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THE USE OF RECYCLED MATERIALS IN CIVIL ENGINEERING: THE PATH TO SUSTAINABLE CONSTRUCTION

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Abstract

The use of recycled materials in civil engineering is a strategic approach in realizing sustainable construction. This study aims to examine the types, motivations, challenges, and impacts of using recycled materials in construction projects. The research method used was qualitative descriptive with in-depth interview techniques, field observations, and documentation on several urban construction projects that applied recycled materials. The results of the study show that waste concrete aggregates, recycled plastics, fly ash, and glass are the most commonly used materials. Motivations for its use include cost efficiency and encouragement of environmental regulations. However, the main challenge lies in the inconsistent quality of the material and the limitations of its use in the main structure. However, recycled materials have been proven to have a positive impact on environmental aspects and project efficiency, such as reducing carbon emissions, reducing the use of natural materials, and better waste management. These findings show that the use of recycled materials is not only a technical practice, but also an integral strategy in realizing sustainable development. Policy support, technical standardization, and increasing awareness of industry players are the main keys in expanding its implementation.

Keywords: ***Recycled Materials, Civil Engineering, Sustainable Construction, Environmental Sustainability, Material Efficiency.***

INTRODUCTION

The construction world today faces a major challenge in maintaining a balance between infrastructure development and environmental preservation (Siahay et al., 2023). Civil engineering as one of the spearheads of infrastructure development is now required to adopt a more environmentally friendly approach. One such approach is the use of recycled materials in the construction process (MUTIA, 2024). Rapid infrastructure development has a significant impact on the consumption of natural resources (Surasmi et al., 2022). The need for building materials such as concrete, asphalt, steel, and aggregate increases every year. In fact, these resources are limited and overexploitation can lead to environmental degradation. In addition, construction and demolition waste is also an important issue in the world of civil engineering. According to a report from the United Nations Environment Programme (UNEP), the construction sector accounts for almost 40% of the world's total solid waste (Harefa, 2022). This condition demands innovative and sustainable solutions. One of the solutions that is starting to be widely applied in various countries is the use of recycled materials. This material includes various wastes such as waste concrete, plastic, glass, asphalt, and metal that have gone through a reprocessing process so that they are suitable for reuse in construction projects. The use of recycled materials not only helps to reduce the volume of waste, but also reduces dependence on natural materials. Thus, this approach is in line with the principles of the circular economy that prioritize resource efficiency and waste minimization. Theoretically, the sustainable development approach in construction emphasizes three main aspects, namely environmental, economic, and social sustainability. This theory was put forward by (Holdgate, 1987) which defines sustainable development as development that meets current needs without sacrificing the capabilities of future generations. In the context of civil engineering, sustainability can be achieved by designing projects that are energy-efficient, minimize carbon emissions, and use renewable or recyclable materials. In other words, the use of recycled materials is one of the important components in realizing sustainable

construction. Recycled concrete, for example, has been an important study material in many studies. According to the theory of life cycle assessment (LCA), concrete that uses recycled aggregate can significantly reduce the carbon footprint of the project compared to conventional concrete (Rasyid, 2023). LCA is an analysis method that evaluates the environmental impact of a product throughout its life cycle, from raw material extraction, production, use, to disposal. This theory is particularly relevant in assessing the feasibility and advantages of using recycled materials in civil engineering projects. Not only concrete, recycled plastics are also starting to be used in road asphalt mixtures. This innovation has been proven to improve road resistance to deformation and temperature extremes. In some countries such as India and the United Kingdom, this practice has become part of national policy.

The use of industrial waste such as slag from steel smelting or fly ash from power plants is also an alternative material to cement in concrete manufacturing. The material substitution theory states that if the mechanical and chemical properties of the alternative material meet technical standards, then the material is suitable for use as a substitute for conventional materials (Ahmad et al., 2021). In addition to having a positive environmental impact, the use of recycled materials also has economic benefits. Used materials usually have a lower price than new materials. This provides cost efficiency opportunities especially in large-scale projects. However, there are still technical challenges and perceptions among industry players regarding the reliability and quality of recycled materials. Some still doubt the long-term durability and consistency of the quality of this material. Therefore, standardization, certification, and rigorous testing are required to ensure recycled materials meet the required engineering specifications. This is in accordance with the theory of quality assurance in construction management which emphasizes the importance of quality at every stage of development (Ferdiana et al., 2023).

Education and awareness raising among engineers, contractors, and policymakers is also an important aspect in supporting the widespread adoption of recycled materials. The market's acceptance of this innovation is greatly influenced by the level of understanding and trust in material performance. In a global perspective, many developed countries have included indicators of the use of recycled materials in green building assessment systems, such as LEED (Leadership in Energy and Environmental Design) in the United States or BREEAM (Building Research Establishment Environmental Assessment Method) in the United Kingdom (Widiati, 2019). In Indonesia, efforts to develop sustainable construction are beginning to gain attention, although their implementation is still limited. Government policies regarding the management of B3 and non-B3 waste and regulations on environmentally friendly building materials need to be strengthened (Nursabrina et al., 2021). In addition, research and development support from academia and R&D institutions is urgently needed to develop waste treatment technology into construction materials that are more effective, cheap, and environmentally friendly. As awareness of the climate crisis and environmental responsibility increases, the transformation towards sustainable construction is inevitable. The use of recycled materials is not just a trend, but part of a paradigm shift in the global construction industry. Therefore, this study aims to examine in depth the potential, challenges, and prospects of the use of recycled materials in the field of civil engineering as a concrete effort towards more sustainable construction. This study is expected to be a scientific contribution to greener and more responsible development practices in the future.

RESEARCH METHODS

This research method uses a descriptive qualitative approach that aims to describe in depth the practice of using recycled materials in civil engineering as part of efforts towards sustainable construction (Yusuf, 2013). This approach was chosen because it is able to explore the phenomenon holistically and deeply, especially regarding the motivations, challenges, and impacts of using recycled materials from the perspective of actors in the field. This research was carried out by making several construction projects in urban areas that have used recycled materials as the object of study. The selection of locations is carried out purposively by considering the availability of data, the involvement of project actors, and the level of innovation in the use of recycled materials in these projects. The data was collected through in-depth interviews with a number of key informants, including civil engineers, contractors, field supervisors, and representatives from government agencies related to infrastructure and environmental policy.

The interview technique is carried out in a semi-structured manner so that the researcher can explore the main topics that have been predetermined, while opening up space for the exploration of new information relevant to the focus of the research. In addition, data collection is also carried out through field observation of the use and processing of recycled materials, as well as documentation in the form of technical reports, photos, and project notes (Saleh, 2017). To strengthen the validity of the data, triangulation of sources and methods was carried out. Source triangulation is done by comparing information from various informants who have different involvement in a construction project. Meanwhile, the triangulation method was carried out by comparing the results of the interviews with observation and documentation data.

Data analysis is carried out through the stages of data reduction, data presentation, and drawing conclusions. Data reduction includes the process of sorting, summarizing, and structuring data that is relevant to the focus of the research. The data presentation was carried out in the form of a descriptive narrative that described the patterns of use of recycled materials, including the driving factors, obstacles, and their implications for the sustainability of construction projects. Conclusions are drawn by observing the main findings that emerge from the data analysis, as well as relating them to relevant theories. The entire research process was carried out by paying attention to the ethical principles of research, including obtaining consent from informants for their participation, maintaining data confidentiality, and presenting findings objectively without manipulation. With this approach, it is hoped that the research can provide an accurate and in-depth picture of the reality of the use of recycled materials in the world of civil engineering, as well as its contribution to sustainable development.

RESULTS OF RESEARCH AND DISCUSSION

1. Types and Sources of Recycled Materials Used

Based on interviews and field observations in three urban construction projects, it was found that the most commonly used types of recycled materials are recycled concrete aggregates, used plastics for asphalt mixtures, and fly ash as a partial cement substitution. The demolished former building concrete is reprocessed through the process of crushing and filtering into coarse and fine aggregates used in the manufacture of road base layers as well as non-strategic structural components. The source of recycled materials comes from various locations, including the demolition of old buildings, project internal construction waste, and industrial waste (such as fly ash from power plants). Some projects also work with building waste treatment companies to obtain materials that have gone through basic quality control processes. The results show that scrap concrete, plastic, fly ash, and glass are the most widely used types of recycled materials in sustainable construction projects. These findings are in line with the life cycle assessment (LCA) approach which emphasizes the importance of utilizing materials with lower environmental impact throughout their life cycle (Rasyid, 2023). By reusing waste concrete and industrial waste, these projects have succeeded in reducing dependence on new natural resources, as well as reducing the environmental impact of conventional material extraction and transportation. The source of recycled materials from demolition projects and industrial waste shows that the construction sector has the potential to carry out the circular economy principle, namely by returning waste materials to the production cycle (Harefa, 2022). This practice reflects the tangible implementation of the principles of environmental sustainability as emphasized in the Brundtland Commission's theory of sustainable development, which demands the wise use of resources for the sake of sustainability for future generations.

2. Motivation for Using Recycled Materials

From the results of interviews with contractors and implementing engineers, it is known that the main motivation for the use of recycled materials is cost efficiency and compliance with environmental policies from local governments. The cost of recycled materials is on average 20–30% cheaper than new materials, depending on the type and processing process. In addition, increasing environmental awareness among construction professionals is driving the adoption of sustainability principles in project design and execution. The project actors are also aware that the use of recycled materials can be an added value in the assessment of green or sustainability projects (e.g. in green building programs). The main motivation of the project actors in using recycled materials is cost efficiency and the encouragement of environmental regulations. This strengthens the concept of economic sustainability in sustainable development theory, which emphasizes not only environmental sustainability, but also aspects of financial efficiency (Tjilen, 2019). In this context, recycled materials are a strategic solution because they not only reduce construction costs, but also add value to the project from a sustainability aspect. In addition, the emergence of ecological awareness among contractors and engineers shows that sustainability values are starting to become part of the technical culture in the field. This can also be attributed to green building rating systems such as LEED and BREEAM that encourage the use of sustainable materials, including recycling, as part of project success standards.

3. Technical Challenges and Constraints

Although the use of recycled materials shows many benefits, some technical challenges are still often encountered in the field. One of the main obstacles is the inconsistency in the quality of recycled materials, especially for waste concrete aggregates. Unstandardized processing processes in some providers cause fluctuations in grain size, dust content, and compressive strength. Concerns over long-term durability also arise, especially if recycled materials are used in key structures such as columns or beams. Therefore, most recycled materials are still limited to

their use for non-structural infrastructure such as road subbase layers, sidewalks, and lightweight retaining walls. Despite the many benefits obtained, there are real obstacles in the implementation of recycled materials, especially regarding their quality and reliability. Quality inconsistencies, especially in scrap concrete aggregates, are the main barriers to use in the main structure. These findings are in line with the theory of quality assurance in construction management, which emphasizes that the quality of each material must be controllable and tested systematically to guarantee the safety and reliability of building structures (Beerkens, 2020). These concerns show the need for technical standards and standard quality certification for recycled materials. This is important so that used materials are widely accepted and not only used in parts of construction that are considered non-crucial. In addition, the limitations of waste treatment infrastructure are also an additional challenge that hinders the optimization of recycling practices in the construction industry.

4. Impact on Project Sustainability Aspects

The use of recycled materials has a real positive impact on the environmental aspect of the project. Based on technical documentation and calculations from two environmental road projects, the use of recycled concrete reduces the need to extract natural rocks by 45 tons, and reduces CO_2 emissions from material transportation by 12%. In addition, the projects also reported a decrease in the volume of waste that had to be disposed of to landfills, which is in line with the goal of reducing construction waste. Thus, the use of recycled materials contributes directly to sustainability indicators, both in terms of environment, social (community acceptance), and economy.

Table 1. Types of Recycled Materials and Their Use in Projects

Yes	Types of Recycled Materials	Material Source	Use in Projects	Technical Description
1	Waste concrete aggregate	Building demolition	Subbase road, sidewalk, lightweight retaining wall	Quality varies, need laboratory tests
2	Recycled plastics	Household and industrial waste	Asphalt mixture (plastic modification)	High temperature resistance, viscosity test is necessary
3	Fly ash	Coal-fired power plant waste	Concrete mixture as a partial replacement for cement	Reduce the use of conventional cement
4	Recycled glass	Household and commercial waste	Light concrete aggregate mixture	High aesthetics, suitable for non-structural

The use of recycled materials directly contributes positively to the three pillars of sustainability: environmental, social, and economic. Reducing the need for natural materials and reducing carbon emissions from material transportation support environmental sustainability. The decrease in the volume of construction waste dumped in landfills shows that these projects have begun to apply the reduce-reuse-recycle principle in real practice, which is in line with the idea of a circular economy. Socially, the use of environmentally friendly materials helps to increase the positive image of the project in the eyes of the public, and in the long run can build public trust in the construction sector that is more ecologically responsible. Meanwhile, from the economic side, the cost efficiency achieved shows that sustainability and profitability are not two things that are in conflict with each other, but can go hand in hand (Khoiruddin, 2023). These findings support the urgency to expand the implementation of recycled materials in civil engineering projects, not just as a form of technical innovation, but as a systemic need in response to the climate crisis and global resource limitations. If supported by regulations, advanced research, and adequate infrastructure, the use of recycled materials will become a key pillar of sustainable construction in the future.

CONCLUSION

This research shows that the use of recycled materials in civil engineering is a strategic step towards more sustainable construction practices. Various types of recycled materials such as waste concrete aggregate, recycled plastic, fly ash, and glass have been successfully utilized in construction projects with the aim of reducing the exploitation of natural resources, reducing costs, and minimizing environmental impact. The source of materials derived from the demolition of buildings and industrial waste proves that the construction sector has great potential to carry out the principles of circular economy and resource efficiency. The motivation for the use of recycled materials is not only driven by cost efficiency, but also by compliance with environmental regulations as well as

increasing awareness of industry players on the importance of ecological responsibility. These findings are in line with sustainable development theory that emphasizes the importance of balancing environmental, social, and economic aspects in every development activity. However, the main challenge still lies in the quality and technical reliability aspects of recycled materials, particularly in their use in the main building structures. Inconsistencies in material quality demand stronger technical standards and a more thorough quality testing system. This shows that sustainability in construction requires not only goodwill, but also an adequate regulatory framework and technical support. Overall, the study underscores that recycled materials have a real contribution to the sustainability of construction projects. The use of this material helps to reduce waste volume, reduce carbon emissions, and increase project cost efficiency. Therefore, collaborative efforts are needed between the government, the construction industry, academia, and the community to expand the application of recycled materials through regulation, education, and technological innovation. Thus, civil engineering can play an important role in creating a greener and more ecologically responsible development future.

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