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Waste Glass Powder "An Alternative of Cement in Concrete": A Review

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ABSTRACT: Cement plays a vital role in concrete production; as a binding agent, it holds together the aggregates in concrete. Manufacturing of cement and glass causes depletion of natural resources and endangerment of the environment. Both the glass and cement industries are energy consumers and are responsible for hazardous greenhouse gases, particularly CO_2 and nitrogen oxides. The contribution of the cement industry toward CO_2 emissions is 5% globally, and it is estimated that one ton of cement production produces 0.9 to 1 ton of CO_2. The rising population rate, which is a concern today, necessitates proper construction and infrastructure. This leads to more production of cement and glass and as a result, millions of tons of glass waste are produced every year globally and deposited directly into landfills without being recycled. The global Waste Glass (WG) production was estimated to be over 130 million tons in 2005. Because of its non-biodegradable nature, it is a huge burden on landfills, especially in metropolitan areas. At the same time, it exhibits pozzolanic behavior in finely ground form. To overcome these problems and to use them as a source, the concrete industry provides a better solution. Adaptation were taken to use it as an out of the ordinary to cement in concrete and examine its effects on concrete in both fresh and hardened states. According to the study, the mechanical characteristics of Waste Glass Powder (WGP) concrete are influenced by particle size and percentage replacement. This review is aimed at studying glass powder concrete.

KEYWORDS: Concrete; Cement replacement; Mechanical properties; Waste management; Waste Glass Powder (WGP).

INTRODUCTION

Concrete is a frequently used construction material. Looking into its composition, it contains cement, sand, gravel, and water, and sometimes admixtures are added to achieve desired effects. Cement, being a binding material and a crucial element of concrete, makes up 7–15% portion of it [1]. Aggregate makes up 70%–75% of the total volume of concrete. Aggregates were used as a construction material in 48.3 billion tons worldwide in 2015 [2]. It is expected that by 2050, more than 70% of the world's countries and territories will be more than 60% urban, and the remaining 38% will be at least 80% urban. Only two continents, Africa and Asia, will be able to accommodate the world's expected population growth. By 2050, these continents will have attracted nearly 90% of the world's 2.5 billion new residents. A growing population is definitely connected to the proper construction and sustainable infrastructure [3]. The global concrete production rate is estimated to be about one ton per person per year, and that this rate is continuously rising [4]. The cement industry contributes 5% of worldwide CO_2 emissions due to its energy-intensive nature [5]. Depending on the type of fuel used, one ton of cement is estimated to produce 0.9 to 1 ton of CO_2. The largest environmental challenge of present time, according to scientists, is simulated climate change which has lead the path for global warming, which is the result of continuous and steady rising quantities of greenhouse gases, mainly CO_2, in the earth's atmosphere over the past 100 years [6]. In order to reduce cement content, enhance workability, boost strength and extend the life of concrete, supplementary cementitious materials are frequently used in concrete mixes [7]. Waste Glass Powder (WGP) is potentially pozzolanic and, with proper preparation, can be used as a cement paste material. The adequate replacement level of WGP is 10% for cement in concrete [1]. Concrete with suitable properties might be made by replacing 40% of the cement with WGP. However, concrete with the substitution level of 10–20 percent shows high tolerance to chloride ion penetration, thus making it perfect for structures near the shore [4]. Glass is a useful member of the garbage family in many rural and urban areas, and it is made up of a variety of inorganic raw materials that are processed into a stable, inert, hard, homogenous, amorphous, and isotropic material [8]. The tremendous amount of WG is a concern for the world now, with countless amount of tons of glass trash produced every year around the world. Because of its non-biodegradable nature, it takes up a lot of space in landfills and poses serious environmental risks [9]. Calcium and silicon are the major constituents of the glass, and because of its pozzolanic nature in finely grounded form, it can be utilized as a cement alternative in concrete [10]. To turn the problem into a solution and to minimize the adverse effects of WG, is to utilize them in various fields. The construction industry is one of the best sites for the recycling of WG. On one hand, it is economical and environmentally friendly, and on the other hand, it relieves society of a burden. However, the introduction of WG of different types and quantities into concrete creates both drawbacks and solutions. At the beginning, the drawback was the introduction of a procedure to convert WG into useful cullet. Impact and abrasion crushers are evident in this regard to carrying out this operation. Glass is more abrasive as compared to most natural aggregates, which results in excessive wear and also high maintenance costs of the equipment. Moreover, the shortcoming of most crushers is the creation of sharp elongated glass cullets, which are at the same time both unsafe to handle and unfit to use [11]. Implosion technology was defined in mid-90s of 20th century, allowing for a revolutionary method of producing glass cullet with no sharp edges. In its apparatus, it includes a gravity chamber, a high-speed rotor that produces a harmonic resonance, and a feed system [12]. An attempt has been made in this review to present the effects of WGP used in concrete as partial replacement of cement.

GlASS

The exact date of making glass is unknown. The grown history of glass production goes to Mesopotamia around 3000 B.C., and the first vessels of glass were made in Egypt and Mesopotamia about 1500 B.C. Because of small furnaces and the heat required to liquefy the basic materials, glass was out of reach at that time. For the first time in history, the invention of the blowpipe made glass production more affordable and efficient, and the glass became accessible to the general public. The introduction of manganese oxide made the glass having no color in the first A.D. century [13],[14]. In 1674, lead glass was introduced by adding a tremendous quantity of lead oxide to the primal matter. In the year 1688, a new procedure for producing plate glass was developed in France, and it proved to be useful in the manufacturing of superior strengthen mirrors. In 1910, with the application of lamination technique, safe and secure Triplex glass was invented [9]. The method of float which has been proposed by Britain's Pilkington Brothers Ltd. in 1959, is responsible for about 90% of flat plate glass production [13],[14]. Dolomite $\{CaMg(CO_3)\}$, silica (SiO_2), sodium carbonate $(NaCO_3)$, and limestone $(CaCO_3)$ are the raw materials used to make glass. The mixture of these raw materials is heated up to 1600 ℃ and then allowed to cool to solidify without crystallization to obtain an amorphous state of glass [9]. Some particular supplements are used to create glasses with distinct colors and features [15],[16],[17]. Based on these supplements, glass has many types. Barium glasses, alkali silicates, vitreous silica, borosilicate glasses, soda-lime glasses, lead glasses, and aluminosilicate glasses are prominent in this regard. They are mostly green, brown, or colorless [18]. In the year 2007, the world's total glass manufactured rate was estimated to be around 89.4 million tons. The EU produced 38.3 million tons of glass in the same year, accounting for 30 percent of the total world production and making it the world's biggest glass producer [9]. Glass production is inextricably linked to waste glass. For instance, in 2002, the total glass waste of the EU was 3 million tons, but by 2008, it had increased to 4.1 million tons [19]. The United Kingdom produces more than three million tons of WG every year, with trash containers accounting for 71% of this total [20]. The global WG production was predicted to be over 130 million tons in 2005, in which the contributions of the European Union, China, and the USA were 33, 32, and 20 million tons, respectively [21],[22].

CEMENT

Cement is a binding material widely used all over the world in construction and plays a vital role in concrete in holding together materials. The world cement production rate is 2.8 billion tons per year, and due to rapid urbanization in India, China, Northern Africa, and the Middle East, this rate will exceed 4 billion tons per year [5],[23]. Ancient Egypt, Greece, and Mesopotamia employed lime sediment as an alternative to cement in construction. Joseph Aspdin was the first to produce Portland Cement (artificial hydraulic lime) in 1824, which had properties similar to the Roman Cement invented in 1796 by James Parker. Later, in 1842, William Aspdin produced Portland Cement in the modern sense in England [9]. The first issued standard on Portland Cement is referred to German government [24]. Silica (SiO_2), limestone $(CaCO_3)$, magnesium oxide (MgO), ferrous oxide (Fe_2O_3), and alumina (Al_2O_3) are the primary materials used in cement production [9]. Material consisting of all mentioned oxides can be used as primal matter for the construction of cement. Cement is classified into several categories based on its chemical composition and ingredient proportions. The types of cement range from type 1 to type 5. Type 1 is Ordinary Portland Cement (OPC), as it is generally used. Type 2 has moderate sulfate resistance. It is used in structures which are in contact with water or soil. Type 3 is used in ultra-high strength concrete. After being poured, most concrete takes a month to acquire full strength. However, this cement hardens much faster. Type 4 cement is a low-heat cement that needs less heat as it sets and dries. It is used where too much heat is unacceptable and concrete needs more time to reach its strength. Type 5 cement is highly resistant to sulfates and is utilized in highly alkaline soils and water. Types 1A, 2A, and 3A are variants of 1, 2, and 3 types of cement, which are examples of other cement types. To make certain forms of cement resistant to moisture damage, air-entraining elements are added in. The cement of the types Portland-Limestone (IL), Portland Slag Cement (IS), Portland Pozzolana (IP), and Ternary Blended (IT) are hydraulic and have special characteristics. There are two methods for producing cement: the wet and dry processes. The raw materials are crushed to the size of less than 20 mm in the wet process, and then precisely blended to the correct proportion. Water is then added to the mixture to make a slurry of the water content of 35–40%. The slurry is then transferred to an encircling furnace for the burning of clinker at 1500℃ in order to dry up the mixture. In contrast to the wet process, in the dry process the crushed unprocessed materials are dried in a rotating drier before being carefully mixed to the desired value. The slurry is further mixed to achieve homogeneity before being transferred to an encircling furnace for the burning of clinker burning at 1500℃ [9].

CHALLENGES TO GLASS AND CEMENT INDUSTRIES

Glass industries are facing a huge amount of energy consumption, constant depletion of natural resources, a lower recycling rate of glass waste, and a contribution to climate change and global warming. With the development of civilization, the use of glass has increased, resulting in a significant increase in these issues. The cement industry, like the glass industry, is also confronting a lot of obstacles. These include the cost and energy of fuels, the production of dangerous greenhouse gases, particularly CO_2, and the supply and cost of depleted raw materials [9]. Natural resources are constantly depleted as a result of cement manufacturing, as for as cement production uses 1.5 to 1.7 tons of natural resources per ton. For instance, the Chinese cement industrial area uses 1.5 billion tons of clay and limestone in a single year [25]. These challenges are inextricably linked to the production of cement. The cement industry is facing constant pressure to solve or mitigate the adverse effects of these problems.

ENERGY CONSUMPTION OF GLASS AND CEMENT INDUSTRIES

The production of glass necessitates a significant amount of energy. The production of 1 ton of European glass requires 7.8Gj of energy. The energy expending rate of the European glass industry was 352Pj in 2007, accounting for 13 to 17 percent of Europe's overall industrial consumption [26]. As a result of the huge consumption of energy, it is calculated that for every kilogram of glass produced, 16.9Mj of energy is lost as waste heat [27]. Like the glass industry, energy consumption is one of the constraints on the cement industry. A temperature of about 1500 °C is required in the construction process. The cost of energy is approximately 40% of its entire cost, and in some countries, it can be as high as 50-60% [28]**.** In 2006, an estimation was carried out that the energy expending rate of the cement industry was 5% of the total world industrial energy utilization [29]. Currently, the energy utilization rate of the cement industry accounts for 12–15% of total global industrial energy utilization and it is rising with the production rates of cement [25],[28],[30].

THREAT TO THE ENVIRONMENT

Intensive use of energy results in high emissions of CO_2 as well as other hazardous greenhouse gases, which create serious environmental problems. It was pointed out in 2007 that for every ton of European glass production, 0.57 tons of CO_2 were produced [26]. In the melting step for a single ton of the glass container, only 0.2 tons of CO_2 are produced [31]. The CO_2 concentration in the cement industry was 280 ppm at the beginning of the industrial revolution and increased to 368 ppm at the beginning of this century [32]. Being an energy-intensive industry, the cement industry's contribution to CO_2 emissions is 5% globally [5]. Cement production consumes a huge amount of energy, and it contributes to greenhouse gases is about 7% worldwide [33]**.** It is estimated that one ton of cement production produces 0.9 to 1 ton of CO_2, depending on the type of fuel used. According to scientists' opinion, the greatest environmental concern of today is man-made climate change due to global warming, which is the result of continuous and constant rising concentrations of greenhouse gases, especially CO_2, in the atmosphere of earth over the past 100 years [6]. Global warming and climatic change are becoming serious problems for the world because of their global effects. The increased amount of CO_2 emissions is thought to be to blame [34]. As a major CO_2 emitter, it is estimated that during the production of every ton of clinker one ton of CO_2 is released [30],[32]. Industry accounts for around 7% of the global CO_2 emissions [30]. Furthermore, in 2007, the European cement industry was accounted for 4.1% of total CO_2 emissions in the EU [35]. CO_2 emissions will increase by 50% by 2030 due to increased cement production [29].

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RECYCLING AND LIMITATIONS OF RECYCLING OF WASTE GLASS

Reduction of the energy utilization by 2-3% can be achieved with the using of only 10% crushed WG as a resource for glass production [26]. Using crushed WG as a resource for the manufacturing of glass can reduce energy consumption by up to 40% as compared to glass produced from the sand as a raw material [36]. Recycling all types of WG is both impractical and quite expensive. The recycling of broken and mixed-color glasses is quite difficult because of the difference in the chemical composition of recycled glass [8]. Glass consists of sand, soda ash, and limestone, which are quite common and cheap, and it has been confirmed that due to the complicated recycling process, recycling of glass is more expensive than storing it [37]. Impurities and contaminants present in the WG can influence the characteristics of the newly manufactured glass [8],[31]. The WG reprocessing and recycling rate is very poor throughout the world because it mainly concentrates on the container and packaging sectors [38]. In 2010, just 27% of the 11.5 million tons of WG generated in the United States was recycled [39]. In 2008, about 60% of the 4.1 million tons of glass waste was recycled in EU countries [19]. In 2019, only 45% of the WG was recycled in India out of 21 billion tons of WG produced [2].

WASTE GLASS AS CEMENTITOUSE MATERIAL

Due to its non-biodegradable nature, non-recyclable WG is a significant burden on landfills. Because of its non-decomposition nature and the scarcity of landfills in metropolitan areas, its disposal is considered a major concern. Glass waste provides a better solution for glass waste because of its identical physical properties and chemical composition to sand and cement. On one hand, it will safeguard the environment, and on the other, it will conserve natural resources and save the economy. WG can be utilized to some extent instead of cement in concrete production. Because of its pozzolanic tendency, it is a highly recommended alternative to cement in concrete production. The pozzolanic behavior of WG is a matter of its particle sizes. WG of particle size of 38 μm has the potential to replace cement by 30% [40]. The pozzolanic characteristics of WG are inversely related to glass particle sizes. Alkali-silica reaction (ASR) expansion could be reduced by using smaller particle sizes. Using 20% fine-ground WG as partial substitute for cement in concrete production could drastically reduce ASR expansion [41].

EFFECTS

A. *Slump Test*

Workability is the property of freshly mixed concrete which indicates the ease with which it can be properly mixed, placed, consolidated, and finished with minimal loss of homogeneity. The conventional slump test is used to determine the workability of fresh concrete. The workability of concrete is increased by adding WGP [42]. The usage of milled WG in concrete results in an increment in a slump because of the low water absorption capability of glass [43]. WG material increases the workability of concrete mixes as compared to reference mixes [44]. Increased glass powder material enhances the workability of concrete [45]. The amount of WGP used to replace cement in concrete is directly proportional to the slump of the concrete. It increases from 40mm for the control mix to 160mm at a 40% replacement level [46]. There was increasing systematically in the slump of concrete containing glass powder content as compared to the reference mix [47]. According to some investigations, the workability of concrete decreases with the replacement percentage of cement by WGP. The addition of glass powder to concrete reduces its workability [48]. The workability of concrete is inversely related to the replacement level of cement by glass waste powder in concrete [49]. The slump of concrete decreases as the substituted percentage of cement with glass powder increases [50].

B. *Compressive Strength*

The optimal replacement of cement by WGP was observed to be 30% concerning the development of concrete compressive strength after 7 days [38]. The compressive strength of lime-glass-containing concrete exceeded the desired limit of 4.1 MPa. The concrete with 30 percent cement replacement by 38-m glass powder had strength activity indexes of 91, 84, 96, and 108% at 3, 7, 28, and 90 days, exceeding the target limit by 75% as suggested by ASTM C618 [40]. With the replacement of 20% of cement with WGP, an increase of compressive strength is occurred as compared to the reference mix at 28 days [42]. [47] studied the effect of WGP as partial substitute for cement on concrete was investigated, and it was found that a 10% replacement level is best for maximum compressive strength. The compressive strength increases by up to 20% when 40% of the cement are replaced, but it declines beyond that [48]. The compressive strength of concrete improves directly with the percentage of cement replaced by WGP content at 7 days, 14 days, and 28 days, and reaches a maximum of about 20% [50]. When 20% cement was replaced by WGP, the concrete gives satisfactory compressive strength, and it was 46.54 Mpa for M-40 grade. However, when 10% of the cement was replaced with WGP, the maximum compressive strength was found 16.56 percent higher than the reference mix [51]. The compressive strength of concrete improves with an increase in the percentage of glass powder replacement up to 20% replacement and then decreases when compared to the control mix [52]. Due to the pozzolanic reactivity of the glass powder, concrete containing glass powder shows a considerable improvement in compressive strength development at 28 days when compared to the control specimen. However, by 28 days, a considerable improvement in the hardened concrete's compressive strength was found at 21% replacement, followed by a progressive reduction in strength. However, since the pozzolanic reaction of the glass powder continues, a longer curing time beyond 28 days is expected to improve compressive strength. To alleviate the effects of ASR, it is suggested that glass powder be used in place of cement up to 21% as pozzolan in the manufacturing of normal weight concrete [53]. When compared to the control specimen, the compressive strength of concrete improves up to 8.64 %, and the highest strength is attained by 30 % replacement of cement through a mixture of WGP and silica fume at the age of 28 days [54]. Compared to the control sample, the compressive strength of concrete is increased by 26.34% and 22% for 10% and 15% glass powder content replacement, respectively [55]. [56] Experimented and concluded that 20% glass content is optimal, accounting for a 2% increment in the compressive strength of mortar and concrete at 90 days as compared to conventional samples. The researchers experimented to substitute cement with WGP and found that at 15% GP, there is a 29 percent gain in strength at 7 days compared to the control mix, and this difference in strength decreases to 23 percent at 28 days. The best replacement is 10% of the strength increment. The experiment shows that replacing 20%, 30%, and 40% of the cement with WGP results in compressive strength increases of 19.6%, 25.3 %, and 33.7 %, respectively, at 28 and 60 days, as compared to the control specimen [57]. The compressive strength of mortar decreases as the percentage of cement replaced by WGP increases, although it becomes less evident with prolonged curing times. The crucial factor in developing strength is the particle size of used glass [58]. The investigation reveals that the optimal replacement level is 15% using coarse and fine glass powder as cement replacement [59]**.** WGP replacement of 10% and 15% of the cement can increase compressive strength to around 9% and 16%, respectively [60]. Compared to the reference mix, a 20% substitute of cement by WGP is optimal for the compressive strength of concrete [61]. Initially, the compressive strength of concrete improves as the percentage replacement of cement with glass powder increases, reaching a peak value at around 20%, and beyond that, it declines [62]. When the water/cement ratio remains constant, a 20% cement replacement results in a 27% increase in concrete strength [63]. Initially, the compressive strength of glass powder added to concrete improves and attains a peak value at around 10% replacement percentage and later decreases [64]. The optimal replacement level for the compressive strength of concrete ranges from 25% to 30% [65].

C. Flexural Strength

The results of the experiment show that a 35 percent substitution of cement by WGP results in a 20% increase in flexure strength when compared to the standard mix and that it declines after that [48]. The flexural strength was studied with the substitution of cement by WGP, and a considerable increase was observed at a 10% replacement level [49]. The flexure strength of concrete increases directly with the percentage of cement replaced by WGP content, reaching a maximum of about 20% [50]. With the replacement up to 20% of cement by WGP, the concrete gives satisfactory flexural strength, and it was 8.35Mpa for M-40 grade. However, when 10% of the cement was replaced with WGP, the maximum flexural strength was found to be 6.57 % higher than the reference mix [51]. Compared to the control mix, the flexural strength of concrete increases directly with an increase in the percentage of glass powder up to 20% replacement, and beyond it drops off [52]. When 30 % of the cement is replaced with a mixture of WGP and silica fume at the age of 28 days, the flexural strength of concrete increases up to 7.08 %, and the maximum strength is achieved by 30 % replacement of cement through the mixture of WGP and silica fume, as compared to the control specimen, and it declines after that [54]. When WGP substitutes for 20%, 30%, and 40% of the cement, the flexural strength of concrete rises by 83.07 percent, 99.07 percent, and 100 percent, respectively [57]. The flexural strength of concrete can be enhanced by replacing up to 20% of the cement with WGP [61]. Initially, the flexural strength of glass powder added to concrete increases and attains its peak value at around 10% replacement percentage, and beyond it declines [64]. The optimal replacement level for the flexural strength of concrete ranges from 25% to 30% [65]. The flexural behavior of reinforced concrete beams containing WGP is increased, particularly at a 15% glass powder replacement level as compared to reference beams without WGP [66]. The optimal level of cement replacement by WGP is 20% of the flexure strength when compared to a control sample [67]. Experimentally, it was proved that the optimal replacement was 20% for both concrete affected to sulfate attack and when it was not [68].

D. Split Tensile Strength

An increase in WG content can reduce split tensile strength [44]. A marginal increment occurs in the tensile strength of glass powder concrete [49]. The tensile strength of cement-replaced concrete is higher than that of control concrete. The amount of cement replaced by WGP content immediately enhances the split tensile strength of concrete, reaching a maximum of about 20% [50]. Up to 20% substitute of cement by WGP, the concrete gives satisfactory split tensile strength, and it was 6.23Mpa for M-40 grade. However, the maximum value of split tensile strength was found at 10% replacement of cement by WGP and was 7.16% more than the reference mix [51]. As the amount of glass powder content increases, the tensile strength decreases. However, it is believed that tensile strength will grow with age [53]. The split tensile strength of concrete increases up to 15%. The maximum strength is achieved by 30% replacement of cement through the mixture of WGP and silica fume at the age of 28 days compared to the control specimen and beyond it declines [54]. The splitting tensile strength of concrete is increased by 23.5% and 28.7%, respectively, when 10% and 15% glass powder content is replaced [55]. When 40% of the cement is replaced with WGP, the split tensile strength of concrete increases by 4.4 % [57]. In the first stage, the split tensile strength of concrete increases as the replacement percentage of cement with glass powder increases reaches a peak value at around 20%, and beyond that, it declines [62]. Initially, the split tensile strength of glass powder added to concrete increases and attains a peak value at around 10% replacement percentage and later decreases [64]. The optimal replacement level for the split tensile strength of concrete is 10%, and beyond 10%, it is almost insignificant [65]. The study of Steel Fiber Reinforced Concrete (SFRC) reveals that the optimal replacement of cement by WGP is 20% for a peak flexural strength of 27,000 psi [67].

CONCLUSIONS

Large amount of WG is produced every year. Moreover, due to its non-biodegradable nature, it exerts huge pressure on landfills, particularly in metropolitan and urban areas, which are most affected in this regard. This tremendous amount of WG is directly deposited into landfills without being recycled. Glass and cement industries use a lot of energy and natural resources, and they can contribute to the hazardous gases available in the atmosphere, specially CO_2 that causes global warming and climate change. In order to mitigate the issues related to the glass and cement industries and to overcome the burden on landfills by using waste glass in a beneficial manner, the concrete industry can offer an environmentally friendly solution. The studies reviewed shows that substituting cement in concrete with WGP produced concrete with superior characteristics in both the fresh and hardened states when compared to conventional mixes. Concrete properties such as compressive strength, flexural strength, workability and split tensile strength are prominent in this regard. However, cement replacement level by WGP is a shortcoming. Various research studies have shown various optimal replacement levels. Despite all these limitations, the WGP is recommended to be partially used in concrete to conserve natural resources, save energy, and safeguard the environment.

To the author's knowledge, there is no literature exist on the combined use of WGP as cement and fine aggregate replacement simultaneously in concrete production. Therefore, it is advised that researchers should investigate the effects of WGP on the fresh and hardened characteristics of concrete when they're utilized in different measures.

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REFERENCES

1. F. A. Olutoge and C. Strength, “Effect of Waste Glass Powder (WGP) on the Mechanical Properties of Concrete,” Am. J. Eng. Res., vol. 38, no. 511, pp. 2320–847, 2016, [Online]. Available: www.ajer.org.
2. R. Gowtham, S. Manikanda Prabhu, M. Gowtham, and R. Ramasubramani, “A Review On Utilization Of Waste Glass In Construction Field,” IOP Conf. Ser. Mater. Sci. Eng., vol. 1130, no. 1, p. 012010, 2021, doi: 10.1088/1757-899x/1130/1/012010.
3. United Nations, “World Urbanization Prospects: The 2014 Revision, United Nations Department of Economic and Social Affairs/Population Division.,” New York, NY, USA, 2014.

4. J. Cassar and J. Camilleri, "Utilisation of imploded glass in structural concrete," Constr. Build. Mater., vol. 29, pp. 299–307, 2012, doi: 10.1016/j.conbuildmat.2011.10.005.
5. A. M. Matos and J. Sousa-Coutinho, "Durability of mortar using waste glass powder as cement replacement," Constr. Build. Mater., vol. 36, pp. 205–215, 2012, doi: 10.1016/j.conbuildmat.2012.04.027.
6. P. K. Mehta, "Greening of the Concrete Industry for Sustainable Development," Concr. Int., vol. 24, no. 7, pp. 23–28, 2002.
7. A. D. Neuwald, "Supplementary cementitious materials- part 1: pozzolanic SCMs," MC Magezine, pp. 8–17, 2004.
8. L. M. Federico and S. E. Chidiac, "Waste glass as a supplementary cementitious material in concrete - Critical review of treatment methods," Cem. Concr. Compos., vol. 31, no. 8, pp. 606–610, 2009, doi: 10.1016/j.cemconcomp.2009.02.001.
9. Y. Jani and W. Hogland, "Waste glass in the production of cement and concrete - A review," J. Environ. Chem. Eng., vol. 2, no. 3, pp. 1767–1775, 2014, doi: 10.1016/j.jece.2014.03.016.
10. C. Shi and K. Zheng, "A review on the use of waste glasses in the production of cement and concrete," Resour. Conserv. Recycl., vol. 52, no. 2, pp. 234–247, 2007, doi: 10.1016/j.resconrec.2007.01.013.
11. "http://www.p2pays.org/ref/13/12062.pdf."
12. "http://www.remade.org.uk/media/12928/small%20scale%20recycling%20technology%20%28sept%202205%29.pdf."
13. D. Klein and W. Lloyd, The History of Glass. 1984.
14. R. . Knittle, Early American Glass. 1927.
15. [J. . Heldman, Techniques of glass manipulation in scientific research. 1946.
16. J. . Stanworth, physical properties of glass. 1950.
17. D. . Koryani, Surface properties of silicate glass. 1963.
18. G. . McLellan and E. . Shande, Glass engineering handbook. 1984.
19. Environmental statistics and accounts in Europe. 2010.
20. P. Turgut and E. S. Yahlizade, "Research into Concrete Blocks with Waste Glass," Int. J. Civ. Environ. Eng., vol. 1, no. 4, pp. 203–209, 2009.
21. A. M. Rashad, "Recycled waste glass as fine aggregate replacement in cementitious materials based on Portland cement," Constr. Build. Mater., vol. 72, pp. 340–357, 2014, doi: 10.1016/j.conbuildmat.2014.08.092.
22. "Tracking Industrial Energy Efficiency and CO2 Emissions," Track. Ind. Energy Effic. CO2 Emiss., 2007, doi: 10.1787/9789264030404-en.
23. M. Schneider, M. Romer, M. Tschudin, and H. Bolio, "Sustainable cement production-present and future," Cem. Concr. Res., vol. 41, no. 7, pp. 642–650, 2011, doi: 10.1016/j.cemconres.2011.03.019.
24. A. . Francis, "The cement industry 1796-1914: A history."
25. T. Zhang, P. Gao, P. Gao, J. Wei, and Q. Yu, "Effectiveness of novel and traditional methods to incorporate industrial wastes in cementitious materials - An overview," Resour. Conserv. Recycl., vol. 74, pp. 134–143, 2013, doi: 10.1016/j.resconrec.2013.03.003.
26. A. Schmitz, J. Kamiński, B. Maria Scalet, and A. Soria, "Energy consumption and CO2 emissions of the European glass industry," Energy Policy, vol. 39, no. 1, pp. 142–155, 2011, doi: 10.1016/j.enpol.2010.09.022.
27. M. Saito and M. Shukuya, "Energy and material use in the production of insulating glass windows," Sol. Energy, vol. 58, no. 4–6, pp. 247–252, 1996, doi: 10.1016/S0038-092X(96)00056-4.
28. N. A. Madlool, R. Saidur, M. S. Hossain, and N. A. Rahim, "A critical review on energy use and savings in the cement industries," Renew. Sustain. Energy Rev., vol. 15, no. 4, pp. 2042–2060, 2011, doi: 10.1016/j.rser.2011.01.005.
29. L. Szabó, I. Hidalgo, J. C. Ciscar, and A. Soria, "CO2 emission trading within the European Union and Annex B countries: The cement industry case," Energy Policy, vol. 34, no. 1, pp. 72–87, 2006, doi: 10.1016/j.enpol.2004.06.003.
30. M. B. Ali, R. Saidur, and M. S. Hossain, "A review on emission analysis in cement industries," Renew. Sustain. Energy Rev., vol. 15, no. 5, pp. 2252–2261, 2011, doi: 10.1016/j.rser.2011.02.014.
31. M. Ruth and P. Dell'Anno, "An industrial ecology of the US glass industry," Resour. Policy, vol. 23, no. 3, pp. 109–124, 1997, doi: 10.1016/s0301-4207(97)00020-2.
32. R. Rehan and M. Nehdi, "Carbon dioxide emissions and climate change: Policy implications for the cement industry,"

Environ. Sci. Policy, vol. 8, no. 2, pp. 105–114, 2005, doi: 10.1016/j.envsci.2004.12.006.
33. M. S. Imbabi, C. Carrigan, and S. McKenna, "Trends and developments in green cement and concrete technology," Int. J. Sustain. Built Environ., vol. 1, no. 2, pp. 194–216, 2012, doi: 10.1016/j.ijsbe.2013.05.001.
34. N. Oreskes and E. M. Conway, "Defeating the merchants of doubt," Nature, vol. 465, no. 7299, pp. 686–687, 2010, doi: 10.1038/465686a.
35. N. Pardo, J. A. Moya, and A. Mercier, "Prospective on the energy efficiency and CO2 emissions in the EU cement industry," Energy, vol. 36, no. 5, pp. 3244–3254, 2011, doi: 10.1016/j.energy.2011.03.016.
36. H. Isa, "The need for waste management in the glass industries: A review," Sci. Res. Essays, vol. 3, no. 7, pp. 276–279, 2008.
37. R. Idir, M. Cyr, and A. Tagnit-Hamou, "Use of fine glass as ASR inhibitor in glass aggregate mortars," Constr. Build. Mater., vol. 24, no. 7, pp. 1309–1312, 2010, doi: 10.1016/j.conbuildmat.2009.12.030.
38. H. Du and K. H. Tan, "Waste glass powder as cement replacement in concrete," J. Adv. Concr. Technol., vol. 12, no. 11, pp. 468–477, 2014, doi: 10.3151/jact.12.468.
39. "United State Environmental Protection Agency report, 2012."
40. Y. Shao, T. Lefort, S. Moras, and D. Rodriguez, "Studies on concrete containing ground waste glass," Cem. Concr. Res., vol. 30, no. 1, pp. 91–100, 2000, doi: 10.1016/S0008-8846(99)00213-6.
41. C. Shi, Y. Wu, C. Riefler, and H. Wang, "Characteristics and pozzolanic reactivity of glass powders," Cem. Concr. Res., vol. 35, no. 5, pp. 987–993, 2005, doi: 10.1016/j.cemconres.2004.05.015.
42. G. Vasudevan, S. Ganis, and K. Pillay, "Performance of Using Waste Glass Powder In Concrete As Replacement Of Cement," Am. J. Eng. Res., vol. 02, no. 12, pp. 2320–847, 2013, [Online]. Available: www.ajer.org.
43. R. U. D. Nassar and P. Soroushian, "Strength and durability of recycled aggregate concrete containing milled glass as partial replacement for cement," Constr. Build. Mater., vol. 29, pp. 368–377, 2012, doi: 10.1016/j.conbuildmat.2011.10.061.
44. M. I. Malik, "Study of Concrete Involving Use of Waste Glass as Partial Replacement of Fine Aggregates," IOSR J. Eng., vol. 3, no. 7, pp. 08–13, 2013, doi: 10.9790/3021-03760813.
45. S. Rehman, S. Iqbal, and A. Ali, "Combined influence of glass powder and granular steel slag on fresh and mechanical properties of self-compacting concrete," Constr. Build. Mater., vol. 178, pp. 153–160, 2018, doi: 10.1016/j.conbuildmat.2018.05.148.
46. N. Kumarappan, "Partial Replacement Cement in Concrete Using Waste Glass," Int. J. Eng. Res. Technol., vol. 2, no. 10, pp. 1880–1883, 2013.
47. J. M. Khatib, E. M. Negim, H. S. Sohl, and N. Chileshe, "Glass Powder Utilisation in Concrete Production," Eur. J. Appl. Sci., vol. 4, no. 4, pp. 173–176, 2012, doi: 10.5829/idosi.ejas.2012.4.3.1102.
48. J. B. Jangid and P. A. C. Saoji, "Experimental investigation of waste glass powder as the partial replacement of cement in concrete production," vol. 2014, pp. 55–60, 2014.
49. R. Vandhiyan, K. Ramkumar, and R. Ramya, "Experimental Study On Replacement Of Cement By Glass Powder," Int. J. Eng. Res. Technol., vol. 2, no. 5, pp. 234–238, 2013.
50. R. Sakale, S. Jain, and S. Singh, "Experimental Investigation on Strength of Glass Powder Replacement by Cement in Concrete with Different Dosages," IJSTE-International J. Sci. Technol. Eng., vol. 2, no. 8, pp. 76–86, 2016, [Online]. Available: www.ijste.org.
51. A. Anwar, "The influence of waste glass powder as a pozzolanic material in concrete," Int. J. Civ. Eng. Technol., vol. 7, no. 6, pp. 131–148, 2016.
52. S. Raju and P. R. Kumar, "Effect of Using Glass Powder in Concrete," Int. J. Innov. Res. Sci. Eng. Technol., vol. 2014, no. 5, pp. 421–427, 2015.
53. O. M. Olofinnade, J. M. Ndambuki, A. N. Ede, and C. Booth, "Application of waste glass powder as a partial cement substitute towards more sustainable concrete production," Int. J. Eng. Res. Africa, vol. 31, pp. 77–93, 2017, doi: 10.4028/www.scientific.net/JERA.31.77.
54. A. G. Khan, B. Khan, and E. Abdul, "Effect of Partial Replacement of Cement by Mixture of Glass Powder and Silica

Fume Upon Concrete Strength To cite this version : HAL Id : hal-01569488 Effect of Partial Replacement of Cement by Mixture of Glass Powder and Silica Fume Upon Concrete Strengt," Int. J. Eng. Work. Kambohwell Publ. Enterp., vol. 4, no. 7, pp. 124–135, 2017.

55. H. S. Ubeid, S. M. Hama, and A. S. Mahmoud, "Mechanical Properties, Energy Impact Capacity and Bond Resistance of concrete incorporating waste glass powder," IOP Conf. Ser. Mater. Sci. Eng., vol. 745, no. 1, 2020, doi: 10.1088/1757-899X/745/1/012111.
56. G. M. S. Islam, M. H. Rahman, and N. Kazi, "Waste glass powder as partial replacement of cement for sustainable concrete practice," Int. J. Sustain. Built Environ., vol. 6, no. 1, pp. 37–44, 2017, doi: 10.1016/j.ijsbe.2016.10.005.
57. G. Vijayakumar, M. H. Vishaliny, and D. Govindarajulu, "International Journal of Emerging Technology and Advanced Engineering Studies on Glass Powder as Partial Replacement of Cement in Concrete Production," Certif. J., vol. 9001, no. 2, pp. 153–157, 2008, [Online]. Available: www.ijetae.com.
58. S. O. Nwaubani and Ik. I. Poutos, "The Influence of Waste Glass Powder Fineness on the Properties of Cement Mortars," Int. J. Appl. or Innov. Eng. Manag., vol. 2, no. 2, p. 7, 2013, [Online]. Available: http://www.ijaiem.org/Volume2Issue2/IJAIEM-2013-02-20-026.pdf.
59. D. Patel, "Strength Characteristics of Cement Mortar Paste Containing Coarse and Fine Waste Glass Powder," vol. 03, no. 02, pp. 683–686, 2012.
60. A. A. Aliabdo, A. E. M. Abd Elmoaty, and A. Y. Aboshama, "Utilization of waste glass powder in the production of cement and concrete," Constr. Build. Mater., vol. 124, pp. 866–877, 2016, doi: 10.1016/j.conbuildmat.2016.08.016.
61. M. M. Yassin, A. S. Mahmoud, and S. M. Hama, "Effectiveness of Glass Wastes as Powder on Some Hardened Properties of Concrete," Al-Nahrain J. Eng. Sci., vol. 22, no. 1, pp. 14–17, 2019, doi: 10.29194/njes.22010014.
62. P. Kumar, A. M. B, and V. K, "Effect of Partial Replacement of Cement With Waste Glass Powder on the Properties of concrete," Int. J. os Struct. Civ. Eng. Res., vol. 3, no. 2, pp. 1–6, 2014.
63. V. V Bhat and N. Bhavanishankar Rao, "Influence of Glass Powder on the Properties Of Concrete," Int. J. Eng. Trends Technol., vol. 16, no. 5, pp. 196–199, 2014, doi: 10.14445/22315381/ijett-v16p242.
64. A. Jena and M. Paikaray, "Strength Assessment and Feasibility Study on Waste Glass Powder as Partial Replacement of Cement in Concrete Production," vol. 5, no. 3, pp. 280–283, 2018.
65. B. N. Manoj Kumar Meena, Jagriti Gupta, "Performance Of Concrete By Using Glass Powder, An Experimental Study," Int. Res. J. Eng. Technol., vol. 5, no. 9, pp. 840–844, 2018, [Online]. Available: www.irjet.net.
66. S. M. Hama, A. S. Mahmoud, and M. M. Yassen, "Flexural behavior of reinforced concrete beam incorporating waste glass powder," Structures, vol. 20, no. February, pp. 510–518, 2019, doi: 10.1016/j.istruc.2019.05.012.
67. S. M. Chikhalikar and S. N. Tande, "an Experimental Investigation on Characteristic Properties of Fibre Reinforced Concrete Containing Waste Glass Powder As Pozzolan a an Experimental Investigation on Characteristic Properties of Fibre Reinforced Concrete Containing," 37th Conf. OUR WORLD Concr. Struct., p. 3, 2012.
68. C. D. M. and A. K. D. M.N.Bajad, "Effect of Glass on Strength of Concrete Subjected," vol. 1, no. 2, 2011.

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