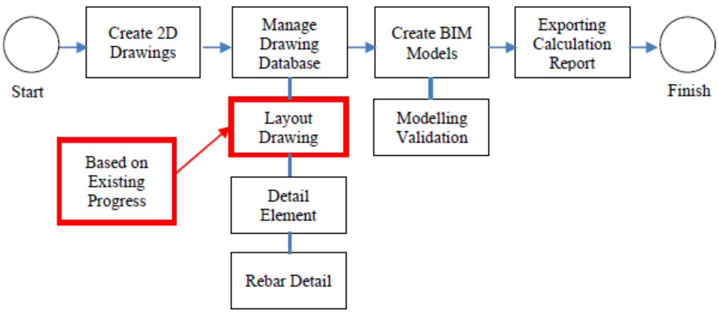

Figure 2. Process Flow Building Information Modelling Modelling to determine the volume of work at a certain progress (Prasetyo, 2021)

In general, the calculation method for the level of rebar waste rate is as follows:

1. Make a model of the building as a whole to find out the overall volume of reinforcing steel that must be ordered.
2. Determine certain progress to be used as a calculation simulation.
3. Make building modeling in accordance with the progress which is used as a simulation reference to determine the volume of reinforcing steel installed during the progress.
4. Calculate the amount of reinforcing steel that has been fabricated manually
5. Count the amount of reinforcing steel in the Warehouse
6. Evaluate the level of waste steel using calculation modeling in the research of Prasetyo

et al (2021)

There are several methods for calculating the rebar waste rate obtained from previous studies. The level of waste reinforcing steel (4) can be calculated by calculating the cumulative deviation of the amount of rebar ordered (1) minus the amount of rebar that has been worked (2) and then divided by the amount of rebar that has been worked. [4].

$$(4)\ Wastage\ Level = \frac{(1)\sum Order\ Quantity - (2)\sum Workdone}{(2)\sum Workdone}$$

Previous research has also succeeded in obtaining a model for calculating rebar waste rate for infrastructure projects. Modeling the calculation of the rate of reinforcing steel waste (6) is obtained from the cumulative amount of steel ordered (Vp) minus the cumulative amount of steel installed (Vi) minus the cumulative amount of steel stored in the Warehouse (Vs) minus the cumulative amount of steel that has been stored fabrication (Vf) then divided by the cumulative amount of steel reinforcement that has been ordered in accordance with the contract document (Vp1). [4] The calculation modeling succeeded in obtaining the value of the waste rate of reinforcing steel so that it can be used as a reference for making decisions related to the implementation of structural ironing work on the project.

$$(6) Waste\ Rate\ (\%) = \frac{\sum Vpurchased(Vp) - \sum Vinstalled(Vi) - \sum Vstock(Vs) - \sum Vfabricated(Vf)}{\sum Vpurchased(Vp1)}$$

3. Findings

Based on the method of calculating rebar waste rate, the following results are obtained:

1) Modeling of the building as a whole was successfully obtained. The total reinforcing volume for this project is 25,350,550 kg. Due to software limitations, the volume of reinforcing bars that can be calculated are pile caps, tie beams, retaining walls, columns, beams and floor plates. The overall building modeling results can be seen in Figure 3. In addition to making the modeling of the building as a whole, in this first stage reinforcement form validation is carried out to ensure that the length of distribution, the length of the bend of the steel is in accordance with the detail standard. This validation process can be seen in Figure 4.
2) The progress selected for the simulation is the project progress of 35% of the contract value, or 60% of structural work only. Next is to calculate how much reinforcing steel has been ordered until the progress of the structure is 60%. The output volume of reinforcing steel was 17,271,890 kg.
3) After determining the progress that is used as a reference for calculating the level of waste reinforcing iron. Next is to make building modeling in accordance with the progress that is used as a reference. The modeling results can be seen in Figure 5. From the modeling, it was possible to obtain the number of installed reinforcing bars. The output of field volume calculations can be seen in Table 1.

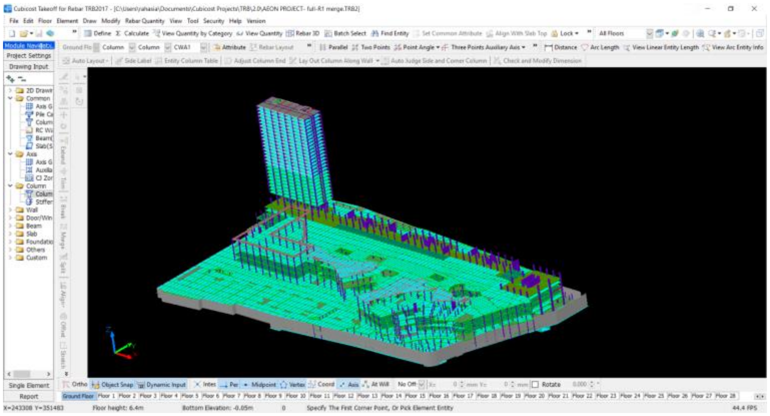

Figure 3. Whole Building Information Modelling building modelling

Figure 4. Rebar shape validation process

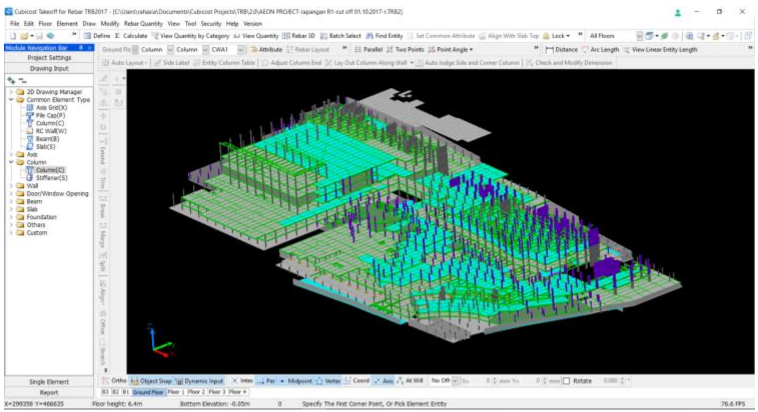

Figure 5. Building Information Modelling modelling at 60% structural progress

Table 1. Worked Rebar Volume (Building Information Modelling Output)

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Rebar Use Monitoring		10	13	16	19	22	25
60% Structural Progress	Floor Plates	1.067.216,99	364.474,29	1.083.293,93	1.464.335,06	246.526,51	
	Pile Cap	-	-	27.674,25	354.731,92	-	3.274.045,36
	Tower Crane Pile Cap					337.067,00	41.641,49
	Column	240.436,17	851.053,26	-	-	1.436.952,04	497.652,59
	Beam	446.934,54	245.570,20	185.498,29		1.859.979,93	560.592,79
	Wall	138.084,60	105.481,14	13.009,50	53.954,14	168.862,90	56.934,03
TOTAL	kg	**1.892.672,29**	**1.566.578,89**	**1.309.475,97**	**1.873.021,11**	**4.049.388,40**	**4.430.866,26**
	Bars	255.836,00	125.301,00	69.143,00	70.133,00	113.092,00	95.829,00

4) Next is to calculate the amount of rebar that has been fabricated during the 60% progress of the structure. From the results of observations, materials that can be counted as materials that have been fabricated are those that are being assembled (columns, retaining walls, beams) as well as reinforcing steel for ties and supports. From the results of manual calculations, it was found that it was 50,000 kg.
5) The total amount rebar in the Warehouse as a whole is 1,366,883 kg. This value obtained from manual calculations of reinforcing steel that has not been fabricated and is still available in the material storage warehouse.
6) After obtaining all the required data, the next step is to calculate the level of waste reinforcing steel to determine the level of waste in the progress of the structure of 60%. From the results of the calculation and evaluation, the value of the waste steel reinforcement level is obtained as described in Table 2

Table 2. Rebar Waste Rate Calculation Evaluation at 60% Structural Progress (Building Information Modelling Output)

Worked Rebar		Rebar Diameter					
		10	13	16	19	22	25
60% Structural Progress	Floor Plates	1.067.216,99	364.474,29	1.083.293,93	1.464.335,06	246.526,51	
	Pile Cap	-	-	27.674,25	354.731,92	-	3.274.045,36
	Tower Crane Pile Cap					337.067,00	41.641,49
	Column	240.436,17	851.053,26	-	-	1.436.952,04	497.652,59
	Beam	446.934,54	245.570,20	185.498,29		1.859.979,93	560.592,79
	Wall	138.084,60	105.481,14	13.009,50	53.954,14	168.862,90	56.934,03
	Total	**1.892.672,29**	**1.566.578,89**	**1.309.475,97**	**1.873.021,11**	**4.049.388,40**	**4.430.866,26**
TOTAL		**15.122.002,91**					

	8	10	13	16	19	22	25	TOTAL
Total Delivered (a)	25.003,50	1.893.415,90	2.154.734,40	1.715.178,48	1.902.421,92	4.338.868,08	5.242.267,80	**17.271.890**
***Rebar Stock*(b)**	21.330,00	165.715,20	234.049,05	83.331,07	147.287,89	399.598,53	315.570,94	**1.366.883**
Delivered - Stock '© = (a)-(b)	3.673,50	1.727.700,70	1.920.685,35	1.631.847,41	1.755.134,03	3.939.269,55	4.926.696,86	**15.905.007**

Total of Rebar Delivered	=	17.271.890
Total of Stock	=	1.366.883
Total Worked	=	15.122.002,91
Total Fabricated Rebar	=	50.000
Deviation	=	733.004
Waste Rate	=	4,24 %

4. Conclusion

Modeling simulation for calculating rebar waste rate in the high-rise building case study was successfully carried out. By modeling calculations from Prasetyo's research (2021), it is possible to find out the value of the level of reinforcing iron waste of 4.24% at 60% structural progress. This simulation successfully applies the calculation modeling of the rebar waste rate utilizing the Building Information Modelling function. The success of this calculation simulation concludes that the calculation modeling of the rebar waste rate can be applied to types of high-rise building projects and infrastructure projects.

However, in the process of collecting data for the need to calculate the rebar waste rate, there are several things that need attention.Some data such as the volume of reinforcing steel in the storage warehouse and the volume of fabricated rebar needs to be done by staff who have good knowledge and experience, especially for reinforcement work. Because to get accurate results of calculating the level of waste steel, very accurate data is needed. In order to control the use of reinforcing steel material to work properly, there needs to be a document that is updated every day in order to facilitate control of outcoming and incoming reinforcing steel material from the material storage warehouse to the rebar fabrication location.

The project team must set a maximum limit for the rate of rebar waste so that when a daily level of rebar waste is found that exceeds the planning maximum limit, the project team can evaluate the implementation of the reinforcement work.

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