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Original Article

Analysis of Minimizing Iron Material Waste for Construction Work in Wetlands with Bar Bending Schedule Method

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Abstract *- The components of the material structure that are important in calculating requirements are iron requirements because iron requirements have a high value in construction work. Iron requirements such as reinforcing columns, beams, pile caps, sloofs, and others are widely used for reinforcement. The research aims to determine the need for stirrup reinforcement using a method based on field data with the Bar Bending Schedule (BBS) approach. The BBS method minimises the waste of material so that it only leaves the material in the screw-type iron reinforcement, around 14.79% for iron reinforcement with a diameter of 10 mm and 6.65% for iron reinforcement with a diameter of 16 mm. As well as for plain iron reinforcement, only leave material around 0.01% on mm diameter iron reinforcement. The bar bending schedule method can optimize the remaining material from the remaining length of the iron by reusing it for other iron piece plans where the piece's dimensions can meet the previous rest.*

Keywords *- Bar bending schedule, Leftover material, Stirrup reinforcement, The volume requirement.*

1. Introduction

Waste is commonly encountered during the life of a building, from the design phase to the construction phase, including modification and demolition. Project managers do not notice or monitor most of this construction waste, leading to serious environmental problems [1]. The components of the material structure that are important in calculating needs are iron requirements because iron needs have a high value in construction work [2].

Iron requirements, such as reinforcing columns, beams, pile caps, and sloops, are widely used for reinforcement. Therefore, iron requirements must be calculated optimally with high accuracy to not cause losses caused by errors in calculating material requirements differences. The building construction project is the project reviewed for this research. The project certainly includes a lot of reinforcement work, including cutting iron, bending, and assembly, which is also part of the work on stirrup reinforcement.

For reinforcing ironwork, as mentioned above, the cutting and other processes usually follow the plan drawing, and based on the plan drawing, the stirrup reinforcement has different dimensions between each support, so this kind of work can cause the most waste material. Resource Venture states that waste material, often residual material, is a tangible, harmless object obtained from construction and cleaning activities, which can then be utilized, used, or reprocessed [3]. Some building construction projects have similar problems, namely the emergence of excessive material waste. The work of reinforcing iron in a project is carried out by workers, most of whom do not understand the problem of reinforcement because they usually only work based on experience without seeing and being armed with the correct knowledge in its application in the field.

In addition, waste of material is considered natural in development projects, so there is little or no handling in reducing waste. Due to the lack of handling in reducing waste of material from the project implementer and in the field, the waste of material for reinforcing bars has been mixed with all materials, so there are no particular details for specific waste of material. The project implementer does not know for sure how much waste of material, as shown in Figure 1.

Waste of rebar material directly impacts operational costs, so this can be a paramount concern. This is also based on considering environmentally friendly insights, simple technology, and cost [4,5].

Fig. 1 Waste of material

In determining the calculation of iron reinforcement requirements, using the Bar Bending Schedule method. The method is easier to use because its application in the calculation process is very detailed. The Bar Bending Schedule (BBS) method calculates the length of iron needed, the amount of reinforcing iron used, and the total weight of all iron applied to a structure.

This Bar Bending Schedule method is expected to facilitate the work of construction management in calculating the need for reinforcing iron to the maximum so that there is no excess material waste; it can optimize costs and time when work is in progress.The objectives to be achieved in this study are to determine the need, the percentage of waste of material against the need for iron reinforcement based on calculations with the Bar Bending Schedule (BBS) method, as well as the results of the difference between the need for iron reinforcement in the field with the need for iron reinforcement based on the calculation method.

2. Materials and Methods

2.1. Construction Project Management

Project management is an application of science, expertise, and skills in organizing the best technical means with limited resources to achieve the goals and objectives determined to get optimal results in terms of cost, quality time performance, and work safety [6]. Generally, the public recognises three management functions or stages: planning, scheduling, and controlling. Project management can be said to be successful if it has achieved goals that can be identified in terms of timeliness and cost accuracy; following the proper performance and technology level, there are only minor changes to the scope of work, effectiveness and efficiency in resource utilization, and accepted by the Owner (quality conformity) [6].

2.2. Construction Materials

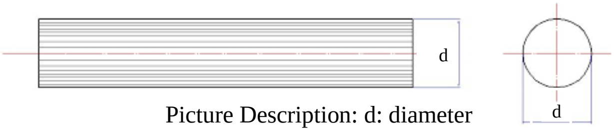
Material is obtained from local purchases, imports or own processing, which is then processed by industrial companies into raw materials or a product or item made from several materials that are put together so that a product becomes a valuable definition of material [7, 8].

A quality construction product results from choosing quality construction materials. Construction materials can be obtained from any source. However, the procurement of building materials must be regulated and utilized effectively because if the procurement of materials occurs excessively, it can create cost overruns, and costs can be used for other work [9].

2.3. Concrete Iron (Rebar)

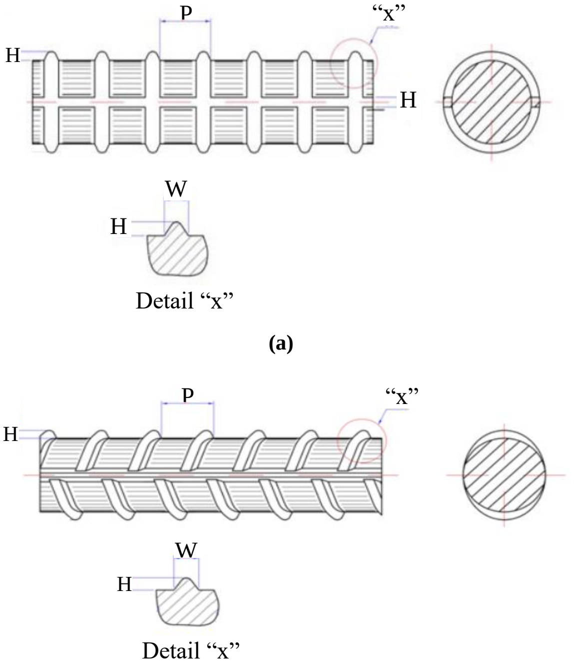
Concrete iron, also known as substantial reinforcing steel, reinforces the strength of construction structures. Steel in concrete reinforcement is produced through hot rolling with a billet base material, which is then formed into round bar-shaped steel [10]. Concrete is weak in resisting tensile forces without cracking; this makes concrete need reinforcement strength assistance to increase the strength of tensile forces caused by loads arising in a system [11]. Iron exposed to a heat source will receive more heat than closed iron. Therefore, it is necessary to know that when the outside of the rebar is burned, the temperature is not always the same as the temperature of the rebar in the closed part [12].

The types of rebar can be divided into two based on their shape, namely: (1) Plain Concrete Reinforcing Steel (BjTP) and (2) Threaded Concrete Reinforcing Steel (BjTS), as shown in Figures 2 to 3.



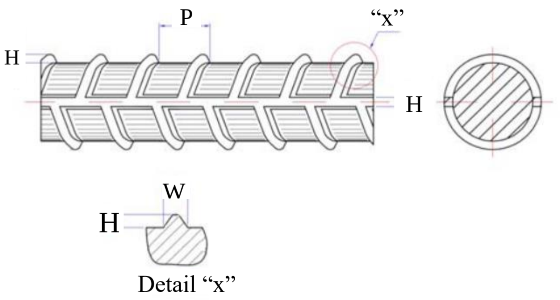
Picture Description: d: diameter

Fig. 2 Plain concrete rebar steel (BjTP)



(a)

(b)



Picture Description :
H : fin/thread height
P : transverse fin/thread spacing
W : fin width/longitudinal thread
T : Gap/rib

(c)

Fig. 3 Concrete reinforcing steel threads (a) Bamboo fins, (b) Steep fins, (c) Fish fins

2.4. Analysis of Reinforcement Requirements

There are several variables needed in the calculation process of analyzing the need for reinforcing iron, such as the dimensions of reinforced concrete, the amount of reinforcement, the length of the support, the diameter of the reinforcing iron, and the specific gravity of the support by the diameter of the iron used. For the calculation of concrete support, it is calculated based on the weight in kg or tons [10]. In addition, reinforcement details such as anchorage lengths, bends, hooks, joints, standard hooks, a minimum inner diameter of bends, seismic hooks angles, etc., are also required.

2.5. Reinforcement Work

The dominant factor causing the phenomenon of material residues during the implementation of construction projects in Aceh province is the residual factor with the indicator needle error when cutting materials [13].

Reinforcing iron is an essential component in the strength of the structure; considering this, the reinforcement work has a significant role in the quality aspect of its implementation. Reinforcement work includes cutting, bending, and installing reinforcement. Reinforcement work indeed cannot be separated from the role of tool composition.Each concreting work has its process; the iron bending work requires one pair of bar bender tools to bend the concrete iron, which is quite long in size, and the cutting work also requires a bar cutter.

In the bending and cutting work, using tools is beneficial in speeding up the implementation process. The reinforcement installation process is usually carried out by human resources or labor whose installation is adjusted to the plan on the working drawings.

2.6. Residual Material

Residual material is any material that comes from natural parts of the earth that are moved and processed to a place so that it can then be used in the construction process either at a location or between locations with various kinds of possibilities that can be caused such as damage, excess, unused, not following with the results of specifications or the results of the construction work process [2,14,15]. The remaining material cannot be used/wasted /inefficient in the consequences resulting from equipment, materials, labour, or costs in large enough quantities, which are then considered in the development process [16-19].

Construction waste has been shown to harm the budget situation of construction companies and the environment. Construction waste management is an aspect that will help the country develop sustainably. Applying waste management theories will reduce environmental and social impacts and bring economic benefits to businesses [20-22,28]. Calculating the remaining material comes from comparing the material planning before the work and the remaining material when completing the work [21]. Some issues that cause the remaining material are design changes or inappropriate construction methods [14,29].

2.7. Method of Calculation of Reinforcement Requirements

2.7.1. Manual Approach Method

The approach method, or what can be called the manual method, is a method that is based on direct observation in the field. Field observations are made to observe how cutting iron in the area occurs. Observation of the iron-cutting process is also helpful for obtaining the number of iron reinforcement requirements in this manual method. This method is usually required to observe more than one project because this method, in addition to getting the number of iron reinforcement requirements, will also see which iron cutting pattern produces less waste of material. Then, after the calculation of reinforcement requirements, the cutting pattern is also calculated first so that it can be applied in the field [3].

2.7.2. Bar Bending Schedule Method (BBS)

This method can help reduce the amount of residual material wasted. This BBS method can direct iron cutting according to the reinforcement work's needs [22]. The calculation of reinforcement using the Bar Bending Schedule (BBS) method requires more detailed data to produce a seasonably accurate quantity requirement. The BBS is a method for determining the length of each iron needed, the amount of reinforcing iron used, and the total weight of all iron applied to a building structure [22,23]. The BBS method produces an iron quantity in bar units, then converted to weight units. The calculation process uses the SNI 2847-2019 reference based on the shop drawing data previously approved by the planner [23].

2.7.3. Linear Programming Method

Linear Programming is a tool used to solve the optimization problem of a linear model with the limitations of available resources. The Linear Programming method solves problems using linear equations or inequalities with many solutions by paying attention to the existing conditions to obtain an optimum solution (maximum or minimum value).

In general, preparing the Linear Programming method involves three crucial essential components: the objective function, constraint function, and decision variables. Based on research by Novita, Ulfiyati, and Hardiyanti in 2021, the Linear Programming method can save on material waste by 21.56%. The total iron saved is 23.46% [24] and 23.9% [25].

2.8. Method

The problem raised in this study is to analyze the calculation of iron reinforcement requirements using the BBS method to minimise material waste. So, at the end of the research, the results of the difference between the calculation of the need for iron reinforcement using the BBS method and the need for iron reinforcement based on observations and interviews in the field and secondary data provided by the project are obtained.

The comparison of the difference obtained will prove whether the calculation method used in the research can minimize material waste. In the process of this research method, first analyzing the plan drawings and then calculating the need for iron reinforcement using the BBS method to minimize waste of material in the work of iron.

Primary data is obtained based on direct review and observation in the field in the form of interviews with workers or parties concerned regarding how the work of iron is carried out in the area, how to handle the remaining material arising in the work of iron, and to find out how much the need for iron reinforcement has been used in the area as far as the construction stage.

Secondary data include shop drawing data for detailed reinforcement planning and data on the volume of reinforcing iron used in the Guntung Payung Public Health Center Construction Project. This data is obtained from the contract document on the contractor as the executor of the project under review.

3. Results and Discussion

3.1. Reinforcing Iron Requirements for the Project

Secondary data from the Guntung Payung Public Health Center Construction Project in the form of volume of iron reinforcement with diameters of 10 mm, 16 mm, and 8 mm, as shown in Table 1.

Table 1. Recapitulation of the volume of 10mm, 16mm and 8mm diameter iron reinforcement used

Description	The Volume of 10 mm Diameter Iron (Kg)	The Volume of 16 mm Diameter Iron (Kg)	8 mm Diameter Iron Volume (Kg)
Column K1	7,298.09		
Column K2	1,797.55		
Beam B1a	3,804.26		
Beam B2	8,123.73		
Beam B3	1,642.94		
Beam B4	4,541.61		
Beam S1	1,566.36		
Foundation P1		1,551.84	
Foundation P2		3,282.96	
Practical Column			2,257.64
Letai Beam			1,727.56
Beam S2			1,206.64
Total	28,774.54	4,834.80	5,191.84

3.2. Data Processing

In this research, the reinforcement work to be studied is limited to cutting reinforcing iron for stirrup reinforcement in beam and column reinforcement. From the results of reading the project development plan drawings, the amount of iron reinforcement procurement is obtained for the work of stirrup reinforcement in beam and column reinforcement, which then afterwards will calculate the amount and length of iron to be cut in the use of stirrup support in beam and column reinforcement using Ms Excel [26]. So that it will get the final result of the previous calculation in the form of amount of iron that is needed along with percentage of waste so that it will get the final result of the previous calculation in the form of the amount of iron that will be needed along with the percentage of waste of material; it will be compared with the amount of iron that has been used in the field to obtain the final result in the form of comparison results and the percentage of waste of material for work on stirrup reinforcement in column and beam reinforcement.

3.3. Iron Requirement with Bar Bending Schedule Method

For the need for stirrup reinforcement iron in beam and column reinforcement, the calculation will be based on secondary data obtained from the Guntung Payung Public Health Center Building Construction Project, namely in a plan or shop drawing. The calculation steps are (1) calculating the length of the column or beam and (2) calculating the reinforcement requirements in units of pieces, volumes, and pieces.

The following is an example of the calculation of stirrup reinforcement requirements for column K1. A picture of the cross-section of the reinforcement in column K1 reinforcement can be seen in Figure 4.

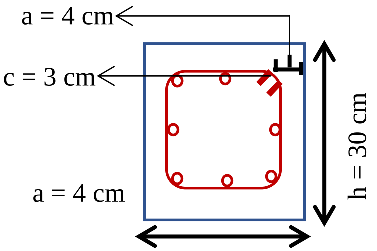


Fig. 4 Cross section of reinforcement in column k1 reinforcement

- Length of stirrup reinforcement

$$L = \{(h-a)+(b-a)+c\}\times 2 \quad (1)$$

$$L = \{(30-4)+(30-4)+3\}\times 2 = 110\ cm$$

- Number of stirrups

In stirrup reinforcement, there are two placement areas: The pedestal area and the field area.

$$\text{Pedestal Section} = \frac{(L\times 1/4)\times 2}{s} \quad (2)$$

$$= \frac{(4\times 1/4)\times 2}{0.10} = 20 \text{ pieces}$$

$$\text{Field Section} = \frac{(L\times 1/2)}{s} \quad (3)$$

$$= \frac{(4\times 1/2)}{0.15} = 14 \text{ pieces}$$

- Number of pieces

In this section, calculations will be made to obtain pieces based on the number and length of stirrup reinforcement that has been calculated previously. The analysis of this part is taken from a whole iron reinforcement sold in the market, namely with an iron reinforcement length of about 12 m, which will then be divided by the size of the stirrup reinforcement that has been calculated previously. Then, after getting a piece that matches the amount and length of support estimated previously, the remaining length of the iron reinforcement used can be seen.

$$Number\ of\ Pieces = \frac{reinforcement\ length\ per\ bar}{stirrup\ reinforcement\ length} \quad (4)$$

$$= \frac{1200\ cm}{110\ cm} = 10\ pieces$$

Ten pieces were obtained for a stirrup reinforcement length of 110 cm, with the remaining length of the iron reinforcement 100 cm. The rest of the pieces will then be reused in the following sufficient calculation, namely in the calculation of Column K2, so the rest of the material has been well optimized. The calculation of the needs and remaining reinforcement requirements for Column K1, it can be seen in Table 2. The same analysis is also carried out for 16 mm, and 8 mm diameter iron.

After calculating the BBS method for iron reinforcement requirements, the results are obtained in the form of the total number of pieces, volume of reinforcement required, the volume of the remaining material, the entire length of support used, and the total volume of the remaining reinforcing iron material. The recapitulation of the calculation results is shown in Table 3-5.

Based on Table 6, it can be seen the comparison between the volume of stirrup reinforcement requirements in the project, and the volume of stirrup reinforcement requirements calculated using the Bar Bending Schedule method. As shown in the table, the results of the importance of research data on the project are more significant than the results of the calculation data done.

This is because the calculation of reinforcement requirements with the Bar Bending Schedule method can utilize the remaining pieces of iron reinforcement to be reused for sufficient needs to be reused, while in the project the rest of the iron reinforcement in the process is discarded or not reused so that it becomes the remaining material that accumulates in the project, but the calculation for the volume of needs is still calculated based on how much iron reinforcement is used up as a whole (the remaining pieces of iron reinforcement are also counted).

Reducing material waste will not only improve project performance and increase value for individual customers, but also positively impact the national economy [27-31].

Table 2. Example of bar bending schedule calculation table for column K1 diameter 10 mm

No. Code	**Length (cm)**	**Quantity (Piece)**	**Diameter (mm)**	**Volume (Kg)**	**Retrieved**			**Remaining Pieces**			
					Quantity (Piece)	**Length (cm)**	**Quantity (Piece)**	**Residual (cm)**	**Description**	**Remaining Quantity (Piece)**	**Volume (Kg)**
K1A No.01 Pedestal	110	20	10	13.57	1	1200	10	100	Moved to K2A No.01 Pedestal	-	-
				-	1	1200	10	100	Moved to K2A No.01 Pedestal	-	-
K1A No.01 Field	110	14	10	9.50	1	1200	10	100	Move to K2A No.01 Field	-	-
				-	1	1200	4	760	Move to K1A No.02 Pedestal	-	-
K1A No.02 Pedestal	110	20	10	13.57	1	760	6	100	Move to K2A No.01 Field	-	-
				-	1	1200	10	100	Move to K2A No.02 Pedestal	-	-
					1	1200	4	760	Moved to K1A No.02 Field	-	-
K1A No.02 Field	110	14	10	9.50	1	760	6	100	Move to K2A No.02 Pedestal	-	-
					1	1200	8	320	Move to K1A N0.03 Pedestal	-	-

Table 3. Number of remaining pieces of reinforcing bars at 10 mm diameter

Part Name	**Remaining Pieces of Each Length (Piece)**										**Remaining Quantity (Piece)**	**Residual Volume (Kg)**	**Residual Volume (%)**
	10 cm	20 cm	30 cm	40 cm	50 cm	60 cm	70 cm	80 cm	90 cm	100 cm	1	1	1
Column 1	-	4	-	-	-	-	-	-	-	113	117	70.4	1.33
Column 2	147	-	92	-	-	-	-	1	-	-	240	26.59	3.52
Beam B1a	-	-	-	-	-	-	-	-	-	-	-	-	-
Beam B2	184	-	396	-	-	2	-	-	-	-	582	89.65	3
Beam B3	-	-	86	-	-	-	1	1	-	-	88	16.84	2.62
Beam B4	-	-	-	-	-	3	-	-	-	-	3	1.17	0.05
Beam S1	-	13	58	10	15	13	16	10	16	-	151	57.32	4.27
Total												261.97	14.79

Table 4. Number of remaining pieces of reinforcing bars at 16 mm diameter

Part Name	Remaining Pieces of Each Length (Piece)										Remaining Quantity (Piece)	Residual Volume (Kg)	Residual Volume (%)
	10 cm	20 cm	30 cm	40 cm	50 cm	60 cm	70 cm	80 cm	90 cm	100 cm			
Foundation P1	-	-	-	-	-	-	-	-	-	-	-	-	-
Foundation P2	10	-	47	-	46	-	81	-	-	-	184	164.27	6.56
Total												164.27	6.56

Table 5. Number of remaining pieces of reinforcing bars at 8 mm diameter

Part Name	Remaining Pieces of Each Length (Piece)										Remaining Quantity (Piece)	Residual Volume (Kg)	Residual Volume (%)
	10 cm	20 cm	30 cm	40 cm	50 cm	60 cm	70 cm	80 cm	90 cm	100 cm			
Practical Column	-	-	-	-	-	-	-	-		-	-	-	-
Letai Beam	-	1	-	-	-	-	-	-	-	-	1	0.08	0.01
Beam S2	-	-	-	-	-	-	-	-	-	-	-	-	-
Total												0.08	0.01

Table 6. Comparison of iron reinforcement requirement volume and residual volume

Diameter of Reinforcing Iron	Volume of Iron Reinforcement Requirements Based on Secondary Data (Kg)	Volume of Iron Reinforcement Requirements Based on Calculation with BBS Method (Kg)	Residual Volume BBS Method (%)
10 mm	28,474.54	15,077.37	14.79
16 mm	4,834.80	3,352.3	6.56
8 mm	5,191.84	1,607.81	0.01
Total	38,501.18	20,037.48	
Difference	18,463.70		

4. Conclusion

The volume of threaded iron requirements with the Bar Bending Schedule method with a diameter of 10 mm is 15,077.37 kg than for iron reinforcement with a diameter of 16 mm is 3,352.3 kg and 1,607.81 kg for plain iron reinforcement with a diameter of 8 mm. The difference in the total amount of reinforcement requirements with both methods is 38,501.18 kg. The Bar Bending Schedule method optimises the waste of material so that it only leaves material in the screw type iron reinforcement of around 14.79% for the entire calculation of the need for 10 mm diameter iron reinforcement and 6.65% for 16 mm diameter iron reinforcement. For plain iron reinforcement, it only leaves material around 0.01% in 8 mm diameter iron reinforcement. The comparison results show that the difference regarding the need for reinforcement is quite significant. This shows that the Bar Bending Schedule method can optimize the remaining material from the remaining length of the iron piece by reusing it for other plans where the piece's dimensions can meet the previous rest.

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