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REVIEW ARTICLE

Potential of Waste Material as Coarse Aggregates for Lightweight Concrete Production: A Sustainable Approach

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ABSTRACT - In recent times, there has been growing interest in utilizing waste materials as coarse lightweight aggregates in the production of lightweight aggregate concrete. This approach has been gaining momentum as it has the potential to address the environmental concerns that come with conventional construction practices. The objective of this review paper is to evaluate the viability and potential of waste materials as coarse lightweight aggregates for producing lightweight aggregate concrete. This paper reviews the current research on various types of waste materials, including waste plastic, recycled concrete aggregate, slag, fly ash, and expanded polystyrene, as potential candidates for coarse lightweight aggregates. The paper highlights the properties and characteristics of these waste materials and their suitability for use as coarse lightweight aggregates. Additionally, the evaluation explores the mechanical characteristics of lightweight aggregate concrete that is generated using waste materials as coarse lightweight aggregates. Specifically, it compares the compressive strength, splitting tensile strength, flexural strength, and modulus of elasticity of lightweight aggregate concrete that includes waste materials with those of typical concrete. Furthermore, the paper discusses the sustainability benefits of using waste materials as coarse lightweight aggregates. By using waste materials in construction, not only are resources conserved, but waste is also diverted from landfills, reducing the negative impact on the environment. In conclusion, this review paper demonstrates that the use of waste material as coarse lightweight aggregate for lightweight aggregate concrete production is a viable and sustainable approach. The application of waste materials as coarse lightweight aggregates in lightweight aggregate concrete demonstrates mechanical characteristics that are similar to traditional concrete. Moreover, utilizing waste materials in this manner provides environmental advantages. This study offers valuable insights into the implementation of waste materials in construction, and it emphasizes the possibility of further exploration and advancement in this domain. For this review, a total of 15 articles were analyzed, with publication dates ranging from 2005 to 2021. The study contributes to several Sustainable Development Goals (SDG 9/11/12/13) set by the United Nations such as providing insights into the role of industry, innovation, infrastructure, sustainable cities, responsible consumption, production practices, and climate action.

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1.0 INTRODUCTION

Concrete is one of the most widely used construction materials in the world. It is versatile, strong, durable and can be easily molded into any desired shape or form. However, conventional concrete is a heavy material that requires a significant amount of energy to produce and transport. This has led to a growing interest in developing lightweight concrete that can offer the same structural properties as conventional concrete but with a reduced environmental impact [1][2][3]. Lightweight aggregate concrete (LWAC) is one such alternative that has been gaining popularity in recent years. LWAC is a type of concrete that is made using lightweight aggregates instead of conventional heavy aggregates like sand and gravel. Lightweight aggregates are materials that have a lower density (less than 1200 kg/m^3) than conventional aggregates, which makes them an ideal choice for producing lightweight concrete. Incorporating lightweight aggregates into concrete results in a reduction of the structure's total weight. This decrease in weight subsequently reduces the dead load and enhances the structure's seismic resistance.

Waste materials such as fly ash, slag, and recycled plastics have been explored as possible sources of lightweight aggregates for LWAC production [4][5][6]. The utilization of these waste materials not only provides a sustainable solution to the disposal of waste but also reduces the need for virgin materials, thereby reducing the carbon footprint of the construction industry. This article aims to review the viability and potential of waste material as coarse lightweight aggregates for LWAC production, with a focus on their sustainability and economic feasibility. The production of conventional concrete is a highly energy-intensive process that involves the extraction of raw materials, such as sand and gravel, which are then transported to a processing plant where they are crushed, graded and mixed with cement and water

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to form concrete. This process results in a significant amount of greenhouse gas emissions and other environmental impacts. For example, the cement industry alone accounts for 7% of global carbon dioxide emissions. Additionally, the transportation of heavy aggregates from the quarry to the processing plant and then to the construction site adds to the environmental impact of concrete production.

LWAC is an alternative to conventional concrete that can help to reduce the environmental impact of concrete production. It is made by replacing heavy aggregates with lightweight aggregates that have a lower density. The most commonly used lightweight aggregates are expanded clay, shale, and slate, which are produced by heating and expanding natural raw materials. However, the production of these aggregates still requires energy and raw materials, which has led to the exploration of waste materials as an alternative source of lightweight aggregates. Waste materials have been found to possess the necessary properties to serve as lightweight aggregates for LWAC production. LWAC production using waste materials has the potential to reduce the environmental impact associated with conventional concrete production. The greenhouse effect, which refers to the trapping of heat in the Earth's atmosphere due to the presence of greenhouse gases, can be influenced by the production of LWAC using waste materials in several ways. First, the use of waste materials as lightweight aggregates can help to reduce the demand for natural raw materials, such as clay, shale, and slate, which are typically used in the production of conventional lightweight aggregates [7]. This can help to decrease the energy consumption and associated greenhouse gas emissions from the extraction and processing of these natural resources. Second, the incorporation of waste materials in LWAC production can help to divert these materials from landfills, where they may contribute to the generation of methane, a potent greenhouse gas [8]. By using waste materials as lightweight aggregates, LWAC production can help to mitigate the greenhouse gas emissions associated with landfilling. However, it is important to note that the overall impact of LWAC production using waste materials on the greenhouse effect will depend on the specific waste materials used and the processes employed in their production. Some waste materials may require additional processing or treatment before they can be used as lightweight aggregates, which could result in increased energy consumption and greenhouse gas emissions [7]. Therefore, a comprehensive life cycle assessment is necessary to determine the net environmental impact of LWAC production using waste materials on the greenhouse effect.

Fly ash and slag, which are by products of coal-fired power plants and steel manufacturing, respectively, have been widely studied as possible sources of lightweight aggregates. In addition, waste materials such as recycled plastics and rubber tires have also been explored as potential lightweight aggregates. By utilizing waste materials as lightweight aggregates, we not only find a sustainable solution for waste disposal but also decrease the demand for virgin materials. This reduction in virgin material usage ultimately leads to a decrease in the environmental impact of concrete production [9][10].

This article aims to assess the feasibility and potential of utilizing waste materials as coarse lightweight aggregates for producing Lightweight Aggregate Concrete (LWAC). Specifically, it evaluates the technical, economic, and environmental practicality of using waste materials as lightweight aggregates, focusing on their performance in LWAC. Additionally, it explores the challenges and limitations of using waste materials as lightweight aggregates, while also addressing strategies that can be employed to overcome these obstacles. This study’s scope is centered on reviewing the potential and practicality of using waste materials as coarse lightweight aggregates for producing LWAC. It seeks to assess the sustainability of this approach and evaluate its economic, environmental, and technical feasibility. The study focusses on waste materials that could be used as coarse lightweight aggregates, such as agricultural waste, industrial by-products, and recycled materials. Additionally, it considers the concrete’s physical and mechanical characteristics, such as durability, strength, and thermal insulation.

The main goal of an optimization problem is to obtain the best combination of variables of a fitness function such that the value of the fitness is maximum or minimum. This can be done effectively by using a population-based optimization algorithm. A new population-based optimization algorithm termed as simulated Kalman filter (SKF) is inspired by the estimation capability of Kalman filter [1]. Designed from the procedure of Kalman filtering, which incorporates prediction, measurement, and estimation, the global minimum or maximum can be estimated. Measurement process, which is needed in Kalman filtering, is mathematically modelled and simulated. Agents interact with each other to update and optimize the solution during the search process.

The concept of opposition-based learning (OBL) can be used to improve the performance of population-based optimization algorithm [2]. The important idea behind the OBL is the concurrent consideration of an estimate and its corresponding opposite estimate which is closer to the global optimum. OBL was initially implemented to improve learning and back propagation in neural networks [3], and until now, it has been employed in various optimization algorithms, such as differential evolution, particle swarm optimization and ant colony optimization [4].

In this research, inspired by the concept of current optimum opposition-based learning (COOBL), a modified SKF model is proposed which is called as current optimum opposition-based simulated Kalman filter (COOBSKF) to enhance the performance of SKF. From the SKF perspective, this is the first attempt to improve its performance through COOBL strategy. The COOBSKF compares the fitness of an individual to its opposite and maintain the fitter one in the population. Experimental results show that the proposed algorithm can achieve better solution quality.

2.0 SUITABLE WASTE MATERIALS FOR USE AS COARSE LIGHTWEIGHT AGGREGATES

Lightweight aggregates have become increasingly popular in construction due to their advantageous properties such as lower density and thermal conductivity. The use of waste materials as aggregates in concrete can not only reduce environmental pollution but also provide a sustainable solution for waste management. However, the selection of suitable waste materials for use as lightweight aggregates is critical to ensure the desired properties of the resulting concrete. In this article, the characteristics and potential of various waste materials for use as coarse lightweight aggregates in concrete has been explored.

2.1 Introduction to Suitable Waste Materials as Coarse Lightweight Aggregates

The construction and engineering industries use the term "coarse lightweight aggregates" to describe materials that can be employed in creating structures like bridges, roads, and buildings. These materials have a low weight and are often derived from waste materials that are not typically used in construction. The term "suitable waste materials" denotes materials that can be effectively used as coarse lightweight aggregates. Often, these materials are industrial or municipal waste products that have been adapted for use in construction. For instance, examples of suitable waste materials that can serve as coarse lightweight aggregates include fly ash, expanded clay, and recycled plastic [11][12][13]. The description of these materials usually includes details regarding their properties, the manufacturing processes employed, and the benefits and drawbacks of using them in construction. The objective of this introduction is to equip engineers and builders with the knowledge they need to make informed decisions about the implementation of these materials in their projects. By repurposing waste materials for construction, these materials can contribute to sustainable building practices while also decreasing environmental waste.

2.2 Characteristics of Coarse Lightweight Aggregates

Coarse lightweight aggregates are materials commonly used in the construction industry to reduce the weight of structural concrete while maintaining its strength and durability. These aggregates are typically made from natural or synthetic materials that are lightweight and porous, which reduces the overall weight of the concrete mix. Some common examples of coarse lightweight aggregates include expanded clay, shale, slate, perlite, and vermiculite. There are several important characteristics of coarse lightweight aggregates that affect their suitability for use in concrete mixes:

- **Density**: Coarse lightweight aggregates have a lower density than traditional aggregates, which makes them a popular choice for lightweight concrete [14]. The density of coarse lightweight aggregates typically ranges from 550 to 1860 kg/m^3, compared to the density of traditional aggregates, which is around 2400 kg/m^3 [14].
- **Porosity**: Coarse lightweight aggregates have a higher porosity than traditional aggregates, which means they can absorb more water. This can lead to a decrease in the workability of the concrete mix, so it’s important to carefully control the amount of water used in the mix to prevent problems with segregation or bleeding [15].
- **Absorption**: Coarse lightweight aggregates have a higher absorption rate than traditional aggregates, which means they can hold more water. This can affect the strength and durability of the concrete mix, so it’s important to carefully control the amount of water used in the mix and to ensure that the aggregates are properly cured before use.
- **Shape**: Coarse lightweight aggregates typically have a more irregular shape than traditional aggregates, which can affect the workability of the concrete mix. The irregular shape can lead to problems with segregation or bleeding if the mix is not properly designed and mixed.
- **Size**: Coarse lightweight aggregates come in a range of sizes, which can affect the strength and durability of the concrete mix [16]. Larger aggregates can lead to a decrease in the workability of the mix, while smaller aggregates can lead to problems with segregation or bleeding.
- **Strength**: Coarse lightweight aggregates have a lower strength than traditional aggregates, which can affect the overall strength of the concrete mix. It is important to carefully design the mix to ensure that the strength and durability of the final product are sufficient for the intended use.

In summary, the characteristics of coarse lightweight aggregates are important to consider when designing concrete mixes for construction projects. By carefully selecting and controlling the properties of these materials, it is possible to create lightweight concrete that is strong, durable, and suitable for a range of applications.

2.3 Types of Suitable Waste Materials for Coarse Lightweight Aggregates

In the construction industry, coarse lightweight aggregates are materials utilized as insulators or fillers. They possess characteristics like low density, high porosity, and excellent thermal insulation properties. The selection of waste materials suitable for use as coarse lightweight aggregates depends on various factors, including the material’s availability, cost, and physical and chemical properties. Here are some examples of waste materials typically used as coarse lightweight aggregates:

- **Fly Ash**: Fly ash is a by-product of coal-fired power plants and is one of the most widely used waste materials for producing coarse lightweight aggregates [17]. Fly ash has a low density and high porosity, making it ideal for use as a filler material.

- **Blast Furnace Slag**: Blast furnace slag is a by-product of the steel and iron industry and is also commonly used as a coarse lightweight aggregate. The material is light in weight, has good insulation properties, and is relatively cheap.
- **Rice Husk Ash**: Rice husk ash is a waste material produced from the combustion of rice husks and is a good alternative to traditional aggregates. Rice husk ash has a low density and high porosity, making it ideal for use as a filler material in construction projects.
- **Sewage Sludge Ash**: Sewage sludge ash is a by-product of the treatment of sewage sludge and is sometimes used as a coarse lightweight aggregate [6]. The material is relatively lightweight and has good insulation properties, but its use as an aggregate is limited due to the presence of pollutants and pathogens that may be present in the ash.
- **Volcanic Ash**: Volcanic ash is a waste material that is produced from volcanic eruptions and can be used as a coarse lightweight aggregate. Volcanic ash is lightweight, has good insulation properties, and is relatively cheap [18].
- **Glass Powder**: Glass powder is a waste material that is produced from the crushing of glass and can be used as a coarse lightweight aggregate. Glass powder has a low density and high porosity, making it ideal for use as a filler material in construction projects.

In conclusion, the selection of suitable waste materials for coarse lightweight aggregates depends on several factors, including the material's physical and chemical properties, avail ability, and cost. The most commonly used waste materials for coarse lightweight aggregates include fly ash, blast furnace slag, rice husk ash, sewage sludge ash, volcanic ash, and glass powder.

2.4 Production and Properties of Coarse Lightweight Aggregates from Waste Materials

Lightweight aggregates are materials that have a lower density than conventional aggregates and are used in construction to reduce the weight of structures and lower transportation costs. Coarse lightweight aggregates (CLWA) are those with particle sizes between 5 and 20 mm and are often made from waste materials such as fly ash, slag, and recycled concrete. The production process of CLWA from waste materials typically involves several steps [19]. Firstly, the waste material is crushed and screened to obtain particles of the desired size range. Next, the material is mixed with water and a foaming agent, which can be a surfactant or a protein-based agent. The mixture is then agitated to create bubbles that expand the volume of the mixture and form the lightweight aggregate. The aggregates are then cured, either by airdrying or by heating in a kiln, to increase their strength and durability.

One of the main benefits of using waste materials to produce CLWA is the reduction of waste disposal, as these materials would otherwise be sent to landfills. Additionally, the production process requires less energy than traditional aggregates since the raw materials are already in a particulate form, and the foaming agent is typically a low-energy input. This can lead to reduced carbon emissions and lower production costs. The properties of CLWA depend on the type of waste material used and the production process employed [20][21]. In comparison to traditional aggregates, Coarse Lightweight Aggregates (CLWA) generally have a lower density and higher water absorption capacity, which may impact the strength and durability of concrete produced with them. Nevertheless, studies have demonstrated that CLWA can improve the workability of concrete and decrease the overall weight of structures. This can be particularly advantageous in seismic zones or when erecting tall buildings.

In terms of durability, studies have found that CLWA made from fly ash and slag can have good freeze-thaw resistance, and recycled concrete aggregates can have high compressive strength and durability. Nevertheless, more extensive research is necessary to comprehend the long-term performance of CLWA under diverse environmental conditions and to optimize the production process to enhance their properties further. To conclude, generating CLWA from waste materials is a promising method to decrease waste disposal and carbon emissions in the construction sector. While the properties of CLWA can vary depending on the materials and production processes used, their use can lead to lighter and more sustainable concrete structures. Coarse lightweight aggregates have several properties that make them suitable for use in construction, including:

- **Lightweight**: The aggregates are lighter in weight compared to traditional construction materials, making them suitable for use in lightweight structures.
- **Insulating**: Coarse lightweight aggregates have good insulation properties, making them suitable for use in walls, roofs, and floors.
- **High Strength**: The aggregates have a high compressive strength, making them suitable for use in load-bearing structures.
- **Fire Resistant**: The aggregates are non-combustible, making them suitable for use in fire-resistant structures.
- **Durable**: The aggregates are resistant to weathering, making them suitable for use in outdoor structures.
- **Sustainable**: By using waste materials, the production of coarse lightweight aggregates reduces waste and promotes sustainability.

- **Cost-effective**: The use of waste materials as a raw material reduces the cost of production compared to traditional construction materials.
- **Improved environment**: The production of coarse lightweight aggregates reduces the environmental impact of waste disposal.

2.5 Applications of Coarse Lightweight Aggregates from Waste Materials in Concrete and Construction Industry

Coarse lightweight aggregates are materials used in the construction industry to reduce the density of concrete structures, thereby reducing their weight and enhancing their thermal insulation properties. These materials are produced from waste materials such as industrial by-products and agricultural wastes, and can provide an eco-friendly solution for the construction industry, as they help to reduce waste and conserve natural resources [22][23]. In this response, we discuss in detail the applications of coarse lightweight aggregates from waste materials in the concrete and construction industry.

- **Structural Lightweight Concrete**: Substituting traditional coarse aggregates with coarse lightweight aggregates is a common practice in creating structural lightweight concrete. This type of concrete, produced with coarse lightweight aggregates, has a lower density compared to conventional concrete, making it a suitable material for building high-rise structures and bridges. The reduced density also leads to a lower concrete requirement, which, in turn, minimizes the environmental impact of the construction process [24].
- **Insulating Lightweight Concrete**: In the realm of construction, the implementation of insulating lightweight concrete for walls and roofs is made possible by incorporating coarse lightweight aggregates. This variant of concrete is well-suited for buildings situated in regions with extreme temperatures as it exhibits exceptional thermal insulation properties. By utilizing such aggregates in insulating lightweight concrete, energy consumption can be minimized and buildings can become more energy-efficient [25].
- **Geotechnical Applications**: Coarse lightweight aggregates can be used in geotechnical applications such as embankments, retaining walls, and slope stabilization. The lightweight nature of these aggregates means that they exert less pressure on the underlying soil, reducing the likelihood of soil settlement and slope instability. This makes them an ideal material for use in areas with weak or unstable soils.
- **Landscaping and Decoration**: Coarse lightweight aggregates can be used in landscaping and decoration, such as in the production of decorative concrete blocks and landscaping elements. These aggregates are available in a variety of colors, shapes, and sizes, making them ideal for creating aesthetically pleasing structures and features.
- **Filtration and Drainage**: Coarse lightweight aggregates can be used in filtration and drainage applications, such as in the production of permeable pavement and green roofs [26]. These aggregates provide a porous medium that allows water to permeate through the structure and be absorbed by the underlying soil. This helps to reduce stormwater runoff and improve the quality of the water in the surrounding environment. In conclusion, the applications of coarse lightweight aggregates from waste materials in the concrete and construction industry are diverse and varied. The utilization of these resources offers an environmentally conscious approach to constructing concrete structures, ultimately decreasing the ecological impact of the building process. The incorporation of these materials not only amplifies the robustness and thermal insulation of the structures but also adds to their visual allure.

2.6 Understanding the use of Waste Materials as Coarse Lightweight Aggregates for Concrete Production

In this section, the aim is to provide a comprehensive understanding of the relevant concepts and theories related to the use of waste materials as coarse lightweight aggregates in the production of lightweight aggregate concrete. The section begins with a discussion on the concept of lightweight aggregate concrete and its significance in the construction industry. The discussion highlights the benefits of using lightweight aggregate concrete over conventional concrete, such as reduced weight, increased durability, and improved thermal and acoustic insulation [27][28][29].

Next, the section delves into the topic of waste materials as coarse lightweight aggregates. This includes a detailed discussion on the types of waste materials that can be used as coarse lightweight aggregates, such as fly ash, bottom ash, slag, and recycled concrete aggregate [30][31][32][33]. The discussion further highlights the properties of these materials that make them suitable for use as lightweight aggregates, such as low density, high porosity, and good thermal insulation. The section also covers the theoretical principles that govern the use of waste materials as coarse lightweight aggregates in the production of lightweight aggregate concrete. This includes a discussion on the concepts of particle packing, interfacial transition zone, and the role of pore structure in determining the properties of lightweight aggregate concrete. The discussion also highlights the importance of optimizing the mix design of lightweight aggregate concrete to ensure that it meets the required specifications [34][35].

Moreover, this segment delves into the diverse methodologies that can be employed to fabricate lightweight aggregate concrete utilizing discarded substances as coarse aggregates [36][37][38]. The discourse encompasses an overview of the mixing, casting, and curing of lightweight aggregate concrete, alongside the utilization of additives and admixtures to enhance its attributes. Additionally, the segment scrutinizes the environmental and sustainability facets of incorporating discarded materials as coarse lightweight aggregates in the production of lightweight aggregate concrete. This encompasses a dialogue on the potential decline in carbon dioxide emissions achievable via waste materials and the financial gains of utilizing waste materials as a sustainable substitute to traditional materials [39][40][41].

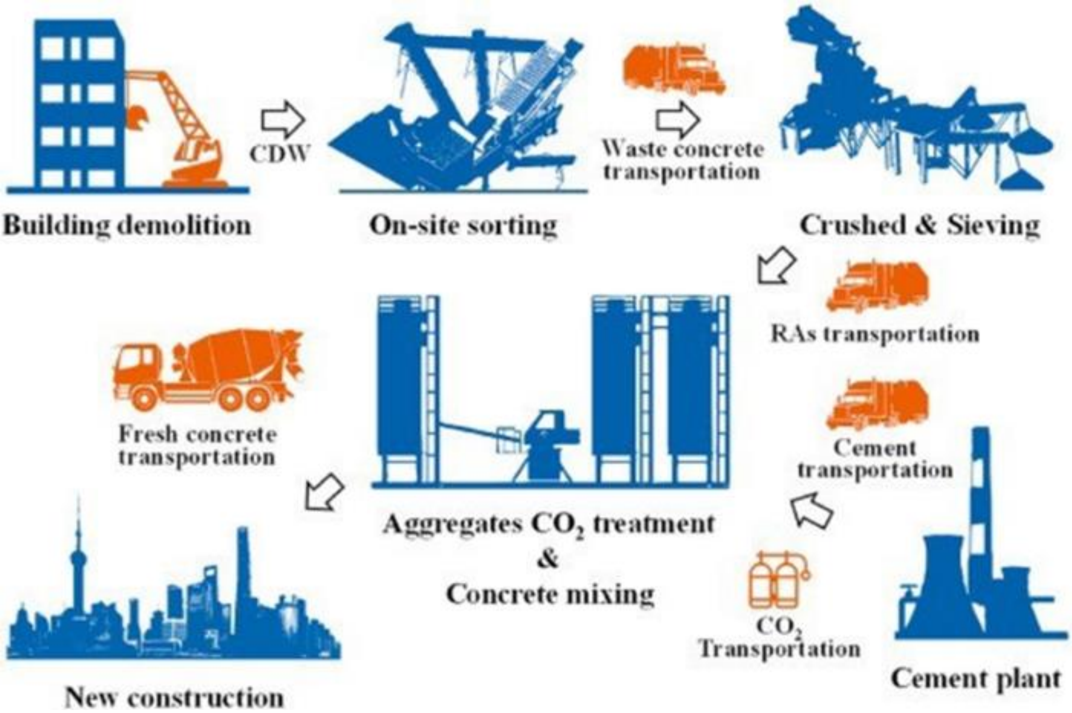

Figure 1: Illustrating the process of concrete production using fully carbonated recycled aggregates (RAs) [20]

Figure 1 illustrates the process of concrete production using fully carbonated recycled aggregates. It involves several steps to reduce the environmental impact of concrete production. Firstly, recycled aggregates are obtained from construction and demolition waste and subjected to accelerated carbonation, where they are exposed to a high concentration of CO_2 to form calcium carbonate ($CaCO_3$). This carbonation process not only sequesters CO_2 but also improves the quality of the aggregates. The carbonated recycled aggregates are then mixed with cement, water, and additives to create the concrete mixture, with the proportion of aggregates varying based on desired properties. The mix design is optimized to ensure adequate workability, strength, and durability. Finally, the concrete mixture is poured into molds and allowed to cure, enabling the cement to hydrate and bind the carbonated recycled aggregates and other components together, resulting in a solid and durable material. This approach contributes to a more sustainable construction industry by reducing waste and CO_2 emissions.

Finally, the section concludes with a summary of the theoretical concepts and principles discussed in the section, highlighting their relevance to the research topic. The section also provides a framework for the subsequent sections of the research article, which focusses on the empirical aspects of the research, such as data collection, analysis, and interpretation. In essence, this section theoretical framework is established for the research subject by examining the pertinent concepts and theories associated with utilizing discarded materials as coarse lightweight aggregates for the creation of lightweight aggregate concrete. Additionally, it underscores the environmental and sustainability facets of the research theme, emphasizing the necessity for sustainable and environmentally conscious resolutions within the construction sector.

2.7 Concept of Lightweight Aggregate Concrete and its Significance in the Construction Industry

Lightweight aggregate concrete is an innovative form of concrete that replaces conventional coarse aggregates, such as crushed stone or gravel, with lighter materials like expanded shale, clay, slag, sintered fly ash, or pumice. When blended with cement, sand, and water, the result is a mixture of concrete that is considerably lighter than traditional concrete [42][43][44][45]. The use of lightweight aggregate concrete provides numerous advantages, particularly in the construction industry. One of the most notable benefits is its reduced weight, making it a desirable choice for projects where weight is a crucial factor. For instance, in the case of high rise buildings, incorporating lightweight aggregate concrete can decrease the overall weight of the structure, leading to significant savings in costs as it can reduce the amount of reinforcement steel required [46][47][48].

Another significant advantage of lightweight aggregate concrete is its insulating properties. Due to the presence of air voids within the lightweight aggregate, it has excellent thermal insulation properties. This can help in reducing the heating and cooling loads of a building, which can lead to energy savings and ultimately cost savings for the building owner. Furthermore, lightweight aggregate concrete has good fire resistance properties. The presence of air voids within the concrete provides an excellent barrier to the transfer of heat and reduces the risk of structural failure in case of a fire. The use of lightweight aggregate concrete also contributes to environmental sustainability. As lightweight aggregate concrete uses less traditional coarse aggregates, it can help in reducing the demand for natural resources [49][50][51][52]. Additionally, many of the materials used for creating lightweight aggregates, such as fly ash, are byproducts of industrial processes, which would otherwise be considered as waste and discarded into landfills. Therefore, using these materials in construction can help in reducing the environmental impact of industrial waste.

In terms of durability, lightweight aggregate concrete has good resistance to freeze thaw cycles, which is a significant advantage in regions with harsh weather conditions [53][54][55]. This is because the air voids within the lightweight aggregate can accommodate the expansion of water during freezing, which reduces the risk of cracking and spalling. There are, however, some challenges associated with the use of lightweight aggregate concrete. One of the significant issues is its lower strength compared to traditional concrete. This can limit its use in structures that require high compressive strength, such as bridge piers or foundation walls. However, advances in concrete technology have resulted in the development of high-strength lightweight aggregate concrete, which can overcome this limitation to some extent [56][57][58][59]. Another challenge associated with the use of lightweight aggregate concrete is its higher cost compared to traditional concrete. The manufacturing process for lightweight aggregate is more complex than that for traditional coarse aggregates, which can result in higher production costs. Additionally, due to its lower weight, more volume of lightweight aggregate concrete is required to fill the same space, which can increase the overall cost of the project [60][61][62][63].

To sum up, lightweight aggregate concrete has considerable ramifications for the construction sector. Its reduced weight, thermal insulation, fire resistance, and sturdiness render it a compelling alternative for application in a broad range of construction projects. Notwithstanding some of the obstacles linked to its usage, technological advancements have engendered the production of high-strength lightweight aggregate concrete, which can surmount certain limitations. In general, the implementation of lightweight aggregate concrete can result in reductions in costs, energy consumption, and contribute towards ecological sustainability, highlighting its importance as a breakthrough innovation in the construction industry [64][65][66][67].

2.8 Types of Waste Materials that can be used as Coarse Lightweight Aggregates

Adopting waste materials as coarse lightweight aggregates holds significant promise for sustainable construction. A variety of waste materials can serve as coarse lightweight aggregates, each with its distinct qualities and prospective benefits. Among them, fly ash is a waste product generated by coal combustion in power plants that can be used as a lightweight aggregate. It is lightweight and possesses excellent insulating properties, making it an appealing alternative for lightweight concrete. Additionally, it has the potential to enhance the sturdiness and strength of concrete. However, utilizing fly ash can expose environmental hazards such as the emission of heavy metals, which requires careful management to ensure its safe application [1][68][69].

Blast furnace slag is another waste material that can be utilized as a lightweight aggregate. This byproduct is derived from the steel making process and possesses lightweight, porous, and good thermal insulation properties. Furthermore, it has the potential to improve concrete workability and strength. However, blast furnace slag can contain heavy metals and other contaminants that need to be handled carefully. Additionally, recycled concrete aggregates can be employed as a lightweight aggregate by substituting natural aggregate with crushed concrete. The usage of recycled concrete aggregates is lightweight and can diminish the amount of waste going to landfills. They also have the potential to improve concrete strength and durability. However, the quality of recycled concrete aggregates can vary depending on the source, necessitating proper processing and quality control [70][71][72].

The production of recycled concrete aggregates (RCAs) from demolished building waste involves several steps depicted in Figure 2. It starts with waste collection, where various materials like concrete, bricks, wood, metals, and others are gathered. The collected waste is then sorted to separate concrete from other materials through manual or mechanical processes like air classification and magnetic separation. Next, the concrete is crushed using jaw or impact crushers, and the resulting RCAs are sieved and graded for size consistency. Quality control tests ensure that the RCAs meet construction standards. Developing a strategy for recycled concrete aggregates (RCAs) design involves material characterization, mix design, evaluating structural performance, and considering environmental aspects. Material characterization entails assessing properties like particle size distribution, density, water absorption, and strength to determine the suitability of RCAs in concrete mixtures. Mix design involves carefully selecting the proportion of RCAs to achieve desired workability, strength, and durability, potentially adjusting water-to-cement ratios or using supplementary materials and admixtures. Structural performance evaluation is crucial to ensure that the mechanical properties of RCA-based concrete meet application requirements. Lastly, environmental considerations come into play as the use of RCAs reduces the need for natural aggregates, diminishes construction and demolition waste in landfills, and can be assessed through life cycle assessment (LCA) to compare its environmental impact to conventional concrete.

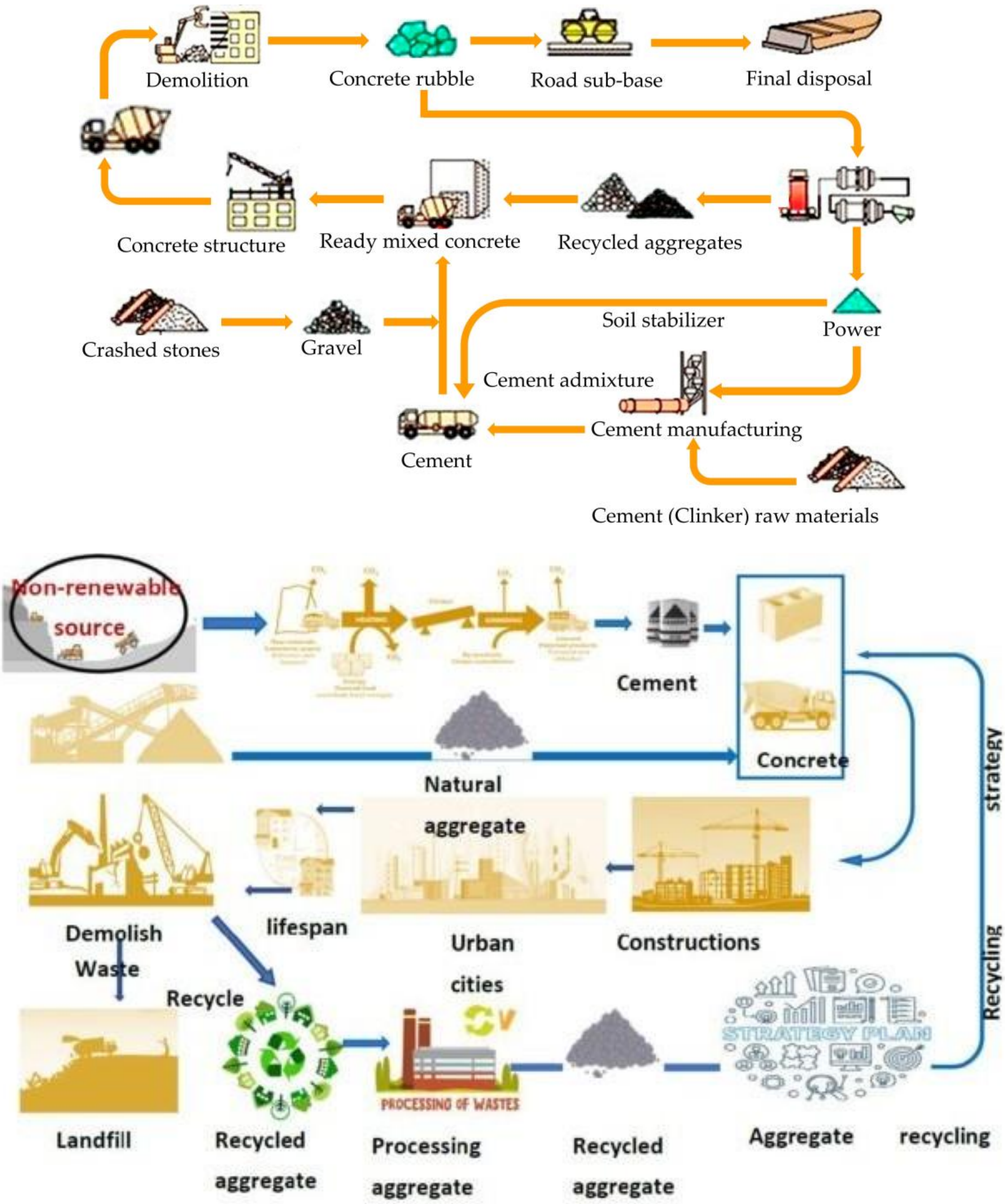

Figure 2: (Top) Production of recycled concrete aggregates (RCAs) from demolished building waste [3]. (Bottom) fundamentals of developing a strategy for recycled concrete aggregates (RCAs) design [31]

There are various waste materials that can be used as coarse lightweight aggregates, including expanded polystyrene, waste plastic, rice husk ash, and sawdust. Expanded polystyrene is a lightweight foam material with good insulation properties, and can be used to produce lightweight concrete. Waste plastic, on the other hand, can be shredded and used as a substitute for natural aggregates. Rice husk ash is a byproduct of rice milling that has pozzolanic properties, and can improve the strength of concrete [2][73][74][75]. Sawdust can also be used as a lightweight aggregate when properly processed and mixed with cement. However, it is crucial to carefully evaluate the properties and potential risks of each waste material, as well as ensure proper processing and quality control, to produce high-quality lightweight concrete. Using waste materials as coarse lightweight aggregates can help reduce waste, preserve natural resources, and enhance sustainability in the construction industry.

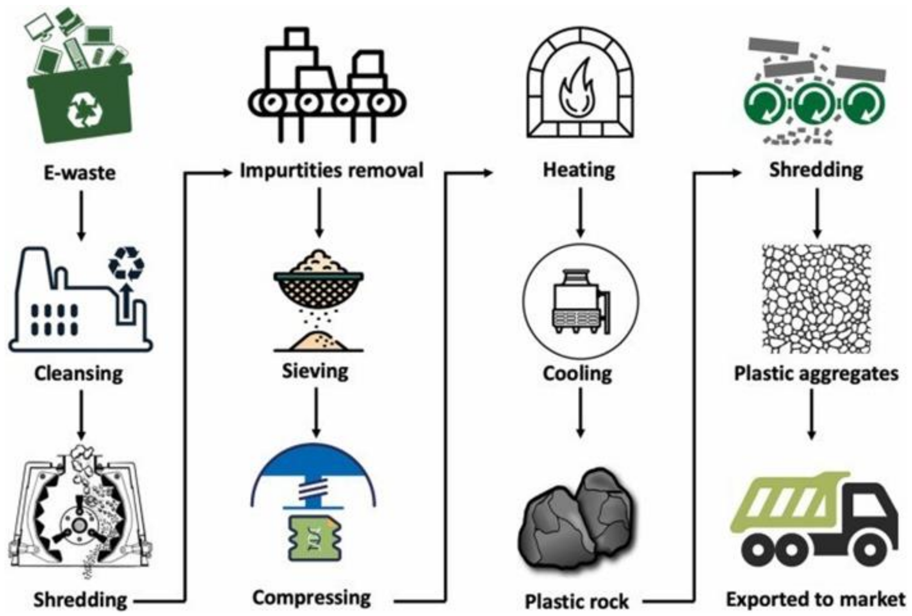

Figure 3: Manufacturing e-waste plastic aggregates through preparation process [25]

Figure 3 outlines the manufacturing process of plastic aggregates through electronic waste or e-waste. It begins with the collection of e-waste plastics from various sources like electronic devices, appliances, and packaging materials. The collected plastics are then sorted based on their type to ensure compatibility and uniformity. Next, the sorted plastics undergo size reduction through shredding, grinding, or milling to produce smaller particles, which can be adjusted according to the desired application. These e-waste plastic particles are blended with other materials like natural aggregates, cement, or bitumen to create a composite material with enhanced properties. The blending process can involve mechanical mixing, melt blending, or extrusion. The resulting blended material is cured, and its properties, including compressive strength, tensile strength, and durability, are tested to ensure it meets the required specifications for its intended application.

2.9 Theoretical Principles

The use of waste materials as coarse lightweight aggregates in the production of lightweight aggregate concrete is based on several fundamental principles, including density, strength, and porosity. Density is a critical principle that governs the use of waste materials as coarse lightweight aggregates. To produce lightweight aggregate concrete, traditional coarse aggregates such as gravel and crushed stone are replaced with lightweight aggregates, resulting in a reduction in the density of the concrete [76][77][78][79]. The density of lightweight aggregate concrete is typically between 1,400 and 1,800 kg/m^3, which is significantly lower than that of normal weight concrete, which has a density of about 2,400 kg/m^3. The reduction in density has numerous benefits, including the reduction in weight of the concrete, which can lead to lower transportation costs and a decrease in the amount of material required to produce the same volume of concrete [80][81][82][83].

The use of waste materials as coarse lightweight aggregates in the production of lightweight aggregate concrete is based on various theoretical principles, including the principle of strength. The compressive strength of concrete is a significant parameter in determining its structural integrity, and it is essential to maintain this strength even when using lightweight aggregates. The use of lightweight aggregates in concrete can lead to a reduction in compressive strength, which can be a significant challenge in some applications. However, studies have demonstrated that the use of waste materials as coarse lightweight aggregates can lead to concrete with comparable compressive strength to that of normal weight concrete [84]. This is due to the pozzolanic properties of many waste materials, including fly ash and blast furnace slag, which react with calcium hydroxide to form additional cementitious compounds, enhancing the strength of the resulting concrete.

Porosity is also a crucial principle that influences the use of waste materials as coarse lightweight aggregates in the production of lightweight aggregate concrete. Porosity, expressed as a percentage of the total volume of concrete, refers to the quantity of voids or empty space in the concrete. Porosity can have a significant impact on the durability of concrete, affecting its ability to resist water and other harmful substances. The use of lightweight aggregates in concrete can result in increased porosity, which may be an issue in some applications. However, research has shown that waste materials such as fly ash and silica fume have pozzolanic properties that can reduce porosity in concrete, resulting in porosity levels comparable to those of normal weight concrete.

The utilization of waste materials as coarse lightweight aggregates in lightweight aggregate concrete is guided by various theoretical principles, including density, strength, and porosity, as well as practical considerations such as availability, cost, and environmental impact. The accessibility and cost of waste materials are essential considerations in deciding their suitability for usage as lightweight aggregates. Environmental impact and the potential for carbon dioxide emissions are other critical factors that can impact their suitability. By adhering to these principles and considering practical concerns, it is possible to select and use waste materials in a way that maximizes the benefits of lightweight aggregate concrete while minimizing its negative impacts.

2.10 Methods used for production

There are various methods that can be used to produce lightweight aggregate concrete using waste materials as coarse aggregates. Some of these methods include:

- **Sintering Method**: In this method, waste materials such as fly ash, sludge, and bottom ash are heated in a rotary kiln to produce lightweight aggregates. The temperature is maintained at around 1100 to 1200 degrees Celsius to produce the aggregates. The resulting aggregates have a porous structure and are lightweight, making them suitable for use as coarse aggregates in lightweight aggregate concrete.
- **Pelletizing Method**: This method involves compressing the waste materials into pellets using a pelletizing machine. The pellets are then heated in a furnace at a temperature of around 1200 to 1300 degrees Celsius to produce lightweight aggregates. The resulting aggregates have a high strength to weight ratio and are suitable for use in lightweight aggregate concrete.
- **Foaming Method**: In this method, a foaming agent is added to the waste materials and mixed with water to produce a foam. The foam is then added to cement and sand to produce lightweight aggregate concrete. The foaming method is a simple and cost-effective method of producing lightweight aggregate concrete using waste materials.
- **Expanded Clay Method**: In this method, waste materials such as clay, shale, and slate are heated in a rotary kiln at a temperature of around 1100 to 1200 degrees Celsius. The resulting aggregates are lightweight and have a porous structure, making them suitable for use as coarse aggregates in lightweight aggregate concrete.
- **Lightweight Aggregate Pre-wetting Method**: This method involves pre-wetting the lightweight aggregates with water before adding them to the concrete mix. This helps to improve the bonding between the aggregates and the cement paste, resulting in a higher strength lightweight aggregate concrete.

In conclusion, the use of waste materials as coarse aggregates in the production of lightweight aggregate concrete offers an environmentally friendly and sustainable solution to the problem of waste disposal. The various methods of producing lightweight aggregate concrete using waste materials as coarse aggregates offer a wide range of options for the construction industry, enabling them to choose the most suitable method based on the type of waste material available and the required properties of the concrete.

2.11 Analysis of Waste Material Properties and Concrete Performance for Sustainable Construction

The construction industry is a major contributor to environmental degradation due to the significant amount of waste generated from construction activities. To reduce the environmental impact of the construction industry, the use of waste materials in construction has been identified as a potential solution. In recent years, researchers have focused on investigating the use of various waste materials, such as fly ash, slag, and recycled concrete aggregate, in concrete production. These materials have been found to improve the properties of concrete while reducing the amount of waste generated from construction activities. Analyzing the properties of waste materials and concrete performance is critical in developing sustainable construction practices. It is important to understand the physical and mechanical properties of waste materials and their impact on the properties of concrete to design and optimize concrete mixtures that incorporate waste materials. Using waste materials in concrete production can also result in economic and environmental benefits, such as reducing waste disposal costs and decreasing greenhouse gas emissions.

This section aims to provide an overview of the analysis of waste material properties and concrete performance for sustainable construction. The present focus is on the characterization of waste materials and the investigation of their effects on the properties of concrete. This section also discusses the challenges and opportunities associated with the use of waste materials in concrete production and the potential for further research in this area.

2.12 Characterization of Waste Material Properties

Characterization of Waste Material Properties refers to the process of identifying and quantifying the physical and mechanical properties of the waste materials that are used in the production of concrete. This characterization is important because the properties of the waste materials can affect the properties of the resulting concrete, such as its strength, porosity, and thermal conductivity. The characterization process can involve a range of tests and measurements, such as density tests, compressive strength tests, porosity tests, and chemical analysis. These tests can provide information on the chemical composition, microstructure, and mechanical properties of the waste materials, which can be used to determine how they interact with other materials in the concrete mix. Overall, the characterization of waste material properties is a crucial step in the development of sustainable and effective concrete production methods, as it helps to ensure that waste materials are used in a way that maximizes their potential and minimizes any negative impacts on the environment or the performance of the resulting concrete [85][86].

To effectively utilize waste materials for sustainable construction, it is important to first characterize their properties. This involves collecting data on the physical and mechanical properties of the waste materials, such as density, strength, and porosity. The characterization process is crucial as it helps to determine the potential uses of the waste materials in construction applications, as well as their compatibility with other materials. The characterization process typically involves a series of laboratory tests, including compressive strength tests, tensile strength tests, and thermal conductivity tests. Other tests may be conducted to determine properties such as moisture content, specific gravity, and particle size distribution. The data collected from these tests is then analyzed to identify any potential issues or limitations with the use of the waste materials. Characterization of waste material properties is an important step towards sustainable construction, as it helps to identify opportunities for recycling and reusing materials that would otherwise be discarded. By understanding the properties of waste materials, researchers and engineers can design concrete mixes that incorporate these materials in a way that maximizes their potential while still meeting the performance requirements of the final product. Overall, characterization of waste material properties is an essential part of the sustainable construction process.

2.13 Evaluation of Mechanical Properties of Waste Materials

The evaluation of mechanical properties of waste materials is an important step in analyzing their suitability for use in sustainable construction. Mechanical properties refer to the behavior of materials under load or stress, and include properties such as strength, stiffness, toughness, and durability. To evaluate the mechanical properties of waste materials, various testing methods can be used. For example, compressive strength tests can be conducted to measure the maximum compressive stress that a material can withstand before failure. Tensile strength tests can also be performed to measure the maximum tensile stress that a material can withstand before failure. Other tests may include bending tests, impact tests, and fatigue tests, depending on the specific properties of the waste materials being evaluated. The results of these mechanical tests can provide important information about the strength and durability of the waste materials and their potential use in construction applications. By analyzing the mechanical properties of waste materials, researchers and engineers can determine their suitability for use as sustainable building materials, and identify any potential limitations or weaknesses in their performance.

2.14 Analysis of Concrete Performance

The assessment of waste material properties is critical for the development of sustainable construction practices. Concrete performance is evaluated by analyzing the properties of concrete produced with waste materials to determine its suitability for use in sustainable construction. The properties of concrete that are usually examined include its compressive strength, tensile strength, and thermal conductivity. Compressive strength measures the capacity of concrete to resist compression or crushing, which determines its load-bearing ability. Tensile strength is the ability of concrete to resist pulling or tension forces, which is vital for structures exposed to twisting or bending forces. Thermal conductivity measures the capacity of concrete to conduct heat and is an essential property for buildings located in hot or cold climates, as it impacts the transfer of heat between the inside and outside of the structure [87][88][89].

To evaluate the performance of concrete made from waste materials, a number of tests can be conducted. These tests include compressive strength tests, tensile strength tests, and thermal conductivity tests. Compressive strength tests involve applying a compressive load to a concrete sample and measuring the amount of force required to cause the sample to fail.

Tensile strength tests involve applying a tension load to a concrete sample and measuring the amount of force required to cause the sample to fail. Thermal conductivity tests involve measuring the rate at which heat flows through a concrete sample. In addition to these tests, other properties of concrete can also be evaluated, such as its workability, durability, and permeability. Workability is a measure of how easily concrete can be placed and compacted in its final position. Durability is a measure of how well the concrete resists the effects of weathering, chemical attack, and other forms of deterioration. Permeability is a measure of the ability of concrete to allow water and other fluids to pass through it. Overall, the analysis of concrete performance is an important aspect of sustainable construction as it helps to ensure that the use of waste materials in concrete production does not compromise the quality or safety of the final product. By evaluating the mechanical and physical properties of concrete made from waste materials, it is possible to identify the optimal mix of materials and production methods that can be used to create high-performance concrete that is both sustainable and cost-effective.

2.15 Assessment of Compressive and Tensile Strengths of Concrete

Concrete strength is a vital factor in determining the performance and durability of concrete. Compressive strength and tensile strength are two significant parameters that affect the strength of concrete. Compressive strength is the maximum load that a concrete sample can withstand without collapsing in compression. Tensile strength, on the other hand, is the maximum stress that a concrete sample can resist before it fails or cracks in tension. The compressive strength of concrete is evaluated by performing a compressive strength test on a cylindrical or cubical concrete sample. The sample is prepared, cured, and subjected to compressive loading until failure occurs. The maximum load that the sample can bear without collapsing is recorded as the compressive strength of the concrete. However, estimating the tensile strength of concrete is more challenging than the compressive strength. Therefore, indirect methods such as splitting tensile tests, flexural strength tests, or pullout tests are used to estimate the tensile strength of concrete. The splitting tensile test involves applying a tensile load that is perpendicular to the axis of a cylindrical or prismatic concrete sample. The maximum tensile stress that the sample can resist before cracking is measured as the splitting tensile strength of the concrete [90][91][92].

The compressive and tensile strengths of concrete are crucial for determining its load carrying capacity, durability and resistance to cracking and deformation under different service conditions. These parameters are also important for designing and optimizing the mix proportions and reinforcement requirements of concrete structures for different applications. Therefore, the assessment of compressive and tensile strengths of concrete is an essential aspect of the analysis of concrete performance.

2.16 Investigation of Thermal Conductivity in Concrete

Thermal conductivity is an important property of concrete, especially in construction projects where energy efficiency and thermal insulation are crucial. Thermal conductivity is the ability of a material to conduct heat, and it is measured in watts per meter-kelvin (W/mK). In the context of concrete, it is a measure of how well the material can transfer heat, both in terms of heat loss and heat gain. To assess the thermal conductivity of concrete, various methods can be used, including experimental and numerical techniques. In experimental methods, a sample of concrete is subjected to a heat flow under controlled conditions, and the temperature distribution is measured over time. By analyzing the temperature data, the thermal conductivity of the concrete can be determined. Numerical methods involve using mathematical models to simulate heat transfer in concrete. These models can be used to predict the thermal performance of different types of concrete under different environmental conditions, such as temperature and humidity.

The thermal conductivity of concrete is an essential factor that can be influenced by different components, including the concrete mix composition, water-cement ratio, and curing conditions. The analysis of thermal conductivity in concrete can help optimize the mix design and other construction parameters to enhance the energy efficiency and thermal insulation of buildings. Therefore, investigating the thermal conductivity in concrete is a vital aspect of evaluating waste material properties and concrete performance for sustainable construction. This analysis can help identify ways to utilize waste materials in concrete more efficiently while improving the energy efficiency and thermal insulation of buildings.

Due to the growing demand for construction materials and the consequent environmental degradation and depletion of non-renewable resources, sustainable building practices are becoming increasingly popular. One of these practices is the use of waste materials as construction aggregates. This study aims to assess the economic and environmental feasibility of using waste materials as coarse lightweight aggregates. It considers various factors such as production costs, environmental impact, and potential carbon dioxide emissions to evaluate the viability of using waste materials in construction. By conducting this assessment, we aim to explore the potential of waste materials as a sustainable construction material and identify any challenges or obstacles that may hinder their adoption in the construction industry [93].

2.17 Background and Context of the Study

This section would introduce the idea of using waste materials as construction aggregates and explain why there is a growing interest in sustainable building practices. The purpose of this section is to provide a foundation for the economic and environmental assessment that follows. For example, this section may discuss the increasing demand for construction materials and the environmental impact of traditional construction practices, such as the extraction of natural resources and the generation of construction waste. It may also discuss the need for sustainable building practices and introduce the idea of using waste materials as a potential solution. The section may further discuss the benefits and challenges of using waste materials, as well as any relevant regulations or policies that encourage or discourage the use of waste materials in construction. Overall, the goal of this section is to provide readers with a context for the assessment of using waste materials as coarse lightweight aggregates and to set the stage for the subsequent sections of the article.

2.18 Purpose and Objectives of the Assessment

The "Purpose and objectives of the assessment" section of the article would outline the reasons for conducting an economic and environmental assessment of using waste materials as coarse lightweight aggregates, as well as the specific goals of the assessment. The purpose of this section is to provide readers with a clear understanding of the research questions that the assessment aims to answer and the expected outcomes. The objectives of the assessment could be framed as research questions, such as:

1) What is the cost of production of using waste materials as coarse lightweight aggregates compared to traditional aggregates?
2) What is the environmental impact of using waste materials as coarse lightweight aggregates compared to traditional aggregates?
3) What is the potential for carbon dioxide emissions from using waste materials as coarse lightweight aggregates, and how does it compare to traditional aggregates?
4) What are the economic and environmental benefits and challenges of using waste materials as construction aggregates?

By clearly stating the research questions and objectives, this section sets the expectations for the reader and clarifies the scope of the assessment. It also provides a framework for the subsequent sections of the article, allowing the reader to understand the relevance and importance of the analysis and its implications for sustainable building practices.

2.19 Economic Assessment

This section of the article provides an evaluation of the economic feasibility of using waste materials as coarse lightweight aggregates in construction. The purpose of this section is to assess the potential cost savings or increases associated with using waste materials compared to traditional aggregates. In this section we begin with an overview of the cost of construction aggregates and the role they play in the construction industry. It could then introduce the concept of using waste materials as a potential alternative to traditional aggregates, explaining that the economic assessment evaluates the feasibility of using waste materials in construction [94].

Construction aggregates play a critical role in the construction industry, providing the necessary materials for the foundation, structure, and finishing of buildings and infrastructure. However, the cost of production and transportation of traditional aggregates can be a significant financial burden on construction projects, as well as a major contributor to greenhouse gas emissions. As such, there has been growing interest in finding alternative materials for construction, with waste materials emerging as a viable option. In this section, an economic assessment of using waste materials as coarse lightweight aggregates in construction is conducted. Specifically, the cost of production of using waste materials compared to traditional aggregates is evaluated, and then the economic feasibility of using waste materials in construction is analyzed.

2.20 Overview of the Cost of Production of using Waste Materials as Coarse Lightweight Aggregates

The cost of utilizing waste materials as coarse lightweight aggregates for construction projects involves various expenses, including the collection, transportation, and storage of the waste material prior to its use as an aggregate. The cost of production can differ depending on factors such as the type and quality of the waste material and the methods employed to create the construction aggregates. Using waste materials as aggregates may involve additional expenses, such as sorting, cleaning, or processing the waste material to meet the required standards, which may increase the cost of production in comparison to traditional aggregates [95].

Secondly, there is the cost of processing the waste material to create construction aggregates. This can involve crushing, screening, and grading the waste material to meet the desired specifications for size, shape, and strength. The costs associated with processing the waste material depends on the type of material, the desired aggregate size, and the processing techniques used. Finally, there are the costs associated with transporting the construction aggregates to the construction site. These costs may be higher for waste materials if they are not available locally, compared to traditional aggregates that are often sourced locally. Overall, the cost of production of using waste materials as coarse lightweight aggregates can be influenced by many factors. An economic assessment of using waste materials as construction aggregates would seek to evaluate the costs and benefits associated with using waste materials as an alternative to traditional aggregates, in order to determine the feasibility and economic viability of this approach to construction.

2.21 Comparison of the Cost of Production Between Waste Materials and Traditional Aggregates

The comparison of the cost of production between waste materials and traditional aggregates is an important part of the economic assessment of using waste materials as coarse lightweight aggregates in construction. This comparison seeks to evaluate the cost effectiveness of using waste materials in construction by analyzing the costs of producing construction aggregates from waste materials compared to traditional aggregates. To make this comparison, it is important to first identify the types of waste materials that can be used as coarse lightweight aggregates in construction. Common examples include fly ash, slag, and recycled concrete. Each of these materials may have different characteristics and may require different processing methods, which can influence their cost of production.

Once the waste materials have been identified, it is necessary to compare the cost of producing construction aggregates using these materials to the cost of producing traditional aggregates such as gravel, sand, or crushed stone. This comparison should take into account all the factors involved in the production of both types of aggregates, including the cost of sourcing the raw materials, processing the materials, and transporting the finished aggregates to the construction site. In some cases, using waste materials as construction aggregates can result in cost savings compared to traditional aggregates. For example, recycled concrete can be crushed and processed at a lower cost than virgin concrete aggregates, and fly ash

can be produced as a byproduct of coal-fired power plants, reducing the cost of sourcing the raw material. However, in other cases, using waste materials as construction aggregates may be more expensive, due to additional processing or transportation costs. The economic assessment should also consider any long-term cost savings or benefits that may arise from using waste materials as construction aggregates, such as reduced waste disposal costs or environmental benefits associated with reducing the use of virgin materials. Overall, a thorough comparison of the cost of production between waste materials and traditional aggregates is critical in determining the economic feasibility of using waste materials as coarse lightweight aggregates in construction.

2.22 Analysis of Economic Feasibility of using Waste Materials as Construction Aggregates

Assessing the economic feasibility of utilizing waste materials as construction aggregates is a crucial aspect of evaluating the viability of this sustainable building approach. The objective of this analysis is to determine the financial viability of incorporating waste materials as construction aggregates by taking into account the associated costs and benefits. To conduct an economic feasibility analysis, various factors must be considered, such as the cost of production of both traditional and waste materials, the availability and quality of waste materials, the potential cost savings or benefits associated with utilizing waste materials, and their impact on project timelines and budgets. Additionally, regulatory and policy factors must also be evaluated to determine if they have any influence on the utilization of waste materials as construction aggregates, as certain regions may have restrictions or regulations on the use of waste materials in construction, which can affect their availability and cost [96].

In addition to these factors, the analysis should consider the potential environmental and social benefits associated with using waste materials as construction aggregates. For example, using waste materials can help reduce the amount of waste sent to landfills, conserve natural resources, and reduce the carbon footprint of construction projects. To conduct the economic feasibility analysis, it may be necessary to use financial models, such as cost benefit analysis, to quantify the costs and benefits of using waste materials as construction aggregates. This analysis can help project managers and stakeholders make informed decisions about the most economically viable approach to construction. Overall, the analysis of economic feasibility of using waste materials as construction aggregates is a critical step in determining the viability of this approach to construction. By considering all relevant factors and conducting a thorough analysis, project managers can make informed decisions that can help reduce costs, conserve resources, and promote sustainable construction practices.

2.23 Environmental Assessment

The "Environmental Assessment" is a key component of the overall assessment of using waste materials as coarse lightweight aggregates in construction. This assessment is designed to evaluate the environmental impact of using waste materials in construction, considering factors such as carbon dioxide emissions, energy consumption, and waste generation. By conducting a thorough environmental assessment, project managers can identify potential environmental risks and benefits associated with using waste materials as construction aggregates, and make informed decisions about the most sustainable and environmentally responsible approach to construction.

2.24 Evaluation of the Environmental Impact of using Waste Materials as Coarse Lightweight Aggregates

Assessing the environmental impact of using waste materials as construction aggregates is crucial for sustainable construction practices. The purpose of this assessment is to evaluate the environmental impact of using waste materials as coarse lightweight aggregates and to identify measures to mitigate any negative effects. The evaluation should consider vari- ous environmental factors, including energy consumption, greenhouse gas emissions, air and water pollution, and waste generation. These factors are influenced by the type of waste material used, the production process, and the transportation and placement of the aggregate. To conduct the environmental assessment, it is necessary to compare the environmental impact of using waste materials as construction aggregates with that of traditional aggregates. This comparison should take into account all the environmental factors involved in the production, use, and disposal of both types of aggregates. The results of this assessment help identify ways to minimize the environmental impact of using waste materials in construction while promoting sustainable building practices [97].

For example, using waste materials as construction aggregates may reduce greenhouse gas emissions, as it avoids the energy-intensive process of producing traditional aggregates from virgin materials. However, using waste materials may also result in increased transportation costs or require additional processing, which can increase energy consumption and carbon emissions. The environmental evaluation should also consider any potential long-term benefits or risks associated with using waste materials as construction aggregates. For example, using waste materials can help reduce the amount of waste sent to landfills, conserving natural resources and reducing environmental impacts associated with waste disposal. To conduct the evaluation, it may be necessary to use specialized software or environmental assessment tools, such as life cycle assessment (LCA) or environmental impact assessment (EIA), to quantify and compare the environmental impacts of using waste materials and traditional aggregates. Overall, the evaluation of the environmental impact of using waste materials as coarse lightweight aggregates is a critical step in determining the sustainability of using waste materials in construction.

By considering all relevant environmental factors and conducting a thorough evaluation, project managers can identify opportunities to minimize environmental impacts and make informed decisions about the most environmentally responsible approach to construction. This comparison is necessary to evaluate the environmental impact of using waste materials and to identify ways to minimize or mitigate any negative impacts. To compare the environmental impact of waste materials and traditional aggregates, it is necessary to consider a range of environmental factors. These may include energy consumption, greenhouse gas emissions, air and water pollution, and waste generation. The environmental impact of the aggregates is influenced by factors such as the type of material used, the production process, and the transportation and placement of the aggregate. For example, traditional aggregates typically require energy-intensive processes to extract, crush, and transport the material to construction sites. This process can result in significant greenhouse gas emissions and other environmental impacts, such as land degradation and air pollution. In contrast, using waste materials as aggregates can reduce these impacts, as it avoids the need to extract and process new materials [98].

However, using waste materials as construction aggregates may also have negative environmental impacts. For example, some waste materials may contain hazardous chemicals that can pose risks to human health or the environment. Additionally, the transportation and processing of waste materials can result in increased energy consumption and carbon emissions. To compare the environmental impact of waste materials and traditional aggregates, it is necessary to conduct a life cycle assessment (LCA) or similar analysis. This analysis evaluates the environmental impacts of both types of aggregates throughout their life cycle, from extraction or collection to processing, transportation, and placement.

By comparing the environmental impact of waste materials and traditional aggregates, project managers can identify opportunities to reduce environmental impacts and make informed decisions about the most sustainable and environmentally responsible approach to construction. Overall, the comparison of the environmental impact of waste materials and traditional aggregates is a critical component of the environmental assessment of using waste materials as construction aggregates. By considering all relevant environmental factors and conducting a thorough comparison, project managers can identify the most sustainable approach to construction and promote environmentally responsible practices.

2.25 Analysis of the Potential Environmental Benefits of using Waste Materials in Construction

The "Analysis of the potential environmental benefits of using waste materials in construction" is an important aspect of the environmental assessment of using waste materials as coarse lightweight aggregates. This analysis involves identifying the potential environmental benefits of using waste materials as construction aggregates and assessing their magnitude. There are several potential environmental benefits of using waste materials in construction, including:

1) **Waste reduction**: Using waste materials as construction aggregates can help reduce the amount of waste sent to landfills, which conserves natural resources and reduces environmental impacts associated with waste disposal.
2) **Energy savings**: Using waste materials as construction aggregates can reduce the need for energy-intensive processes to extract and process virgin materials.
3) **Reduced greenhouse gas emissions**: Using waste materials as construction aggregates can help reduce greenhouse gas emissions associated with traditional aggregates, such as emissions from transportation, energy consumption, and land-use changes.
4) **Reduced environmental impacts**: Using waste materials as construction aggregates can reduce the environmental impacts associated with the extraction and processing of traditional aggregates, such as land degradation, water pollution, and habitat destruction. To assess the potential environmental benefits of using waste materials in construction, it is necessary to quantify the environmental impacts associated with traditional aggregates and compare them to the potential benefits of using waste materials. This analysis can be conducted using environmental assessment tools such as life cycle assessment (LCA) or environmental impact assessment (EIA). For example, an LCA could be used to compare the environmental impact of using traditional aggregates to the impact of using waste materials as construction aggregates. The LCA would consider factors such as energy consumption, greenhouse gas emissions, and waste generation associated with the production, transportation, and placement of both types of aggregates. The analysis would then identify the potential environmental benefits of using waste materials, such as waste reduction and energy savings, and assess their magnitude. The results of the analysis could be used to inform decisions about the most environmentally sustainable approach to construction. Overall, the analysis of the potential environmental benefits of using waste materials in construction is an important step in determining the sustainability of using waste materials as construction aggregates. By identifying the potential benefits and assessing their magnitude, project managers can make informed decisions about the most environmentally responsible approach to construction.

2.26 Assessment of Carbon Dioxide Emissions

Assessment of carbon dioxide emissions is a crucial component of the economic and environmental assessment of using waste materials as coarse lightweight aggregates. The production, transportation, and placement of construction materials contribute to greenhouse gas emissions, including carbon dioxide (CO_2), which is a major contributor to climate change. Therefore, assessing the potential for carbon dioxide emissions associated with using waste materials as construction aggregates is essential to evaluating their sustainability. Assessment of carbon dioxide emissions involves estimating the amount of CO_2 emitted during the production, transportation, and placement of waste materials as construction aggregates, and comparing it to the CO_2 emissions associated with traditional aggregates. The assessment typically involves conducting a life cycle assessment (LCA), which is a standardized method used to evaluate the environmental impacts of a product or process throughout its entire life cycle, from cradle to grave [99].

In the case of using waste materials as construction aggregates, the LCA would consider the CO_2 emissions associated with the production and transportation of the waste materials, as well as the emissions associated with their use in construction. The LCA would also consider the emissions associated with the production and transportation of traditional aggregates, as well as the emissions associated with their use in construction. The analysis would then compare the CO_2 emissions associated with using waste materials as construction aggregates to the emissions associated with using traditional aggregates. This would allow project managers to assess the potential for carbon dioxide emissions reduction associated with using waste materials in construction.

Moreover, the assessment would also identify ways to reduce carbon dioxide emissions associated with using waste materials as construction aggregates, such as optimizing transportation routes, reducing energy consumption during production, and improving construction techniques. Overall, the assessment of carbon dioxide emissions associated with using waste materials as construction aggregates is crucial for evaluating their sustainability. By identifying the potential for emissions reduction and identifying ways to reduce emissions further, project managers can make informed decisions about the most sustainable approach to construction.

The evaluation of the potential for carbon dioxide emissions from using waste materials as coarse lightweight aggregates is an important aspect of the economic and environmental assessment of these materials. The use of waste materials as construction aggregates has the potential to reduce carbon dioxide emissions by reducing the need for traditional aggregates, which require significant amounts of energy to extract, process, and transport. However, the use of waste materials also has the potential to generate carbon dioxide emissions, particularly during their production and transportation. Therefore, it is important to evaluate the potential for carbon dioxide emissions from using waste materials as construction aggregates, in order to determine their overall sustainability. The evaluation typically involves conducting a life cycle assessment (LCA) to estimate the carbon dioxide emissions associated with the production, transportation, and use of the waste materials as construction aggregates. The LCA takes into account the energy and materials inputs required for the production of the waste materials, as well as the emissions generated during the transportation and use of the materials [100].

The evaluation of the potential for carbon dioxide emissions would also compare the emissions associated with using waste materials as construction aggregates to the emissions associated with using traditional aggregates. This comparison would allow for an assessment of the potential for emissions reduction associated with using waste materials in construction. Additionally, the evaluation would identify ways to reduce carbon dioxide emissions associated with using waste materials as construction aggregates, such as optimizing transportation routes, reducing energy consumption during production, and improving construction techniques. Overall, the evaluation of the potential for carbon dioxide emissions associated with using waste materials as construction aggregates is critical for understanding the sustainability of these materials. By identifying the potential for emissions reduction and identifying ways to reduce emissions further, project managers can make informed decisions about the most sustainable approach to construction.

2.27 Comparison of Carbon Dioxide Emissions from Waste Materials and Traditional Aggregates

A comparison of carbon dioxide emissions from waste materials and traditional aggregates is an essential part of the economic and environmental assessment of using waste materials as coarse lightweight aggregates. The comparison typically involves evaluating the carbon dioxide emissions associated with the production, transportation, and use of waste materials and traditional aggregates, and determining which material has a lower carbon footprint. The comparison is typically performed by conducting a life cycle assessment (LCA), which is a standardized method used to evaluate the environmental impacts of a product or process throughout its entire life cycle. The LCA takes into account the energy and materials inputs required for the production of both waste materials and traditional aggregates, as well as the emissions generated during the transportation and use of the materials.

The results of the LCA can then be used to compare the carbon dioxide emissions associated with using waste materials as construction aggregates to the emissions associated with using traditional aggregates. This comparison allows for an assessment of the potential for emissions reduction associated with using waste materials in construction. The comparison may show that using waste materials as construction aggregates results in lower carbon dioxide emissions than using traditional aggregates. For example, waste materials may require less energy to produce or transport, or may be produced from materials that would otherwise be disposed of in landfills, reducing methane emissions. On the other hand, traditional aggregates may be produced with lower emissions due to the use of more efficient processes or cleaner sources of energy [101].

Overall, the comparison of carbon dioxide emissions from waste materials and traditional aggregates is critical for understanding the environmental impacts of using waste materials as construction aggregates. By identifying which material has a lower carbon footprint, project managers can make informed decisions about the most sustainable approach to construction. The analysis of the potential reduction in carbon dioxide emissions by using waste materials in construction is a critical component of the economic and environmental assessment of these materials. The analysis aims to determine the extent to which using waste materials as construction aggregates can reduce carbon dioxide emissions, which is an important consideration for meeting sustainability goals. The analysis typically involves comparing the carbon dioxide emissions associated with using waste materials as construction aggregates to the emissions associated with using traditional aggregates. The difference between the two is used to estimate the potential reduction in carbon dioxide emissions that could be achieved by using waste materials in construction.

The analysis also takes into account the various stages of the production and transportation of waste materials and traditional aggregates, as well as their use in construction. This includes evaluating the energy and materials inputs required for the production of both types of aggregates, as well as the emissions generated during their transportation and use. The analysis can also identify the potential for further reducing carbon dioxide emissions by optimizing production and transportation processes or implementing alternative construction techniques. For example, using electric vehicles for transportation or incorporating renewable energy sources into the production process can further reduce carbon dioxide emissions.

The potential reduction in carbon dioxide emissions by using waste materials in construction depends on the type of waste material and its source, as well as the specific construction project. However, in general, using waste materials as construction aggregates has the potential to reduce carbon dioxide emissions by decreasing the demand for traditional aggregates, which require significant amounts of energy to extract, process, and transport. Overall, the analysis of the potential reduction in carbon dioxide emissions by using waste materials in construction is an important consideration for understanding the sustainability benefits of using these materials. By identifying the potential for emissions reduction and implementing strategies to further reduce emissions, project managers can make informed decisions about the most sustainable approach to construction.

2.28 Aggregate Sourced from Agricultural Waste

The average moisture content and water absorption of the crushed coconut shell was found to be 4.20 and 24 percent respectively. Since the coconut shells are basically wood based and organic material and therefore moisture retaining capacity would be more compared with the crushed stone aggregates. Due to the high-water absorption of CS, the aggregates were pre-soaked for 24 hours in potable water prior to mixing and were in saturated surface dry (SSD) condition during mixing to prevent absorption of mixing water. In case of agricultural and wood-based materials used in cement concrete, the pre-treatment is necessary to ensure that extractable materials do not upset the hardening qualities of the cement. The experiments have shown that most kinds of wood-based materials can be improved substantially by soaking and washing with water before mixing [102]. This procedure is found suitable and easier and is therefore adopted in this investigation. The specific gravity under SSD condition of CS and crushed granite was found to be 1.05 and 2.82 respectively. The specific gravity of an aggregate is used in mixture proportioning calculation to find the absolute volume that a given mass of material occupying in the mixture. Absolute volume of aggregate refers to the space occupied by the aggregate particles excluding the voids between the particles. The specific gravity for normal weight aggregate used in concrete ranges from 2.30 to 2.90. However, the specific gravity of coconut shell is very close to that of oil palm shell (OPS) aggregates [103]. The aggregate impact value gives relative measure of the resistance of an aggregate to sudden impact or shock. The aggregate impact value should not be more than 45 % by weight for aggregate used in concrete [104][105]. The rapid urbanization and industrialization have increased the consumption of aggregates. So, the researchers have to find the alternative for the coarse aggregate. The increase in population increases the industrial byproducts, domestic wastes etc. In India that coconut shell (CS) is an agricultural waste, which requires high dumping yards and also is environmental polluting agent. If this can be utilized as a coarse aggregate, then it should be a boom rather than ban for civil engineering society. As coconut shell is available at a low price in most of the tropical countries. The concrete obtained using coconut shell aggregates satisfy the minimum requirements of lightweight concrete. Hence it is possible to made lightweight concrete making use of coconut shells as an aggregate in concrete. The main objective is to encourage the use of waste products as construction materials in low cost housing. It serves the purpose of encouraging housing developers in investing these materials in construction.

2.29 Aggregate Sourced from Industrial Waste

Rutting, fatigue cracking, and cracking brought on by low temperatures are the three most common severity levels that may appear in flexible pavements. Due to fatigue cracking brought on by continuous loads, the service life of flexible pavements may be drastically limited. In the process of separating molten steel from impurities in steel-making furnaces, steel slag is produced as a waste byproduct. Chemical reactions that occur during the mixing of asphaltic materials and mineral aggregates alter the mixture’s mechanical characteristics and appropriateness for use in a range of technological applications. It is challenging to generalize about the mechanical properties of asphaltic mixes due to the variability in their chemical composition.

Maharaj et al. [106] in Trinidad and Tobago examine if employing steel slag with a maximum particle size of 20 mm is practical. This steel slag has been processed in an electric arc furnace. According to the experimental results, adding 15% steel slag aggregates to Hot Mix Asphalt (HMA) mixtures satisfies the Marshall requirement (SSA). By utilizing SSA, large steel slag heaps may be treated and removed for less money [41]. According to the available studies, asphalt concrete is thought to perform better due to the unique physical properties of BOF slag. The geometric characteristics of BOF slag haven’t been measured, however, and neither have their effects on asphalt mixtures. Zhu and Nodes [107] looked at how the angularity number affects the performance of bituminous mixes. Experiments into the physical and chemical properties of asphalt mixes incorporating BOF slag, enhanced angularity of the coarse particles improved the interlocking between them, which raised the resistance of bitumen mixtures to rutting [108]. Using SEM, XRD, and EPMA tests, the physiochemical characteristics of the BOF slag were investigated. The findings demonstrated that the coarse microtexture of BOF slag enhances the bonding properties of asphalt. The BOF slag blended asphalt compositions now have improved temperature rutting resistance, fatigue resistance, and antiskid resistance [37]. We conducted slide resistance tests on asphalt mixes including steel slag aggregate. The blend that contains 30% steel slag performs better than the other samples [43]. Steel slag gave reliable and consistent results in asphalt compositions whether it was utilized as a coarse or fine aggregate. The probable increase in steel slag is among the most crucial factors to consider. Free lime and magnesium in steel slag make it brittle and susceptible to breaking in wet situations [44]. To avoid difficulties with expansion, aggregate must be aged before being added to asphalt mixtures. The coarse and fine steel slag aggregate contains 3% non-slag components in the form of mild lime particles or lime-oxide agglomerations [45]. Another study looked at the efficiency of the steel slag aggregate used to hot-mix asphalt mixtures. The results were evaluated using tests for indirect tensile strength, resilient modulus, rutting resistance, fatigue life, and creep modulus. The study's findings persuaded the research team that steel slag aggregate could be utilized in Hot Mix Asphalt (HMA) mixes since it met both Jordanian and Superpave physical property standards. Improved mechanical characteristics were seen in hot bituminous mixture blends containing 75% coarse steel slag aggregate [46]. A steel slag aggregate-based HMA mix's efficacy was investigated. The tire wear caused by studded tires is intended to be lessened by utilizing SSA, a surface substance. According to the Superpave mix design, four alternative asphalt mixtures were created, each of which substituted natural aggregates with SSA in weight percentages of 0, 20, 40, and 60%. In terms of corrosion, moisture susceptibility, thermal cracking resistance, and studded tyre wear resistance, the performance of the combination was carefully assessed [47]. Asphalt concrete (AC) mixes with steel slag inclusion and AC mixes with typical particle sizes were examined for efficacy by Azahar et al. [109] Marshall Mix design samples were developed in compliance with Malaysian standards to evaluate the efficacy of experiments. For the manufactured samples, a robust modulus test and a creep test were run.

In comparison to conventional asphalt mixes, steel slag compositions demonstrated much less persistent deformation, according to the study. Steel slag blended compositions use less energy to produce than regular aggregates because they can store more heat [48]. Khan and colleagues studied asphalt mixtures with a wearing layer that was 48% lighter than typical particles. For the base course, two different asphalt mixtures incorporating steel slag in amounts ranging from 100 to 61% of the total weight of virgin aggregates were created. By adding steel slag aggregate to asphalt mixes, the fatigue life of the paved area and the mixture's resistance to surface sliding are both extended. Using steel slag aggregate increases the preservation of these irreplaceable raw materials by reducing the requirement for natural aggregates. It may be used in asphalt layers or as an unbound granular foundation. [49]. By Louzi et al. [110], steel slag was included into asphalt concrete (AC) mixes in three different amounts: 15, 30, and 45% of the aggregate weight. The suggested combination's resilient modulus, indirect tensile strength, fatigue resistance, and loss of indirect tensile strength were all measured in several laboratory tests. The stability, resilience modulus, indirect tensile strength, and fatigue life of asphalt mixtures are all improved by steel slag, per the research. [50]. Steel slag aggregates used in Stone Mastic Asphalt (SMA) compositions were the subject of a study by Behnood et al. [111] The results of the trials show that the resilience modulus, tensile strength, resistance to moisture damage, and resistance to permanent deformation of SMA mixes are all enhanced by the addition of coarse steel slag particles [51].

Yilmaz et al. [12] carried out an experimental examination to determine the compressive strength of a flexible pavement base layer coupled with ferrochrome slag aggregate. To create cylindrical samples, a variety of binder agent ratios, including Portland cement and silica fume in proportions of 2%, 4%, 6%, 8%, and 10% by dry weight of the mixture, were utilized. Both destructive and non-destructive tests were carried out to gauge the compressive strength of the manufactured specimens. The highest dry density was 2.38 g/cm3, and the ideal moisture content was 7.5%. Compressive strength requirements are met by ferrochrome slag mixtures containing 3% or more Portland cement and 5% to 10% silica fume. The strength doesn't actually increase much after the silica fume level approaches 8%. Managing slag blends becomes increasingly challenging as silica fume concentrations rise. This is due to the finer silica fume. The findings of destructive Unconfined Compressive Strength (UCS) tests and nondestructive Ultra Sonic Pulse (UPV) testing were equal. The results of the UPV and UCS tests were related for cement-bound FeCr slag with a lower binder%. Regression analysis was used to achieve R2 values of 0.99 for Portland cement and mixed slag mixes with silica fume. It has been carefully researched to see if SSA might be utilized to complement aggregate materials in bituminous pavements [52]. Nevertheless, the results, particularly those concerning the doses of SSA added to asphalt mixtures, cannot be broadly used.

The origin of the bituminous base material has a considerable impact on the blend's ultimate rheological and performance properties, which is the main driver for the formulation changes [53]. Because of its superior abrasion resistance and crushability compared to other materials, FCS may be utilized to construct pavement [11]. In the granular layers of the flexible pavement, Yilmaz et al. [12] examined the mechanical characteristics of FeCr slag. Since the physical properties of FCS aggregate mixes meet the requirements for flexible pavement granular layers, FeCr slag is a suitable aggregate for use in pavement layers, according to the results of the trials. Because to the enhanced physical characteristics of FCS aggregates, thinner pavements are achievable than with regular aggregates. A base layer for an unbound flexible pavement that included different concentrations of steel slag, fly ash, and lime was tested for its structural performance by Pai et al. [112]. During the trials, tests for resilient modulus, unconfined compressive strength, and grain size analyses were also conducted. The base layer of the Wet Mix Macadam should consist of a mixture of 75% steel slag, 19% fly ash, and 6% lime, according to the study (WMM). The experimental analysis of a steel, fly ash, and lime blended mix revealed increased stiffness capabilities when a flexible pavement test section with a base thickness of 150x250 mm was developed. This was confirmed by carrying out a complete structural analysis of the ready test component using a portable deflectometer.

In comparison to the base layer of the traditional WMM, peak deflections were less visible in the combined base layers of steel, fly ash, and lime. Also, when compared to a normal WMM layer, test sections with a steel, fly ash, and lime mixed base layer demonstrated a service life ratio of up to 2.6 and significant cost savings of up to 15% [54]. Several studies have looked at the usage of steel slag aggregates in the building construction industry. FCS has been considered as a concrete and mortar replacement aggregate because to its advantageous chemical, physical, and mechanical properties. Moreover, studies have been conducted to see if alkali-activated and treated FCS may completely or partially replace cement. The quality of the aggregate used to make the concrete mix is the most important aspect in determining the overall quality and performance of the concrete. Using the proper ratios and mixing for the aggregate improves strength and mechanical properties [55]. Aggregate, which takes up between 60 and 75 percent of the total volume of concrete, is one of the most practical applications for FCS in the concrete mix [56]. In order to assess if FCS can replace fine or coarse aggregate in concrete, many investigations have been carried out. Ferrochrome Slag (FCS) is an excellent substitute for natural aggregates in concrete because of its beneficial characteristics.

Islam and colleagues are looking at the potential effects of adding FCS fine aggregate to concrete on its mechanical and physical characteristics in constrained spaces and at higher temperatures. The microstructures of slag blended mixes at high temperatures were examined using SEM and EDS. The FCS fine aggregate blended concrete mix outperformed traditional concrete in terms of mechanical qualities. The aggregate strength and mass loss were also shown to be lower than in traditional concrete. The enhanced strength characteristics are brought about by modifications in chemical composition and abrasive surface roughness. According to ultrasonic pulse velocity and microscopic examination of the concrete mixture, FCS concrete was less affected by high temperatures [57]. The combined effect of fly ash and ferrochrome waste on the characteristics of concrete was examined. Fly ash was substituted for cement in weight ratios of 10, 20, and 30, while ferrochrome slag was substituted for natural aggregates in weight ratios of 25, 50, and 75. For newly formed concrete mixes, slump, air content, and unit weight were measured; however, for already-cured concrete mixtures, compressive strength, splitting tensile strength, elasticity modulus, abrasion resistance, freeze-thaw resistance, porosity, and water absorption were measured. Fly ash reduces the unit weight, elastic modulus, compressive strength, and split tensile strength of concrete while increasing its workability and air content. The use of coarse ferrochromium aggregate improves the unit weight, slump value, compressive strength, split tensile strength, freeze-thaw resistance, and wearing resistance of concrete.

The very rough surfaces of FCS particles, which promote interparticle locking between slag particles and cement paste in concrete mixes, may be the cause of this enhancement in strength attributes over natural sand [27]. The compressive strength properties of the ferrochrome slag aggregate blended concrete mixture are better than those of the conventional aggregate blended concrete mixture. The researchers have not yet established the ideal ratio of ferrochrome replacements to replace traditional aggregate. The range in compressive strength data was expected to be influenced by a variety of variables, such as mixed design difficulties and source-dependent slag characteristics. The surface of FCS aggregate is rougher than that of sand, which makes it easier for slag particles and the cement matrix to bind together. Nevertheless, conflicting results from other studies were obtained. The compressive strength of concrete is impacted by the addition of up to 50% FCS aggregate [58]. Kopuri and Ramesh et al. [113] claim that utilizing ferrochrome slag as a partial replacement for natural sand increased the compressive strength of concrete mixtures. Compressive strength rose by 36% when ferrochrome slag fine aggregate was used in place of 40% and this strength variation may be caused by changes in the crystallinity phases of FCS fine aggregates as well as grain size dispersion. Due to its favourable physical and mechanical characteristics, FCS has been shown to be suitable for use as an aggregate replacement in building mortar, concrete, and bitumen mixtures [59]. Alkali-activated FCS has been successfully shown as a substitute to cement in several studies [30][60]. Blends with FCS performed worse in terms of workability and slump because to greater water absorption and angularity [61]. Mohanty et al. [61] examined the mechanical and physical characteristics of concrete using fly ash and ferrochrome ash to partly replace cement. The compressive strength, flexural strength, and mechanical properties of conventional Portland cement were examined in laboratory testing at 7, 28, and 56 days by replacing fly ash with ferrochrome ash at percentages of 10%, 20%, 30%, and 3%. The compressive strength rises from 7 to 28 days and 56 days when 30% and 3% fly ash are used as cement replacements, respectively, by 39.45% and 49.43%. Moreover, the split tensile strength and flexural strength of the concrete mix both increase by 33.33% and 2%, respectively. When fly ash and ferrochrome slag are added to concrete, it becomes stronger.

Fly ash and ferrochrome ash, which have progressively higher SiO_2 and Al_2O_3 contents, are the sources of C2S [62]. Masilamani et al. [114] looked at the physical and mechanical characteristics of steel slag concrete aggregates from Energy Optimized Furnace (EOF) as an alternative to traditional natural aggregates. The degree of hardness of the transition zone between two surfaces in hardened cement paste as well as the presence of staining agents in steel slag were both assessed. Chemical analysis shows how powerful the oxides in steel slag are. SEM and XRD studies on the microstructure of the EOF steel slag were carried out. The circularity, homogeneity, form factor, and roundness of naturally occurring and EOF steel slag aggregates are examined using digital image processing (DIP). EOF steel slag aggregates are less angular than natural aggregates, making them simpler to work with. EOF steel slag has substantially higher crushing, impact, and abrasion values than regular steel slag. Alkali aggregate reaction (AAR) and soundness tests on the EOF steel slag demonstrate the iron compound breakdown and lack of expandable components. Steel slag aggregate blended concrete mix offers increased microhardness and interfacial transition zone strength due to the abrasive surface roughness and stronger chemical reactivity with the cement matrix [63].

Aggregates are the primary component of concrete, accounting for 60 to 80 percent of its volume. They are used to provide volume, stability, and durability to concrete. Traditionally, aggregates have been sourced from natural sources such as riverbeds and quarries. However, with the increasing demand for construction materials, the depletion of natural resources, and the rising cost of extraction, there has been a growing interest in utilizing industrial waste as a source of aggregates for concrete production. Over the past few decades, researchers have explored the use of various types of industrial waste as a replacement for natural aggregates in concrete production [115][116]. The main aim of this research is to reduce the environmental impact of concrete production by diverting waste from landfills and reducing the need for natural resources. The research has focused on evaluating the physical, chemical, and mechanical properties of the waste aggregates and their impact on the strength, durability, and workability of concrete.

Several studies have been conducted on the use of various types of industrial waste, including fly ash, slag, recycled concrete aggregate, and foundry sand, as a replacement for natural aggregates in concrete. These studies have demonstrated that industrial waste can be successfully used as a substitute for natural aggregates without compromising the strength and durability of concrete. Furthermore, the use of industrial waste aggregates in concrete production has been shown to reduce the carbon footprint of concrete and promote sustainable construction practices. The aggregates that have been used until today are:

1) **Fly Ash**: Fly ash is a byproduct of coal-fired power plants that is commonly used as a replacement for cement in concrete production. Fly ash has been used as a partial replacement for natural aggregates in concrete and has been shown to improve the workability, strength, and durability of concrete.
2) **Slag**: Slag is a byproduct of the steel industry that is commonly used as a replacement for natural aggregates in concrete production. Slag has been shown to improve the strength and durability of concrete and reduce its carbon footprint.
3) **Recycled Concrete Aggregate**: Recycled concrete aggregate is made from crushing and reusing old concrete. It has been shown to be a viable substitute for natural aggregates in concrete production and can improve the strength and durability of concrete.
4) **Foundry Sand**: Foundry sand is a byproduct of the metal casting industry that is commonly used as a replacement for natural aggregates in concrete production. Foundry sand has been shown to improve the workability and strength of concrete and reduce its carbon footprint.

Despite the significant progress made in the use of industrial waste as a source of aggregates for concrete production, there are still some gaps in knowledge. These include:

1) **Long-term Durability**: Most of the research conducted on the use of industrial waste aggregates in concrete has focused on short-term durability. There is a need for further research to evaluate the long-term durability of concrete made with industrial waste aggregates.
2) **Standardization**: There is a lack of standardization in the use of industrial waste aggregates in concrete production. There is a need for standard guidelines and specifications to ensure the quality and consistency of concrete made with industrial waste aggregates.
3) **Cost-effectiveness**: The cost of producing concrete using industrial waste aggregates may be higher than that of producing concrete using natural aggregates. There is a need for further research to evaluate the cost-effectiveness of using industrial waste aggregates in concrete production.

In conclusion, the use of industrial waste as a source of aggregates for concrete production has shown great potential in reducing the environmental impact of concrete production. Further research is needed to address the gaps in knowledge and promote the use of industrial waste aggregates in concrete production on a larger scale.

2.30 Aggregate Sourced from Construction Waste

The aggregates that have been used until today:

1) **Recycled Concrete Aggregate**: Recycled concrete aggregate is made from crushing and reusing old concrete. It is one of the most commonly used construction waste aggregates in concrete production. Recycled concrete aggregate has been shown to be a viable substitute for natural aggregates in concrete production and can improve the strength and durability of concrete.
2) **Brick Aggregate**: Brick aggregate is made by crushing old bricks and has been used as a replacement for natural aggregates in concrete production. Brick aggregate has been shown to improve the compressive strength and durability of concrete.
3) **Ceramic Aggregate**: Ceramic aggregate is made by crushing old ceramic tiles and has been used as a replacement for natural aggregates in concrete production. Ceramic aggregate has been shown to improve the compressive strength and durability of concrete.
4) **Glass Aggregate**: Glass aggregate is made by crushing waste glass and has been used as a replacement for natural aggregates in concrete production. Glass aggregate has been shown to improve the workability and durability of concrete.

Despite the significant progress made in the use of construction waste as a source of aggregates for concrete production, there are still some gaps in knowledge. These include:

1) **Contamination**: Construction waste aggregates may be contaminated with hazardous materials such as lead, asbestos, and PCBs. There is a need for further research to evaluate the potential health and environmental risks associated with the use of construction waste aggregates in concrete production.
2) **Standardization**: There is a lack of standardization in the use of construction waste aggregates in concrete production. There is a need for standard guidelines and specifications to ensure the quality and consistency of concrete made with construction waste aggregates [114].
3) **Cost-effectiveness**: The cost of producing concrete using construction waste aggregates may be higher than that of producing concrete using natural aggregates. There is a need for further research to evaluate the cost-effectiveness of using construction waste aggregates in concrete production.

In conclusion, the use of construction waste as a source of aggregates for concrete production has shown great potential in reducing the environmental impact of construction activities. Further research is needed to address the gaps in knowledge and promote the use of construction waste aggregates in concrete production on a larger scale.

2.31 Identification of Potential Benefits and Challenges to the Adoption of Waste Materials in Construction

It is important to evaluate the potential benefits and challenges associated with the adoption of waste materials in construction to gain insight into their economic and environmental impact. This analysis aims to identify both the advantages and disadvantages of using waste materials as construction aggregates and to explore potential barriers to their adoption in the construction industry. One significant advantage of using waste materials as construction aggregates is the potential to reduce costs, improve environmental sustainability, and promote social responsibility. The utilization of waste materials provides a cost-effective alternative to traditional aggregates, which can help lower construction costs. Additionally, it can reduce environmental impacts by decreasing waste sent to landfills and reducing the need for natural resource extraction. The use of waste materials also demonstrates a commitment to social responsibility by supporting a circular economy and contributing to the development of more sustainable construction practices. However, potential challenges may include regulatory or policy limitations, technological barriers, and variable availability and quality of waste materials. The analysis should consider these factors to gain a comprehensive understanding of the feasibility of adopting waste materials in construction [117].

However, there are also potential challenges associated with the adoption of waste materials in construction. These include concerns over the quality and consistency of the materials, potential health and safety risks, and limitations in the availability and accessibility of the materials. The quality and consistency of waste materials can be influenced by factors such as their origin, composition, and processing methods, which can make it challenging to ensure that the materials meet construction standards. There may also be health and safety risks associated with the handling and use of waste materials, such as exposure to hazardous substances or risks related to the stability of the materials. Finally, the availability and accessibility of waste materials can vary depending on the location and type of waste stream, which can limit their feasibility for use in certain construction projects. To address these potential challenges, project managers can develop strategies to ensure the quality and safety of waste materials, including establishing quality control measures and safety protocols. They can also work with waste management providers to improve the availability and accessibility of waste materials, such as through the development of more efficient and effective waste processing and distribution networks. Overall, the identification of potential benefits and challenges to the adoption of waste materials in construction is a critical aspect of the economic and environmental assessment. By understanding the advantages and limitations of these materials, project managers can make informed decisions about their suitability for use in construction projects and can develop strategies to address any potential challenges.

2.32 Recommendations for Future Research and Development in this Area

As with any research and development project, the economic and environmental assessment of using waste materials as construction aggregates is an ongoing process. Therefore, it is important to make recommendations for future research and development in this area to continue to improve the sustainability and feasibility of these materials in construction. Some potential recommendations for future research and development could include:

1) Further evaluation of the long-term durability and performance of structures constructed using waste materials as coarse lightweight aggregates. This research can help to better understand the potential long-term benefits and drawbacks of using waste materials as construction aggregates, and can help to identify opportunities to further optimize their performance.
2) Investigation of new processing methods and technologies to improve the quality and consistency of waste materials as construction aggregates. This research can help to address concerns over the quality and consistency of waste materials, and can help to identify new opportunities to increase the feasibility and value of these materials for use in construction.
3) Assessment of the potential health and safety risks associated with the handling and use of waste materials in construction, and development of new safety protocols to mitigate these risks. This research can help to ensure that waste materials are used safely and effectively in construction projects, and can help to promote greater adoption of these materials in the construction industry.

4) Examination of the environmental impacts associated with the production, transportation, and use of waste materials as construction aggregates, and identification of new opportunities to reduce the carbon footprint and environmental impacts of these materials. This research can help to further optimize the sustainability of using waste materials in construction, and can help to promote greater adoption of these materials in the construction industry.

Overall, continued research and development in this area can help to optimize the sustainability and feasibility of using waste materials as construction aggregates, and can help to promote greater adoption of these materials in the construction industry. By continuing to explore new opportunities and challenges associated with these materials, we can better understand their potential value and limitations, and work to further optimize their use in construction projects.

3.0 CONCLUSIONS AND RECOMMENDATIONS

The primary objective of this literature review is to examine the potential of utilizing waste materials as coarse lightweight aggregates for the production of lightweight aggregate concrete. The increasing demand for sustainable building practices has led to a growing interest in waste materials as an alternative to traditional construction aggregates. The review focuses on several waste materials, including waste plastic, recycled concrete aggregate, slag, fly ash, and expanded polystyrene. The characteristics of each waste material are analyzed, such as mechanical properties, particle size, shape, and density, and their suitability as coarse lightweight aggregates for lightweight aggregate concrete is evaluated based on their ability to meet technical requirements, including compressive strength, splitting tensile strength, flexural strength, and modulus of elasticity. The economic and environmental benefits of using waste materials as coarse lightweight aggregates in lightweight aggregate concrete production are also assessed. The use of waste materials can not only conserve natural resources but also reduce the amount of waste sent to landfills, thereby minimizing the negative impact on the environment. Overall, this literature review provides a comprehensive analysis of the potential of using waste materials as coarse lightweight aggregates for lightweight aggregate concrete production, highlighting their viability as an eco-friendly alternative to traditional construction aggregates. The incorporation of waste materials as coarse lightweight aggregates in the production of lightweight aggregate concrete can offer substantial sustainability benefits. This approach promotes the principles of the circular economy, which aims to minimize waste and optimize resource use. By utilizing waste materials, natural resources can be conserved, and waste can be diverted from landfills, reducing the negative impact on the environment. In addition, the use of waste materials reduces the need for the extraction of virgin materials, which can lead to environmental problems such as soil erosion, water pollution, and habitat destruction. Another environmental benefit of diverting waste from landfills is the reduction of methane emissions, which is a potent greenhouse gas that contributes to climate change. Overall, incorporating waste materials into construction projects can help reduce the environmental impact of the construction industry and encourage more sustainable building practices. Based on the findings of this review article, there are several recommendations for future research and development in the field of using waste materials as coarse lightweight aggregates for lightweight aggregate concrete production:

a) Further research should be conducted to identify new types of waste materials that can be used as coarse lightweight aggregates. This research should focus on waste materials that are readily available and have properties that make them suitable for use in construction.

b) The use of waste materials in lightweight aggregate concrete production should be explored further to determine their long-term durability and resistance to environmental factors such as freeze thaw cycles, moisture, and chemical exposure.

c) Standardized testing methods should be developed and implemented to ensure that the mechanical properties of lightweight aggregate concrete containing waste materials are consistent and reliable.

d) Life-cycle assessments should be conducted to evaluate the overall environmental impact of using waste materials as coarse lightweight aggregates for lightweight aggregate concrete production, including the impact of transportation and processing.

e) Efforts should be made to raise awareness among stakeholders in the construction industry about the potential benefits of using waste materials in construction, and to promote the development of policies and regulations that encourage the use of waste materials in construction.

By following these recommendations, it may be possible to further develop and refine the use of waste materials as coarse lightweight aggregates for lightweight aggregate concrete production, and to realize the full potential of this sustainable approach to construction.

4.0 AUTHOR CONTRIBUTIONS

Mohammad Umar Usmani: Conceptualization, Methodology, Writing- Original draft preparation
Khairunisa Muthusamy: Supervision, Writing- Reviewing and Editing.

5.0 CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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