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Impact of concrete waste management by using life cycle assessment

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A B S T R A C T

The rapid expansion of Dubai and the United Arab United infrastructure in the Middle East over the past twenty years has resulted in a large accumulation of concrete waste in landfills and dumping sites. The subsequent hasty increase in the construction and demolition of the infrastructure has outstripped effective waste management facilities, posing a serious natural challenge. This concrete waste greatly endangers human health, property, and biological systems when buried. To find effective solutions to this issue, different waste management methods were researched and compared to find the most effective. This paper aims to differentiate the most appropriate waste management strategies and determine their impact on the environment. These methods included reducing the waste, reusing those wastes that can be reused, recycling, and disposal in landfills and government dumping sites. This paper opens the door for future studies to determine the impact indicators and specific waste management methods that substantially influence the environment and the cost of damage. In addition, a Life Cycle Cost Assessment (LCA) may be carried out to supplement this research and determine the financial benefits of the various specific waste management options and the cost of damages. The study predominantly assesses the different construction and demolition waste management strategies. It primarily adds valuable knowledge concerning these waste recycling management techniques and their environmental effect. This study also suggests directions for future exploration, such as identifying key impact indicators and management strategies that have a significant impact on the environment. Alternatively, LCA can complement the results by assessing the financial benefits of different physical waste management options. To sum up, the exponential growth of infrastructure in Dubai has led to a considerable challenge regarding concrete waste. The LCA-based comparison between landfill and recycling methods highlights the urgency of adopting sustainable waste management practices. This study not only broadens the understanding of damage cost models but also provides a comprehensive assessment of practical waste management options, contributing to informed decision-making to minimize environmental impact.

1. Introduction

The waste from construction and demolition is covered in numerous sections of this study. The theoretical foundation of the study is covered in the first Section (Choi et al., 2018). It emphasizes recycling for effective management of building and demolition waste and primarily identifies research and problem presenting gaps. Additionally, emphasis is placed on the study's significance as well as its goals and pertinent research topics. The terms “concrete”, “construction and demolition waste”, “C&D waste components”, and “environmental impact” are all defined in detail (Muthu, 2015). The waste management policies, management techniques, and management strategies for building and demolition waste are introduced. The study also covers the research findings, such as recycling techniques for C&D wastes, and outlines the research structure and methods. The research findings are also discussed, and the findings and discussion are summarized considering the knowledge that has been gained because of the research. The study also includes suggestions for additional investigation. Waste management done right is crucial (de Oliveira Neto et al., 2017). For treating building and demolition trash, scientists have investigated several approaches. Reducing the amount of garbage produced is the initial goal when implementing waste management solutions. The first stage of the 3Rs principle, including Reduce, reuse, and recycle, is used to reduce waste output. When production is inevitable, it can be recycled or used again. If the 3R procedures do not produce satisfying outcomes, the item might be disposed of in a landfill, a phase requiring accurate time estimation and careful planning to

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ensure proper waste management. Recycling waste offers sustainability and economic advantages (Giusti, 2009). As a result, garbage generated during construction has a negative influence on the environment, particularly during transportation and dismantling. Construction expenses have increased because of rising construction material costs, however using recyclable alternatives like steel and bricks can reduce or even eliminate these costs. According to Giusti (2009), suitable measures should be taken before disposing of these raw materials in landfills because they can create more cash through recycling techniques.

The project gains quality and sustainability by implementing the best waste management techniques. Environmental damage from the huge increase of landfills is severe (Zhang & Tan, 2016). In Yuan (2013), Bossink and Brouwers (1996) illustrated how the 3Rs of trash management are essential for lowering the costs of raw materials, transportation, and disposal. The sale of waste might also result in increased revenue. Furthermore, nations that do not use sustainable waste management practices frequently spend a lot of resources on garbage disposal, including time and money. As a result, the ecosystem is also significantly impacted. The building industry can attain sustainability, a better economy, and quality if there are efficient ways to manage and dispose of trash, he is making an assertion. Waste disposal and landfill space are reduced by effective waste management (Mansor, 2014).

Many countries place a great deal of significance on waste management strategies. According to Sales and de Souza (2009), it depends on how trash is used. For instance, recycled aggregates are mainly used to build pavement in Brazil, whereas they are frequently used to build public projects in Hong Kong. Furthermore, several nations, such as Germany, have established procedures to verify the high caliber of recycled materials (Weil, Jeske, & Schebek, 2006). In terms of economics, 47% of garbage in Europe is routinely recycled. However, according to Torgal and Ding (2013)'s reference to the garbage Framework Directive, non-hazardous garbage will be recycled at a rate of 70% by 2020. In addition, further research is being done on the use of surplus demolition and construction waste to recycle concrete pieces into brand-new materials. To better understand construction and demolition waste management techniques, this study offers insightful information and prospects. Through this research, one will gain an understanding of trash management techniques including the 3Rs of waste management, which emphasize reducing, reusing, and recycling, as well as other techniques such dumping into landfills when recycling is not an option. It attempts to optimize the economic benefits from reducing, recycling, and reusing these wastes in order to minimize waste of construction materials, environmental pressure from expanded landfill regions, and trash generation.

1.1 Statement of Problem

Concrete is used more frequently than water worldwide (Nazari & Sanjayan, 2015). According to Collins (2010), the primary component of concrete manufacture, cement, is responsible for 8% of the world's carbon dioxide emissions. Reusing and Recycling building and Demolition trash. As Vieira and Pereira (2015) have noted, reusing and recycling building and demolition trash contributes to preserving resource inventory and easing the burden on landfills. According to Elchalakani and Elgaali (2012), excess building supplies and demolition trash are the main sources of concrete waste. Dubai and other Gulf Cooperation Council (GCC) nations struggle with substantial garbage issues. Dubai produced 120 million tons of trash in 2010, making it one of the top waste-producing nations in the world. Approximately 75% of the waste in landfills is C&D waste. Additionally, Dubai produces the most rubbish per person in the world—roughly 76,000 tons per day according to Elchalakani and Elgaali (2012). These figures demonstrate the pressing need for targeted waste management techniques.

There is an extensive research gap concerning concrete, construction, and demolition waste management strategies, especially in developing and third-world countries. While in most developed countries, there are effective measures to ensure limited disposal of C&D wastes into landfills, many underdeveloped and developing countries lack the measures to ensure the implementation of these measures (Coelho & De Brito, 2013). According to Richardson 2013, concrete consumption will have increased from 1500 million to 3500 million tons by 2020, yet no previous studies have existed on the appropriate methods of ensuring zero wastage from construction activities. Many studies demonstrate the benefits of recycling concrete waste, but the metrics studied focus on specific waste products and recycling techniques (Torgal, 2013). The methods are not comprehensive. These wastes' impacts on the environment have comprehensively been stated, but on the other hand, there is no precise information on the impacts on resources, human well-being, and biological systems. It slows down the efforts to design effective strategies for effective management strategies.

1.2 Research aims and objectives

This paper seeks to investigate effective concrete, construction, and demolition waste management strategies with a major focus on the United Arab Emirates. It will seek to accomplish the main objective which is to find out the available waste management strategies and determine the most effective strategy among them all. It will explore different waste management strategies such as the 3Rs of waste management, reducing, reusing, and recycling, and compare them to establish their effectiveness. It also explains the different waste management policies in the world and then narrows down to those policies in the United Arab Emirates. It will also define concrete as a construction material besides explaining the various types of construction and demolition wastes. It will go further to explain the impact these wastes have on the environment too. Lastly, it also seeks to answer the following questions: What are the available concrete, construction, and demolition waste management methods in the UAE? What is the most effective approach to waste management in the UAE? What is the waste management policy in the UAE?

2. Literature Reviews

A thorough review of existing information about waste in the construction industry is provided. It elaborates on the definitions of concrete, construction, and demolition waste, along with detailing the various elements found in C&D waste.

2.1 Concrete Waste in the Construction Industry

Concrete ranks as the second most frequently utilized material worldwide. After water, concrete is the second most utilized substance globally. It is the most frequently utilized substance in the world for constructing objects (Henry & Kato, 2014). The construction industry uses concrete to build roads, foundations for buildings, walls, roofs, columns, and beams. Additionally, it finds application in various other settings, such as drainage projects or the production of durable blocks needed for paving and Construction. Concrete comprises various constituents: sand, small and large rocks, cement, and water. The mixture of these substances in specific ratios forms concrete. As this industry grows, more waste is produced and accumulated, which over time becomes harmful to the environment. There are various types of construction wastes, such as steel, concrete, excavated soils, and masonry materials. Mercante et al. (2012) state that waste production encompasses non-decomposable (inert) and decomposable materials (non-inert). These wastes originate from public dumping sites and other locations where people dispose of their trash. Inorganic substances such as soil, sand, brick, and concrete can be discarded in regular garbage bins at public landfills. However, non-inert materials like timber, bamboo, glass, and paper cannot be disposed of similarly (Xu et al., 2019).

2.2 Construction and Demolition Wastes

Construction and Demolition waste (C&D) is the uncontrollable materials that result from building and infrastructural endeavors such as Construction, renovation, and demolition and produce large quantities of waste globally. This waste ends up in landfills when better management strategies are not considered. Like concrete waste, it consists of inert and non-inert materials, necessitating sorting before disposal into public or private landfills. Inert Construction and demolition waste include concrete, marble, plastic, petrochemicals, paper, asphalt, and paint. Additionally, the leftover concrete cannot be fully separated from small pieces of rock and a small amount of metal, so they cannot be used again. Others include gypsum, ceiling panels, marble, and ceramics that can be used again without recycling them. According to the Eurostat 2015 statistics, the Construction industry created more than 2.5 billion tons of waste in 2012, with 34% of it coming from Construction and demolition.

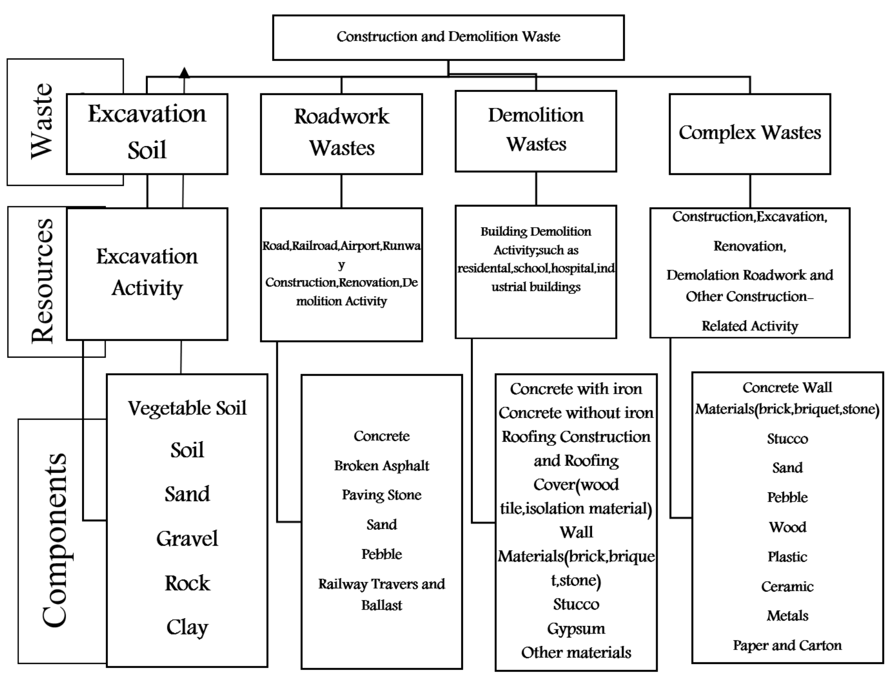

Fig. 1. Construction and Demolition Wastes Groups

2.3 Environmental Impact of Concrete Waste

The utilization of concrete in construction practices has diverse impacts on the environment. Making, constructing, maintaining, and disposing of things leads to the emission of harmful substances into the environment. Large amounts of carbon dioxide are released into the environment during cement and aggregate production from raw materials. For instance, rocks sourced from rivers and sand must be removed, prepared, and transported within the desired location. This uses up a lot of energy and harms the environment. These emissions produced are calculated about the distances of transportation and energy use in each stage. Further emissions arise from activities such as reinforcing rods and steel. Concrete waste also exploits natural resources, besides increasing pollutants in the environment. For instance, the disposal of construction wastes into landfills and dumping sites results in large amounts of environmental debris, minimizing the amount of waste space for future disposal. The extraction of raw materials also results in violation of the landscape beds, ideas increasing air pollution. For instance, aggregate production requires the crushing of rocks, consequently, exhausting precious natural resources such as rocks sourced from rivers and sand.

2.3 Concrete Waste Management Strategies and Disposal

2.3.1 The 3Rs Management Strategy

The increase in urbanization has resulted in a significant increase in construction waste, resulting in a higher environmental risk. It necessitates waste management practices and options to be employed to combat this menace. Waste management comprises several stages generally referred to as the 3Rs, which stand for reduction, reuse, and recycling to minimize the amount of waste generated from these activities. Waste that cannot undergo either of the three stages is disposed of in landfills. Peng et al. (1997) demonstrated the hierarchy of handling construction waste in order of their preference. Reducing waste from the beginning is the most effective method since it ensures one has the exact amount of material required. It also involves implementing other regular and general societal practices, such as banning unsorted waste landfills and recycling material. Certain materials should also be utilized in the demolition process to reduce the destruction of materials (Giusti, 2009; Marchesini, 2023). The second most important stage is reusing the materials for another purpose instead of throwing them away. The third stage is recycling them, which ensures sustainability and minimizes the materials being disposed of. Ultimately, the most disliked stage by individuals is the act of disposing of waste in landfills. This stage is considered after the other three stages (Peng et al., 1997). These steps help reduce the amount of trash in landfills and allow us to get energy from the waste. It reduces the harm to the environment from greenhouse gases. Sorting the waste is an important practice in identifying and segregating the types of waste for recycling. The sort aims at minimizing wastage and maximizing material recovery. Construction materials are obtained from the environment, which poses another problem. It results in the depletion of natural raw materials. They are also processed using chemical compounds to yield final products, leading to environmental pollution.

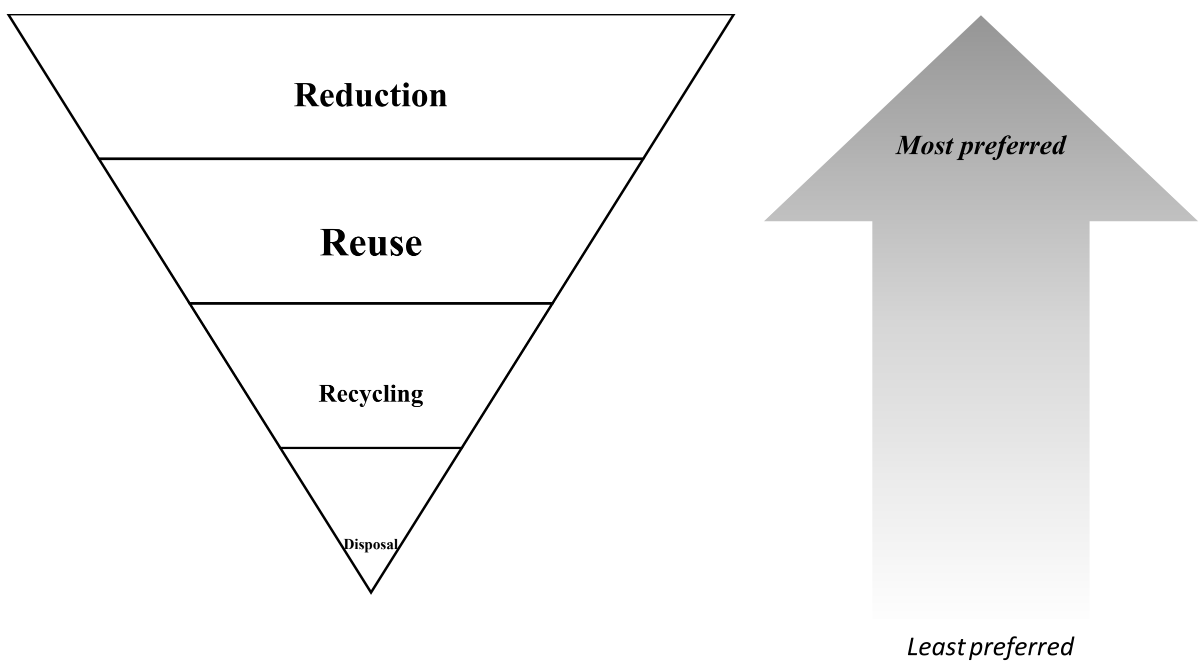

Fig. 2. Hierarchy of handling construction wastes

Reusing Concrete, Construction, and demolition waste in various sectors, for instance, is useful in waste management. For instance, aggregate materials reclaimed from demolition sites can be reused in asphalt pavement materials after ensuring it has the right qualities and properties. As the diagram below demonstrates, other wastes can be reused for various purposes in different sectors.

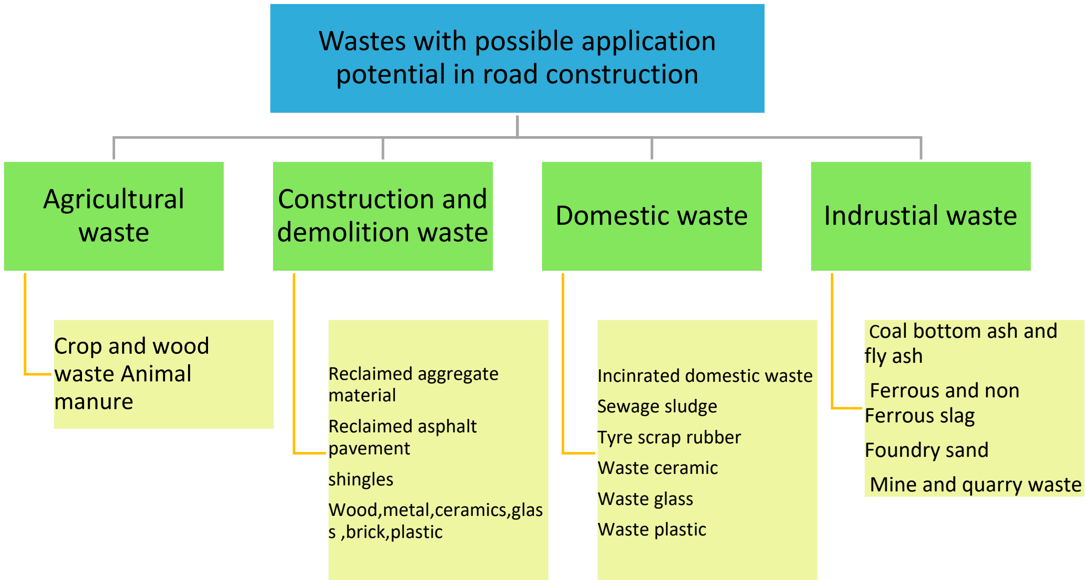

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Fig. 3. Segregation of C&D waste (Das & Swamy 2014, p. 421)

2.3.2 Recycling technique

Recycling is the most sustainable strategy that minimizes waste accumulation in landfills. It also provides a larger area and ensures energy recovery from the recovered waste materials. It also helps to reduce the harmful effects of waste on the environment, such as emissions like carbon dioxide, methane, and nitrous oxides. Recyclable waste materials in construction and demolition sites include,

Table 1
Recycleable waste materials in demolition sites in india (ponnada & kameswari 2015,p. 6)

Architectural waste	**Non-ferrous metals**	**Land- clearing residuals**
Doors and door frames	Wiring/Conduit	Trees, Stumps, Brush
Windows and frame	Plumbing (pipes)	SOIL
Millwork	HAVC	**Ferrous metals**
Furniture and Furnishings	**Asphalt**	Structured steel
Office furniture	**Aggregate**	Steel frame members
Partition Systems	Concrete	Porcelain fixtures
Medical laboratory equipment	Brick	Ceiling tiles
Locker equipment	Concrete block	Gypsum wallboard
Reception furniture	**Wood**	**Roofing**
Carpeting	Dimensional lumber	Shingles
Broadloom	Panels (plywood, OSB)	Commercial membrane
Carpet tiles	Engineered beams	Wood, metal, slate

Recycling waste from construction and demolition is the best way to take care of the environment. Moreover, waste management methods are important in certain countries. For example, European countries have a goal to use, recycle, and recover non-dangerous construction and demolition waste at 70% of the total weight by 2020. Five countries achieved this goal: the Netherlands, Denmark, Estonia, Germany, and another country that reached 79%. The Netherlands had the highest achievement at 98. 1%, followed by Denmark at 94. 9%, Estonia at 91. 9%, and Germany at 86. 3% Germany has created a process to evaluate how good, recycled products are.

2.3.3 Local practices

With increasing size and rapid development, the United Arab Emirates is making strides on the global stage, and hence a significant rise in the demand for construction materials due to the economy and urbanization. As a result, huge quantities of generated waste find their way into landfills each year (UAE Government Waste Management, 2017). This rapid construction, population increase, and economic growth and development have led to cities such as Abu Dhabi and Dubai establishing strategies for effective waste management, such as recycling the waste and converting it into energy. It subsequently reduces greenhouse gas emissions and municipal waste rates at the landfills. Dubai municipality also set up proper plans aimed at managing waste. It sought to minimize the quantity of waste sent to landfills to zero in approximately 20 years by recycling the waste (Dubai Municipality, 2012). In addition, Abu Dhabi created a Waste management center called Tadweer. This center collects and recycles waste from the City.

2.3.4 Waste Management policy

The European Union Waste Framework Directive Legislation explains the best ways to manage waste. It tells apart ways to prevent waste, prepare things for reuse, recycle, recover, and put in a landfill. The amount of trash varies in different countries because of each country's culture and how rich or poor they are. Manowong (2012) sets out the steps for handling waste, and these guidelines and rules are important in managing waste. The Environmental Agency controls waste management in the City of Abu Dhabi. It identifies the strategies, laws, and regulations for waste management. It also establishes laws that govern this process. It also established two recycling plants in Abu Dhabi to ensure proper waste recycling, hence minimizing disposal. Consequently, the Dubai Municipality has created instructions and rules for handling waste. It imposes charges on individuals for certain products while also facilitating waste removal services. In addition, it monitors the final disposal location of waste to guarantee its safe transportation. This helps reduce waste. Lastly, the government of UAE has also set up proper channels of waste disposal and management strategies that enhance the conversion of waste into energy, reducing greenhouse gas emissions and dumping into landfills. It also imposes fines for non-compliance, such as accumulating construction waste in the building sites.

3. Methodology

It discusses research methodology and framework. It clearly shows the method used to carry out the research. It also gives a summary of the results. The research explores methods for handling and eradicating waste generated from construction and demolition activities. The primary focus is on the three Rs of waste management, which include reducing, reusing, and recycling. The research used data and evidence from existing sources and previous research to constitute its findings. It analyzes the different methods of managing construction waste and emphasizes how different countries worldwide employ recycling techniques to manage this waste. The research also analyzes recycling in the United Arab Emirates, focusing mainly on Dubai and Abu Dhabi cities as the main case studies. Lastly, it explores the different C&D waste management policies worldwide and in the United Arab Emirates.

4. Discussion and analysis

Concrete is an important construction material. It is the second most frequently used material globally where it comes second to water. It is the most utilized material in construction of objects (Henry & Kato, 2014). For instance, it is employed in the building of roads, foundations, walls, roofs, columns, and beams. Other places such as drainages and pavement utilize concrete too. It comprises of several ingredients such as sand, cement, rocks, and water. With the rapid growth of the industry, more waste is produced and accumulated. Over time, this waste becomes harmful to the individuals, and the environment. Classifies construction wastes into steel, concrete, extracted soil, and masonry materials. On the other hand, Mercante et al. (2012), classifies the waste into inert and non-inert materials. They are found mostly in landfills and public dumping sites commonly used by individuals to dispose of the waste. Inert materials also termed as inorganic materials include soil, brick, and concrete which are mostly disposed in landfills. On the other hand, non-inert materials include timber, bamboo, glass, and paper that warrant other ways of disposal. The uncontrollable matter resulting from construction and other infrastructural works such as renovation and demolition is termed Construction and Demolition (C&D) waste. Like concrete it is divided into two categories, inert and non-inert wastes. Inert waste cannot be reused again and hence includes concrete, marble, plastics, paper, and asphalt while non-inert waste can be reused again, and it includes gypsum, ceiling, and ceramics. The Construction industry created more than 2. 5 billion tons of waste in 2012, with 34% of it coming from Construction and demolition (Eurostat, 2015). This has since being increasing due to the rapid surge in construction and demolition activities globally.

Construction and demolition waste pose a significant challenge globally. These wastes have diverse impacts on the environment. For instance, production, construction, maintenance, and disposal results in production of harmful gases into the environment. These harmful gases include carbon dioxide released during cement and aggregate production. The river rocks must be excavated, prepared, and then transported to the desired location hence consuming large amounts of energy which harms the environment significantly. Other emissions arise from activities such as steel and rod reinforcement. Besides being a pollutant, concrete production also leads to exploitation and depletion of important resources from the earth. The disposal of these wastes into landfills results in large accumulations of debris. This subsequently results in reduction of space for future disposal activities. It also leads to disturbances of landscape beds, hence resulting in air pollution surge. The production of aggregates depletes precious river rock from the environment too.

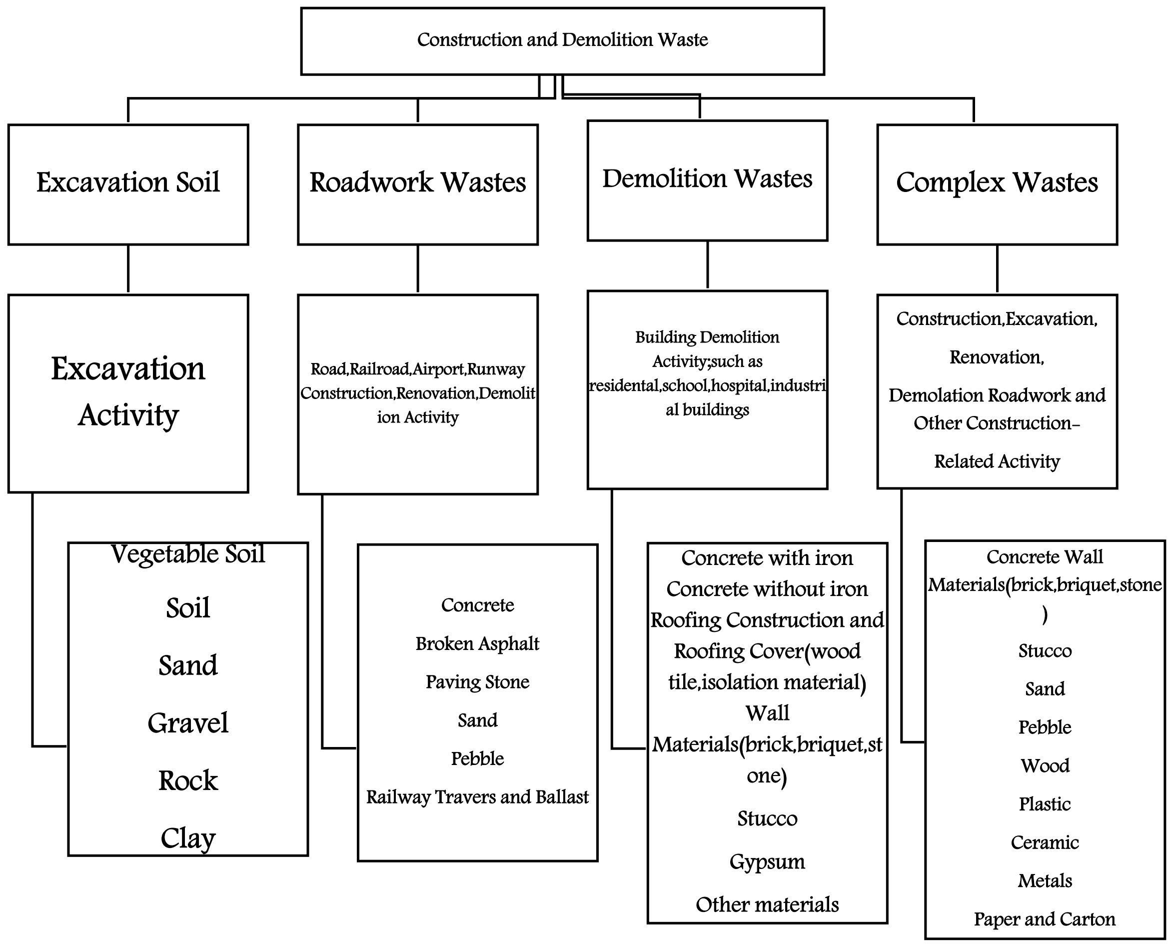

Fig. 4. Construction and Demolition Wastes Groups

Effective waste management is very significant. It involves taking necessary steps and measures to affect this practice. Researchers have identified several methods of handling concrete waste. Effective waste management has three main stages, which are commonly referred to as the 3Rs. The first step is reduction. It involves taking necessary steps to minimize the waste generated from the construction and demolition activities. The reduction strategies involve ordering the right construction materials and sorting the waste after demolition to determine how to minimize the disposal amount. Reusing involves using the materials to do other work instead of disposing of them. Recycling is the most applied method. It poses economic benefits since the materials can be resold to generate money. It also enables the generating of energy from the waste. Recycling also enhances project sustainability. It also reduces the cost of purchasing materials, besides saving on transportation costs. The use of alternative recyclable construction materials is also highly recommended. These materials include bricks and steel, and they help reduce concrete waste production significantly (Giusti, 2009). Recycling waste has significance in different countries, and it is dependent on the nature of waste usage (Sales & de Souza, 2009). For instance, in Brazil, recycled aggregates are utilized in pavement construction, while in Hong Kong, they are beneficial in building public projects. In Germany, one must seek permission to use recycled products since they have established systems that check and guarantee the quality of these materials and ensure they are of the right quality (Weil et al., 2006). In Europe, roughly 47% of all concrete waste is effectively recycled, however, by 2020 there was a 23% increase bringing the figure to around 70%. The application of the best waste management strategies brings quality and sustainability to the project. The rapid increase in landfills places a significant burden on the environment, necessitating the development of better environmentally friendly management strategies. Bossink and Brouwers (1996) assert in Yuan (2013) that the 3Rs constitute the basic steps for minimizing the cost of extraction, transportation and handling of raw materials. They also save on waste disposal costs, improving sustainability. Different regions and countries have adopted different waste management policies too. The European Union Waste Framework Directive Legislation for instance stipulates the best practices for waste management. It explains the different ways of preventing waste production, preparing the sorted wastes for reusing, recovery, and recycling. It also explains the procedures of landfill disposing, hence mitigating the severe environmental impacts. Waste production differs depending on the country's culture and wealth. Manowong (2012) sets out the steps for handling waste, and these guidelines and rules are important in managing waste. In the UAE too, different bodies actively take part in concrete and construction waste management. For instance, the environmental Agency is actively involved in waste management in the city of Abu Dhabi. It sets the strategies, laws, and processes of waste management. It has gone further to set up two recycling plants in the city hence ensuring recycling of the waste to minimize disposal. On the other hand, the Dubai city municipality plays a significant role in waste management. It sets up the instructions to be followed in waste disposal and handling. It also fines individuals for non-compliance to certain rules regarding handling of wastes. Lastly, it effectively monitors the waste disposal locations to ensure safe transportation, hence reducing pollution. Lastly, the government of UAE also plays a significant role in waste management. It has also set up proper channels of waste disposal and management strategies that enhance the conversion of waste into energy, reducing greenhouse gas emissions and dumping into landfills. It also imposes fines for non-compliance, such as accumulating construction waste in the building sites. From the research, we can define that concrete is very important. However, the rise in construction and demolition due to the surge in urbanization has resulted in waste that must be properly managed. Improper management is hazardous since it endangers human life, biological systems, and natural resources. It also results in land pressure due to the rampant increase in landfills and dumping sites.

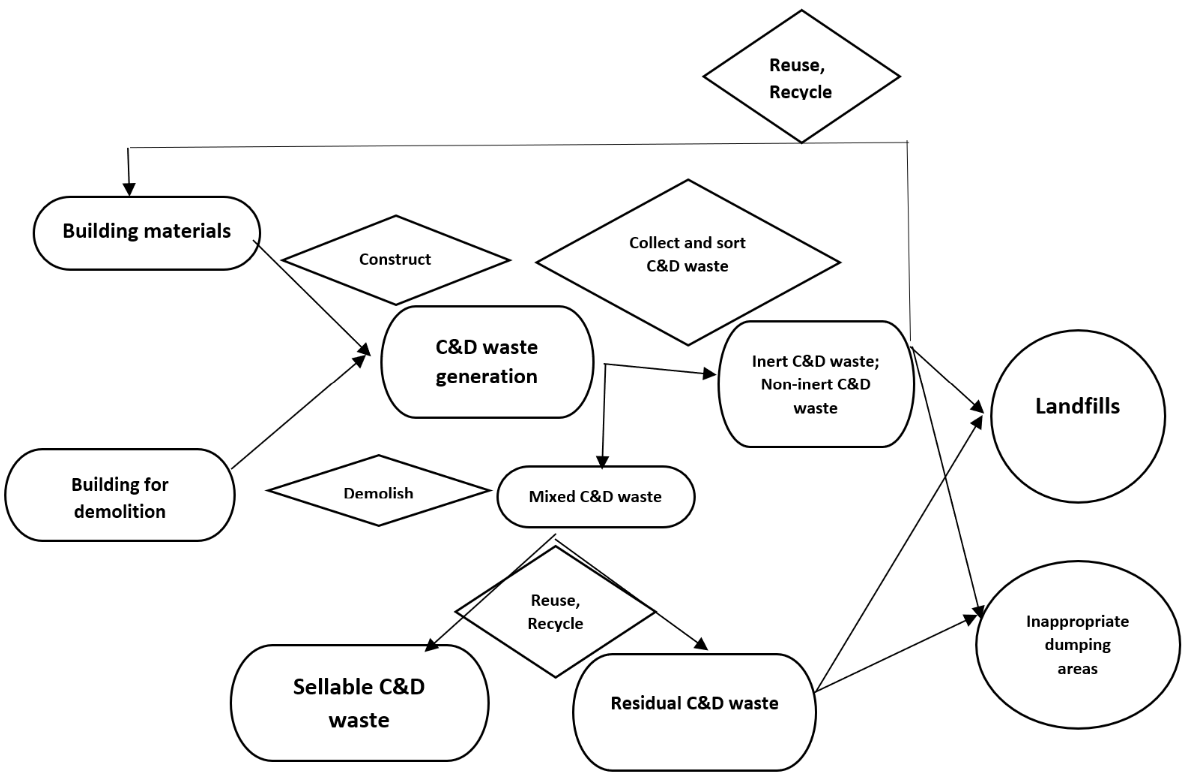

Fig. 5. The process of construction and demolition waste management in Shenzhen city in China (Yuan 2017, p.4)

5. Conclusion

Concrete is a major environmental pollutant from its production, Construction, and after demolition. Making things requires the utilization of finite resources such as rocks and sand that are obtained from the earth. Aggregate, conversely, involves crushing rocks, which reduces the number of natural resources in the ground. It also involves transporting these raw materials to industries, polluting the environment through emissions into the air. Construction and demolition also produce both inert and non-inert waste that, upon accumulation, results in pollution of the environment. However, there are effective waste management strategies, such as the 3Rs: reduction, reuse, and recycling. Other less recommended modes involve using dumping sites and landfills. Reusing involves utilizing those construction and demolition waste materials that can be used again without recycling. Reduction involves minimizing the production rates of waste materials. It encompasses taking the necessary steps to avoid overproduction of waste such as ordering the correct amounts of materials and ensuring proper utilization of the available materials to minimize wastage. On the other hand, recycling entails converting the waste into useful products that can be used again for building and construction or for other purposes. In instances where these steps cannot apply or do not work properly, disposal in landfills is utilized which disadvantageous. First, it puts pressure on the environment since it minimizes the available land and secondly, it pollutes the environment through emission of harmful greenhouse gases.

6. Strengths and limitations Research

Paper has several key strengths. First, it has demonstrated how construction and demolition waste could be managed. It clearly demonstrates the 3Rs of waste management giving examples of each management strategy and the procedures. It also helps in the conservation of the environment since it discourages waste disposal in landfills through giving alternatives ways of management. It also ensures sustainability since construction waste can be recycled and used for other purposes. Lastly, this paper minimizes pressure on the land hence providing more land for use in Agriculture amongst other uses. While this paper has positive impacts on the United Arab Emirates, it has also some limitations. For instance, recycling waste is not a common practice in some areas of the United Arab Emirates. This is due to lack of awareness, and ignorance and it results in environmental pollution, and land pressure.

7. Recommendation

This paper identified several key areas that would benefit from further research. There is a need to continue developing better and more effective recycling techniques with the increase in urbanization that subsequently increases concrete usage. The increasing demand on building and construction material has caused a substantial increase in waste production hence necessitating the invention of better novel waste management strategies across the UAE. Also, further research should be done on how recycling is done in these countries to gain more insights into the topic and hence create awareness to foster waste management. It is also necessary to perform a life cycle cost assessment of concrete waste management to determine the financial benefits of different options for managing this waste. In addition, adequate LCA should be conducted for various waste management methods, from raw material sourcing to processing, end products and waste management methods. Finally, it is necessary to establish LCA cost models for different concrete waste treatment methods.

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