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Investigation the Use of Waste Glass and Waste Paper as an Alternative Construction Binding Material: An Approach Towards Sustainable Environment

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ABSTRACT

The idea of repurposing garbage as a resource within the building industry has drawn much attention in light of growing worldwide concerns about sustainable development and waste management. This thesis explores the intriguing idea of using waste materials as a practical and ecological replacement for construction materials and also carefully evaluates the technical, environmental and financial viability of incorporating various waste products, like household waste paper and waste glass into different construction applications. The results of this research project are incredibly insightful. Regarding waste paper as a cement replacement, the experiment demonstrated that substituting 10%, 20% or 30% of cement with waste paper is not a recommended practice. In all instances, the resulting concrete blocks exhibited a significant reduction in strength when compared to traditional concrete formulations. This outcome underscores the limitations of waste paper as a viable substitute for maintaining concrete strength. Conversely, findings regarding glass waste replacement in cement are particularly exciting. At just 7 days of curing, concrete blocks incorporating 10% and 20% glass waste replacements displayed higher strength than their conventional counterparts, showcasing an early strength advantage. By the 14-day mark, the strength of these glass waste-reinforced blocks closely approached that of standard concrete, highlighting their potential for use in sustainable construction practices. Even more impressively, at 21 days of curing, when conventional concrete reached its peak strength at 28.33 KN per square meter, the blocks with 10%, 20% and 30% glass waste replacement-maintained robustness, with strengths of 26.4, 25.26 and 19.44 KN per square meter respectively. This prolonged strength retention suggests that glass waste-reinforced concrete can serve as a sustainable alternative without compromising structural integrity, even in the long term.

INTRODUCTION

Waste management has become a crucial issue for society due to the increasing amount of waste produced every day. With growing environmental concerns and the need for sustainable development, there is a greater need for waste reduction and recycling. The construction industry is one of the major contributors to waste generation, accounting for about 40% of the global waste produced. However, advances in technology and increasing environmental awareness have created new opportunities to address this problem. One such opportunity is the use of waste products as an alternative to traditional construction materials.

The concept of using waste products as construction materials is not new. For centuries, builders have used locally available materials, including waste products, to construct buildings. However, with the advent of modern construction techniques and materials, the use of waste products declined, and the focus shifted to using virgin materials. But with the growing need for sustainable construction, waste products are once again gaining attention as a valuable resource.

The benefits of using waste products as an alternative to traditional construction materials are numerous. By repurposing waste, we can reduce the amount of waste that ends up in landfills and incinerators. This, in turn, reduces the environmental impact of waste disposal and conserves resources. Additionally, using waste products as construction materials can reduce the demand for virgin materials, thereby reducing the need for resource extraction and processing. This reduces the carbon footprint of construction and contributes to climate change mitigation. Furthermore, using waste products in construction can create economic benefits, as waste products are often cheaper than virgin materials. There are several types of waste products that can be used as an alternative to traditional construction materials. These include:

Industrial By-Products

Many industrial processes generate waste materials that can be used as construction materials. For example, coal fly ash, a by-product of coal-fired power plants, can be used as a substitute for Portland cement in concrete. This not only reduces the amount of waste sent to landfills but also reduces the carbon footprint of construction.

Municipal Solid Waste

Municipal solid waste, also known as household waste, is another potential source of construction materials. For example, crushed glass can be used as a substitute for aggregate in concrete, while plastic waste can be used as insulation material.

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Construction and Demolition Waste

Construction and demolition waste, which includes concrete, bricks, and other construction materials, can be recycled and used as construction materials. This reduces the need for virgin materials and reduces the environmental impact of waste disposal.

Agricultural Waste

Agricultural waste, such as rice husks, straw, and coconut fibers, can be used as insulation materials or as a substitute for wood in construction. Benefits of using waste products as construction materials the use of waste products as an alternative to traditional construction materials offers numerous benefits.

LITERATURE REVIEW

This chapter includes a survey of the academic works that provided the theoretical foundation for the study and supported its need. The glass waste, on the other hand, are the subject of the second part which covers their principles, technical aspects of their manufacturing process, historical usage of solid wastes in their creation, etc. Finally, a comprehensive overview of the literature review's two sections, the found research gaps, and the necessity of the current study served to wrap up this chapter.

According to Hoornweg and Bhada-Tata 2012 (Hoornweg & Bhada-Tata, 2012), recycling is the third most preferred method of trash disposal in the world. Addressing the world's rising rate of garbage creation is a crucial part of the 3Rs, which are advised for all nations to follow. Contrary to claims made by detractors about the environmental benefits of recycling, a review and analysis of several life cycle assessments (LCA) of recyclable wastes, including paper, cardboard, glass, plastics, aluminum, steel, wood, and aggregate, have revealed and confirmed that recycling is the most practical method of waste disposal (or waste management) that can provide environmental benefits and minimize environmental impacts when compared to other methods.

In light of the many aforementioned advantages of recycling, its use in construction appears to be an ineffective way to solve the issues of concerns related to the activities of the building sector.

The forecasted enormous increase in construction activity in the near future (Global Construction Perspectives and Oxford Economics (GCPOE) forecasts, 2015) and the anticipated rise in urban population growth, which may increase housing demand in the future, are other indirect factors that necessitate the urgent need to implement the recycled use of waste in construction. According to a United Nations assessment, 2.5 billion more people will live in cities throughout the world by the year 2050, with Asia and Africa anticipated to contribute 90% of that growth (United Nations, 2015). The problems of sustainable development are also anticipated to be on the high side as a result of the ongoing urbanization of the world, particularly in cities found in lower middle-income nations (United Nations, 2015).

According to the UNEP GWMO report 2015, (Wilson, *et al.*, 2015) Speaking of waste generation, the increasing standard of living and growth of civilization have prompted remarkable growth in the rate of waste generation over the past years. The World Bank's review of global solid waste generation and also showed that the amount of waste produced per capita worldwide was increasing excessively quickly, outpacing both urban population growth and projections for the year 2025 (Hoornweg *et al.*, 2012).

The amount of building is predicted to increase dramatically in the near future on a worldwide scale. A new estimate titled "Global Construction 2030" projects that the global construction production would increase by 85% to $15.5 trillion by 2030 (Asadi & Satish, 2021). The worldwide construction volume was expected to expand by over 70% by 2025, which is a 15% increase from the prior prediction (Asadi & Satish, 2021). The forecast also predicts that developed nations, which are recovering from economic instability, and emerging nations, which are currently industrializing, will make significant contributions to the global construction volume, leading to a projected 3.9% growth in construction volume on an annual basis up to 2030.

There are, however, just a few significant negative aspects of sustainability. According to the (European Commission, 2013), two of these effects are high resource consumption and high waste output. Other negative effects include resource depletion, greenhouse gas emissions, and energy use. (Hawken *et al.*, 2002)

Environmental deterioration could result from the foregoing consequences occurring repeatedly. The repercussions of the building industry are known to pose an immediate threat to the environment, including global warming, pollution, and the depletion or collapse of natural resources (Giljum, 2009), For instance, according to (United Nations Environment Programme, 2009), buildings are responsible for about 40% of the world's energy consumption and are thought to contribute to around one third of the entire amount of greenhouse gas emissions. This is mostly due to the usage of fossil fuels throughout the construction process.

(MEHTA , 2002)recommended using less energy, less natural resources, and reducing carbon dioxide emissions to create concrete that is ecologically friendly. The European Union Commission's Eco Innovative program promotes the design of novel products using recycled materials, the use of novel environmentally friendly building materials, and novel manufacturing techniques, as well as the use of construction products and related techniques that reduce resource consumption, embodied carbon, and by-product waste production (European Commission, 2013). (McCaffrey, 2002) recommended utilizing less calcined material in cement, using less cement in concrete, and reducing the number of cement-consuming buildings. The use of alternate cement types in concrete has the potential to reduce the environmental effect of concrete production by up to 39%, according to research done on the LCA of concrete and asphalt (Blankendaal, 2014).

The implementation of environmentally friendly construction processes (which include reduced resource consumption, embodied carbon emissions, and waste production from by-products) and environmentally friendly construction materials (which include less/non-cement inclusion and recycled waste use) will significantly contribute to the much-anticipated sustainability in the construction industry.

Due to population growth, an increase in living standards, and urbanization, a significant amount of solid waste (including plastic, metal, textile, wood, glass, paper, and concrete) is being produced globally from various human activities in both developed and developing countries (Oriyomi *et al.*, 2015).

In the majority of industrialized and developing nations, paper and paper products make up a sizeable portion of the municipal solid waste stream. Wastepaper is the second-largest component of solid waste globally, and according to projections of future paper consumption, both developed and developing nations will continue to produce large amounts of wastepaper (Fallah, Joseph, Isaac, Ademola, & James). This might be explained by the rising demand for paper and paperboard that often coincides with increases in a nation's GDP (Elizabeth , 2007).

In the United States and Europe, municipal solid trash has remained to consist mostly of waste paper for a number of years. According to the (EPA's Office of Resource Conservation and Recovery (ORCR), 2023), between 1960 and 2013, the percentage of paper and paperboard creation in the USA fluctuated between 30% and over 20% of the total amount of solid waste created. Waste paper and paperboard were the second-largest component of municipal solid waste (MSW) in the UK in 2001, accounting for 21% of all MSW, the largest component of commercial waste, at 41.2%, and the largest component of liter and street sweeping wastes, at 31% of all MSW (Burnley et al., 2007). Paper and cardboard trash creation has been on the rise in Europe from 2005 through 2013. Paper and cardboard trash make up the majority of the packaging waste produced in Europe over the same time period, according to Eurostat data for the 28 member states of the European Union (Eurostat Statistics Explained, 2016). As of 2012, there were 400 million tons of paper produced annually on a worldwide scale (Pulp and paper capacities annual survey, 2021-2026), and per-capita paper consumption is increasing every year, with industrialized economies consuming more paper than emerging economies (Mukete et al., 2016). According to estimates from 2004, the per-capita paper usage in the USA was over 317 kg/person/year, compared to less than 50 kg/person/year in China and Asia. The yearly per capita use of paper was also estimated by a recent (Global Waste Management Outlook, 2015)article to be 240 kg/capital/year for North America, 140 kg/capital/year for Europe, 40 kg/capital/year for Asia, and 4 kg/capital/year for Africa (United Nations Environment Programme, 2009)). As a result, taking into account the apparent rising rate of per capital wastepaper consumption various forecasts indicating a potential increase in global paper production from the current 450 million tons per year to 500 million tons by 2020 (Source: Estimated by the Author, using paper consumption and population information from; (The statistics portal, 2014) and (Hoornweg and Bhada-Tata, 2012) respectively.), and the predicted 60% increase in global demand for paper and paperboard from the 368 million tons recorded in 2005 to 579 million tons by the year 2021 (Paper consumption worldwide from 2021 to 2032 in million metric tons, n.d.).

For instance, despite a 2012 recycling rate of 71.7% in Europe (Confederation of European Paper Industries (CEPI), 2014) and a disposal rate of 48 million tonnes in the United States ((Nepal & Aggarwal, 2014; Zavala, 2013; Yun *et al.*, 2007; Fuller *et al.*, 2006; Decard *et al.*, 2001)), an estimated 10 million tonnes of paper and board that could have been recycled still end up in landfills and incineration. Additionally, contrary to popular belief, the use of paper has increased globally at a rate that is higher than the rate of population growth, as evidenced by literature. This is in contrast to the common belief that the introduction of electronics will cause a decline in paper consumption. this is supported by estimates of a 5.5% rise in worldwide per-capital paper consumption and a matching 0.0037% growth in global population (Hoornweg et al., 2012).

An upward trend between 1995 and 2015 was also predicted by earlier forecasts of paper production, consumption, and usage in Europe. A prediction of worldwide paper consumption over the next 15 years, broken out by grade (Mukete et al., 2016), also points to a continual rise in the use of various types of paper in the future, which is a sign that waste paper will continue to be available for recycling.

According to data in the literature, wastepaper has the potential to be used to create a variety of construction materials. Wastepaper-based According to reports, a variety of building materials, such as concrete, infill materials, plastering mortar, and green cement, have behaviors and qualities that make them suitable for use in construction ((Nepal & Aggarwal, 2014; Zavala, 2013; Yun *et al.*, 2007; Fuller *et al.*, 2006; Decard *et al.*, 2001)). Therefore, given that the less desirable features are improved upon, using wastepaper to create civil engineering building materials and other engineering goods might be seen as a sustainable solution to the ever-increasing global wastepaper supply.

Most people use glass every day; it is essentially a translucent frozen liquid made of silica, soda ash, and calcium carbonate ($CaCO_3$) that liquefies at very high temperatures. The liquid is allowed to cool quickly to prevent crystallization (Bauchy & Micoulaut, 2015; Butler & Hooper, 2019). It is made up. From plentiful basic materials and may be utilized right away as a feedstock for making glass. a glass. Endlessly recyclable without sacrificing quality or worth (British Glass Recycling., 2017). The stream of solid garbage includes glass. And it makes up, according to estimates (Olutaiwo, Akinwale , & Ezegbunem, 2018) (Omole, Isiorho, & Ndambuki, 2016), 8.7% of the waste stream in Nigeria. within the range between 80% and 85% of the bulk production from the whole glass industry.

According to Rabbani & Sarker (2017) The major sources that cause pollution to Turag River water are various consumer goods industries (soap and detergent), garments industries, pharmaceuticals industries, lots of tanneries, dyeing industries, aluminum industries, battery manufacturing, match industries, ink manufacturing industries, textile, paint, iron industries, pulp and paper factories, chemical factories, frozen food factories and steel workshop etc.

Ashutosh and Satish (2015) conducted multiple studies to examine the impact on compressive strength and durability of substituting cement with 5%, 10%, and 15% glass powder. Glass powder with a particle size range of 600 to 100 microns was used to assess the impact of particle size. The findings demonstrated that the pozzolanic behavior was attained with a 10% replacement of the glass powder, which resulted in the greatest gain in concrete strength. It combines with the lime at the start of the hydration to create an extra CSHgel, which creates a denser cement matrix. (Ashutosh & Ashutosh, 2015)

Tamanna *et al.* (2013) emphasized the current state of affairs and advances in the recycling of glass waste and offered a solution for using glass waste properly in place of cement. The used glass can be successfully utilized in concrete as a filler (fine or coarse aggregate) or as a cement replacement. When the particle size is smaller than 75 microns, the glass is potentially pozzolanic or even cemented due to its amorphous nature and relatively high silicon and calcium content. (Tamanna et al., 2013)

Vijayakumar *et al.* (2013) used of finely ground restorative glass as a partial replacement for cement in concrete was investigated, and it was compared to regular concrete. 10%, 20%, 30%, and 40% of glass powder were substituted, and the concrete's compression, tensile strength, and bending strength for up to 60 days were measured and compared. The findings indicate that glass powder can be used as a substitute for cement with particles smaller than 75 microns in order to stop the reaction of alkali silica. (Vijayakumar et al., 2013)

According to Malik *et al.* (2013) the effects of replacing FA to some extent with glass waste at 10%, 20%, 30%, and 40% by weight were explored. In order to assess the concrete samples' low weight for various glass waste percentages, durability (water absorption), and compression, tensile, and compressive strength were all examined. It was discovered that a concrete mixture containing 20% glass waste in the form of fine particles had the highest compressive strength when the findings were compared to those obtained for a typical M-25 concrete mix. (Malik et al., 2013)

Gautam *et al.* (2012) shown that the resistance to compression during the course of 7 days rises on average by 47.75% when the fine aggregates are replaced with 10% of glass residues. However, it is clear that at the same amount of replacement, the improvement in compressive strength for 28 days is only 3.30%. However, the increase in compressive strength is 2.18% after 28 days. A about 11.32 percent increase in compressive strength is shown over the course of seven days, however a modest decline in compressive strength at replacement levels of 30 and 40 is seen after 28 days. (Gautam et al., 2012)

MATERIALS AND METHODS

A methodical trial-and-error technique is used to create the concrete block (CB) technology. The main goal is to develop a block-specific mix proportioning technique that is efficient and aligned with the research goals (identifying of key variables, ideal mix composition, and engineering features). Following current production and testing procedures for masonry blocks makes it easier to get acceptance in the building sector after creation. As a key factor in structural design (Neville, 2011), compressive strength is chosen as the mixture composition benchmark parameter.

Materials

Wastepaper, sand, and water were employed as study materials.

Waste Paper

This experimental study not only attempts to generate a useful building material but also adds to the larger discourse on sustainable construction by including post-consumer wastepaper as a crucial aggregate filler. The use of such cutting-edge materials in building might open the way for resource-saving substitutes, resolving issues with waste management and ecological preservation.

Processing of Waste Paper into Usable Form

The transformation of waste paper into a functional

Figure 1: Post-Consumer Wastepaper

binding agent for the production of concrete blocks is currently taking place. This intricately designed multi-step process is actively being executed, with the objective of empowering the waste paper to play a substantial role in enhancing both the structural integrity and attributes of the resulting concrete blocks. The process involves a typical sequence of steps that includes:

Collection and Preparation of Waste Paper

The gathering and preparation of waste paper play a crucial part in the process' first stage. This entails collecting post-consumer waste paper from various sources, including newspapers and discarded paper goods.

Waste paper is being used as a binder within concrete blocks, demonstrating a sustainable building method that turns waste resources into useful assets. This ground-breaking method efficiently fosters the continued development of environmentally friendly building techniques by reducing waste while also introducing a potential replacement for traditional binder ingredients. The building approach corresponds with sustainability goals and lessens the environmental effect of trash disposal by using waste paper as a binder. This strategy encourages resource-efficient use and represents a significant change toward a building industry that is environmentally conscious. Repurposed materials provide a substantial contribution to the composition of crucial structural components. This strategy thus reflects a forward-looking viewpoint, establishing a path toward sustainable and ethical building methods.

Waste Glass

By utilizing waste glass as a crucial binder element, the present experimental investigation actively adds to the larger conversation on sustainable construction, going beyond the simple development of a useful building material. The possibility for the introduction of resource-efficient alternatives is created by combining such cutting-edge materials into construction techniques. This innovative strategy might help with waste management issues and promote ecological preservation, adding another dimension to the developing field of sustainable construction techniques.

Figure 2: Schematic of Procedure for making WPB (waste paper binder)

Processing of Waste glass into Usable form

Waste glass is meticulously and purposefully transformed into a useful binder for the production of concrete blocks in an effort to maximize the use of these materials as binding agents. Waste glass is given the opportunity to play a crucial part in strengthening the properties and structural integrity of the final concrete blocks thanks to this transforming process. The process's sequential steps are as follows:

Figure 3: Post-Consumer Waste glass

Collection and Sorting

Glass garbage is gathered and sorted from a variety of sources, including post-consumer glass goods, glass containers, and industrial waste. The collected glass is carefully sorted to get rid of impurities and non-glass materials.

Cleaning and Preparation
To get rid of impurities, grime, and any residual residues, the collected waste glass goes through a thorough cleaning procedure. The removal of any impurities at this stage guarantees that the glass's quality and performance are not jeopardized.

Size Reduction
The cleaned waste glass is crushed or ground into smaller pieces using specialized machinery. The glass is reduced in size to manageable granules or shards, which makes it ideal for use as a binder.

Homogenization
To attain uniform particle sizes and consistent characteristics, the crushed glass particles go through a homogenization process. This step is essential to ensuring the waste glass binder behaves consistently and predictably while producing concrete blocks.

Mixture Proportioning
Based on the required properties of the resulting concrete blocks, precise proportions of waste glass binder, aggregates, and other components are painstakingly calculated. At this point, factors including strength, durability, and workability are carefully taken into account.

Concrete Block Formation
Skillfully poured or molded into elaborately crafted block molds is the slurry containing the waste glass binder. The waste glass binder, along with other ingredients, is crucial to bringing the mixture together during the molding process.

Curing and Quality Control
The freshly created concrete blocks go through a thorough curing regimen that allows the waste glass binder to solidify and create strong linkages between the different parts. The efficacy of the waste glass binder in the concrete blocks is confirmed by stringent quality control tests, which also include assessments of compressive strength and durability.

Waste glass is being converted into a useful binder for concrete blocks as part of a sustainable strategy to reduce the impact of glass waste on the environment. By introducing a revolutionary binder material endowed with special qualities, this ground-breaking technology not only increases waste reduction but also advances environmentally friendly construction methods.

Sand
This topic was concerned with the incorporation of fine aggregates (sand) as an additional aggregate filler during the creation of CWLB (Concrete with Lightweight Aggregates). These fine aggregates (sand) were actively used to establish a uniform and consistent distribution of electrical conductivity among both the smaller and larger particles within the resulting mixture of concrete.

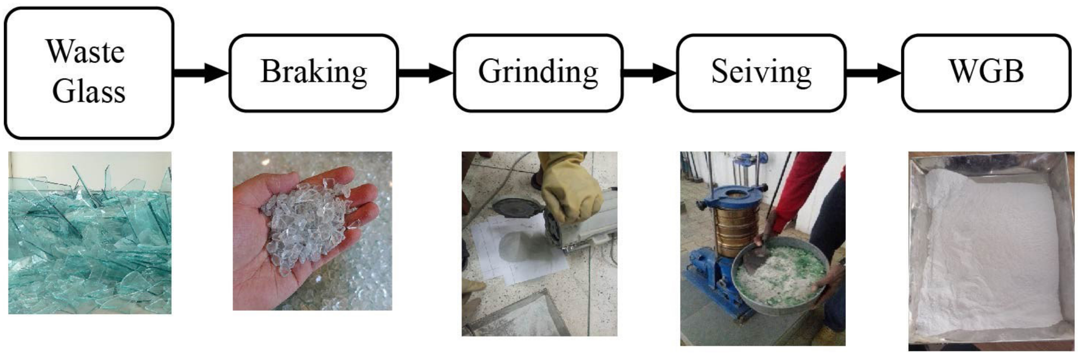

Figure 4: Schematic of Procedure for making WGB (waste glass binder)

Cement
During the experiment, the suitability of cement with various waste products was examined to ascertain how well it promoted structural integrity. The purpose of this test was to determine if cement made from domestic garbage could adhere to predetermined requirements for building purposes. The environmental effects of using cement, such as energy use and CO_2 emissions, were

Figure 5: Sand Utilized as Fine Aggregate

probably taken into account when waste materials were being used.

Brick Chips

Brick chips become an important resource for varying the aggregate composition in the field of concrete block manufacture. By reusing waste materials and adhering to ecologically friendly construction methods, these remnants, retrieved from abandoned or fractured bricks, provide a sustainable option. Brick chips can be used in place of standard aggregates like gravel or sand for making concrete blocks, offering a variety of benefits.

Figure 6: Cement Utilized as main binder

Laboratory Experimentation

The main laboratory experimentation may be divided into six basic phases, each of which is essential to the development of WPGCB with different percentages of cement replacement:

Figure 7: Brick chips Utilized as main filler

Phase of Measuring

At the start of the procedure, careful measurements of the component materials are made. A preset mixing ratio, such as the ratio of cement to sand to aggregate (1: 1.5: 3), is used to quantify the solid components, including aggregates, cement, and sand. For the appropriate mix uniformity and performance to be maintained, accurate measurement is essential.

Phase of Mixing

The phase of mixing follows the measuring phase. To guarantee an even dispersion of particles, the solid ingredients are carefully mixed. The correct amount of each component must be mixed in according to the ratio, in this example, 1: 1.5: 3. Effective mixing tools are used to speed up homogenization, resulting in a cohesive combination that serves as the foundation for WPGCB.

Phase of Applying the Mold

After the mixture has been homogenized, it is carefully applied to the molds. These precisely crafted molds are used to mold the mixture into the desired WPGCB shapes and sizes. In order to prevent air gaps and ensure structural integrity, the mixture is properly distributed

Figure 8: Mixing

and compressed inside the molds while maintaining the set mixing percentage.

Phase of Compacting and Leveling

After putting the mixture within the molds, the phase of compacting and leveling begins. To get rid of air pockets and produce a dense, compacted mixture, pressure or mechanical compaction is used. To achieve

Figure 9: Molding

consistent compaction and level surfaces while keeping the constancy of the 1: 1.5: 3 ratios, tools like tampers or vibrating machinery are used.

Phase of Curing

After compacting, the phase of curing is started. The molded specimens are put under strict monitoring during this crucial stage in order to promote hydration and bonding. The final WPGCB product must be properly cured in order to acquire the appropriate strength and durability while maintaining the right mixing percentage.

Phases of Testing and Analysis

Following the allotted curing time, the cured WPGCB specimens are carefully removed from the molds. These

Figure 10: Curing

samples go through a thorough testing and analysis process in order to assess mechanical parameters including compressive strength, density, and other pertinent features. The test findings reveal useful information about how well the combination is proportioned, supporting the significance of the 1: 1.5: 3 ratios in getting desired results.

RESULTS AND DISCUSSION

The results of the tests that were carried out over a

Figure 11: Testing

range of time periods after different percentages (10%, 20%, and 30%) of the total cement content had been substituted by wastepaper and waste glass. These tests used a combination of cement, sand, and brick chips in the proportions of 1:1.5:3.

The findings provide important information about the viability and sustainability of using wastepaper and waste glass in construction materials in the same proportion as cement, sand, and brick chips (1:1.5:3).

Results Obtained after 7 Days Curing Period for Wastepaper

Results Obtained after 14 Days Curing Period for wastepaper

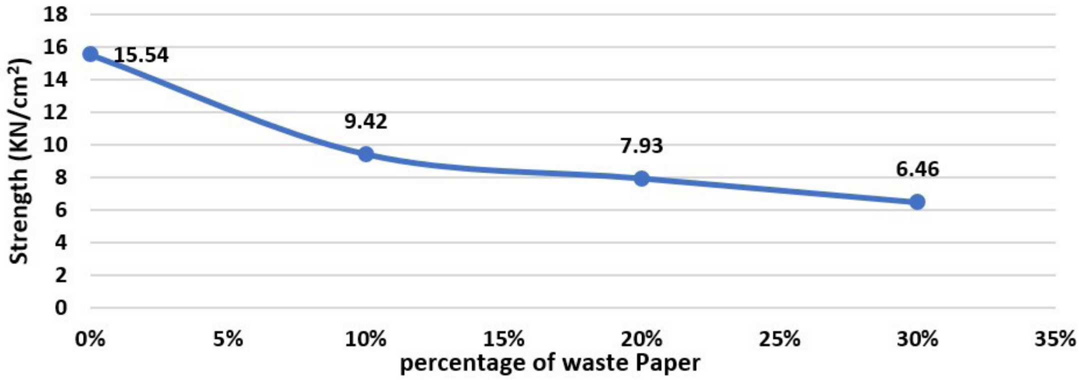

Figure 12: Wastepaper concrete block compressive strength after 7 days of curing

Results Obtained after 7 Days Curing Period for Glass Waste

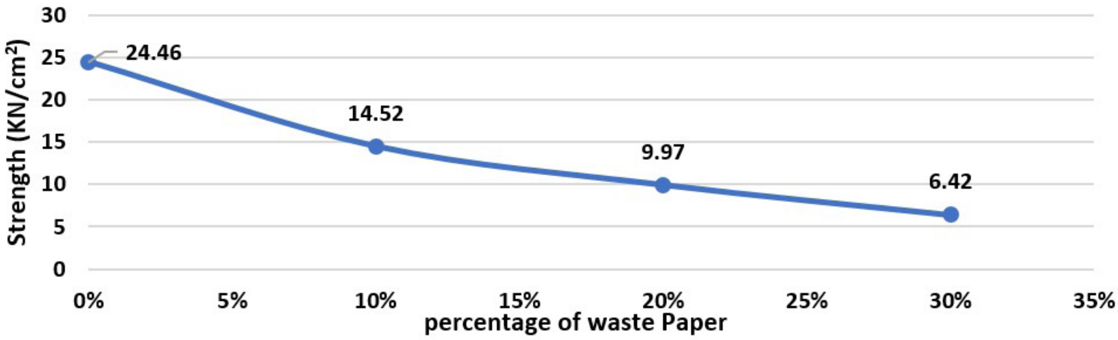

Figure 13: Wastepaper concrete block compressive strength after 14 days of curing

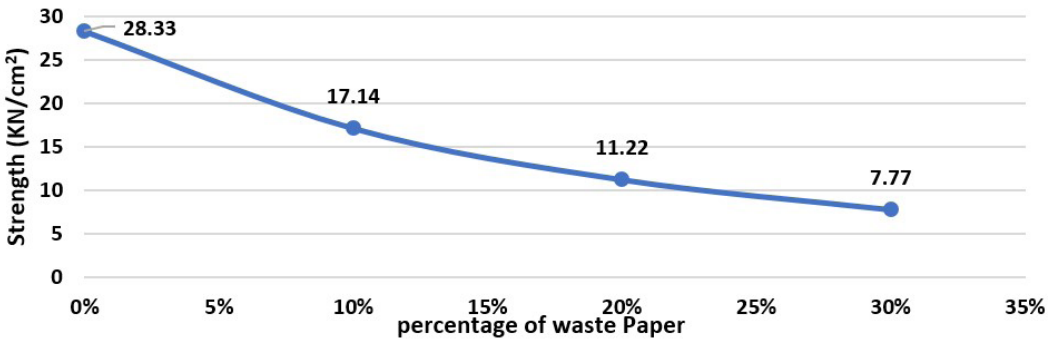

Figure 14: Wastepaper Paper concrete block compressive strength after 21 days of curing

Results Obtained after 14 Days Curing Period for Glass Waste

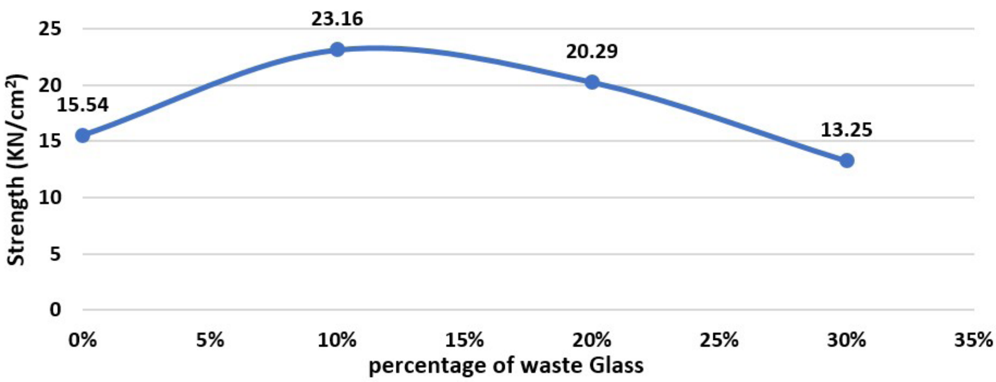

Figure 15: Wastepaper glass concrete block compressive strength after 7 days of curing

Results Obtained after 21 Days Curing Period for Glass Waste

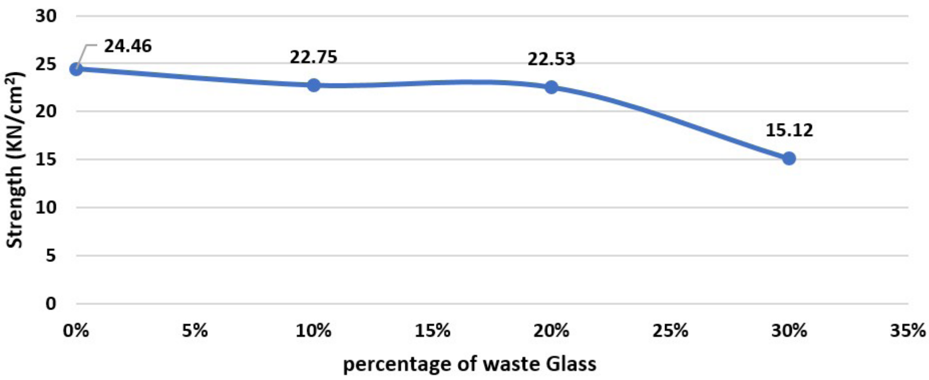

Figure 16: Wastepaper glass concrete block compressive strength after 14 days of curing

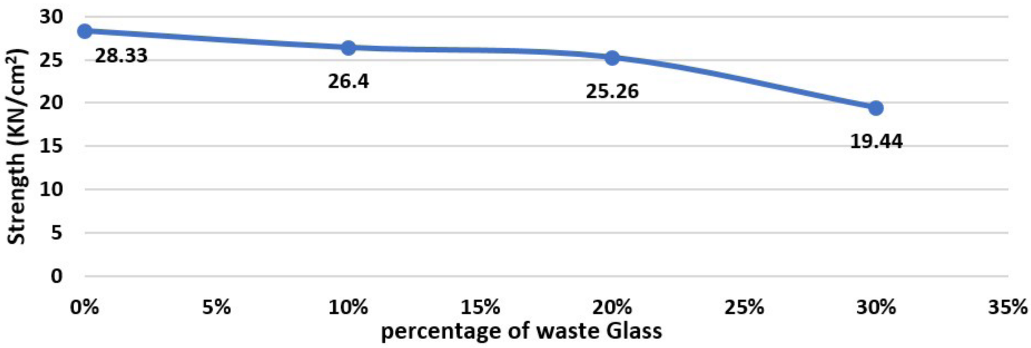

Figure 17: Wastepaper glass concrete block compressive strength after 21 days of curing

Data Analysis

A comprehensive series of compressive strength tests was conducted on concrete samples with diverse compositions. These tests encompassed varying levels of cement replacement, spanning from 10% to 30%, and the incorporation of waste paper/glass at different percentages: 1.81%, 3.62%, and 5.43%. The experiments were carried out over various curing durations to capture the development of concrete strength over time.

The primary objective of this study was to thoroughly investigate how the inclusion of waste paper, at different substitution rates, was affected by the compressive strength of the concrete specimens throughout the curing process. Compressive strength, as a fundamental property in construction, was assessed for its ability to withstand loads and pressures without failure.

To facilitate a clear and in-depth analysis of the results, a graphical representation was created. This graphic visually contrasted the compressive strengths of three distinct concrete conditions:

Concrete with 10% Cement Replacement by Waste Paper

In this condition, concrete had undergone a 10% cement replacement using waste paper. i.e 1.81 percent of the total share, to be exact

Concrete with 20% Cement Replacement by Waste Paper

In this scenario, 20% of the cement content had been replaced with waste paper. i.e 3.62 percent of the total share, to be exact

Concrete with 30% Cement Replacement by Waste Paper

The highest substitution rate, 30%, was employed in this concrete condition. i.e 5.43 percent of the total share, to be exact.

Comparative Analysis for Waste Paper Replacement

The replacement of various amounts of waste paper in a particular setting is the topic of this comparative research. By analyzing the effects of various degrees of trash replacement on factors including performance, sustainability, and efficiency, it seeks to give educated insights into the best usage of waste.

The main finding of the study is that the strength of the product reduces as the amount of paper substitution rises. The visual representation of this inverse link between paper replacement and strength emphasizes how stronger structures result from greater paper replacement levels. This result highlights the compromise between employing waste materials for sustainability and preserving the necessary degree of functionality or strength in the setting under study.

A comparative diagram of obtained strengths is presented below

Comparative Analysis for Waste Glass Replacement

This comparative study examines the replacement of various quantities of waste glass in a particular setting while taking varied curing durations of 7, 14, and 21 days

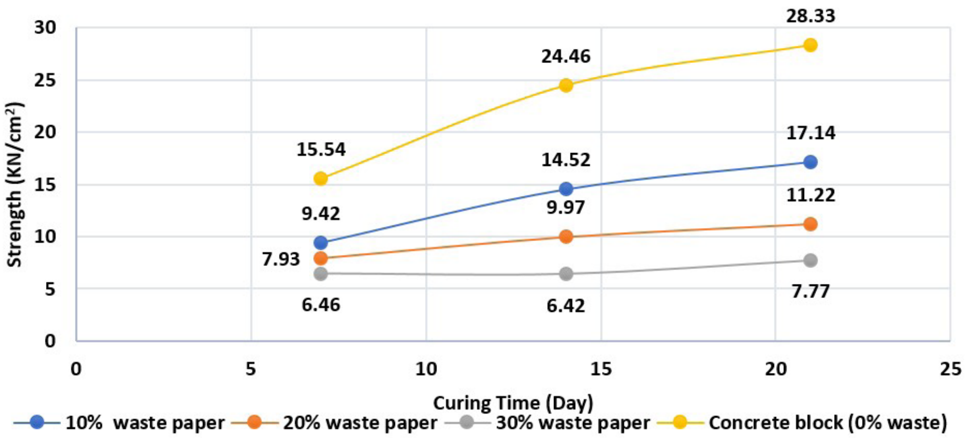

Figure 18: Comparative graphical representation for different percentage waste paper replacement

into consideration. By analyzing the impacts of various levels of glass replacement on crucial elements including performance, sustainability, and efficiency at various curing intervals, it seeks to offer educated insights into the best usage of waste glass.

Taking into account the curing period, the main conclusion of this study is that the product's strength decreases as the degree of glass replacement increases. Within the first seven days of cure, this diminution is particularly noticeable. Although the strength does improve slightly after 14 and 21 days compared to the baseline without glass replacement, it still falls short of the baseline. The curing period has a moderating influence on this connection, which is seen visually by the inverse relationship between strength and glass replacement. Stronger constructions may be constructed with lower amounts of glass replacement.

This result emphasizes the trade-off between using recycled glass for sustainability and maintaining the required level of usefulness or strength in the study area; while also taking into account the amount of time the material has to cure to attain the needed strength. However, the trade-off continues to be a crucial factor in construction and engineering applications. It shows that longer curing durations may somewhat reduce the initial strength drop associated with greater levels of glass replacement.

A comparative diagram of obtained strengths is presented below.

RESULTS DISCUSSION

Different percentages of waste paper and waste glass (10%, 20%, and 30%) were used as replacements in a concrete block mixture with a ratio of 1:1.5:3. The study

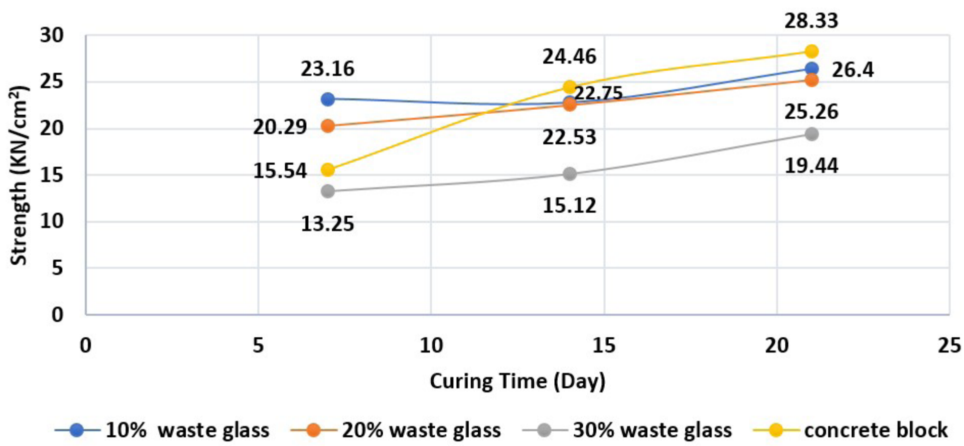

Figure 19: Comparative graphical representation for different percentage waste glass replacement

aimed to investigate how these replacements affected the block's strength at varying curing times (7, 14, and 21 days). For waste paper replacement, the results exhibited an irregular rate of strength reduction as the percentage of waste paper increased:

- At 7 days of curing: (Figure 12)
- 10% waste paper replacement led to a strength decrease from the normal concrete strength of 15.54 to 9.42 KN/cm^2.
- 20% waste paper replacement resulted in a strength

of 7.93 KN/cm².

• 30% waste paper replacement had a strength of 6.46 KN/cm².

• At 14 days of curing: (Figure 13)

• 10% waste paper replacement decreased the strength from 24.46 to 14.5 KN/cm².

• 20% waste paper replacement led to a strength of 9.97 KN/cm².

• 30% waste paper replacement resulted in a strength of 6.42 KN/cm².

• At 21 days of curing: (Figure 14)

• 10% waste paper replacement decreased the strength 28.33to 17.14 KN/cm².

• 20% waste paper replacement had a strength of 11.22 KN/cm².

• 30% waste paper replacement resulted in a strength of 7.7 KN/cm².

On the other hand, for glass waste replacement:

• At 7 days of curing: (Figure 15)

• 10% glass waste replacement increased the strength from the normal concrete strength of 15.54 to 23.16 KN/cm².

• 20% glass waste replacement had a strength of 20.29 KN/cm².

• 30% glass waste replacement resulted in a strength of 13.25 KN/cm².

• At 14 days of curing: (Figure 16)

• 10% glass waste replacement decreased the strength to 22.75 KN/cm².

• 20% glass waste replacement had a strength of 22.3 KN/cm².

• 30% glass waste replacement resulted in a strength of 15.12 KN/cm²

• At 21 days of curing: (Figure 17)

• 10% glass waste replacement increased the strength to 26.4 KN/cm².

• 20% glass waste replacement had a strength of 25.26 KN/cm².

• 30% glass waste replacement resulted in a strength of 19.44 KN/cm².

These findings highlight the varying impact of waste paper and waste glass replacements on concrete strength over different curing periods and replacement percentages, demonstrating the complex relationship between material composition and strength.

More can be seen from the combined graph (Figure 18) made for replacement of cement by waste glass are

• After 7 days of curing with 10%, 20%, and 30% waste glass replacement of the total cement content, the strength of the normal concrete increased from 15.54 to 23.16, 20.29, and 13.25 KN/cm2 respectively. This indicates that 10% and 20% replacement improved the strength compared to standard concrete, while 30% replacement led to a decrease in strength.

• Moving to 14 days of curing, the standard strength of the concrete block was 24.46 KN/cm². With 10% and 20% replacement, the strength slightly decreased to 22.75 and 22.53 KN/cm2, which is still very close to the standard value. However, for 30% replacement, the strength decreased further to 19.44 KN/cm².

• As we progress to 21 days of curing, the standard strength of the concrete block increased to 28.33 KN/cm². With 10% and 20% replacement, the strength slightly decreased to 26.4 and 25.26 KN/cm², remaining very close to the standard value. However, for 30% replacement, the strength decreased further to 19.44 KN/cm².

These findings suggest that at 7 days of curing, lower percentages of waste glass replacement can enhance the strength of the concrete block, while at 14 days of curing, the strength remains close to the standard value for 10% and 20% replacement but decreases significantly at 30% replacement.

CONCLUSION

In conclusion, our in-depth exploration of waste paper and glass waste replacements in concrete has unveiled

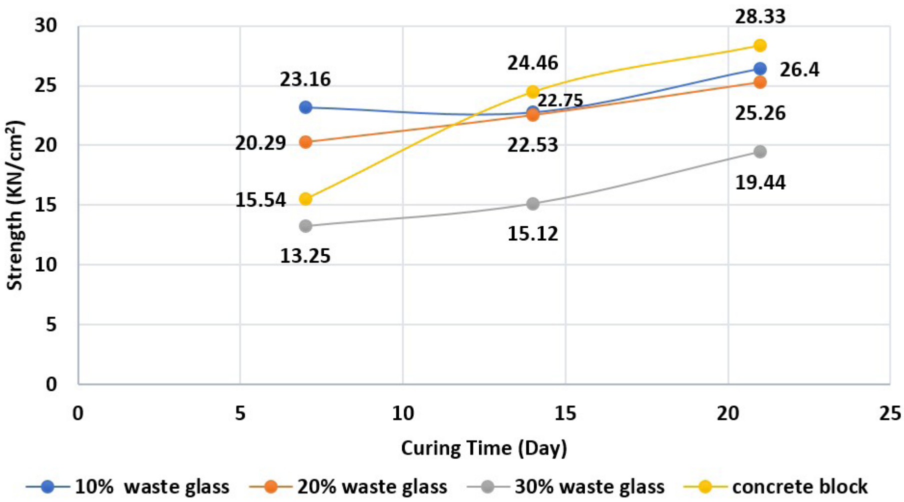

Figure 20: Combined graphical representation for different percentage of waste glass as a replacement of cement

critical insights into sustainable construction practices.

Regarding waste paper as a cement replacement, the experiment demonstrated that substituting 10%, 20%, or 30% of cement with waste paper is not a recommended practice. In all instances, the resulting concrete blocks exhibited a significant reduction in strength when compared to traditional concrete formulations. This outcome underscores the limitations of waste paper as a viable substitute for maintaining concrete strength.

Conversely, our findings regarding glass waste replacement in cement are particularly exciting. At just 7 days of curing, concrete blocks incorporating 10% and 20% glass waste replacements displayed higher strength than their conventional counterparts, showcasing an early strength advantage. By the 14-day mark, the strength of these glass waste-reinforced blocks closely approached that of standard concrete, highlighting their potential for use in sustainable construction practices.

Even more impressively, at 21 days of curing, when conventional concrete reached its peak strength at 28.33 kilonewtons per square meter, the blocks with 10%, 20%, and 30% glass waste replacement-maintained robustness, with strengths of 26.4, 25.26, and 19.44 kilonewtons per square meter, respectively. This prolonged strength retention suggests that glass waste-reinforced concrete can serve as a sustainable alternative without compromising structural integrity, even in the long term.

Perhaps the most significant revelation from our research is the innovative role of glass waste powder. In cases of 10-20% cement replacement, this material can effectively act as a supplementary binder alongside cement. This discovery has the potential to revolutionize sustainable construction practices, offering a path to greener, more resilient structures that meet both environmental and structural demands.

REFFERENCE

Asadi, S., & Satish, A. (2021). *Assessment of resources using analytical hierarchy process for optimum management in construction industry.* Lulu Publication.

Ashutosh, S., & Ashutosh, S. (2015). Glass powder: A partial replacement for cement. *International Journal of Core Engineering & Management, 1*(11).

Bauchy, M., & Micoulaut, M. (2015). Densified network glasses and liquids with thermodynamically reversible and structurally adaptive behavior. *Nature Communications, 6,* 6398.

Blankendaal, E. (2014). Reducing the environmental impact of concrete and asphalt: A scenario approach. *Journal of Cleaner Production, 66,* 27-36. https://doi.org/10.1016/j.jclepro.2013.10.012

British Glass Recycling. (2017). *Recycle it right.* https://www.britglass.org.uk/our-work/recycling/recycle-it-right

Burnley, S., Ellis, J., Flowerdew, R., Poll, A., & Prosser, H. (2007). Assessing the composition of municipal solid waste in Wales. *Resources, Conservation and Recycling, 49*(3), 264-283.

Butler, J., & Hooper, P. (2019). Glass waste. In *Waste* (pp. 307-322). Academic Press.

Confederation of European Paper Industries (CEPI). (2014). *CEPI.* https://www.cepi.org/

Elizabeth, A. K. (2007). Embodied reflection and the epistemology of reflective practice. *Journal of Philosophy of Education, 41*(3), 395-409.

EPA's Office of Resource Conservation and Recovery (ORCR). (2023). Retrieved from United States, Office of Resource Conservation and Recovery : https://www.epa.gov/aboutepa/epas-office-resource-conservation-and-recovery-orcr

European Commission. (2013). Retrieved from https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2013:0499:FIN:en:PDF

Eurostat Statistics Explained. (2016). Retrieved from https://ec.europa.eu/eurostat/statistics-explained/index.php?title=New_and_updated_articles_2016

Fallah, N., Joseph, F. C., Isaac, A. B., Ademola, K. A., & James, S. E. (n.d.). Generation, characterization, and management practices of household solid wastes in Cowfield, Paynesville City, Liberia. *Vol. 9*(4).

Gautam, S., Srivastava, V., & Agarwal, V. (2012, November). Use of glass wastes as fine aggregate in concrete. *Journal of Academic and Industrial Research, 1*(6).

Giljum, S. (2009). *WRAP 2007; Sustainable aggregate 2009; UNEP SBCI 2009.*

Global Construction Perspectives & Oxford Economics (GCPOE). (2015). *Global construction 2030: A global forecast for the construction industry over the next decade.* http://www.cvf.or.kr/uploads/bestpractice/GlobalConstruction2030_ExecutiveSummary_WEB(0).pdf

Global Waste Management Outlook. (2015). *United Nations Environment Programme.* https://www.unep.org/resources/report/global-waste-management-outlook

Hawken, P., Brown, L. R., & Bardi, U. (2002). *Confederation of International Contractors' Associations (CICA).*

Hoornweg, D., & Bhada-Tata, P. (2012). *What a waste: A global review of solid waste management.* Urban development series; knowledge papers no. 15. World Bank.

Hoornweg, D., Bhada-Tata, P., & Perinaz, B. (2012). *What a waste: A global review of solid waste management* (Urban development series; knowledge papers no. 15). World Bank. http://hdl.handle.net/10986/17388

Malik, M., Bashir, M., Ahmad, S., & Tabis. (2013, July). Study of concrete involving use of waste glass as partial replacement of fine aggregates. *IOSR Journal of Engineering (IOSRJEN), 3*(7), 08–13.

McCaffrey, R. (2002). *Literature review.* ShodhGangotri. https://shodhgangotri.inflibnet.ac.in/bitstream/20.500.14146/6999/3/03_literature%20review.pdf

Mehta, P. K. (2002). *Greening of the concrete industry for sustainable development.* EcoSmart Concrete. https://

ecosmartconcrete.com/docs/trmehta02.pdf

Mukete, B., Sun, Y., Zama, E., & Monono, S. K. (2016). Consumption and environmental impact in an emerging economy. *Journal of Energy, Environmental & Chemical Engineering, 1*(1), 13–18. https://doi.org/10.11648/j.jeece.20160101.12

Mukete, B., Sun, Y., Zama, E., & Monono, S. K. (2016). Paper consumption and environmental impact in an emerging economy. *Journal of Energy, Environmental & Chemical Engineering, 1*(1), 13–18. https://doi.org/10.11648/j.jeece.20160101.12

Neville, A. (2011).

Olutaiwo, A., Akinwale, M. B., & Ezegbunem, I. (2018). The use of waste glass cullet (WGC) and waste tyre crumb (WTC) as fine aggregate in concrete for rigid pavement. *Journal of Construction and Building Materials, 8*(4), 29–35.

Omole, D., Isiorho, S., & Ndambuki, J. (2016). Waste management practices in Nigeria: Impacts. *International Journal of Waste Management, 46,* 28–34.

Oriyomi, M. O., David, A. O., & Jamal, M. K. (2015). A review on recycled use of solid wastes in building materials. *International Journal of Civil and Environmental Engineering, 9*(12), 234–245.

Rabbani, M. L., & Sarker, S. (2017). Pollution sources assessment of Turag River, Bangladesh. *Environmental Monitoring and Assessment, 14,* 84–91.

Statista. (n.d.). *Pulp and paper capacities annual survey (2021-2026).* Retrieved September 9, 2024, from https://www.statista.com/statistics/871733/production-capacity-paper-and-paperboard-forecast-worldwide/#:~:text=Projected%20global%20production%20capacity%20of%20paper%20and%20paperboard%2-02021%2D2026&text=In%202021%2C%20the%20total%20paper,around%20257%2

Statista. (n.d.). *Paper consumption worldwide from 2021 to 2032 in million metric tons.* Retrieved September 9, 2024, from https://www.statista.com/statistics/1089078/demand-paper-globally-until-2030/#:~:text=The%20global%20consumption%20of%20paper,global%20paper%20and%20paperboard%20production

Tamanna, N., Mohamed Sutan, N., & D. T. C. L. (2013). Utilization of waste glass in concrete. In *Proceedings of the 6th International Engineering Conference: Energy and Environment (ENCON).*

United Nations. (2015). *World urbanization prospects: The 2014 revision* (ST/ESA/SER.A/366). Department of Economic and Social Affairs, Population Division. https://population.un.org/wup/Publications/Files/WUP2014-Report.pdf

United Nations Environment Programme. (2009). Retrieved from https://unfccc.int/resource/docs/2009/smsn/igo/044.pdf

Vijayakumar, D., Vishaliny, M., & Govind, D. (February 2013). Studies on Glass Powder as Partial Replacement ofCement in Concrete Production. *International Journal of EmergingTechnology and Advanced Engineering, 3*(2).

Wilson, D. C., Rodic, L., & Modak, P. (2015). Global Waste Management Outlook. Report. UNEP ISBN 978-92-807-3479-9.