EVALUATION OF REMAINING MATERIALS FOR RAILWAY CONSTRUCTION PROJECT

NI'MAH IZZATI ATIKO PUTRI, DAVID MALAIHOLO, SEPTIANA WIDI ASTUTI*

Departement of Construction and Railway Technology, Politeknik Perkeretaapian Indonesia, Madiun, Indonesia

**Corresponding author: septiana@ppi.ac.id*

(Received: 2 May 2024; Accepted: 10 June 2024; Published on-line: 1 July 2024)

ABSTRACT: This study investigates residual materials in the railway construction project. The Fishbone Diagram method identifies factors causing material waste, while the Waste Hierarchy guides material management by contractors. The remaining materials include spun piles, ballast stopper cover plates, wiremesh, concrete pad anchoring systems, and PVC pipes. The quantities are 1306.5 meters of spun pile, 86 ballast stopper cover plates, 4 wire mesh sheets, and a concrete pad anchoring system with 160 e-clips, 160 insulators, 80 rail pads, and 7 pieces of 6-inch diameter PVC pipe, along with 13 pieces of 8-inch diameter PVC pipe. The largest remaining material costs come from spun piles. Fishbone Diagram analysis categorizes the construction material waste as direct waste. Poor cutting conditions cause waste in spun piles, PVC pipes, and wire mesh. Waste Hierarchy suggests reusing materials where possible, with leftover PVC pipes suitable for recycling into pots or home decorations. Disposal is necessary for non-reusable or non-recyclable materials.

KEY WORDS: remaining construction materials, construction projects, railways, fishbone diagram, waste hierarchy.

1. INTRODUCTION

Improving connectivity and efficiency in the railway sector is a major focus of infrastructure development in Indonesia. As part of this effort, the government has launched a strategic project to construct the Railway Line. This project aims to increase railway capacity, operational efficiency, and regional economic growth. Given the various construction activities involved, including material selection and adoption of state-of-the-art technology, the success of this project is critical.

One of the critical aspects of implementing infrastructure projects like this is the handling of construction material waste. In every construction project, there will be unused materials. These materials are components left over from the construction process, repairs, alterations, or accidents, which can only be directly used with further processing [1]. Historically, research has focused on the construction industry's sustainable use of materials and efficient resource management. Effective use of materials not only impacts the sustainability of the project itself but also contributes to the overall sustainability of the national construction sector.

In the Railway Project, a lot of leftover materials were found both in the field and in the logistics warehouse. Therefore, the study and evaluation of these waste materials are critical. The objectives include identifying sources of waste, measuring the volume of each waste material, and developing solutions and preventive measures for its management. This study aims to provide valuable insights into material management practices, cost optimization, and environmental impact reduction in large-scale infrastructure projects. By answering these questions, we can improve project efficiency and contribute to sustainable construction practices.

2. LITERATURE REVIEW

2.1 Construction Materials

Materials are used in the process of making semi-finished or finished goods. In the context of a construction project, this series of activities aims to build buildings or infrastructure within a specified time, by agreement between the parties concerned, and under applicable regulations. Construction materials generally include all materials needed to complete specific parts of a particular construction project.

Construction materials refer to solid or liquid materials that form buildings and their components according to the desired shape and function. These materials come from various sources, including excavated stone and sand from the earth's layers. Forest materials such as wood and bamboo are obtained from logging, and technological materials undergo processes such as cutting, smoothing, mixing, pressing, and burning manually and mechanically. These materials include concrete, bricks, tiles, and other construction materials. The materials used in construction can be classified into two large parts [2], namely:

a. Consumable material is material that will become a permanent part of the physical structure of the building after the construction process is complete. Examples of consumable materials include cement, sand, gravel, bricks, reinforcing steel, and steel.

b. Non-consumable material is used to support the construction process but will not become a permanent part of the building structure after the process is complete. Examples of this material include scaffolding, formwork, and temporary retaining walls.

2.1.1. Bridge Construction Work

Consists of spun pile work, ballast stoppers, parapet walls, and PVC pipes.

2.1.2. Railway Construction Work

Consists of concrete sleeper anchorage system installation work.

2.2 Material Cost

A project's cost budget can be divided into six main components: materials, labor, equipment, subcontracts, overhead, and profit or risk. Technical planning affects spending in all of these aspects. For example, if material planning involves long-distance transportation, excessive material allocation, or provision of substitute materials of equivalent quality, the total project cost may exceed the initial estimate. Material costs are a significant component in calculating project costs. Material costs can account for around 50-70% of the total project cost. In addition to the purchase price, project owners must consider the costs of storing, shipping, using, and disposing of unused materials [3].

2.3 Material Cost

Construction material remains are processed for use in a project but become leftovers due to damage, excess, or not according to specifications. Construction material remains are divided into two parts [4], namely:

a. Demolition waste: Remains from the demolition of old buildings.

b. Construction waste: Remains from construction or reconstruction, including waste such as concrete, bricks, plaster, wood, tiles, pipes, and electrical components.

Construction waste can be divided into two types [5], namely:

a. Direct waste: Remaining materials that are damaged and can no longer be used, including leftovers from shipping, storage, changes in shape, installation, and cutting.

b. Indirect waste: The remaining materials that cause financial losses and the use of materials exceeding this include Substitution, Production, and Negligence of waste.

Remaining materials in construction are considered losses involving materials, time, and productivity, causing costs without added value to consumers. With proper material management, projects can experience unavailability, material damage, and materials according to specifications. The quantity of waste material will increase as construction progresses, affecting project costs and creating environmental problems. The formula is used to estimate the amount of waste material:

$$Remaining\ volume = Available\ volume - Installed\ volume \quad (1)$$

Meanwhile, to calculate the remaining material costs:

$$Remaining\ cost = Remaining\ volume - Unit\ price \quad (2)$$

2.4 Factors Causing Construction Material Waste

Research in the Netherlands [6] concluded that the sources and causes of construction material waste can be categorized based on the classification made by Gavilan & L. E. Bernold [2], see Table 1:

Table 1. Factors Causing Construction Material Waste

Source	Cause
Design	a. Errors in contract documents b. Incomplete contract documents c. Design changes d. Selection of product specifications e. Selection of low-quality products f. Lack of attention to the dimensions of the products used g. Designers are not familiar with other types of products h. Overly complex drawings i. Lack of adequate information in the drawings j. Lack of synchronization with contractors and lack of knowledge about construction
Material Procurement	a. Errors in ordering, whether excess, shortage, etc. b. Unable to make orders in small quantities
Material Handling	a. Damage due to the transportation process b. Errors in the storage process c. Materials that are not packaged properly d. Throwing away/throwing materials e. Materials sent in a loose/poor condition

	f. Careless handling when unloading materials to be put into the warehouse
Implementation	a. Errors caused by labor b. Equipment that is not functioning properly c. Bad weather d. Worker accidents in the field e. Use of wrong materials that need to be replaced f. Foundation placement method g. The amount of material needed is unknown due to imperfect planning h. Delivery of information on the specifications of the materials to be used is late to the contractor i. Carelessness in mixing, processing, and misusing work materials, and so on j. Inaccurate dimension measurements cause excess volume
Residual	a. Material residue due to the cutting process b. Errors in installing goods due to not mastering the specifications c. Material residue due to the usage process
Other	a. Loss due to theft b. Poor material control in the project and poor management planning for material residue

2.5 Fishbone Diagram Method

A Fishbone Diagram is a graphical method for identifying problems and their causes. This diagram is shaped like a fishbone frame, with the head recording the problem, the fin recording the general cause, and the spine recording the detailed cause.

The steps for compiling a Fishbone Diagram include:

a. Creating a diagram frame: The fish head on the right shows the problem, the fin categorizes the cause, and the spine records the detailed cause.

b. Selecting a problem: The issue is written at the head of the diagram.

c. Identifying causal factors: General factors include humans, materials, management, methods, machines, and the environment (6M).

d. Finding causes in each category: Using brainstorming to identify related causes.

e. Compiling a diagram: Drawing a diagram based on the data that has been collected [7].

2.6 Material Management

Effective material management is needed to minimize material waste in a construction project. This includes detailed and environmentally friendly design, accurate and appropriate material procurement, and careful material handling. Materials must be stored according to their characteristics to prevent damage, and the area around the project must be considered for storing heavy equipment. The implementation of work requires direction, the use of standard equipment, precise measurements, and routine supervision. HR competence involves special training and the use of skilled and experienced workers [8].

2.7 Management of Construction Material Remains

Various materials are used in construction projects, affecting the amount of material waste produced. One approach to managing construction material waste is to apply the waste hierarchy principle [9]. Waste hierarchy refers to the 3R concept:

a. Reduce: Involves preventing the use of materials that produce construction waste and minimizing material waste with good planning.

b. Reuse Reusing material waste that is still suitable. To facilitate the reuse process, the material waste should be classified based on the type of work, such as formwork, wood waste, and casting waste. Reusing the material can reduce the use of new materials in the same project and future projects. Some steps that can be taken to reuse construction waste materials include identifying materials that are still good, planning protection and storage, and discussing them with the contractor, owner, or designer. Subcontractors can also be asked to reuse construction waste materials.

c. Recycle: This involves processing construction waste materials so that they become materials with a quality almost equivalent to new materials. The steps include setting minimum targets for recycling waste materials, identifying recyclable materials, and planning methods or techniques for protecting, handling, storing, or moving recyclable materials.

d. Decision Alternative: Other options include selling materials that have economic value, storing still suitable materials, and disposal as a last alternative [10].

3. RESEARCH METHODS

3.1 Research Framework

The research location was carried out in the Railway Line Construction Project. The research data consists of primary and secondary data. Primary data was obtained through direct observation in the field and interviews with contractors to determine the types and causes of residual materials and the management system applied. Interview sources included logistics, quality control, drafters, HSE, technicians, and field implementers. Secondary data was obtained from the Railway Line Construction Project, including location plans, project schedules, shop drawings, daily/weekly reports, material price lists, and warehouse stock cards.

3.2 Data Processing Methods

a. Calculating the volume of installed material based on shop drawings and daily/weekly reports.
b. Calculating the volume of residual material using Eq. (1).
c. Calculating the cost of residual material using Eq. (2).

3.3 Data Analysis Methods

a. Analysis of Remaining Material: Identifying materials with the most significant residual volume and cost.
b. Fishbone Diagram: Identify the factors causing material waste using 6 causes (design, material procurement, material handling, implementation, residual, and others).
c. Waste Management (Waste Hierarchy): Manage or reduce material waste according to the waste hierarchy principle after analyzing the root cause with a fishbone diagram.

4. RESULTS AND DISCUSSION

4.1 Identification of Work Items

Identification of work items is based on the results of field observations for ±4 months. The selected work items are those whose quantity of remaining materials was directly encountered by the author during the observation.

From the results of field observations, it can be concluded that the sub-works related to remaining material include bridge work (driving piles, ballast stoppers, parapet walls, PVC pipes) and railroad work (installation of concrete sleeper anchorage systems).

4.2 Calculation of Installed Material Volume

The volume of installed material is the volume of material used as a component of building elements. The analysis of this calculation is based on shop drawings and daily project reports.

4.3 Calculation of Purchase or Procurement Volume of Material

The volume of purchase or procurement of material is the quantity of material brought to the project location and ready to use. This volume is calculated based on weekly project reports and data from the logistics party. This report shows the type and quantity of material received or purchased during the project.

4.4 Calculation of Remaining Material Volume and Cost

The remaining material volume is material that is not used or installed in a construction project, see Table 2. This volume is calculated by subtracting the installed material volume from the purchase or procurement volume of the material, see Table 3.

Table 2. Calculation of Residual Material Volume

No.	**Material**		**Unit**	**Material Volume**		
				Procurement x	**Installed y**	**Remaining z = x - y**
1.	Spun Pile		m	4640	3333,5	1306,5
2.	Wiremesh		sheet	421	417	4
3.	Cover Plate Ballast Stopper	Ready Mix Concrete	m^3	63	60,9	2,1
		BjTS D10	bar	971	870	101
4.	Clip		pcs	11572	11412	160
5.	Insulator		pcs	11572	11412	160
6.	Rail Pad		pcs	5786	5706	80
7.	6" PVC Pipe		bar	77	70	7
8.	8" PVC Pipe		bar	313	300	13

4.5 Analysis of Remaining Material

Table 3. Analysis of Remaining Material

No.	Material	Remaining Material Cost (Rp)	Percentage (%)	Cumulative percentage (%)
1.	Spun Pile D60 10-12 m	IDR. 1.242.481.500.00	97.18%	97.18%
2.	BjTS D10	IDR. 10.302.000.00	0.81%	97.99%
3.	8" PVC Pipe	IDR. 9.060.116.00	0.71%	98.70%
4.	Clip	IDR. 6.240.000.00	0.49%	99.18%
5.	6" PVC Pipe	IDR. 3.443.531.00	0.27%	99.45%
6.	Wiremesh	IDR. 2.700.000.00	0.21%	99.66%
7.	Ready Mix Concrete	IDR. 1.764.000.00	0.14%	99.80%
8.	Insulator	IDR. 1.576.000.00	0.12%	99.92%
9.	Rail Pad	IDR. 960.000.00	0.08%	100.00%
	Waste Cost		0.69%	

4.6 Analysis of Factors Causing Remaining Material

The factors causing the remaining material and its percentage were obtained from interviews with contractors, including procurement supervisors, HSE, quality control, field implementers, drafters, and mechanical technicians. The Fishbone Diagram method is used to describe and explain the causes of the problem in detail, see Fig. 1 until 5.

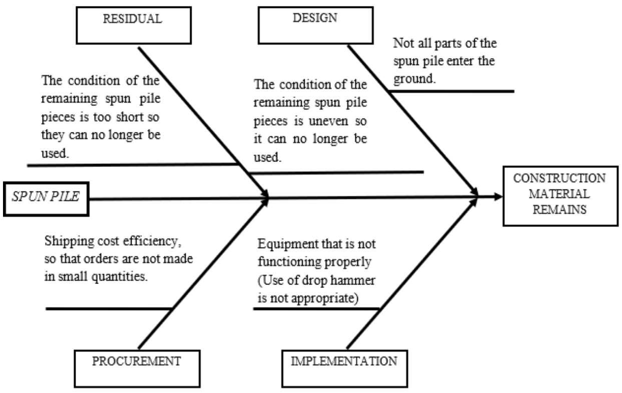

Fig. 1. Fishbone Diagram of Spun Pile

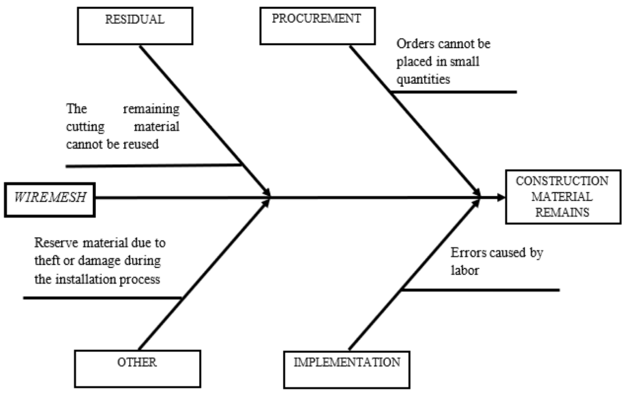

Fig. 2. Fishbone Diagram of Wiremesh

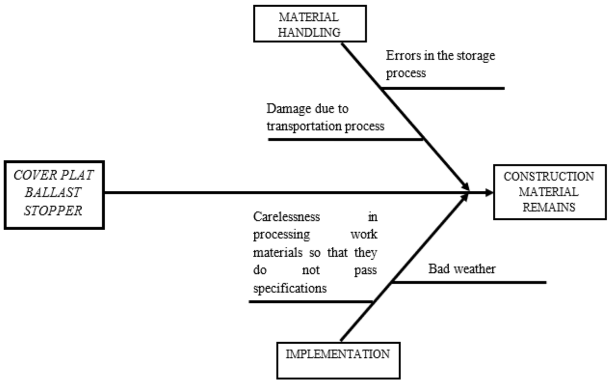

Fig. 3. Fishbone Diagram of Cover Plat Ballast Stopper

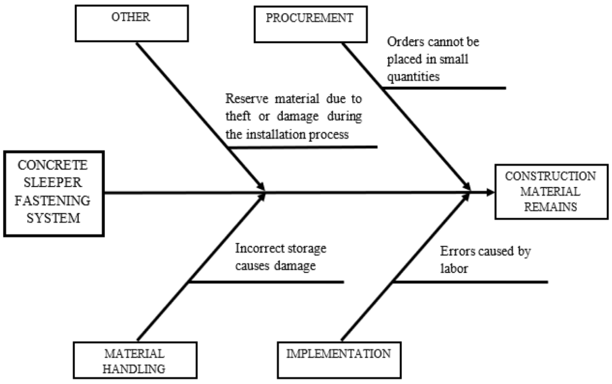

Fig. 4. Fishbone Diagram of Concrete Sleeper Fastening System

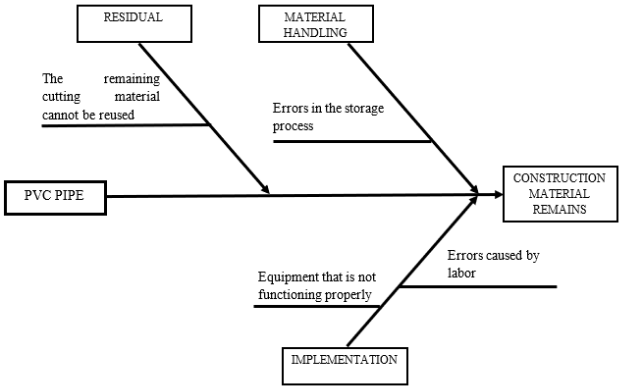

Fig. 5. Fishbone Diagram of PVC Pipe

4.7 Analysis of Material Remains Management

In handling construction material, it remains. Not only the disposal is carried out. However, some stages must be implemented. Namely reducing. Reusing. And recycling materials. The last stage is an alternative decision that includes sales. Storage. And disposal. The steps for handling material remains are arranged based on the waste hierarchy principle. Starting with reducing the formation of material remains. To facilitate the identification of the reuse and recycle processes. Materials are grouped by type. Material remains management is analyzed based on interviews with various related parties in the construction project.

a. Spun Pile
   1) Reuse: The remaining pieces are used as temporary culvert channels.
   2) Decision Alternative: Iron materials are separated and sold for recycling. In contrast, concrete is generally discarded because it cannot be reused.
b. Wiremesh
   1) Reuse: Used for other jobs. Such as HSE sign frames.
   2) Decision Alternative: Sold for recycling.
c. Ballast Stopper Cover Plate
   1) Reuse: Used for other jobs. Such as small channel covers.
   2) Decision Alternative: Iron material is sold for recycling. Concrete is thrown away.
d. Concrete Bearing Fastening System
   1) Reuse: Reuse for the next project or replace damaged material.
   2) Decision Alternative: Discarded if it cannot be reused.
e. PVC Pipe
   1) Reuse: Used for small needs or replacing damaged pipes.
   2) Recycle: Made into pots or home decorations.
   3) Decision Alternative: Discarded if it cannot be reused.

4.8 Recommendations for Reducing the Quantity of Material Remains

After identifying the factors causing material remains. Steps to reduce them can be designed. This approach includes:

a. Spun Pile
   1) Procurement of materials with careful and timely calculations.
   2) Implementation of work with good direction and supervision.
   3) Special training for construction staff.
b. Wiremesh
   1) Procurement of materials with careful calculations and negotiations with suppliers.
   2) Safe storage of materials from fire. Theft. Vandalism. and flooding.
   3) Implementation of work with good direction and supervision.
   4) Special training for construction staff.
c. Cover Plate Ballast Stopper
   1) Procurement of materials with careful calculations.
   2) Handling materials carefully.
   3) Safe storage of materials.
   4) Implementation of work with good direction and supervision.
   5) Special training for construction staff.
d. Concrete Bearing Fastening System
   1) Procurement of materials with careful calculation and negotiation with suppliers.
   2) Safe storage of materials.
   3) Implementation of work with good direction and supervision.
   4) Special training for construction staff.
e. PVC Pipe
   1) Procurement of materials with careful calculation and negotiation with suppliers.
   2) Safe storage of materials.
   3) Implementation of work with good direction and supervision.
   4) Special training for construction staff

This approach emphasizes the importance of planning. Supervision. Furthermore, training to reduce material waste in construction projects.

5. CONCLUSION

Research on the remaining materials in the Railway Construction Project resulted in several conclusions. Namely:

a. The materials that cause remaining materials are 1306.5 m of the spun pile and 86 ballast stopper plate covers. Four sheets of wire mesh. A concrete sleeper anchoring system consisting of 160 e-clips. 160 insulators. And 80 rail pads. Furthermore, PVC pipes consist of 6" diameter 7 rods and 8" diameter 13 rods.
b. The most dominant remaining material costs are spun piles, which have the largest volume and remaining material costs.
c. Based on the Fishbone Diagram, the leading cause of the remaining materials is poor cutting conditions, large orders, and fabrication results that do not meet specifications.
d. All remaining materials can be reused or sold for recycling, except for concrete, which is generally discarded.
e. Material Reduction Recommendations include worker guidance and training, accurate material calculation, material scheduling, warehouse protection, use of standard equipment, and routine supervision.

Suggestions for further research:

a. This study used more interview data because secondary data from contractors took much work to obtain. Ideally. all of this data should be available for further research
b. Expanding the research location
c. Adding the types of materials reviewed for a more complete understanding

REFERENCES

[1] Malaiholo D. Prihartanto R. Puruhita HW. Identification of the Causes of Waste Material in the Railway Bridge Construction Project. ASTONJADRO. 2024;13(2):407–13.
[2] Gavilan RM. L. E. Bernold. Source Evaluation of Solid Waste in Building Construction. J Constr Eng Manag. 1994;536–52.
[3] Handayani E. Veronata F. Analisis dan Identifikasi Sisa Material Konstruksi pada Pekerjaan Beton (Studi Kasus pada pekerjaan Pembangunan Pasar Rakyat Talang Banjar). J Ilm Univ Batanghari Jambi. 2019;19(2):383.
[4] Tchobanoglous. G.. Theisen. H.. and Vigil SA. Integrated solid management. New Jersey: McGraw-Hill. Inc.; 1993.
[5] Intan S. Alifen RS. Arijanto L. Analisa Dan Evaluasi Sisa Material Konstruksi : Civ Eng Dimens. 2005;7(1):36–45.
[6] Bossink B a. G. Brouwers HJH. Wate Quantification and Source Evaluation.pdf. J Constr Eng Manag. 1996;55–60.
[7] Aulia NA. Analisis Dan Evaluasi Sisa Material Konstruksi Menggunakan Metode Pareto Dan Fishbone Diagram (Studi Kasus Pada Proyek Pembangunan Gedung Pascasarjana Universitas Islam Malang). Universitas Brawijaya; 2016.
[8] Thoengsal J. Tumpu M. Model Manajemen Sisa Material Konstruksi Dalam Upaya Efisiensi Proyek Konstruksi. Cetakan I. Makassar: CV. Tohar Media; 2022. 130 p.
[9] Waluyo GA. Analisis Sisa Material Proyek Pembangunan Hotel Kawasan Marvell City. Institut Teknologi Sepuluh Nopember; 2017.

[10] Thoengsal J. Latief RU. Pengelolaan Sisa Material Pada Proyek Kostruksi. Cetakan I. Makassar: CV. Nas Media Pustaka; 2022. 88 p.