Implementation of Circular Economy Principles in Building Construction Waste

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ABSTRACT

Building projects often generate significant amounts of waste. This happens because the building projects mostly adopt a linear economic model of "take, make, dispose of", using materials to the construction of buildings and disposing of them at the end of life. This linear economic model only focuses on human activities because the disposal of materials ultimately does not become a sustainable practice in the future. For this reason, an alternative is needed in reducing and processing construction waste by implementing circular economy principles. This study aims to identify type of construction waste in building projects, provide recommendations for handling it with circular economy principles, and calculate the cost savings. The methods that used in this study are field observation and interview for collecting data. The result showed that steel reinforcement, ready-mix concrete, light brick, ceramic, multiplex, spun pile, and anchor can be handled with circular economy principles are reduce, reuse, recycle, recovery, and repair. The cost savings from handled it in project A, B, and C are Rp. 68.252.490,65, Rp. 84.182.684,96, and Rp. 31.794.238,51, respectively.

Key word: building project; construction waste; linear economy; circular economy; cost saving.

INTRODUCTION

Infrastructure development is one of the critical components of a country. Increased development is inseparable from the utilization of resources such as construction materials. This construction material is used as a constituent of buildings both structurally and non-structurally. However, in the construction implementation, using materials in the field often results in large construction waste, so an effort is needed to minimize the construction waste.

In most countries, the construction sector contributes to the environmental waste of nearly 40% of the total waste generated (Tian & Spatari, 2022). This construction waste comes from construction waste predicted to double to 2,2 billion tonnes by 2025 (Rifdah, 2021). This problem is caused because the construction industry still applies the linear economic concept with the idea of "take, make, dispose of" where products will become waste at the end of their use (Benachio et al., 2020). The concept of a linear economy only focuses on human activities because the disposal of these products ultimately does not become a sustainable practice. This also highlights the need for alternatives to the linear economy to reduce and process the construction waste by applying the circular economy concept.

Circular economy is a concept of development economics that describes the maximum reuse or recycling of materials, goods, and components to reduce landfill waste as much as possible. The implementation of circular economy principles is a prospective solution for overcoming environmental challenges in the construction industry (Yu et al., 2022).

Research related to circular economy implementation was conducted by (Purnawan et al., 2021), (Rifdah, 2021), (Hao et al., 2022), and (Bao, 2023). Based on previous studies, the implementation of circular economy prinsiples in the construction sector, especially in Indonesia, is rarely studied. As for the previous studies, they did not discuss of cost savings from handling construction waste with circular economy principles. For this reason, it attracts the interest of researchers in conducting this research to find out cost savings of construction waste by implementing circular

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economy principles. This research aims to identify type of construction waste in building project, provide recommendations for handling it with circular economy principles, and calculating the cost savings.

RESEARCH METHODS

Field observation and data collection

This research was conducted in 3 buildings in East Java, project A, B, C with 7, 3, 5 storey building, respectively. Field observations is conducted to determine the type construction waste. It supports by interviewing and distributing questionnaires to fifteen respondents in three projects. The respondent including field managers, quality control staff, field supervisors, and logistics staff. The data of bill of quantity (BOQ) and logistic reports also collected.

Construction waste calculation

For calculating construction waste, the first step is identification the type of construction waste referred to the questionnaire results. After knowing the type of construction waste, the next step is calculation the volume of Construction Waste (CW) based on BOQ and project logistics reports, as seen to the following equation (Pertiwi, 2019).

Volume of CW = Project logistics reports – BOQ

CW (%) = $\frac{Volume\ of\ CW}{BOQ}$ x 100%

Construction waste handling based on circular economy principles

Construction waste handling based on circular economy principles is analysis based on interviews and relevant literature studies.

Calculation of cost saving

For calculating cost saving, the first step is interviews were conducted to find out the amount of construction waste that was reused by the contractor. The next step is calculating cost saving from unmanaged construction waste by providing handling recommendations based on circular economy principles, with following equation (Kusuma, 2010):

Cost of CW = Volume of CW x unit price

RESULT AND DISCUSSION

Dominant construction waste

The types of construction waste for each project are presented in Table 1 below.

Table 1. Types of construction waste

No.	Project	Types of construction waste	Volume of construction waste	Unit
1	A	1. Multiplex	891,01	m^2
		2. Ceramic 90x90	117,77	m^2
		3. Light brick	96,34	m^2
2	B	1. Steel reinforcement	5.936,30	kg
		2. Multiplex	802,33	m^2
		3. Ceramics 60x60	395,30	m^2
		Ceramics 30x30	390,18	m^2
		Ceramics 10x60	203,61	m^2
		Ceramics 20x30	153,33	m^2
		4. Light brick	68,28	m^2
		5. Ready-mix concrete	6,61	m^3
No.	Project	Types of construction waste	Volume of	Unit

			construction waste	
3	C	1. Steel reinforcement	15.789,80	kg
		2. Multiplex	1.146,74	m^2
		3. Anchor	727,51	kg
		4. Spun pile	180,00	m^1
		5. Ready-mix concrete	8,46	m^3

Based on Table 1, seven types of construction waste in three projects are steel reinforcement, ready-mix concrete, light brick, ceramic, multiplex, spun pile, and anchor. The results of this study are similar and support previous research by (Devi, 2021), (Pertiwi et al., 2019), (Fajar et al., 2018), (Putra et al., 2018), (Haryadi, 2018), (Aulia, 2016), (Nursyahbani et al., 2016), (Devia et al., 2010), (Kusuma, 2010), and (Ferdiana, 2009), where the seven types of construction waste are the most common waste materials in building construction projects.

Handling construction waste based on circular economy principles

Table 2 below will describe how to handling of construction waste based on circular economy principles.

Table 2. Handling of construction waste based on circular economy principles

No.	Circular economy principles	Construction waste	Handling method
1	Reduce	a. Steel reinforcement b. Ready-mix concrete c. Light brick d. Ceramic e. Multiplex f. Spun pile g. Anchor	• Improve the accuracy and quantity of material orders. • Inspection of condition and suitability sizes of ordered type. • Provide storage construction materials in a safe place to avoid the risk of break and crack. • Carry out the placement and stacking of materials properly. • The construction materials installation process is carried out by skilled and experienced labor who know the proper and correct method of installing material. • Provide training to labors in the efficient use of equipment.
2	Reuse	a. Steel reinforcement b. Ready-mix concrete c. Light brick d. Ceramic e. Multiplex f. Spun pile g. Anchor	• Utilizing materials for future projects. • Remaining materials for the project maintenance period, example, ceramic. • The remaining pieces of materials that have more than half the original size can be reused for areas that require small sizes, example, light brick and ceramic. • Utilizing materials for further work, example, ready-mix concrete, and multiplex.
3	Recycle	Steel reinforcement	Recycling of steel reinforcement into steel powder as an additive to the concrete paste (Apriyadi, 2020).
		Ready-mix concrete	For the manufacture of paving block and

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			concrete cubes (Sari, 2016).
		Light brick	• As a substitute for fine aggregate in concrete mix (Priyono, 2021) & (Amdani et al., 2023). • As a substitute for coarse aggregate in concrete mix (Taher et al., 2021).
		Ceramic	• As a substitute for coarse aggregate in concrete mixes (Utomo, 2018). • As a mosaic element on the wall (Maulana, 2015).
		Multiplex	The multiplex usually used is former formwork which can be used as plasterboard or ceiling material for rooms that do not require aesthetics, such as warehouses (Lumbangaol & Sihombing, 2016).
		Spun pile	As a substitute for coarse aggregate in concrete mix (Hemar & Risdianto, 2020).
		Anchor	Recycling of anchor into steel powder as an additive to the concrete paste (Apriyadi, 2020).
4	Recovery	a. Steel reinforcement b. Ready-mix concrete c. Light brick d. Ceramic e. Multiplex f. Spun pile g. Anchor	Providing a trading platform for construction waste as for practices of construction waste management and resource recovery (Wu et al., 2022).
5	Repair	Steel reinforcement	Realign the curved steel reinforcement with an steel sledgehammer (Ervianto., 2012).
		Ready-mix concrete	Can't be repaired.
		Light brick	Can't be repaired.
		Ceramic	Repaired as mosaics on service area.
		Multiplex	Repaired multiplexes for ceiling on service area.
		Spun pile	Repair of cracked spun pile on the pile body and repair of damaged spun pile on the joint plate (Kementerian PUPR, 2015).
		Anchor	Realign the curved anchor with an steel sledgehammer (Ervianto., 2012).

Handling of construction waste can be carried out in accordance with the five circular economy principles, namely reduce, reuse, recycle, recovery and repair. The handling of construction waste carried out by the contractor only applies reduce, reuse and recovery measures. Remaining steel

reinforcement, ready-mix concrete, multiplex, light brick, ceramics, spun pile and anchor can be reduced (improving the accuracy of estimating material requirements, inspection of condition and sustainability size of ordered type, providing a safe storage area, and provide training to labors) and reuse (allocated for future projects, as stock for the project maintenance period, and for other works such as ready mix concrete for work roads). Handling measures with recycle, recovery and repair are rarely applied by contractors except for recovery measure of remaining steel reinforcement and anchor which can be resold without sorting.

A. Cost saving from construction waste handling

Based on the results of interviews with contractors, the construction waste that can be reused are listed in Table 3 below.

Table 3. Handling of construction waste by contractor

No.	Construction waste	Handling method	Volume	Unit	Unit price	Total price
Project A						
1	Multiplex	For future projects (70%)	623,71	m^2	Rp.222.800	Rp. 138.961.919,60
2	Ceramic	Stock for project maintenance period (80%)	94,22	m^2	Rp.272.250	Rp. 31.667.044,44
3	Light brick	Allocate for future projects (90%)	86,71	m^2	Rp. 62.500	Rp. 5.419.125,00
Total price handling of construction waste by contractor						**Rp. 176.048.089,04**
Project B						
1	Steel reinforcement	For future project or sale (100%)	5936,30	kg	Rp. 15.400	Rp. 91.419.020,00
2	Multiplex	For future projects (60%)	481,40	m^2	Rp.154.000	Rp. 24.904.357,70
3	Ceramic					
	60x60	Stock for project maintenance period (80%)	316,24	m^2	Rp. 92.500	Rp. 29.252.200,00
	30x30		312,14	m^2	Rp. 57.500	Rp. 17.948.280,00
	10x60		162,89	m^2	Rp.142.000	Rp. 23.130.096,00
	20x30		122,664	m^2	Rp. 55.000	Rp. 6.746.520,00
4	Light brick	For future project (80%)	54,62	m^2	Rp. 62.500	Rp. 3.414.000,00
5	Ready-mix concrete	For project work roads as a substitute for paving blocks (assuming a road area of 5x11 meters)	55,00	m^2	Rp.135.000	Rp. 7.425.000,00
Total price handling of construction waste by contractor						**Rp. 204.239.473,70**
Project C						
1	Steel reinforcement	For future project or sale (100%)	15.789,80	kg	Rp. 14.762	Rp.233.089.027,60
No.	Construction waste	Handling method	Volume	Unit	Unit price	Total price

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2	Multiplex	For future project (60%)	688,04	m^2	Rp.194.450	Rp. 44.944.287,76
3	Anchor	For future project or sale (100%)	727,51	kg	Rp. 14.762	Rp. 10.739.502,62
4	Spun Pile	For future project or sale (90%)	162,00	m^1	Rp.728.050	Rp.117.944.100,00
5	Ready mix concrete	For project work roads as a substitute for paving blocks (assuming a road area of 7x10 meters)	70,00	m^2	Rp.135.000	Rp. 9.450.000,00
Total price handling of construction waste by contractor						**Rp.416.166.917,98**

Based on Table 3, it can be seen handling of construction waste carried out by the contractor ranges from 60% to 100%. The way to manage construction waste is through reuse (for future projects and maintenance stock) and recovery (resale). Some of 10% to 40% construction waste are not handled disposed to landfill.

Disposed of construction waste results in reduced profits. Therefore, need a way to handling construction waste by applying circular economy principles. The following describes how to manage construction waste based on circular economy principles to find out the cost savings that can be used as consideration for contractors in applying this circular economy principle for future projects.

Table 4. Construction waste handling based on circular economy principles

No.	Construction waste	Handling method	Volume	Unit	Unit price	Total price
Project A						
1	Multiplex	Recycle for ceiling (30%)	267,30	m^2	Rp.222.800	Rp. 59.555.108,40
2	Ceramic	Recovery for mosaics as wall or other architectural ornaments (20%)	23,55	m^2	Rp.295.000	Rp. 8.578.308,64
3	Light brick	Recycle as a substitute for coarse aggregate (10%)	0,34	m^3	Rp.350.500	Rp. 119.073,61
		Total				**Rp. 68.252.490,65**
Project B						
1	Multiplex	Recycle for ceiling (40%)	320,93	m^2	Rp.154.000	Rp. 16.602.905,13
2	Ceramic					
	60x60	Recovery for mosaics as wall or other architectural ornaments (20%)	79,06	m^2	Rp.295.000	Rp. 23.322.700,00
	30x30		78,04	m^2	Rp.295.000	Rp. 23.020.620,00
	10x60		40,72	m^2	Rp.295.000	Rp. 12.012.990,00
	20x30		30,66	m^2	Rp.295.000	Rp. 9.046.470,00
3	Light brick	Recycle as a substitute for coarse aggregate (20%)	0,48	m^3	Rp.367.300	Rp. 176.999,83
No.	Construction waste	Handling method	Volume	Unit	Unit price	Total price

		Total				**Rp. 84.182.684,96**
Project C						
1	Multiplex	Recycle for ceiling (40%)	458,70	m^2	Rp.194.450	Rp. 29.962.858,00
2	Spun Pile	Recycle as a substitute for coarse aggregate (10%)	3,93	m^3	Rp.466.000	Rp. 1.831.380,00
		Total				**Rp. 31.794.238,51**

Table 4 describes the handling of construction waste are not handled by contractor. It can be seen if the construction waste that is disposed of in landfill still has value if it is handled properly. Based on Table 4, it can be concluded that handling of construction waste in projects A, B, C can save up to Rp.68.252.490,65, Rp.84.182.684,96, and Rp.31.794.238,51, respectively.

CONCLUSION

Types of construction waste in three projects are steel reinforcement, ready-mix concrete, light brick, ceramic, multiplex, spun pile, and anchor. Recommendation for handling of construction waste can be carried out in accordance with the five circular economy principles, namely reduce, reuse, recycle, recovery and repair. The handling of construction waste carried out by the contractor only applies reduce, reuse and recovery measures. Remaining steel reinforcement, ready-mix concrete, multiplex, light brick, ceramics, spun pile and anchor can be reduced (improving the accuracy of estimating material requirements, inspection of condition and sustainability size of ordered type, providing a safe storage area, and provide training to labors) and reuse (allocated for future projects, as stock for the project maintenance period, and for other works such as ready mix concrete for work roads). Meanwhile recovery measure for remaining of steel reinforcement and anchor which can be resold without sorting. Handling measures with recycle and repair are rarely applied by contractors. Based on a literature study the seven types of construction waste can be recycled, while repair measures can only be applied to construction waste such as, steel reinforcement, ceramic, multiplex, spun pile and anchor. From this handled can be concluded that the cost savings from projects A, B, C are Rp.68.252.490,65, Rp.84.182.684,96, and Rp.31.794.238,51, respectively.

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