engineering proceedings

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Proceeding Paper

Diverse Approaches to Construction and Demolition Waste Reuse: A Case of South Africa †

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† Presented at the 1st International Conference on Industrial, Manufacturing, and Process Engineering (ICIMP-2024), Regina, Canada, 27–29 June 2024.

Abstract: Construction and demolition waste management through the reuse of materials has drawn a considerable amount of attention in recent years. Hence, this study examines the diverse approaches to construction and demolition waste reuse in South Africa. Surveying 122 construction professionals, 87 responses were analysed using descriptive statistics. The results show that manufacturing the road base pavement layer from reclaimed asphalt, manufacturing furniture from used timber, using recycled plastic to manufacture plastic strips for soil embankments, and manufacturing fibreglass insulation from recycled glass are the most adopted and significant approaches to construction and demolition waste reuse in South Africa. By embracing these approaches, the construction industry can transition towards more sustainable and resource-efficient practices, thereby minimising waste generation, conserving natural resources, and mitigating environmental impacts.

Keywords: approaches; construction and demolition waste; reuse

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Citation: Otasowie, K.; Aigbavboa, C.; Oke, A.; Adekunle, P.; Ayorinde, E. Diverse Approaches to Construction and Demolition Waste Reuse: A Case of South Africa. *Eng. Proc.* **2024**, *76*, 2. https://doi.org/10.3390/engproc2024076002

Academic Editors: Golam Kabir, Sharfuddin Khan, Mohammad Khondoker and Hussameldin Ibrahim

Published: 15 October 2024

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1. Introduction

Global urbanisation has increased at an astounding rate in the past several years. In 2016, the rate of urbanisation expanded to 54.3% [1,2], and, as of 2018, the rate has risen to 55% globally [3]. At this pace, construction and demolition (C&D) activities will produce an overwhelming amount of waste. According to [4], construction and demolition waste (C&DW) is the main source of gross waste production. The significant volume of waste generated by C&D operations negatively influences the environment due to sedimentation, soil erosion, and increased greenhouse gas emissions, among other things [5,6]. This has been corroborated by the statistics on C&DW that have been made public by different nations and regions, showing that a significant quantity of waste is produced globally each year. Construction waste refers to waste generated during the construction, refurbishment, and maintenance of residential, commercial, and other sorts of buildings. Demolition waste, by definition, is the debris generated from demolished constructions [7]. According to [8], the most typical profiles of C&DW materials are that they are made of masonry, plasterboard, rock, sand, wood, soil, metals, asphalt, plastics, asbestos, and cardboard. Thus, reducing or minimising the generation of C&DW has been advocated through effective management.

C&DW management, encompassing reduction, reuse, and recycling strategies, has been examined by some studies. For example, waste minimisation strategies that prioritise waste reduction are seen to be the most effective [9]. Nevertheless, since some C&DW production is unavoidable, reusing C&DW should be used as a practical managerial technique to reduce the amount of waste that ends up in landfills [10]. C&DW reuse is the technique of utilising the same building materials more than once, even in various

functions. There are several benefits to this C&DW management type, including preventing pollution and environmental degradation, having positive economic effects, using less energy, producing fewer emissions, etc. [9]. According to [11], materials of all kinds can be salvaged from C&D sites and sold, kept for future use, or put back to use on the present project. Except for items like latex paint, adhesives, and chemical solvents that need to be handled carefully, some C&D materials are considered poisonous and are categorised as hazardous waste [12]. Furthermore, refs. [13,14] note that the age of the structures included in demolition operations is another practical decision-making aspect in reusing C&DW.

C&DW management through the reuse of materials has drawn considerable attention from researchers in developing countries in recent years, who have regarded these wastes as pollutants that endanger the water, air, and soil in metropolitan areas. For example, ref. [15] opined that the reuse of materials could increase resource efficiency in developing countries and assist the construction sector clients to save money by lowering the cost of disposing of C&DW. Furthermore, ref. [16] posit that South Africa has evolved from the ancient methods of depositing materials regarded as 'waste' into landfills, transforming towards the reuse approach of the materials. Therefore, the increased awareness of the environmental impacts of construction waste has led to an improvement in waste control, which is an important reactiveness in construction project management and the sustainable design of most instances of building construction. In addition, the rate at which virgin materials are excessively utilised raised concerns; hence, sustainable construction practice has been proposed as an alternative solution to mitigate the excessive usage of the Earth's resources in the construction industry and to promote C&DW management practices distinctively geared towards enhancing the economy, and social and environmental developments through the reuse of C&DW material.

This study's objective is to examine the diverse approaches to construction and demolition waste reuse in South Africa. The study reviewed the extant literature to determine the diverse approaches with which to fulfil the research aim. The significance (weight) of each approach is then ascertained using descriptive statistics. Furthermore, a Kruskal–Wallis test was utilised to compare the responses based on the different construction professions. This research has two contributions to make. It is the first effort to identify the diverse approaches to construction and demolition waste reuse in South Africa. Second, the Kruskal–Wallis test is employed in this study to give a clear idea of the responses based on the different professions within the construction industry.

2. Reuse

The pyramid of waste management ranks reuse as the second priority. The reusability of a material depends on its capacity to reconstitute itself. Reuse has benefits since it uses less energy and minerals, produces less pollution and emissions of greenhouse gases, and uses fewer landfills and solid waste disposal. According to [17], the purpose of this activity is to create a sustainable environment by replacing the use of raw materials and eliminating waste from the economy. As a result, waste that may be valuable is used, and the need for new materials is decreased, conserving energy and lowering pollution from sources like landfilling and incineration [18]. Ref. [19] posits that reuse is a generally preferred approach as an efficient means of minimising the level of waste. One example of this is the case with waste electrical and electronic equipment (WEEE). The reuse and reduce priorities overlap theoretically when it comes to encouraging individuals to keep products after usage instead of throwing them away. However, the first impediment to encouraging reuse is product design. For example, ref. [20] found that the chemistry of lithium-ion batteries posed a low potential for reuse, leading them to propose the idea of "down-cycling", which involves using these batteries from electric cars in grid-attached electric storage systems with lower performance requirements. Applying waste prevention techniques, such as design-for-repair and design-for-disassembly, at the pre-use stage would be crucial to overcoming obstacles brought on by the existing take–make–dispose mentality. Reuse and recycling both face the challenge of creating source-separating collecting systems with

supply chains for various materials or reusable goods and parts. In practical terms, this means that systems for collecting waste should be built to encourage the separation of working from damaged devices [21].

As the industry's history demonstrates, construction and demolition waste (C&DW) is often disposed of in landfills. However, as time passed and there became a shortage of space in major cities worldwide, the problem became more pressing. Using the waste in new buildings is one of the better ways to dispose of it. Some waste components can be used for backfilling, low-traffic roads, walkways, footpaths, and other construction projects. Substantial amounts of this leftover concrete from C&DW may be used as coarse aggregate in fresh concrete. Thus, there is much possibility for reuse with C&D items and elements from restoration projects. However, depending on the product's quality and final worth, different product groupings have varying reuse potentials [22]. Reusable materials and products from remodeling projects are often offered in lesser amounts and with more variability in quality. Those with experience in larger industrial buildings or demolition projects might find this to be different.

3. Approaches to Construction and Demolition Waste Reuse

The global demand for construction materials has increased significantly [23]; hence, waste material generation is a prominent issue in every country. According to [24] statistics, the latest global demand for construction aggregates indicated an anticipated increase of 45 billion tonnes to 66 billion tonnes from 2017 to 2025, respectively. In addition, [25] also highlighted that about 2.7 billion tonnes of aggregates are in high demand. This high demand is primarily caused and contributed to by various factors, the most notable being the sustained robust growth in global construction activity and the rebound in global cement demand to create significant infrastructure in various impoverished countries of the world. The large developments and investments are driven by the continuous increase in the need for commercial and residential buildings, mainly in metropolitan areas, due to the rapid population growth and subsequent economic growth. Therefore, the above-mentioned factors are the core factors contributing to the increase in demand for conventional building materials [26]. Reusing construction and demolition waste (C&DW) materials is one sustainable waste management strategy and system. This approach can contribute significantly to the economy [26].

Ref. [27] outlined various material components that can be yielded from demolition or can be produced from C&DW; these include concrete and aggregate, bricks, tiles, plastic, timber, aluminium, glass, steel, rooftops, copper, and other products. For instance, bricks can be reused for other similar purposes. Bricks can be reused for wall partitions, and bricks can be repurposed for aesthetic creations such as wall dividers, landscaping, and more [28]. Likewise, old tiles encompass inert materials that enable the tiles to be reused as aggregates [29]. According to [27], a significant fraction of timber from the site might be salvaged when historic buildings or structures have been demolished or refurbished. The recovered wood may comprise structural beams, floors, wall paneling, and other items. Deconstruction needs to be handled with care when extracting usable components; this approach has great potential for reserving wood for current and future uses. Timber wastes can be reused for animal bedding, as a secondary sustainable energy source, and as particleboards. Steel and aluminium are the world's leading building materials, and they are commonly used in any civil engineering project. Steel waste produced during the construction, deconstruction, or repair of structures is notably available for repurposing. Ref. [30] posits that demolished steel is reused to manufacture steel products. Furthermore, the transportation sector in America has used Reclaimed Asphalt Pavement (RAP) for many years [31]. Reclaimed Asphalt Pavement is America's most reused material; currently, RAP is being recycled and reused at a rate of over 99%. Reclaimed Asphalt Pavement is used to backfill pavement edges and rework the base and base course [32].

4. Methodology

The research embraced a post-positivist stance and utilised quantitative methods through a questionnaire survey. The questionnaire comprised two sections: the first aimed to gather background information from participants, while the second addressed diverse approaches to construction and demolition waste reuse. Participants, consisting of qualified construction professionals (engineers, architects, quantity surveyors, and construction managers) with at least five years of experience in South Africa, were asked to rate the adoption of these approaches on a 5-point Likert scale. The scale ranged from 1 (strongly disagree) to 5 (strongly agree). Convenience sampling was employed due to constraints in time and finances, resulting in 122 questionnaires being distributed and 87 deemed suitable for analysis. Data analysis utilised various statistical methods, including standard deviation, percentages, mean item scores, one-sample *t*-tests, and Kruskal–Wallis tests, following the approach of [33,34]. The reliability of the questionnaire was confirmed through Cronbach's alpha test, yielding a score of 0.947, surpassing the acceptable threshold of 0.6, as [35] suggested, affirming the questionnaire's high reliability.

5. Results

The survey, which was conducted in South Africa, involved construction professionals, with those in Engineering comprising the largest proportion (65.4%), followed by those in Construction Management (17.2%), Quantity Surveying (9.2%), and Architecture (8.2%). Most respondents (83.3%) hold Bachelor's degrees, while Master's degrees, certificates, and doctoral degrees are held by 3.7%, 13%, and 1.1%, respectively. Remarkably, respondents reported an average working history of 12.3 years, indicating substantial experience in the field. These results indicate that the study's target demographic, construction professionals, were well-represented and possessed the necessary education to engage with the survey questions [36]. Furthermore, the responses were informed by a wealth of professional expertise.

Furthermore, the mean, the standard deviation, and a one-sample *t*-test were adopted to assess the adoption and significance of specific approaches among respondents. Each approach's mean rank was tabulated to offer a comprehensive understanding of the respondents' perspectives. Significance was determined at a 95% confidence level, consistent with established norms [37]. An approach was considered significant if its *p*-value is less than or equal to 0.05 and attained a mean rating of 3.5 or higher on the five-point Likert scale. Table 1 presents the approaches identified for construction and demolition waste reuse. Additionally, it displays the observed data mean alongside the standard deviations. In instances where multiple approaches shared the same mean, priority ranking was assigned based on the approach with the lowest standard deviation [38]. Refer to Table 1 below for detailed one-sample statistics and *t*-test results.

According to the *p*-values (significance (1-tailed)) presented in Table 1, the respondents collectively agreed that approaches such as the manufacturing of the road base pavement layer from reclaimed asphalt, the manufacturing of furniture from used timber, the use of recycled plastic to manufacture plastic strips for soil embankments, the manufacturing of fibreglass insulation from recycled glass, and the manufacturing of coarse aggregates from concrete are significant approaches to construction and demolition waste reuse in South Africa. The approaches listed in Table 1 are presented in order of their significance; hence, the approaches at the bottom of the table have not been adopted in the South African construction industry and are not considered significant by the construction professionals who participated in the study.

Furthermore, to assess variations in responses among participants based on their respective construction occupations, a Kruskal–Wallis test was performed. The analysis revealed no statistically significant differences among participants' responses regarding the approaches to construction and demolition waste reuse, except for manufacturing a sustainable source of power (firewood from old timber) with a *p*-value of less than 0.05. Table 2 provides the detailed findings.

Table 1. One-sample statistics and test of approaches.

Approaches	T	Df	Sig. (1-Tailed)	Mean	SD	95% Confidence Interval of the Diff.		
						Mean Diff.	Lower	Upper
Manufacturing of road base pavement layer from reclaimed asphalt	3.377	86	<0.001	3.91	1.127	0.408	0.17	0.65
Manufacturing of furniture from used timber	2.703	86	0.004	3.84	1.170	0.339	0.09	0.59
Use of recycled plastic to manufacture Plastic strips for soil embankments	2.680	86	0.004	3.84	1.180	0.339	0.09	0.59
Manufacturing of fibreglass insulation from recycled glass	3.062	86	0.001	3.84	1.033	0.339	0.12	0.56
Manufacturing of sustainable source of power (firewood from old timber)	1.830	86	0.035	3.75	1.260	0.247	−0.02	0.52
Manufacturing of coarse aggregates from concrete	1.788	86	0.039	3.71	1.109	0.213	−0.02	0.45
Manufacturing of tabletops from old tiles	1.560	86	0.061	3.69	1.134	0.190	−0.05	0.43
Use old tiles for aesthetic creations and landscaping	0.914	86	0.182	3.62	1.232	0.121	−0.14	0.38
Manufacturing of lightweight concrete	0.814	86	0.209	3.61	1.252	0.109	−0.16	0.38
Manufacturing of steppingstones, and carpet cushions from old carpets	0.802	86	0.212	3.60	1.136	0.098	−0.14	0.34
Manufacturing of tile backer boards from recycled carpet	0.500	86	0.309	3.56	1.178	0.063	−0.19	0.31
Manufacturing of roofing shingles from old carpets	0.420	86	0.338	3.55	1.149	0.052	−0.19	0.30
Manufacturing of cold patch mix asphalt from roof shingles	0.144	86	0.443	3.52	1.119	0.017	−0.22	0.26
Manufacturing of animal bedding from timber	−0.384	86	0.351	3.45	1.255	−0.052	−0.32	0.22
Manufacturing of Hot Mix Asphalt from roof shingles	−0.689	86	0.246	3.41	1.167	−0.086	−0.33	0.16

SD: standard deviation; DF: degree of freedom; and T: *t*-test value.

Table 2. Kruskal–Wallis test showing *p*-values for approaches.

Approaches	*p*-Values
Manufacturing of coarse aggregates from concrete	0.431
Manufacturing of lightweight concrete	0.381
Manufacturing of road base pavement layer from reclaimed asphalt	0.206
Use old tiles for aesthetic creations and landscaping	0.411
Manufacturing of tabletops from old tiles	0.336
Manufacturing of animal bedding from timber	0.099
Manufacturing of sustainable source of power (firewood from old timber)	0.027
Manufacturing of furniture from used timber	0.483
Manufacturing of Hot Mix Asphalt from roof shingles	0.087
Manufacturing of cold patch mix asphalt from roof shingles	0.629
Manufacturing of roofing shingles from old carpets	0.285
Manufacturing of steppingstones, and carpet cushions from old carpets	0.333
Manufacturing of tile backer boards from recycled carpet	0.895
Use of recycled plastic to manufacture plastic strips for soil embankments	0.115
Manufacturing of fibreglass insulation from recycled glass	0.550

6. Discussion

From the study's findings, manufacturing a road base pavement layer from reclaimed asphalt ranked first in terms of approaches to construction and demolition waste reuse in South Africa. This was further corroborated by the Kruskal–Wallis test conducted, as the groups of construction professionals who participated in the study agreed to the ranking. This finding corroborated the study of [31]. Utilising reclaimed asphalt for manufacturing

road-based pavement layers presents a sustainable and cost-effective approach to mitigating the environmental impacts of construction and demolition waste while simultaneously enhancing infrastructure development. The first step in this process is the collection of the Reclaimed Asphalt Pavement (RAP). Instead of disposing of the old asphalt, it is milled or crushed on-site to produce RAP material. This material consists of a mixture of asphalt binder, aggregates, and sometimes other additives used in the original pavement. One of the key advantages of using reclaimed asphalt in road base pavement layers is its environmental benefits. This approach reduces the need for virgin materials and minimises the amount of construction and demolition waste sent to landfills. It also conserves natural resources and reduces the energy consumption associated with asphalt production. Furthermore, using recycled asphalt in road construction can save project owners and taxpayers costs. Since reclaimed asphalt is typically less expensive than virgin materials, recycling RAP can lower the overall cost of road construction projects while still meeting performance requirements.

The study's findings further reveal that manufacturing furniture from used timber ranked second in terms of approaches to construction and demolition waste reuse in South Africa. This was further corroborated by the Kruskal–Wallis test conducted, as the groups of construction professionals who participated in the study agreed to the ranking. This finding corroborated the study of [15]. Manufacturing furniture from used timber presents a compelling approach to reusing construction and demolition waste. Timber, a common material in construction, often ends up as waste after buildings are demolished or renovated. However, instead of discarding this timber, it can be repurposed into high-quality furniture items, thereby extending its lifespan and reducing its environmental impact. One key benefit of using reclaimed timber for furniture manufacturing is its sustainability. By giving new life to old timber, the need to harvest new trees is reduced, helping to conserve forests and mitigate deforestation. This aligns with the principles of the circular economy, where resources are kept in use for as long as possible through recycling, repurposing, and refurbishing. Moreover, furniture made from reclaimed timber often carries a unique aesthetic appeal. Each piece may bear marks of its previous life, such as weathering or nail holes, adding character and charm. This not only enhances the individuality of the furniture but also tells a story of sustainability and resourcefulness.

The diverse approaches to construction and demolition waste reuse encompass a range of strategies aimed at mitigating environmental impacts, promoting sustainability, and maximising resource efficiency within the built environment. These approaches involve various stages, from waste minimisation and segregation to innovative reuse techniques and policy interventions. One fundamental approach is waste prevention and minimisation at the source. This entails adopting sustainable design and construction practices that prioritise reducing material consumption, optimising building layouts, and selecting environmentally friendly materials with minimal waste generation potential. Construction projects can minimise waste generation from the outset by incorporating principles of lean construction and resource efficiency.

7. Conclusions

This study examines the diverse approaches to construction and demolition waste reuse in a bid to understand approaches to the reuse of construction and demolition waste in South Africa. The approaches were discovered after a survey of the available literature, which was then presented to construction professionals. The study results show that the most adopted and significant approach to construction and demolition waste reuse in South Africa is the manufacturing of the road base pavement layer from reclaimed asphalt. Manufacturing furniture from used timber, using recycled plastic to manufacture plastic strips for soil embankments, manufacturing fibreglass insulation from recycled glass, manufacturing sustainable sources of power (firewood from old timber), and manufacturing coarse aggregates from concrete are some of the other adopted and significant approaches. Moreover, there was agreement between the professions in terms of the adopted and significant approaches. Based on the study's findings, it is evident that the diverse ap-

proaches to construction and demolition waste reuse encompass a range of strategies aimed at mitigating environmental impacts, promoting sustainability, and maximising resource efficiency within the built environment. These approaches involve various stages, starting from waste minimisation. Adopting a multifaceted approach to construction and demolition waste reuse involves implementing waste prevention measures, enhancing waste segregation and sorting processes, deploying innovative reuse techniques, fostering collaboration among stakeholders, and implementing supportive policy measures. By embracing these approaches, the construction industry can transition towards more sustainable and resource-efficient practices, thereby minimising waste generation, conserving natural resources, and mitigating environmental impacts. Finally, the study was conducted in South Africa. A similar study can be conducted in other African countries to provide a more robust discussion on the subject matter.

Author Contributions: Conceptualisation, K.O.; methodology, K.O.; software, K.O.; validation, C.A., E.A. and P.A.; formal analysis, P.A.; investigation, E.A.; resources, C.A. and A.O.; data curation, C.A.; writing—original draft preparation, K.O., E.A. and P.A.; writing—review and editing, C.A. and A.O.; visualisation, C.A. and A.O.; supervision, C.A. and A.O.; project administration, C.A.; funding acquisition, C.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics and Plagiarism Committee (FEPC) of the Faculty of Engineering and the Built Environment at the University of Johannesburg (protocol code UJ_FEBE_FEPC_00828 and 6 June 2023).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The original contributions presented in the study are included in the article. Further inquiries can be directed to the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

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