Sustainability Through Reuse of Materials and Components in Buildings: An Indonesian Perspective

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Abstract. Reuse of materials/ components plays a more significant role than recycling because it reduces raw materials and embodied energy at the beginning of construction and minimizes construction waste at the end of the building's life. It is also an embodiment of circular economy in architecture. Although the social, economic, and environmental benefits of reusing materials and components are well established, field practices still need to be established. Few buildings in Indonesia utilize reused materials and components. This study aims to identify public perceptions on the application of materials and components reuse in buildings. Data were collected from the three target research respondents: architects, developers-contractors, and the general public using online questionnaires. The study discovered the potential for reused materials/components in buildings in Indonesia, where there is a high interest in reusing materials/components. The community has also recognized the significance of reuse and its positive environmental impact. Furthermore, there is a favorable opinion of the aesthetic appearance, costs, quality, health risks, and safety of reused materials/components. Barriers in terms of availability, maintenance, and durability require extra attention. Several solutions have also been proposed to increase the application of reused materials/components in buildings.

Keywords: reuse · building · material · component · perception

1 Introduction

The construction industry has a considerable impact on environmental sustainability. Aside from consuming resources during the manufacturing process, construction, and operation, buildings also contribute waste to the environment. With the current urbanization and population growth rate, global waste production is expected to increase by 70% in 2050 [1]. According to World Bank figures from 2012 [2], building material waste accounts for half of the global solid waste. Building demolition waste accounts for 90% of all construction waste, with the remaining 10% from renovation and new building construction [3].

Improving solid waste management is essential to create sustainable, healthy, and inclusive cities and communities, as well as to help cities become more resilient to

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climate change. Around 30% of total waste has been reclaimed through reuse-recycle and waste composting in high-income countries [1], but only 11% in Indonesia [4]. This number is lower than our neighboring countries, such as Malaysia (17.5% [5]) and Singapore (55% [6]).

The Indonesian government, through Presidential Decree Number 97 Year 2017 [7], has required local governments to develop a planning model to achieve the following points by 2025: 1) reduce 30% of waste from the source, and 2) process and manage at least 70% of waste so that it does not accumulate in the landfill. This policy aligns with the current condition where the linear economy system gradually shifts to a circular economy.

A linear economy is a process in which goods are produced, consumed, and disposed of after use. With limited resources and the increasing amount of waste in the environment, this economic system is seen as no longer profitable. The circular economy adopts the concept of restoration and circularity to replace the traditional concept of end-of-life, shifting to the use of renewable energy, eliminating the use of toxic chemicals, and aims to reduce waste through the design of better materials, products, systems, and business models [8].

Circular economy as a concept is related to the green economy. United Nations Environmental Programme (UNEP) [9] explained the term of green economy as:

> "...one which is low carbon, resource efficient and socially inclusive. In a green economy, growth in income and employment should be driven by public and private investments that reduce carbon emissions and pollution, enhance energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services."

Thus, the green economy is considered as a means of improving the environment and reducing environmentally harmful practices. It can also help the economy grow while also making it more socially inclusive.

The concept of materials/components reuse is an embodiment of green and circular economy in architecture. Reclaimed materials/components are reused in a new environment without undergoing chemical transformations, and their physical form remains unchanged [10]. Reusing materials offers far lower environmental impacts than recycling due to the significantly lower treatments and processing required [11]. It is shown in Delft Ladder, which ranks waste management options according to what is best for our environment (Fig. 1). The application of materials/ components reuse plays a significant role in the initial and final phases of the building. At the beginning of construction, it reduces the use of raw materials and embodied energy, while at the end of its life, it reduces the accumulation of construction waste [12].

Reusing building materials/components is encouraged more by the Indonesian government through the Regulation of the Minister of Public Works and Public Housing of the Republic of Indonesia (Peraturan Menteri PUPR RI) Number 02 Year 2015 on Green Building [14]. It states that every new and existing building that meets the criteria should implement green building principles in its design, construction, operation, and deconstruction. Two of the main principles are reducing the use of resources, whether in the form of land, materials, water, natural resources, or human resources, and reusing previously used resources. The use of environmentally friendly materials is required in

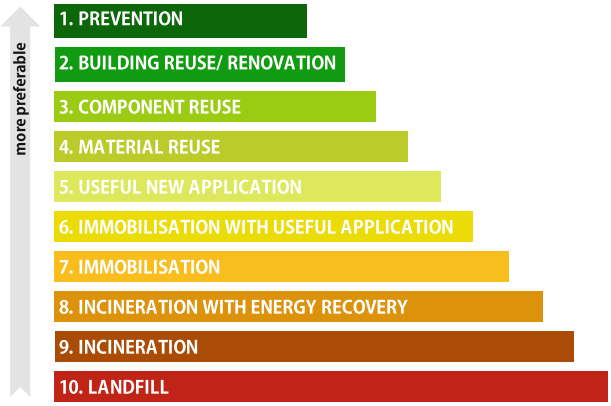

Fig. 1. Delft Ladder of waste management strategy (adopted from Gorgolewski [13])

the technical planning stage of green buildings. The deconstruction/demolition stage is recommended by separating building components to minimize construction waste and increase the use value of the materials. The deconstruction activities include, among others: 1) identification of building components that can be recycled, reused, or destroyed and 2) selecting and separating building components that can be recycled, reused, or destroyed.

Elements that can be reused from a building are not limited in type but can be broadly divided into several categories: primary structure, building envelope, services, interior finishes, feature components, and landscaping [13]. Those elements can be reused in several ways:

1. Reusing an existing structure on the site and possibly adding to it or extending it, often called adaptive reuse.
2. Relocate most or all of an existing building to a new location
3. Reuse individual components extracted from the demolition of one project in a new building
4. Use materials and components that were previously used for a different purpose

Reusing building materials/ components gives benefits in terms of aesthetic, social, economic, environmental, and resource conservation [3, 13]. According to Arora et al. [15], public residential buildings in Singapore currently have 125.7 million tons of non-metallic minerals, 6.52 million tons of steel, 6.45 million windows, 8.61 million doors, 1.97 million toilet accessories, 15.33 million lighting features, 0.99 million kitchen accessories (including stoves and kitchen cabinets) and 52.54 million m^2 of tiles. If these components can be salvaged during demolition, they have the potential to be used to construct 830–1910 new housing units [16].

Although the social, economic, and environmental benefits of reusing materials and components are well established, reusing materials/ components for new construction is still rare in Indonesia. Several studies have identified the potential and supporting and inhibiting factors for the reuse of building materials in various countries [11–13, 17, 18].

However, only some studies have touched on the application in Indonesia. Understanding the local residents' perspective on the subject is critical because acceptance varies depending on cultural background. This study seeks to identify public perceptions on the application of reused materials/components in buildings. As a result, public interest and potential applications in Indonesia can be properly understood.

2 Research Methods

Data was collected through an online questionnaire (Google Form). The questionnaire and research method were based on prior studies by Jin [19] and Strauss [20]. Questionnaires were distributed online from August-October 2021 through social media and email to three target categories of research respondents: architects, developers – contractors, and the general public. The questionnaire is divided into two sections:

- The first section focuses on the demographics of respondents. It consists of 5 questions (gender, age, education level, residence, and profession or type of respondent group) to understand the respondents' backgrounds.
- The second section focuses on public perception. This section consists of 16–17 questions: fourteen general questions are given to all respondents, two additional questions are given to general public respondents, and three additional questions for architect and developer-contractor respondents). This section aimed to determine the level of knowledge, interest, and public perception on the application of materials/components reuse in buildings.

3 Results and Discussion

3.1 Demographic Distribution of Questionnaire Respondents

During the three months of the survey, 181 responses were collected from respondents. The majority of respondents are in the age range of 45–54 years old (36.5%), with the following age groups in order of percentage: 35–44 years old (26%), 55–64 years old (21%), 25–34 years old (9.4%), 18–24 years old (5%), and >64 years old (2.1%). For the education level, most respondents had a doctoral degree (39.8%), followed by a master's degree (36.5%), a diploma/bachelor's degree (22%), and a high school/equivalent education level (1.7%). 93.3% of respondents reside in Java, 3.3% in Sumatra, 2.8% in Kalimantan, and 0.6% in West Nusa Tenggara. Responses were obtained from the three target respondent groups with the following distribution:

- Developers - contractors (3.3%), with the majority having >10 years of work experience (50%)
- Architects (16%), with the majority having >10 years of work experience (62.1%), and
- The general public (80.7%).

3.2 Knowledge and Experience with Reuse

Almost all respondents agree that reuse is a more sustainable waste management option than recycling, and they have seen buildings constructed using reused materials. More than 60% of respondents have experience with reusing building materials such as wooden beams and planks, plywood, door and window frames, roof tiles, galvanized roofing, zinc, steel bars and beams, glass, bricks, paving blocks, ceramic tiles, stones, prefabricated wall panels, formwork in building castings, sanitary wares, furniture, plastics, to wood sawdust. More than 66% of respondents want to reuse building materials. 72.6% of general public respondents stated that the application of reused materials should be encouraged because it positively impacts the environment.

If they have building materials that can be reused, all three groups of respondents choose to save them for later use (50–53.4%). Another alternative by architect respondents is paying a reasonable fee for someone to pick it up for reuse as long as it is less expensive than sending it to a landfill (44.8%). Developer-contractor respondents prefer to sell (50%), and general public respondents prefer to give it away for free (51.4%).

69% of architects have recommended reusing building materials/components to the client throughout the design phase, and 62.1% of architect respondents have received requests from clients to reuse building materials/components. Likewise, 83.3% of respondents in the developer-contractor group have advised architects/clients to reuse building materials/components. 66.7% of developer-contractor respondents have even interacted with collectors or distributors of used materials to explore the possibility of using them in their projects.

3.3 Perceptions Regarding the Application of Reused Materials and Components in Buildings

There is potential for reusing materials/components in buildings in Indonesia based on the respondent's perception, as shown in Table 1. Most respondents thought the reused materials/components were as good as new materials regarding aesthetic appearance, costs, quality, health risks, and safety. However, it is considered quite difficult regarding availability and maintenance; some also question the material's durability.

Regarding the availability of reused building materials, architects and the general public stated that they were aware of their availability but needed to know how and where to access them. Meanwhile, developers and contractors stated that the reused materials/components were easy to access, probably because their field of work was closely related to the supply chain. In Indonesia, used materials are generally collected by scavengers and then deposited to collectors, either local collectors, regional collectors, or collectors with access to industry [21]. Every city has collectors, but their presence needs to be better documented, and very few can be accessed online - the most critical thing in this digital age.

Easy access to products, both online and offline, is vital nowadays. Convenience is among the top five purchase criteria for middle-income customers and the top three for high-income consumers [22]. Even more, although people seek information from various media, they transact through e-commerce platforms or offline retail stores. Today, 80% of shoppers compare prices online, yet 90% purchase offline. ASEAN shoppers go online

Table 1. Comparison of used materials and new materials

Question		Choice of answers	Responses (%)		
In your opinion, when compared between used materials and new materials:			Architect	Developer-Contractor	General public
1	Availability of reused building materials/components	• available & easy to access	17.2	**66.7**	30.1
		• available but difficult to access	**72.5**	33.3	**62.4**
		• not available	10.3	-	7.5
2	Aesthetic appearance of building with reused building materials/components	• excellent	17.2	16.7	6.2
		• acceptable	**79.4**	**83.3**	**82.8**
		• unpleasant	3.4	-	11
3	Costs of reused building materials/components	• lower than new materials	**75.9**	**83.3**	**80.8**
		• same	24.1	16.7	8.9
		• higher than new materials	-	-	10.3
4	Maintenance of reused building materials/components	• lower than new materials	3.4	33.3	6.8
		• same	**48.3**	16.7	**46.6**
		• higher than new materials	**48.3**	**50**	**46.6**
5	Quality of reused building materials/components	• higher than new materials	10.3	16.7	13.7
		• same	**58.7**	**50**	**45.2**
		• lower than new materials	31	33.3	41.1
6	Health risk arising from reusing building materials/components	• non-existent health risk	17.2	16.7	25.3
		• same	**55.2**	**66.6**	**58.3**
		• higher risk than new materials	27.6	16.7	16.4
7	Durability of reused building materials/components	• longer lasting than new materials	10.3	-	11
		• same	**48.3**	**66.7**	30.1
		• shorter lasting than new materials	41.4	33.3	**58.9**
8	Safety of reused building materials/components	• more safe than new materials	10.3	-	6.2
		• same	**51.8**	**66.7**	**54.8**
		• less safe than new materials	37.9	33.3	39

to compare prices, save time and make purchases around the clock. They prefer physical stores because they can touch and feel a product, validate its authenticity, and enjoy the shopping experience [22].

This could be accomplished by establishing stockholding facilities and reuse platforms to facilitate the reuse process (such as material sourcing, mapping, storage, logistics, and testing). This would reduce uncertainties in sourcing materials – the possibility to pre-order used products that will become available at a specific time would make reuse more predictable and allow for planning and designing with reused products from an early stage [17].

Some respondents still doubt the durability of reused material maintenance. Society generally believes that second-hand materials might be subpar and pose a higher risk [13]. This skepticism can be dispelled by clear standards for assessing the possibility of reuse, retrieving material from the deconstruction process, and testing material quality and storage techniques.

Waste is sometimes described as material without information. By providing adequate information about a product or material, it may be possible to pass it on to future generations. Technical specifications can be encoded in 'materials passports' (or resource passports). Such can include information on a product's qualities and properties, as well as product information such as location, date, and manufacturer's name. When a product reaches the end of its initial life, this allows for future reuse or recycling. For some components, it can also aid in maintenance throughout their lifetime [13].

3.4 Challenges and Solutions for Optimal Application of Materials/Components Reuse for Green Buildings in Indonesia

The lack of understanding about whether or not materials may be reused is thought to be the main barrier impeding the usage of reused materials/components in construction. The second reason is that it is easier to dispose of the material than to reuse it. The third issue is the difficulty in obtaining old reusable materials. The result is in line with Sassi's research [23] which states that cost, awareness, and technology are three main barriers to using recyclable materials/components.

The three groups of respondents consider several things that can encourage them to reuse building materials to overcome these barriers; the following is the priority list in order:

1. *The availability of a system that assists in discovering, reporting, purchasing, and selling reusable materials*. This is the most important point because without detailed information on building stock, locating reclaimed materials and components becomes the most challenging phase, potentially slowing down the project [24].
2. *Clear regulations on procedures for materials/components reuse in buildings*. Clear guidelines are needed on how reused materials should be processed, from how they are taken to how they are applied to new buildings. Clear information supported by real-world examples will broaden public knowledge.
3. *Clear regulations for sorting and registering reusable materials/component*. This is related to public concerns about the durability of reused materials/components. The public will have more confidence in the quality of reused materials if there are clear standards for assessing and sorting materials to be sold. It can be supported by detailed information about each item, such as passport material.
4. *Building codes that require the application of reused materials/components*. Regulation of the Minister of Public Works and Public Housing of the Republic of Indonesia (*Peraturan Menteri PUPR RI*) Number 02 Year 2015 [14] governs the application of green building principles at mandatory, recommended, and voluntary levels. However, it appears that the general public is unaware of this rule.
5. *Incentives*. The lack of incentives from the government to reuse materials also acts as a barrier for some respondents. Although it was the least concerned barrier, an incentive such as a tax relief would increase community engagement in reusing materials in their building. Regulation of the Minister of Public Works and Public Housing of the Republic of Indonesia (*Peraturan Menteri PUPR RI*) Number 02 Year 2015 [14] has explained several incentives for buildings that follow proper green building principles, such as:

    a. Reduction in licensing fees and relief of services;
    b. Compensation in the form of; 1) ease of licensing; and/or 2) additional Floor Area Ratio (*Koefisien Lantai Bangunan*/ KLB).
    c. Technical and/or expertise support, such as technical advice and/or assistance from green building experts;
    d. Awards, such as certificates, plaques, and/or tokens of appreciation; and/or

e. Other incentives, such as publications and/or promotions.

Those incentives, however, are only available for buildings in DKI Jakarta. There are also several regional regulations concerning green buildings, each with its incentives. For example, the Bandung Mayor Regulation (*Peraturan Wali Kota Bandung*) Number 1023 Year 2016 on Green Building [25] only provides incentives in the form of additional layers of floors or a reduction in property tax (*Pajak Bumi dan Bangunan/PBB*).

By implementing the solutions above, the application of materials/components reuse is expected to grow even more.

4 Conclusion

The concept of materials/components reuse is an embodiment of the green economy and circular economy in architecture. This study discovered the potential for reused materials/components in Indonesian buildings, with a high interest in reusing materials/components. The community has also recognized the importance of reuse and its positive environmental impact. Furthermore, the community views reused materials/components favorably regarding aesthetic appearance, cost, quality, health risks, and safety. Barriers in terms of availability, maintenance, and durability necessitate special consideration. Several solutions to boost the application of reused materials/components in buildings are: 1) Providing systems that assist in discovering, reporting, purchasing, and selling reusable materials, 2) Establishing clear regulations on how to reuse materials/components in buildings, as well as regulation on how to sort and register reusable materials/component in the market, 3) Dissemination of building codes related to the application of reused materials/components to the general public, and 4) Providing incentives.

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