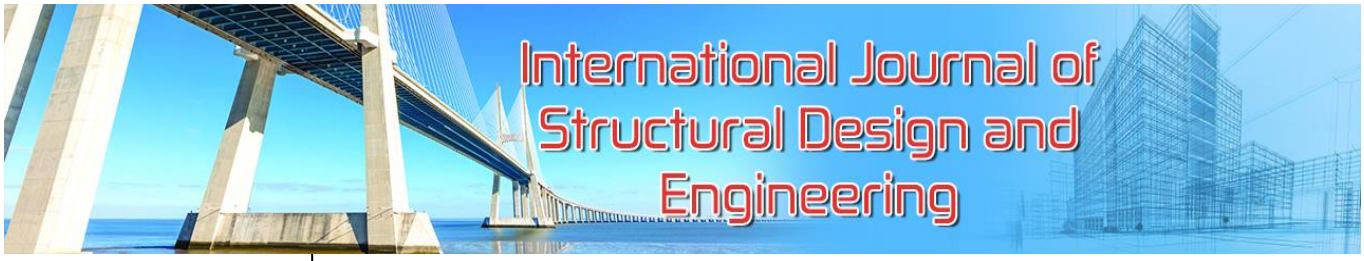

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Review study: Waste glass powder (WGP) with replacement of cement

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Abstract
Every year, millions of tons of waste glass are generated globally, most of which ends up in landfills once it is no longer usable. This is problematic because glass, primarily made of silica, does not break down naturally in the environment. However, recycling crushed waste glass as a partial replacement for cement in concrete can enhance the sustainability, environmental benefits, energy efficiency, and cost-effectiveness of construction projects.
When glass waste is ground into fine particles, it can react with cement to form secondary Calcium Silicate Hydrate, improving the material's properties. Research has also identified variations in the production processes of clear and colored glass. In experiments, ground glass was incorporated into mortar and concrete at levels of up to 25%, while the water content remained unchanged regardless of the glass substitution rate. The study assessed the workability and compressive strength of the resulting mixtures.

Keywords: Durability, waste glass powder (WGP), workability, partial replacement of cement, concrete, strength

Introduction
A growing number of individuals within the construction industry are showing interest in incorporating waste or recycled materials into concrete. Their intention is to develop with the environment's well-being in mind for an extended period. Currently, small shop owners dispose of glass waste by discarding it and burying it in landfills. Presently, glass waste from small establishments is being discarded and buried in landfills. At this moment, the glass waste generated by small shops is being disposed of and buried in landfills. The unique characteristic of glass is that it maintains its chemical integrity, making it a nonreactive material that can be reused countless times without experiencing any changes in its composition. Aside from its role in manufacturing new glass items, waste glass is also crushed into specific measurements for various uses. Some rephrases for this include the utilization of water filtering, the shielding of sports turf, and the exchange of sand in concrete.
Concrete consists of various materials, such as sand, rocks, cement, and water. Various proportions of these components are mixed together to attain a particular strength level. The use of concrete is widespread and highly favored, making it a commonly utilized material worldwide. There are a wide range of environmental concerns associated with the concrete industry. The manufacturing of cement entails the utilization of a large amount of energy, leading to the generation of considerable pollution. The amount of carbon dioxide it generates makes up about 5-8% of the total emissions. The occurrence can be attributed to the fact that whenever one ton of cement is produced, an equal amount of CO2 is discharged into the atmosphere. This originates from the burning of fuel and the utilization of raw materials during the cement manufacturing process. Employing waste materials as a replacement for cement in concrete is a commendable strategy for diminishing the quantity of cement utilized. This helps to reduce the negative effects on the environment caused by concrete production. Glass possesses the capacity to be employed as a renewable material on numerous occasions. It can be used again without losing any worth. When we recycle and reuse cement, we can save space in landfills and decrease the need to extract more cement for building things. Numerous waste materials like fly ash (FA) and silica fume (SF), known as pozzolanas, can be utilized directly without requiring any additional processing.

Using them in cement helps to reduce the amount of energy, raw materials, and CO2 released. Earlier studies on the WGP used in concrete creation found conflicting results in the test findings. These things that don't make sense included the qualities of hardened and fresh concrete.

There has been a growing preoccupation among people with the environmental destruction that we are responsible for in recent years. Due to this, those engaged in construction have demonstrated an increased fascination with incorporating waste or recycled substances into concrete. By simply changing our perspective, we might realize that many objects perceived as trash in our surroundings hold genuine worth. Recycling shops can reuse glass pieces that are discarded, as glass is an environmentally friendly substance that does not necessitate the use of chemicals during the recycling process. Glass is a highly versatile substance that can be recycled and utilized for various purposes, such as construction and other essential requirements in our everyday routines. Using recycled glass on new containers helps to save energy.

The amount of waste glass is gradually increasing as more people are using glass. The utilization of waste glass in cement production helps to minimize the overall expenses associated with manufacturing cement. Crushed glass, when carefully measured and processed, could look like gravel or sand. Cement companies need to compare a mixture of OPC and fly ash to determine its workability, cost, strength, etc. when setting goals for producing PPC. To ensure sustainable growth, it is important to use PPC or a combination of OPC and fly ash. Many studies have been done on concrete made with fly ash instead of cement. Fly ash is very good at protecting against different kinds of damage and is also not expensive.

Ensuring responsible practices towards the environment is crucial for the continued growth of the cement and concrete industry. Through the act of recycling just one ton of glass, we preserve an number of natural resources that exceeds the weight of the glass. When we recycle six tons of container glass, we effectively cut down one ton of CO2 emissions. Several initiatives have been implemented in the concrete industry to incorporate waste glass as a substitute for certain natural materials or cement.

Rahman discovered a clever and innovative event that makes sense. Incorporating Pozzolanic Glass Powder into concrete increases its malleability and improves shaping capabilities. Crushed glass waste was also discovered to prevent harmful reactions in concrete, which makes it last longer. Using crushed leftover glass in concrete instead of some of the cement is a good way to make more environmentally friendly buildings. When glass is ground into very small particles, it can help cement mix with water and react faster. This process can save energy, help the environment, and be cheaper when waste glass is used instead of some cement to make concrete.

Experiments of great significance were carried out by researchers to explore the use of recycled concrete aggregate and alternative materials such as fly ash, silica fume, and ground granulated blast furnace slag as replacements for cement in concrete. Because we were able to mix waste materials with concrete successfully, people want to discover more materials that have been used by consumers and can be used instead of cement. This research investigates using glass instead of cement to make eco-friendly concrete blocks.

Background of waste glass powder (WGP)

In previous times, it was significant to incorporate higher amounts of cementitious material in the composition of concrete, and this significance may persist in the upcoming years. Several scientists are trying to find alternative materials that are inexpensive and can be easily found nearby to replace the components of concrete. This can be attributed to the higher expenses associated with concrete materials and the negative environmental consequences resulting from cement manufacturing. So, people are paying more attention to the supplementary cementitious materials (materials that make cement stronger). The incorporation of pozzolanic materials into concrete has proven to enhance its strength and durability, making it a more effective construction material.

The manufacturing process of silica fume involves melting silicon metal and ferrosilicon alloy. It can be added to cement to help make it stronger. It is mostly made up of SiO2, which is more than 85 percent. When a small amount (less than 15 percent) of Silica fume is added to cement, it makes the concrete stronger and more long-lasting. This material is highly reactive because it contains a lot of a substance called amorphous SiO2 [12-13].

Glass is a substance made of silica with no definite shape. It can be used instead of cement in small particles less than 75µm in size. Glass is made by combining three main things. Sand, limestone, and silica are different types of materials. When you mix glass powder and cement together, it makes concrete stronger and more durable. The examination of the glass powder's structure reveals that it creates a strong layer that makes the concrete more resistant and long-lasting.

The Earth's warming, commonly referred to as global warming, is caused by greenhouse gases including CO2. These gases are responsible for about 65% of the warming effect on our planet. The cement industry in the world releases approximately 7% of greenhouse gases into the air. To lessen the negative effects on the environment, different materials are used to make concrete. Glass is a type of material that doesn't have a definite shape and contains a lot of silica. If the particles of glass are smaller than 75µm, it can potentially become a type of material called pozzolanic. The biggest issue with using crushed glass in cement is that it can cause the cement to expand and crack because of a reaction between the glass and the chemicals in the cement.

Ground glass is classified as a substance with comparable characteristics to other materials containing silica due to its silica content. In this investigation, we implemented powdered waste glasses as a replacement for certain cement content in the concrete, and subsequently, evaluated its performance relative to traditional concrete. By incorporating varying quantities of glass powder, we created various compositions of concrete mixtures. We extended the glass powder percentages from 5% to 40%, with increments of 5%. Subsequently, we assessed the robustness of these concoctions at intervals of 7, 28, and 90 days during the curing process.

Literature study of waste glass powder (WGP)

[G. M. Sadiqul Islam, M. H. Rahman, Nayem Kazi et. al. 2017] [1, 6]. The characteristics of clear and coloured glass were assessed in this examination. The examination of glass and cement samples involved the utilization of X-ray fluorescence (XRF) technique. The identification of subtle

variations in the chemical makeup of transparent and coloured glass was facilitated by this discovery. The addition of ground glass was used to examine the durability and fluidity of mortar and concrete in our experiment. We used different amounts, from 0% to 25%. We kept the same amount of water compared to the cement and glass mixture for all levels of glass replacement. When more glass was added to the mixture, the mortar flowed a little more easily. However, there was a small impact on how well the concrete could be worked with. To understand how the packing and pozzolanic effects work, additional tests were done using the same mixture and adding 1% of a special ingredient that makes the mixture easier to shape. These tests showed that adding the special ingredient made the mortars stronger. Just like with mortar, we made samples of concrete cubes and tested how strong they were after being cured for one year. Comparatively, the test results demonstrated that recycled glass mortar and concrete exhibited greater strength in contrast to the control samples. Using 20% waste glass instead of cement was a good idea because it was cheaper and better for the environment.

[Dr. G. Vijayakumar, Ms H. Vishaliny, Dr. D. Govindarajulu et. al. 2013] [2]. This study looks at whether we can use Glass powder instead of some cement in new concrete. Various proportions (10%, 20%, 30%, and 40%) of a substitute material, glass powder, were employed in place of the conventional concrete in an experiment that assessed its durability over a span of 60 days. The results were compared to regular concrete. By ensuring that the particle size of glass powder is less than 75µm, the research demonstrated that it can effectively substitute cement while preventing the occurrence of alkali silica reaction.

[K.I.M. Ibrahim et. al. 2021] [3]. When the WGP ratio reached 20%, there was a decrease of roughly 13% to 14%. Moreover, when plain, SF and FA concrete mixes include 5% to 20% WGP as a substitute for some of the cement, the ability to absorb water and the density of the concrete decrease compared to regular concrete without WGP. The fresh and dry density of regular concrete also decreases by approximately 3% when using a 20% WGP ratio. The amount of water absorbed by the concrete specimens made with 20% WGP is less compared to regular concrete. Group 1 had a decrease of 27. 78%, Group 2 had a decrease of 14. 75%, and Group 3 had a decrease of 18. 75%Increasing the amount of WGP improved the performance of all types of concrete used in this study.

[Sachin Sironiya, Sagar Jamle, M.P. Verma et. al. 2017] [5]. The objective of this study is to determine whether fly ash and glass powder can be substituted for cement. When initiating the process, we begin by substituting varying amounts of fly ash and glass powder to account for 25% of the cement. Our testing revealed that a blend consisting of 75% cement and 25% fly ash functioned satisfactorily in terms of the specific properties assessed.

[S. Rahman, M.N. Uddin et. al. 2018] [6]. In this paper, they tried using glass powder instead of cement in a small amount, about 10%. The material's strength, both in compression and splitting, exhibited a decrease in all the samples they examined within a week. The utilization of 20% glass powder instead of cement in concrete yielded the highest level of compressive strength when compared to regular concrete. The highest split tensile strength of the concrete was observed at the 28-day mark when 30% of the cement was substituted with glass powder, surpassing that of regular concrete.

[Xiang Ming Zhou, Joel R. Slater, Stuart E. Wavell and Olayinka Oladiran et. al. 2012] [8]. GGBS concrete demonstrated increased resistance to splitting when up to 30% of the material was replaced, surpassing the performance of PC concrete. Nonetheless, with an increase in the quantity of replacement, the concrete exhibited a diminished strength in comparison to PC concrete within the initial 21-day period. Then, it was able to achieve a greater amount of splitting tensile strength compared to PC concrete when replacing up to 70% of its mass at 28 days. Utilizing both PFA and GGBS can mitigate drying shrinkage, and the effectiveness is heightened when a larger proportion of GGBS is incorporated instead of PFA. Adding fibers to PFA concrete made it stronger and less likely to shrink when it dries.

[Ashutosh Sharma Ashutosh Sangamnerkar et. al. 2015] [9]. This study found that when waste glass is ground into very tiny particles (smaller than 600µm), it behaves like a pozzolan. It mixes with lime during the beginning of the hardening process, creating more gel that makes the cement stronger. So, when glass bits start to use up alkalis early on, it helps make the alkali-silica reaction go down. This makes the concrete last longer. Several tests were done to see how using different amounts of glass powder instead of cement affects how strong and long-lasting something is. They looked at replacing 5%, 10%, and 15% of the cement with glass powder. We tested how the size of glass powder particles affects concrete. We used glass powder with sizes ranging from 600µm to 100µm. When 10% of the conventional concrete material was replaced with glass powder, it was found to enhance the concrete's strength according to the results.

[Engr. Abdul Ghayoor khan, Dr. Bazid khan et. al. 2017] [10]. The strength of concrete was investigated by introducing glass powder and silica fume into the mixture, replacing certain portions of the cement. We chose a mix ratio of (1:2:4) 1 part cement, 2 parts sand, and 4 parts aggregate for all the concrete samples. The water to cement ratio was 0. 55 To compare, we made a normal sample of concrete without using glass powder and silica fume. The purpose of this was to observe the variations between the samples containing different proportions of glass powder and silica fume, which were used as substitutes for a portion of the cement in the concrete.

[Shilpa Raju, Dr. P. R. Kumar et. al. 2014] [12]. This paper tries to determine how strong concrete is when waste glass powder is used instead of some cement. We have studied using glass powder instead of cement in amounts ranging from 5% to 40%, increasing by 5%. It was checked how strong it is when squished and bent after 7, 28, and 90 days and compared to normal concrete. The study found that using glass powder instead of 20% of the cement made the material stronger. Additionally, a test was conducted to determine how well something can resist rust.

[Bhupendra Singh Shekhawat, Dr. Vanita Aggarwal et. al. 2014] [13]. In this paper, we want to substitute a portion of cement with a special material called pozzolanic material. This can aid in lowering the amount of cement utilized, consequently mitigating environmental pollution on some level. Certain industrial waste, like fly ash, silica fume, and blast furnace slag, is currently utilized in the production of concrete. New research has found that we can use waste

glass in concrete by either adding it as glass pieces or using it as a powdered form called glass pozzolana. When glass is crushed into a fine powder, it has certain properties that are similar to pozzolanic materials because it contains silica. So, the crushed glass can partly take the place of cement and help make things stronger. It can also make things last longer.

[Ahmed Omran, Arezki Tagnit-Hamou et. al. 2016] [14]. This study shows how well concrete with glass powder instead of some cement works in different places in Quebec, Canada from 2006 to 2012. They tested it in both indoor and outdoor floors and walls. In simple words, using 20% GP to make concrete not only helps the environment, but it also makes the concrete stronger. When GP was used in the concrete, it exhibited a 7% rise in strength after 91 days, a 35% rise in strength after 28 days, and a 4% improvement in flexibility after 28 days, in comparison to GP-free concrete. This means that the material was much more resistant to the penetration of chloride ions compared to its previous state. You can get 2800 Coulombs of electricity by using GP concrete.

[N. Kumarappan et. al. 2013] [15]. This study examines how well concrete performs when some of the cement is replaced with glass powder. Glass powder was used to partly replace Portland cement. The percentage of glass powder used ranged from 0% to 40%. We tested the speed of sound waves, the strength of compression, and the ability to absorb water. The samples were placed in water and treated at a temperature of 20 degrees Celsius. The findings show that the strongest concrete is made with about 10% glass powder. When there is more than 10% glass powder in concrete, the strength of the concrete decreases and becomes weaker than the normal concrete.

[B. Balasubramanian, G.V.T. Gopala Krishna, V. Saraswathy, K. Srinivasan et. al. 2021] [16]. The concrete made with up to 20% waste glass powder and up to 15% waste eggshell powder had improved viscosity and density. WGP filled the tiny holes that were created when WEP was replaced. This made the material less porous. When studying hardened concrete, it was found that using both WGP and WEP together increased the strength by up to 25%. However, beyond that point, the strength decreased.

[Veena V. Bhat, N. Bhavanishankar Rao et. al. 2014] [19]. The results showed that as more glass powder was used instead of cement, the strength of the material increased. To use less cement, we can use glass powder instead. By using glass powder instead of glass, the weight of the material becomes lighter. This also reduces the amount of air or holes in the material, as shown by the lower amount of water it absorbs. It uses less cement in concrete. Glass powder is cheap and good for the environment as a building material.

[Lei Ma, Zhigang Yao, Ieongpo Tai and Zhaobin Li et. al. 2023] [20]. The level of trustworthiness in security systems within green buildings is investigated in this paper. The goal is to give some insight and ideas for the construction industry to develop sustainably. Four main issues are highlighted in this research: embedded security systems, green buildings, the utilization of embedded security systems in green buildings, and the durability of these systems in green buildings. This paper helps explain and support the idea of building things safely and in a way that will last a long time. It does this by looking at real-life examples and talking about them. This paper uses different research methods like reading and studying, analysing real-life situations, and conducting experiments to get accurate and trustworthy results. This helps in achieving the research goals.

[Harish B A, Hanumesh B M, Siddesh T M, Siddhalingesh B K et. al. 2016] [21]. The main focus of this document is to provide a concise summary of the robustness and longevity of cement systems incorporating a fine glass powder. It is demonstrated in this study that it is possible to create concrete blends which possess equivalent or even heightened compressive strength. If we have a better idea of how well glass powder works as a substitute for regular cement, we might use it more often. By doing this, it would facilitate the creation of a more sustainable environment.

Materials Utilized

Waste Glass Powder (WGP)

Through the conversion process, waste glass obtained from Pondicherry stores is turned into a fine and smooth powder known as WGP. The durability of Waste Glass Powder (WGP) is remarkable. Prior to mixing in powdered glass, the concrete must undergo crushing to achieve the suitable size. The glass powder was broken into smaller fragments by the researchers utilizing a machine known as a ball pulveriser. They did this for about 30 to 60 minutes during the studies. By changing the words used, the small pieces became even smaller, less than 150 µm. The broken glass was put through a strainer that had really tiny holes, about 75 micrometres wide. This process helped separate and make the glass better. By subjecting a blend of silica, soda ash, and CaCO3 to heat until it liquifies, it undergoes a transformation into a clear substance called glass. When it gets cold, it becomes stiff without turning into crystals. Making cement using old glass as a material would result in lower production costs for cement. Another way to put it is that the use of old glass in cement production would lead to more affordable cement products. Using old glass to produce cement would result in a more cost-effective manufacturing process for cement. (Shown in Fig.1 Waste Glass Powder)

Fig 1: Waste Glass Powder)

Cement

The addition of water to cement causes it to acquire a sticky texture similar to glue. When it is no longer wet, it becomes firm and sturdy. Cement is a sticky substance. In promoting

swift cohesion between items, cement demonstrates both strength and adhesiveness. Water, large stones, and small stones were combined to make cement. Different types of cement are employed in construction, either to meet specific job demands or when encountering distinctive design considerations. Even though there are many different types of man-made cements, Portland cement is the most commonly used and is seen as the benchmark for comparing other new cements. The process of making Portland cement is easy and only requires regular materials. To produce walls, a mixture of cement and finely ground substances is used, commonly referred to as mortar. Construction often involves the utilization of a mixture comprising cement, sand, and gravel. We call this mix concrete. The reliance of individuals is predominantly placed on concrete and water, without any other substances they depend on as greatly. Calcium oxide is usually created by processing limestone, which is a form of calcium carbonate. Apart from that, it can additionally be detected in substances including chalk, shells, and mud. This sentence implies that people favour the utilization of soil or silt as they come in small pieces by default (Shown in Fig 2).

Fig 2: Cement

Aggregates

In order to function correctly, concrete necessitates more than just water and Portland cement. Sand, gravel, and crushed stones are examples of materials known as aggregates. Concrete requires them as they do not undergo reactions with other substances present in the concrete mixture. Using rocks and sand that are devoid of any dirt or debris is essential in the production of a durable concrete mixture. These objects should not have dirt or harmful substances on them because that could make the concrete weaker or deteriorate. Concrete is a type of building material that is made by combining two different types of materials: fine and coarse. Lots of small particles in rocks can go through a filter that is 3/8 of an inch big. These small particles are usually made up of sand or rocks that are found naturally. A large object that is 19 inches long is called coarse aggregate. They are usually the size of a pencil or a small rubber ball. Rocks that can be easily broken in half are not very strong and don't last for a long time. We need to take out any unwanted stuff, like trash, mud, earth, or natural things, from the sand and gravel. Most of the big rocks used in concrete are called gravel. Combining small pieces of material makes concrete stronger and more durable. Their job is to make it stronger and protect it from getting worse and from getting old. Their powerful shape can cause various changes in the solid material (Shown in fig 3).

Fig 3: Aggregates

Water

To maintain continuity, the researchers collected water from an unblocked stream that was flowing consistently. The water exhibited exceptional cleanliness and remarkable clarity. It was evident that there were no dirt or pollutants present to the naked eye. It is crucial to guarantee that the acidity level remains at a minimum of 6.

Conclusions

The study highlights the potential of Waste Glass Powder (WGP) as a sustainable and eco-friendly partial replacement for cement in concrete. By utilizing finely ground waste glass (particle size <75µm), researchers observed improvements in concrete strength, durability, and workability while reducing environmental pollution and landfill waste. Key findings include:

1. Enhanced Strength & Durability

- Replacing 10-20% of cement with WGP improved compressive strength, with 20% replacement showing optimal performance.
- The pozzolanic reaction between glass powder and cement contributed to the formation of secondary Calcium Silicate Hydrate (C-S-H), enhancing long-term durability.

2. Environmental & Economic Benefits

- Using WGP reduces CO_2 emissions from cement production and minimizes landfill waste.
- It offers a cost-effective alternative, lowering construction expenses while promoting sustainability.

3. Workability & Performance

- Concrete mixtures with WGP exhibited improved flowability without significant changes in water demand.
- Alkali-Silica Reaction (ASR) concerns were mitigated by ensuring glass particles were finely ground (<75µm).

4. Comparative Studies

- Research confirmed that WGP performs comparably to other supplementary cementitious materials (SCMs) like fly ash and silica fume.
- Beyond 20-25% replacement, strength gains diminished, suggesting an optimal threshold for WGP usage.

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