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Management of construction & demolition waste: barriers and strategies to achieving good waste practice for developing countries

O M Olofinnade[1,*] I Manda[1] and A N Ede[1]

[1]Department of Civil Engineering, Covenant University, Ota, Ogun State, Nigeria

*Corresponding author: rotimi.olofinnade@covenantuniversity.edu.ng

Abstract. Environmental contamination due to construction and demolition (C&D) waste management is a global issue. It is an even bigger issue specifically for developing countries that encounter different obstacles due to the construction industry's practices caused by a lack of knowledge and the economic status of these countries. The aim of this study is to review various research conducted in developed and developing countries so as to identify the significant problems and to seek appropriate ways to implement the management of C&D waste in developing countries. The findings of this research were grouped into seven (7) areas, which include the economy, knowledge across the industry, storage and cross-contamination of wastes, technology, design for deconstruction, legislation, and environmental health. Each barrier is attached with a strategy appropriate for developing nations, which would improve the C & D waste management industry if implemented. This study's results can be used as a reference for further research into these barriers to develop comprehensive strategies that will significantly improve the C&D waste management industry.
Keyword: Construction and demolition wastes, recyclable waste, construction waste management, sustainability

1. Introduction

Demolition waste is the rubble obtained from destroying building structures. Despite being destructive, demolition is vital for developing megacities, with space scarcity a significant obstacle. Many buildings are demolished, but they mainly occur to buildings that have approached or exceeded their lifespan and buildings undergoing renovations. Waste on a building construction can unnecessarily be produced due to the excessive ordering or quantification of materials and the mishandling of the materials by unskilled laborers. Natural disasters can also generate construction and demolition (C&D) waste. These few activities result in several significant problems, e.g., how to transport the waste, store it temporarily before processing, and finally, where to dispose, mostly landfill sites. C&D waste has chemical properties that make it difficult to be broken down or changed by waste processing techniques like other forms of waste [1]. The construction industry contributes highly to the depletion of natural resources and degradation of the environment. An estimated 3 billion tons was observed by Saghafi & Teshnizi [2] as the number of raw materials used for the manufacturing of construction materials worldwide. Despite being essential in the

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construction process, the process of extraction, processing, handling, and uses amount to 7% of the total global energy consumption. Furthermore, the transportation of primary materials alone is responsible for the usage of 40% of the total energy consumed by the industry. The construction industry has begun to use different methods for its sustainability by reducing the generation of waste, making sure energy is used efficiently, and reusing construction and demolition waste as recycled aggregates [3].

Furthermore, there has been a rapid increase in urban populations throughout the world, which has led to an increase in construction activities, and this has developed a problem due to the increase in construction and demolition waste as a result of that. In Hong Kong, the amount of C&D waste represented six times that of municipal solid waste. The construction industry is in pressing need of an alternative and sustainable source of raw construction materials. It has become an increasingly important issue to study the effective management of these wastes and their potential to be recycled globally due to their effect on our environment [4]. Many different researchers have proposed ways in which the use of natural resources can reduce with the use of supplementary cementitious materials. These include silica fumes, fly ash, quick lime, or waste products derived from ceramics, palm oil waste, etc. The addition of these materials significantly changes the properties of the resultant concrete, which can be used as an outlet for other waste products in different industries, which also reduces the handling cost of waste [1]. C&D waste is less likely to be used as a different product, which increases the need for landfills, but this is not a sustainable management option due to its immediate effects on the environment. This has made it a necessity to recycle and reuse these wastes as construction materials. Reduce, reuse, and recycle are no longer just a term but are beginning to be realized quickly in some countries. This was observed as the EU in 2010 who set a target of increasing the recycling rate of C&D waste from 10-90% to a minimum of 70% average recycling rate by 2020. This was achieved by a few countries like Belgium, the Netherlands, Switzerland, and Austria by 2013 [4].

Sustainability measures are unavoidable in the construction industry, which means that it is not just meant to reduce the carbon footprint, but it is also meant to contribute to the conservation of natural resources, which are crucial for the constant development of our society and the societies to come. Many developments are underway to reduce the depletion of natural resources, but completely stopping the use of natural resources is practically impossible. It has been discovered that as C&D waste is disposed of and stored, it tends to mix with materials that are not reusable for construction work. These materials alter the properties of the C&D waste and reduce their reusability, making it hard for them to be treated, and some are rendered unusable. The management of C&D waste is crucial in increasing the amount of C&D waste that can be recycled. Developing countries, also known as third world countries, are a large number of dissimilar societies, cultures, and civilizations not part of the Western world with economies that are less industrialized or modernized. A common fact in these countries is that most of their people have a low standard of living and regularly fight wars, they are unstable politically and experience population explosions, which have led to the destabilization of their economies and led to an inadequate financial standing [5]. Although waste reuse and recycling are practiced in developing countries, they only apply to a specific type of waste, mainly steel, paper, wood, and plastic. Inert wastes like concrete and broken bricks are not recycled. As the real estate industry and infrastructure development continue to expand, C&D waste generation is likely to increase further. To improve the sustainable construction in developing countries, we can do this by the effective utilization of resources in construction, material recovery, an improved system for C&D waste management, and energy savings [6].

The C&D waste is a significant problem in both developed and developing countries; what differs is the nature of generation and handling of the waste. Developing countries are beginning to engage in waste management practices, but still, there is a culture of insufficient collection and improper disposal that still reigns supreme in the industry. This waste constitutes a large amount of waste dumped in river banks, roadsides, and many other open spaces. It has resulted in health and environmental impacts coupled with negative economic impacts on nearby properties. There is a need for urgent improvement in construction waste disposal practices to meet the demand for improved construction waste management [7]. In order for C&D waste management's goals to be achieved, significant barriers hindering its implementation need to

be recognized and considered. There is a strong need for a long-term plan combined with adequate development and research. Very few initiatives involving legislation and regulation are followed, and this has failed the necessary economic, technical, and administrative instruments.

2. Methodology

This review aims to identify barriers significantly affecting the growth of the C&D waste management industry by looking into various research conducted in both developed and developing nations and seeks appropriate strategies that can be implemented in developing countries.

3. Discussion

3.1 Economy

Developing countries are known to be low-income countries with a lack of adequate finances to expand and sustain the C & D waste management industry. Therefore, economic instruments can be used to improve waste management, but the framework for regulation and their application are a hindrance to the implementation of these measures. There needs to be sure things set in place before it is implemented like an appropriate public awareness about the environment, excellent management expertise, innovations, and proper accounting practices because the technical, managerial, and social point of view are difficult to manage. There needs to be an application of new charges and it should be a system programed to support itself. The methods of reducing, reusing, and recycling are widely used in municipal solid waste practices but less practiced when it comes to C&D waste. One reason could be that the recycling of building materials is not cost-effective. There is a severe lack of demand for particular wastes of construction like concrete and broken bricks [6], [17-18].
According to Akhtar & Sarmah [1], the recycling of waste and its management can minimize the volume of C&D waste in the ever-growing construction industry. This process increases the prosperity of a country by creating many new jobs, which can be referred to as a circular waste economy. Ferronato & Torretta [8] noted that we need to include the informal sector by finding ways of recycling and reducing waste inflow into final disposal by developing methods that require low technological requirements and economic investments in developing countries. Although to do this, we will need to understand the most appropriate strategy for their involvement by further investigating various methods of involving the informal sector. Mulenga [9] suggested that Zambia with its neighboring countries need to create sustainable practices that will include Climate Change and Green construction principles. Countries and regional organizations such as SADC, SATTC, and ASANRA are encouraged to be frontrunners in providing funds for these attempts. High risk attempts are required to establish sustainable C&D waste management, and there needs to ne coordination between education, training, research and development institutions, and the construction industry at large.

3.2 Industrial knowledge and training

The next challenge would be to change the perception of C&D waste being considered as solid waste and to re-frame it as a raw material in the construction business**.** The uncontrolled disposal of C&D waste into landfills continues to be a significant problem in developing countries, and it is the main reason for the increased waste of land and natural resources [10]. Excessive use of natural resources and the large amount of C&D waste observed in our environment is due to a lack of awareness of source efficient construction practices. A study by Muleya & Kamalondo [11] on the waste management practices in Zambia, targeted groups which were separated into four: contractors, consultants, government units, and regulators. This

research illustrated that what was practiced in waste management did not align fully with the Zambia construction industry (ZCI) waste management hierarchy. There was an agreement between all groups that there was a need for a Site waste management plan (SWMP), which would be a successful and safe way of managing construction waste in the ZCI. Significant challenges identified include; Traditional habits of construction and behavior, inadequate exposure or training, and a lack of funds.
There needs to be an introduction of awareness and information campaigns, implementation of systems for treatment and regulation and control agencies, the improvement of sites of disposal and their management, the enhancement of financial sustainability of the systems and the introduction of future management plans in order to improve the integrated solid waste management of a country, region, municipality or rural area [8]. Zulu [12] evaluated exercises, techniques, and awareness of solid waste management (SWM) in chosen townships in the capital of Zambia, Lusaka. It was found that 91% of the respondents were not aware of solid waste management and did not know the appropriate disposal methods. It was concluded that people were not knowledgeable enough on solid waste management and practiced inferior ways of getting rid of waste among all respondents regardless of their backgrounds. This study signifies how big a task it will be to raise awareness to achieve sustainable waste management and disposal in the construction industry. The municipal solid waste management sector has gone great lengths in raising awareness on the disposal of waste and how to manage it, but even in recent times, serious problems are faced, and a majority of the people still do not engage in these practices. There is a need to change the attitude and perception of construction project stakeholders to show that the waste recycled products fit their needs to influence their behavior and decision-making**.** The Institute of Public Works Engineering Australia Limited has come up with courses in which all stakeholders involved in public works understand the specific requirements of newly introduced products like recycled aggregates and substitute materials and grasp how they can be incorporated in projects. Even as the range of new recycled materials and products increases on the market, the requirement for courses recognizing them will be more critical and the ways in which they can be utilized efficiently [13].

3.3 Storage and Cross-contamination of wastes

Construction material's recovery rates are severely impeded due to cross-contamination with other materials, which is prevalent in the construction and demolition waste industry. It must be ensured that materials are obtained closer to the source, which reduces the likelihood of mixing it with other wastes and obtain high recovery rates. As noticed from the case studies, the highest recovery rates were obtained from waste materials that were captured and segregated early [13]. Segregation of plasterboard increases the total cost of a construction project, but this cost is recouped by gate fees being reduced for waste without plasterboard sort out and the income generated from the recycling of low sulphate C&D waste [14]. There is a challenge in the categorization of C&D waste faced by many developing economies because no specific laws are governing the production, management, and discarding of C&D waste. In most of these countries, it has been considered municipal solid waste (MSW) and planned for in that way. This poses to be a problem for recycling because there are plenty of chemical and physical differences between the two, which means it would need additional treatment if it were to be used for construction [10].
Policies must be set in place to mandate contractors to implement the calculation of waste indices, which will ascertain the quantity of waste generated on-site. This will help plan for the right measure to control it. Much should be done to encourage contractors to make use of prefabricated materials. There should be a correlation between specific materials purchased for use and their design specifications which can guide site personnel on ways in which they can avoid the wastage as they carry out construction works [15]. Material use efficiency can be achieved by the creation of space and the availability of consolidation centers within reach, which are a vital aspect of the adequate sorting and stocking of materials on site. The use of consolidation centers or availability of impromptu deliveries allows for preferable organization of the area; they reduce the waste and increase the efficiency of works on site, which makes savings achievable. Waste sorting and processing is a technology well spread in developed countries and is standard for waste

treatment facilities. This practice needs a way in which waste can be segregated and a constant demand for these products which keeps it away from gathering subsidiary products. Recycled products are relatively cheaper than natural materials. With the implementation of this method, it is possible to raise the confidence of all contributors in the industry as it is also possible to achieve increased amounts of recycled products (higher than 90% for some frontrunners) and it yields notable benefits from the life-cycle perspective on the environment [14].

3.4 Technology

According to a literature review by Mulenga [9], sustainable C&D waste management is possible only if every phase of construction has been considered. It is crucial without attention to the degree of mechanization. C&D waste production and disposal need to be studied in depth in order to benchmark good practice. A great number of studies concerning waste have been overseen in developed countries and tend to focus on municipal waste compared to C&D waste. This has left a gap for the developing world to address and develop models to manage C&D waste.
A significant obstacle to recycling landfilled materials is finding the right equipment to sufficiently clean and segregate these waste products so that they can be reused. This has created an opportunity for a market for recycling plants that could be used for this cause. This study showed that this is specifically a problem for waste produced by timber where the contamination happens due to the treated timber and funding of extensive investigation is required to conquer these barriers [13]. Another challenge is in contingency C&D waste management. This can happen due to a destructive disaster that would need massive scale management in an emergency situation. In an ideal situation, rescue and cleanup of rubble must be done simultaneously because they complement each other. It helps prevent the spread of disease and also assist in returning back to normal life as quickly as possible.
Reuse of materials is viable [20], but there isn't a large market for recycled products, and this has meant that there is a large stockpiling up, which hinders the applicability of these materials. The reuse of materials is a measure applied scarcely, and this is because of its high demand for large sums of funding. However, despite how much is being done, its use as a standard product in construction is far from being achieved. A good case in point is the price of recovered bricks, which can sometimes cost more than standard bricks by 100%, although it is possible to save about 50% of the total cost used for investment by the reclamation of steel frames. It is also possible completely stop the dumping of waste in landfills if reuse is integrated with other best practices [14]. There are many benefits to adopting an SWMP based on findings, which include: reduced amount of waste in landfills, reduced waste on-site, and prevention of pollution. It can provide a prescribed approach to on-site waste management and helps provide an efficient way to allocate resources. Regulators showed a willingness to support SWMP in giving fines for non-compliance and halting of projects that do not meet the guidelines with deregistration as a last resort [11].

3.5 Design for deconstruction

A way in which construction materials can be reused better is by the adoption of deconstruction rather than demolition, which would help in the selection of materials needed for reuse. De-construction demands a lot of manual labor, time, and very specialized light machinery, making it a costly option [10]. Designing for deconstruction is a process by which resource recovery is of the highest priority and is slowly gaining prominence. It is designed so that as it approaches the building's design life, it can be taken apart and offers more excellent resource recovery opportunities. It may influence the design of materials to suit better this new form of design [13]. Building deconstruction can be used when waste management is a costly option, and some materials or components are scarce, which would drive the demand for it. Despite being very expensive, it is efficient with recovery rates of up to 95-99% [14]. De-construction of buildings has been studied by many, and the reuse of materials has yielded positive results. The reuse of construction materials

has many benefits. However, the price and time factor related to it, and the structured operation are noteworthy barriers for this particular technology to be adopted [1].

3.6 Legislation

There is a deficiency in legislation pertaining to C&D waste management for it to be sustainable, a common issue in developing or transitory economies like India, Malaysia, and the Czech Republic. This means that due to the lack of legislation to govern and monitor C&D operations by these governments, there is a high likelihood of experiencing the development of compromised structures due to reduced quality. This becomes a hazard to the environment and is not safe for its occupants, which may lead to the demolition of inferior quality structures, which may lead to non-recyclable materials and materials harmful to the environment. The lack of enforcement in these countries also results in the illegal disposal of this waste into landfills [10]. Site waste management and prevention can be achieved by adequate enforcement of legislation, improvement of facilities, and increasing the accessibility to waste management services because the reduced rate of recovery of waste materials in some countries is not because of below par management. Generally, waste management of construction worst don't exceed 3% of the entire cost. This means that preventing waste will only result in a small amount of savings. Ideally, about 99% of all waste is diverted from landfills [14]. The policy is needed in order to mandate contractors to include a waste management plan in the documents expected to be submitted during tendering processes. Contractors need to form a department that evaluates the plan in order for it to comply with the provisions by building the capacity of the site workers and workforce development. The site workers need to be educated on the environmental and health risks that accompany waste generation from materials that have been used during the construction process [15].

3.7 Environmental Health

The production and transportation of cement and aggregates yield a high carbon footprint with cement having the highest carbon footprint. This is shown in a study that observed that cement production emits 7% of the world's CO_2 emission [3]. There are particular elements of demolition waste like plasterboard that are hazardous to the environment when it is landfilled because it is run down when deposited in landfills and emits sulfide gas, which is toxic. The waste obtained from individual construction and demolition ends up being deposited in municipal bin/waste storage deposits, which makes the municipal waste heavy. It makes the municipal waste quality degrade and also makes it difficult for further treatments like composting. Furthermore, about 10-20% of this waste finds its way into surface drains which chokes them [16]. Ferronato & Torretta [7] reviewed environmental contamination and social issues in developing countries due to solid waste (SW) mismanagement. The results of this review showed that there is a need for solid waste management (SWM) system in order to get through the reduction of the environmental footprint and to improve the targets of sustainable development goals (SDGs). This view was also echoed in the study of [19, 20] on achieving some of the SDGs goals. In developing countries, too often, SWM is considered as a single stream disposed of in open dumpsites. However, it is required that there should be an application of impromptu collection and treatment solutions for each waste flow in the implementation of future management plans in municipal areas: Municipal Solid Waste (MSW) (organic and inorganic), healthcare waste (HW), C&D waste, waste electric and electronic equipment (WEEE) and used batteries, industrial and toxic waste and used tires. Models for quantities of waste to be quantified need to be determined, which can be rooted on the entire price of a construction project or on the amount of space on the floor depending on the building classification [9].

4. Conclusion and Recommendation

The following conclusions can be drawn from these reviews:

i. Developing countries are neglecting the implementation of sustainable C & D waste management practices, and it is required that there should be cooperation amongst the educational, training, research, and development institutions.
ii. The implementation of C&D waste management practices offers a new market for the private sector, which could generate a large source of income as well as increase the jobs for a country's citizens.
iii. The best way to implement sustainable C&D waste in developing countries is by the enforcement of legislation that all parties in the construction industry need to follow. C&D waste management guidelines need to be set in place from tendering to ensure that it is included in all projects' total costs.
iv. De-construction is currently not a viable option due to the current state of C&D waste management in developing countries. This is because De-construction is very expensive to implement and will require the financial input and cooperation of many institutions.
v. Funding is required to push C&D waste management as it will require huge investments before the industry can generate profits. This can be done with the help of governments and regional organizations (ECOWAS, SADC, etc.)
vi. Developing countries can achieve C&D waste management sustainability by developing methods that require low technological requirements and economic investments and not by replicating developed nations' strategies due to their inferior financial status.

Most research on the management of construction and demolition waste has been conducted in developed countries and therefore the solutions obtained are only suitable for these countries. Therefore, there is a need for research in the technologies and strategies that are suitable for implementation in developing countries.

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