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Comparison of Reinforcement Waste of Columns and Beams in the Ditsamapta Building North Sumatra Regional Police Using Conventional Method and COP

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ABSTRACT

Material efficiency is a critical issue in construction projects, as material costs account for approximately 40–60% of the total project budget. One of the major contributors to material waste is reinforcing steel, which often generates excess waste due to inaccurate cutting patterns and manual calculation methods. Conventional reinforcement planning using a Bar Bending Schedule (BBS) is still widely applied; however, this approach is considered less optimal in minimizing waste. Therefore, optimization techniques are required to improve material utilization and reduce reinforcement waste. This study aims to compare the percentage of reinforcement steel waste generated using the conventional Bar Bending Schedule method and Cutting Optimization Pro (COP) software. The research adopts a quantitative comparative approach, using primary data obtained from field observations and secondary data derived from shop drawings of the Ditsamapta Office Building Project of the North Sumatra Regional Police. Reinforcement requirements for columns and beams were calculated using the BBS method, while COP software was applied to generate optimized cutting patterns based on standard bar lengths. Waste percentages were determined by comparing unused reinforcement against total material requirements for each method. The results indicate that the conventional method produced reinforcement waste of 14.102% for Ø8, 9.480% for Ø10, 8.385% for D10, 10.444% for D12, and 9.500% for D16. In contrast, the use of COP software significantly reduced waste to 2.888% for Ø8, 1.855% for Ø10, 8.087% for D10, 6.980% for D12, and 5.756% for D16. Overall, COP reduced reinforcement waste by approximately 5% compared to the conventional method. These findings demonstrate that Cutting Optimization Pro is more effective in minimizing reinforcement waste, improving material efficiency, and supporting cost control and sustainability in building construction projects.

I. Introduction

In construction projects, the use of materials by workers on site can lead to deviations in the form of waste. Waste can be defined as leftover material that is no longer used or has been discarded from a particular process or activity [1]. In other words, waste is an unwanted by-product that remains after a process [2]. Construction material waste accounts for approximately 15–25% of urban solid waste [3]. Waste in construction projects refers to leftover materials that can no longer be reused, whether from new work, repairs, or modifications. Reinforcement waste generally occurs due to reinforcement design characteristics or excessive steel procurement, making accurate calculation of reinforcement requirements essential. The main cause of waste is design changes that result in suboptimal reinforcement cutting patterns, with these patterns being the most influential factor contributing to material waste [4]. The preparation of a bar bending schedule is one of the efforts to control reinforcement waste. A bar bending schedule is a table that contains the detailed specifications and quantities of reinforcement steel, and its application facilitates more accurate ordering of materials [5]. However, this method is still considered less optimal in generating reinforcement cutting patterns, as the resulting waste remains high [6]. To minimize material waste,

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Cutting Optimization Pro (COP) software is utilized, which provides output in the form of the most efficient reinforcement cutting patterns.

From a functional perspective, the calculation of waste percentages plays a crucial role in project sustainability, as the high level of reinforcement waste indicated by the bar bending schedule reflects potential inefficiency particularly when relying on conventional or manual methods that are time-consuming and prone to control errors [7]. Waste control also remains weak under such conventional practices, since it depends solely on field workers and often leads to excessive waste caused by design changes or cutting errors; moreover, material management efforts alone have proven less effective, as they do not address on-site working methods or cutting patterns [8]. To address these issues and minimize reinforcement waste, the use of Cutting Optimization Pro (COP) software is introduced, providing optimized cutting patterns that maximize material efficiency [6].

The construction of the Ditsamapta Office Building of the North Sumatra Regional Police, with a land area of 5,835 m², has so far calculated reinforcement requirements only in terms of material quantity without taking potential waste into account. In fact, reinforcement control significantly affects scheduling, costs, profitability, and structural quality. Reducing trim loss not only benefits the environment but also increases project profitability [3]. Therefore, a comparison of waste calculations between the bar bending schedule method and optimization using Cutting Optimization Pro (COP) software is carried out to obtain more efficient reinforcement cutting patterns and minimize material waste. Additionally, this method helps reduce the volume of waste and mitigate its negative environmental impact [9].

This study aims to maximize the control of reinforcement steel waste in the Ditsamapta Building Project of the North Sumatra Regional Police by comparing beam reinforcement waste calculated using the conventional method and Cutting Optimization Pro software, in order to obtain the most optimal beam reinforcement cutting pattern.

II. Method

A. Location and Time of Research

The research was conducted at the Ditsamapta Building Project of the North Sumatra Regional Police (Polda Sumut). This location was chosen as the research object to analyze the calculation of waste material generated during the construction process. The study focused on identifying and calculating the amount of reinforcement waste material in structural elements such as beams and columns. The research was carried out throughout the construction phases until the required data were completely collected.

B. Specification

The data obtained from the Shop Drawing contains detailed information regarding the building structure. In the case of the Ditsamapta Office Building Project of the North Sumatra Regional Police, the data includes columns and beams, which are presented in the following tables.

1. Columns

Table 1. Specifications of Column Data on the First Floor

Type	Column Dimension Data			
	Dimension (cm)			Quantity
	Width	*Height*	*Length*	
K1 40/40	*40*	*40*	*420*	40
K2 30/40	*30*	*0*	*420*	4
KL 15/15	*15*	*15*	*420*	13

Table 2. Specifications of Column Data on the Second Floor

Type	Column Dimension Data			
	Dimension (cm)			Quantity
	Width	*Height*	*Length*	
K1 40/40	*40*	*40*	*380*	40
K2 30/40	*40*	*30*	*380*	4
KL 15/15	*15*	*15*	*380*	12

2. Beams

Table 3. Specifications of Column Data on the First Floor

Type	Beams Dimension Data		
	Dimension (cm)		
	Width	*Height*	*Length*
B1 40/25	*40*	*25*	*29000*
B2 40/20	*40*	*20*	*6000*

Table 4. Specifications of Column Data on the Second Floor

Type	Beams Dimension Data		
	Dimension (cm)		
	Width	*Height*	*Length*
B2 40/20	*40*	*20*	*21480*

C. Stages in Research

The research method applied in this study is a quantitative approach with a comparative design, aiming to evaluate and compare reinforcement waste calculations using the conventional method and Cutting Optimization Pro software. The data used in this study consist of primary data obtained from field observations of materials available at the construction site, and secondary data derived from shop drawings. The flow process method can be seen in the Figure 1.

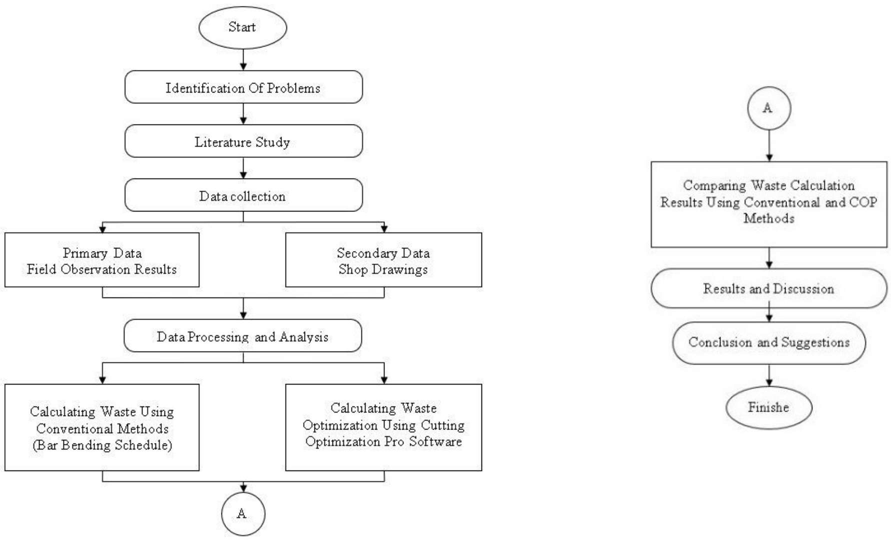

Fig 1. Flow process method.

This study applies two approaches to calculate the reinforcement requirements, namely the conventional method (Bar Bending Schedule/BBS) and the Cutting Optimization Pro (COP) software. The BBS method is carried out by calculating the reinforcement requirements of beams, columns, and floor slabs based on the structural drawings, then preparing a table containing the type, diameter, length, number of bars, and the total reinforcement needed. Meanwhile, the COP method is performed by inputting the standard bar length and the required cutting list into the Cutting Optimization Pro software to obtain the most efficient cutting pattern. The stages of the research are as follows:

- Consultation, discussing with the academic supervisor regarding the research design and the calculation methods of reinforcement waste to be compared.
- Calculation Using the Conventional Method (BBS), calculating reinforcement requirements based on structural drawings to obtain an estimate of material usage and potential waste.
- Drawing Analysis, reviewing the structural drawings to identify the types, sizes, material specifications, design details, and other technical information required.
- Simulation Using COP Software, entering the cutting list and the standard bar length into COP to generate the optimal cutting pattern.
- Comparative Analysis, comparing the results of reinforcement waste calculations between the BBS and COP methods to assess material efficiency.

Verification and Evaluation, verifying the results of both methods, identifying differences in waste, and concluding the advantages and disadvantages of each approach.

III. Findings and Discussion

A. Results of the reinforcement requirement calculation based on the Bar Bending Schedule

Bar Bending Schedule (BBS) is a list of reinforcement requirements that includes information on bar diameter, shape, length, and quantity [10]. The calculation of reinforcement requirements using the Bar Bending Schedule (BBS) has been carried out, and the results are summarized in the following table. The data includes the diameter, total length, quantity, unit weight, and total weight of reinforcement needed for the project. The results are presented in the following table, based on the column and beam data shown in Table 5.

Table 5. Total Reinforcement Requirement Results

Total Requirements					
Length (mm)	***Quantity***	***Diameter (mm)***	***Total Length (m)***	***Unit Weight (kg/m)***	***Total Weight (kg)***
12000	1391	8	16691.885	0.395	6585.950
12000	383	10	4591.781	0.617	2833.434
12000	797	10	9565.840	0.617	5897.340
12000	78	12	932.237	0.888	830,943
12000	662	16	7938.172	1.578	12528.340
				Total	***28676,008***

D. Discussion

The initial step carried out is calculating the reinforcement steel requirements and classifying them according to their length, diameter, and quantity used. This calculation was performed by the author using Microsoft Excel software, based on the detailed drawings mentioned earlier. The calculation results of the reinforcement steel requirements are as follows:

1. Column Reinforcement Calculation for Type K1

The calculation of column reinforcement requirements aims to determine the number of bars, the length of reinforcement, the total length of all bars, as well as the quantity of reinforcement used in the structural elements. With precise calculations, material requirements can be accurately predicted, allowing construction planning to be more efficient and in accordance with technical standards.

The length of the main reinforcement is calculated by adding the column height and the lap splice length, which is generally specified as 40 times the bar diameter.

$$L = H_{column} + \text{overlap}$$

L = 4,2 + (40 × bar diameter) L = 4,2 + (40 × 0,016) = 4,84 m

The stirrup length is obtained by considering the effective dimensions after deducting the concrete cover, along with additional bends:

L = ((l−2c) + (w−2c) × 2) + 5× (4×d) + 2 × (6×d)

L = (((0,40 m) – (2 x 0,04 m) + (0,40 m) – (2 x 0,04 m)) × 2) + 5 × (4 × 0,01 m) + 2 × (6 × 0,01 m) = 1,76 m

Total length of reinforcement:

- *Main Reinforcement*
  L_{total} = L × N
  L_{total} = 4,84 meter × 320 units
  L_{total} = 1548,8 meter

- *Stirrups*
  L_{total} = L × N
  L_{total} = 1,76 meter × 1160 units
  L_{total} = 2041,6 meter

Total Weight of Reinforcement:

- *Main Reinforcement*
  $W_{total} = w_{nominal} \times L_{total}$
  W_{total} = 1,58 Kg/m × 1548,8 m
  W_{total} = 2447,104 Kg

- *Stirrups*
  $W_{total} = w_{nominal} \times L_{total}$
  W_{total} = 0,62 Kg/m × 2041,6 m
  W_{total} = 1258,646 Kg

Number of Bars Required:

- *Main Reinforcement*

$$N_{bars} = \frac{L_{total}}{L_{bar}}$$

$$N_{bars} = \frac{1548{,}8}{12} = 130\ bars$$

- *Stirrups*

$$N_{bars} = \frac{L_{total}}{L_{bar}}$$

$$N_{bars} = \frac{2041{,}6}{12} = 170\ bars$$

At this stage, the calculation of reinforcement requirements was carried out using the K1 type as a sample. The same procedure was then applied to all structural element types until the overall requirements were obtained. The results of these calculations were subsequently summarized into a total reinforcement requirement, as presented in Table 5.

E. Method of Using Cutting Optimization Pro (COP)

Cutting Optimization Pro is a software application designed to assist engineers in obtaining optimal cutting layouts for both one-dimensional (1D) and two-dimensional (2D) elements. The program also supports calculations for more complex product cutting patterns. Its implementation is particularly important as it helps minimize material waste while optimizing the utilization of reinforcement materials more efficiently [11].

The procedure for calculating reinforcement waste using the Cutting Optimization Pro (COP) application is carried out systematically as follows:

1. Data Preparation

Reinforcement data were first calculated based on the shop drawing using Microsoft Excel. The dataset included bending schedule, bar label, quantity, diameter, cutting length, total length, and total weight.

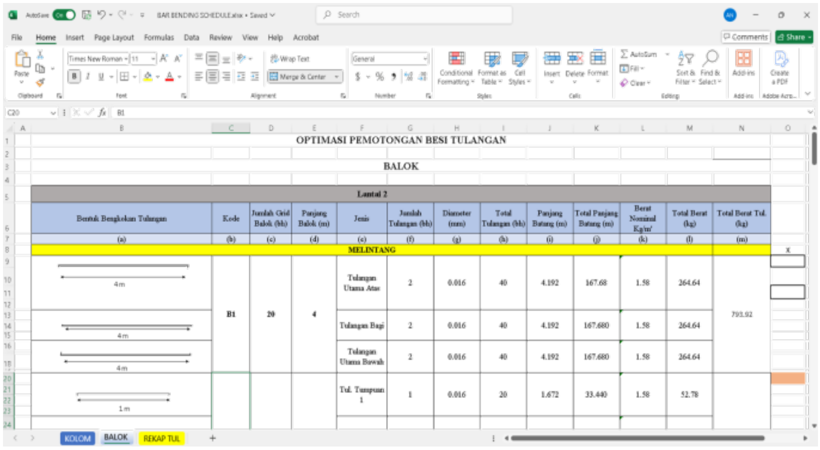

Fig 2. Data preparation

2. Input of Demand Data

The calculated reinforcement requirements were entered into the COP software in the Demand section. The input consisted of length, quantity, bar type (diameter), and label. Since reinforcement bars do not have width, the width field was set to zero. For wire mesh, both length and width were adjusted accordingly.

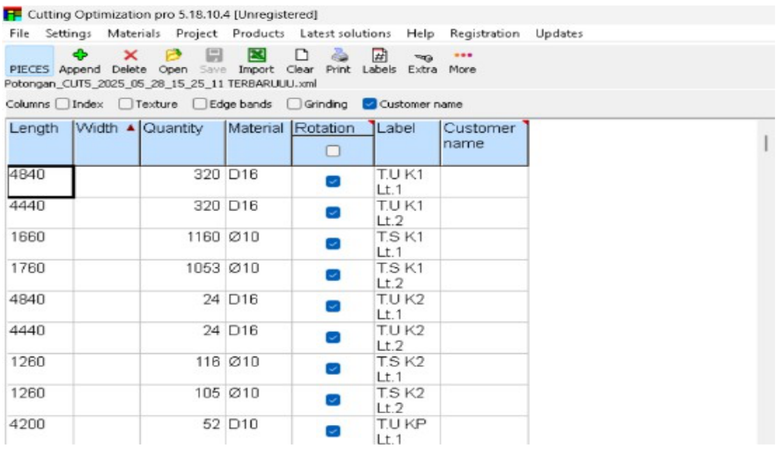

Fig 3. Input of Demand Data

3. Input of Stock Data

The Stock section was then filled with available reinforcement materials in the warehouse. The stock quantity was set higher than the demand to ensure feasibility during the optimization process.

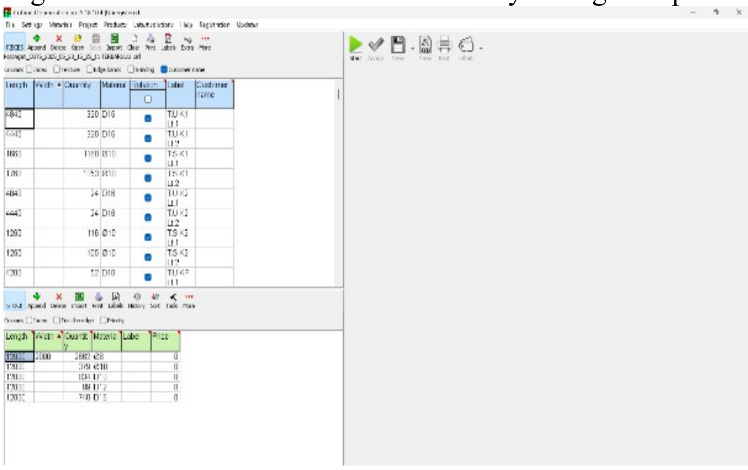

Fig 4. Input of Stock Data

4. Optimization Process

The optimization was executed by clicking the “Start” option. The program generated cutting patterns that minimized waste. If the stock was insufficient, the software indicated this with a warning, and the stock data were adjusted until demand was fully satisfied.

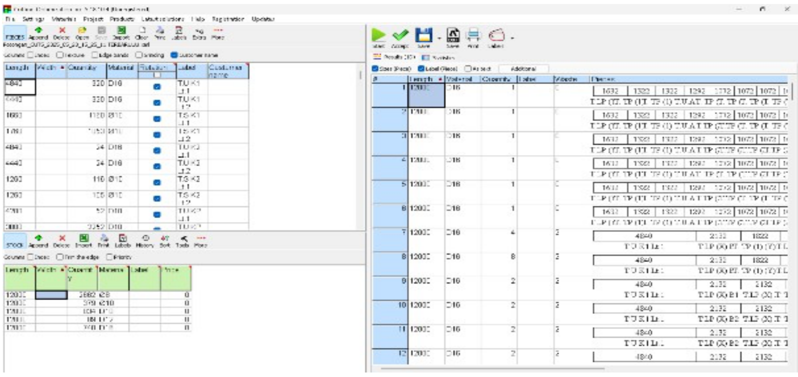

Fig 5. Optimization Process

5. Finalization

After the optimization was complete, the demand data were automatically updated, and the remaining stock was recorded in the warehouse section. The optimized cutting patterns were then saved for documentation and further analysis.

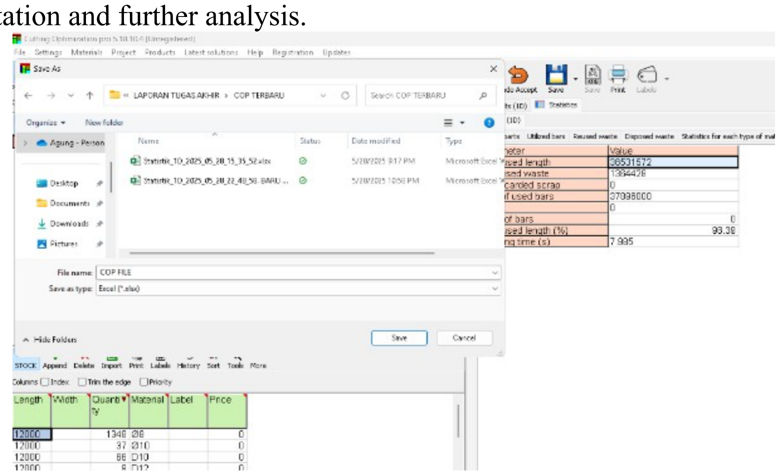

Fig 6. Save data option

D. Results of Reinforcement Requirements Using COP Software

The calculation of reinforcement requirements was carried out using the Cutting Optimization Pro (COP) software to obtain the installed reinforcement data. The results are presented in tabular form, including quantity, cutting length, total length, and weight of reinforcement, as shown in Table 6. This dataset serves as the basis for evaluating material efficiency between the conventional method and the software-assisted method.

Table 6. Results of Reinforcement Requirements Using COP Software

No.	Diameter	Bar Length (m)	Quantity (pcs)	Nominal Weight (kg/m)	Total Weight (kg)
1	Ø8	15601	1300.1	0.37	5772.471
2	Ø10	4057	338	0.62	2515.551
3	D10	8776	731	0.62	5441.120
4	D12	847	71	0.89	752.366
5	D16	7249	604	1.58	11441.407

E. Results of Waste Analysis Using Conventional Method and COP

The percentage of waste was determined by comparing the theoretical reinforcement requirements with the actual cutting results in each method. The conventional method generally produced higher waste due to non-optimized cutting patterns, whereas COP minimized waste through more efficient cutting arrangements. The outcomes are presented in comparative tables for each bar diameter, as shown in Table 7.

Table 7. Total Reinforcement Requirement Results

No	Diameter	Quantity (pcs)	Required Volume (kg)	Installed Volume (kg)	Waste Volume (kg)	Waste Level %
			Metode Konvensional			
1	**Ø8**	1300	6585,950	5771,960	813,990	14,102
2	**Ø10**	348	2833,434	2588,095	245,339	9,480
3	**D10**	731	5897,340	5441,120	456,220	8,385
4	**D12**	71	830,943	752,366	78,577	10,444
5	**D16**	604	12528,340	11441,407	1086,934	9,500
	Total	3054	28676	25995	2681	51,911
					Average	**10,382**
			Cutting Optimization Pro			
1	**Ø8**	1314	5939	5772,471	166,728	2,888
2	**Ø10**	342	2562	2515,551	46,660	1,855
3	**D10**	768	5881	5441,120	440,000	8,087
4	**D12**	75	805	752,366	52,512	6,980
5	**Besi D16**	659	12100	11441,407	658,528	5,756
	Total	3158	27287	25923	1364	25, 565
					Avarage	**5,113**

F. Discussion

The calculation of reinforcement waste was analyzed using two different methods: the conventional approach and the Cutting Optimization Pro (COP) software. Waste percentage is calculated as the ratio of the unused reinforcement volume to the total reinforcement requirement, expressed as a percentage.

1. Conventional method

$$Waste\ (\%) = \frac{\sum Vol.Waste\ (kg)}{\sum Vol.Required\ (kg)} x100\%$$

$$Waste\ (\%) = \frac{2681}{28676} x100\%$$

$$Waste\ (\%) = 10{,}382\%$$

2. *Using the Cutting Optimization Pro Program*

$$Waste\ (\%) = \frac{\sum Vol.Waste\ (kg)}{\sum Vol.Required\ (kg)} x100\%$$

$$Waste\ (\%) = \frac{1364}{27287} x100\%$$

$$Waste\ (\%) = 5{,}113\%$$

IV. Conclusion

This research demonstrates that the conventional method of reinforcement calculation for column and beam structures resulted in an average waste of 10.382%, while the use of Cutting Optimization Pro (COP) was able to reduce the waste to only 5.113%. This significant difference clearly indicates that COP is more effective and efficient in minimizing reinforcement waste compared to the conventional approach. When analyzed by material type, almost all bar diameters showed a substantial reduction in waste with COP, particularly plain bars Ø8 and Ø10, where the waste percentage was reduced by more than half.

Moreover, the overall waste percentages obtained in this study remain within the allowable tolerance limits specified in SNI 7394:2008 on Ready-Mixed Concrete (HSP-Beton), which ranges from 5% to 20%. These findings confirm that the application of COP not only enhances calculation accuracy but also contributes to reducing material waste, lowering construction costs, and supporting efficiency in project management. Therefore, COP can be recommended as a more optimal alternative for reinforcement cutting and scheduling in building construction projects.

In a broader perspective, the results of this research highlight the importance of adopting digital-based optimization tools in modern construction practices. By integrating software such as COP into the planning and execution stages, project stakeholders can achieve higher levels of precision, efficiency, and sustainability. Future studies may further expand on these findings by applying COP to other structural components or comparing its performance with different optimization software, thus providing a more comprehensive evaluation of its long-term benefits for the construction industry.

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