GLASS WASTE AS PARTIAL REPLACEMENT OF CEMENT FOR SUSTAINABLE CONCRETE

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Abstract:-The common assets (aggregate and cement) for the concrete business are un-existent, the examination is to research the chance of utilizing glass powder in concrete as incomplete concrete substitution and doesn't adversely influence the properties of the subsequent cement. Furthermore, the natural advantages of the disposal of the waste glass from the landfill is another objective. Requirement for elective assets is indispensable. The reusing of waste comprises a positive path for the solid business as elective materials to supplant concrete and totals. The fundamental goal of this exploration is to examine the chance of utilizing glass squander powder in concrete as incomplete concrete substitution and doesn't contrarily influence the properties of the subsequent cement. Likewise, the natural advantages of the end of the waste glass from the landfill is another objective.

Key words:- Glass powder, fly ash, Furnace Slag, pozzolanic

INTRODUCTION

1.GENERAL

It is notable that cement is the central constituent that makes concrete, however, the assembling of Portland concrete has a fundamental negative effect, which creation of one ton of Portland cement clinker make around one ton of carbon dioxide and other ozone depleting substances (GHGs). Thusly, the discharge of this noteworthy measure of carbon dioxide ought to be reduced by a reasonable advancement arrangement inside the cement and concrete industry

Regularly glass doesn't hurt the climate in any capacity since it doesn't radiate poisons, yet it can hurt people just as creatures if not managed cautiously and it is less agreeable to climate since it is non-biodegradable. In this manner, the advancement of new innovations has been required. The term glass contains a few substance varieties including soda lime silicate glass, alkali-silicate glass and borosilicate glass. Until now, these kinds of glasses glass powder have been broadly utilized in cement and aggregate blend as pozzolana for civil works. The presentation of waste glass in concrete will expand the alkali substance in the cement.It likewise helps in blocks and ceramic manufacture and it preserves crude materials, diminishes energy utilization and volume of waste shipped off landfill. As valuable reused materials, glasses and glass powder are essentially utilized in fields identified with structural designing, for instance, in cement, as pozzolana (supplementary cementitious materials), and coarse aggregate. Their recycling ratio is close to 100%, and it is also used in concrete without adverse effects in concrete durability.

Meanwhile, concrete is the most commonly used building material in the world (the world's production in 2012 amounted to 7 million m3 per year, i.e., three times more than wood and seven times more than steel per year). According to industry statistics published in The Global Cement Report, 13th Edition , the consumption of cement in the world increased by 2.8% per cent to 4.08 million tonnes in 2019. Therefore, there is a need to look for materials as a replacement for cement or aggregate. Recycled materials are used to limited energy consumption by the concrete industry and the production of concrete as an environmentally friendly material.

GLASS POWDER INFLUENCE

"Glass powder (GP) waste is one among the foremost active research areas" that attracted many researchers in the field of civil engineering and construction materials. The glass is produced as a commercial product commonly exist with different forms such as optical components, windows, mirrors, Shopfronts, balustrades, floor panels, doors, bulbs, tubes, bottles, jars, etc. For sustainable purposes, these limited lifetime products have to be reused in order to avoid environmental issues associated with their disposal . In addition, utilization of the glass in the construction sector is necessary to produce eco-friendly concrete from glass waste.

It has been demonstrated that glass powder of specific sizes and in certain proportions does not affect the mechanical properties of concrete . Moreover, Elaqra and Rustom stated that it is already known that the compressive and flexural strengths of concrete with GP as SCM are controlled by the chemical composition, amount and size of GP. It was proved that the smaller the particle size, the higher the pozzolanic activity , and the optimal size is in the 45–75 µm range. The influence of the amount of GP was widely studied, but it was determined that optimal results are achieved between 10–30%, and even amounts up to 15% enhance the compressive strength. The hydration of cement is also improved because of the particle size and the pozzolanic behavior of GP.

The studies revealed that extensive efforts were made to investigate the effects of using glass powder as partial cement replacement and identify the positive and negative impacts of the replacement process . However, more research is still needed to optimize the behavior of concrete with glass powder and increasing the glass reactivity, therefore, a new approach shall be innovated to introduce glass powder within the concrete matrix and optimizing the properties of concrete with glass powder.

The first manufactured glass was found in ancient Mesopotamia and its production has boosted since then to reach massive capacities, which inevitably entails major waste rates. In spite of the lack of information; in 2012 it was estimated that a high-income country produces 602 million tons of solid waste per year, 7% of which is glass . The main concern of waste glass production is the use of landfill, which is at odds with its properties that make it optimal for recycling .

Silica Fumes

The silica fume is also used by different scholars for investigating its cementitious property in the different works and usually supplied by the Structural Laboratory of Department of Civil Engineering. Silica fume is highly reactive pozzolanic material and is a by product from the production of silicon or ferro- silicon metal. It is composed from the flue gases from electric arc furnaces. Silica fume is very fine powder, with particles about 100th times minor than average cement grain. It is available in a water slurry form. It is used at 5% to 12% by mass of supplementary cementitious materials for concrete structures that requires high strength.

Fly Ash

Fly Ash is another material which is used as partial replacement of cement and has went through with different analysis mainly XRD analysis. Fly ash is largely made up of calcium oxide and silicon dioxide can be used as a substitute or as a supplent for Portland cement. Fly ash is also known as Green concrete.

Ordinary Portland Cement

The OPC(43 grade) used in the present work is of Ultratech brand. This is used as main binder in the mixes. Cement is the adhesive or glue element in concrete, which when set binds particles of aggregate (fine, coarse) together. Cement is a hydraulic material, this means that it depends upon a reaction with water rather than air for strength development. When water is added to cement, a chemical reaction called hydration commences immediately and continues while water is still present.

RECYCLING RATES OF GLASS WASTE

Recycling rates vary according to country. The US recycles just 26% of the 11.48 millions of tons of waste glass produced, while 61.3% ends up in landfills . By contrast, the EU28 reached 74%, the highest recycling rate in 2016, with peaks over 95% in Sweden, Belgium, the Netherlands, and Denmark . There is an imminent need to find a way to reduce the amount of glass waste in those countries where it is still not managed, and it has been proven that high levels of glass recycling can be achieved.

Glass powder (GP) appears to be a solution because it contains silica (SiO_2) in amounts greater than 70%, has high specific surface area and is amorphous in nature, which allows it to react with portlandite. Pozzolanic properties can be noted only with a particle size below 300 µm . The affinity between cement and glass powder can be taken advantage of to reduce the percentage of cement in concrete and manage waste glass generation.

The recycling of waste represents an opportunity in the concrete industry as alternative materials to replace cement and aggregates. Until this moment the only replacement used commonly is the crushed concrete as a replacement for natural aggregates. In the case of SCM, there is a small amount of slag, which comes from the recycling of steel and aluminum waste. There are two main sources for another type of SCM, the first is the Bottom Ash, which can come from the incineration of organic, paper, cartoon and wood. The glass waste represents the second SCMs, it can be grounded into a fine powder similar to cement size.

POZZOLANIC ACTIVITY

Many studies are rising around the world directing the employment of waste glass in construction technology. The concept is that glass powder can be used as a cement replacement in concrete to enhance the strength characteristics to a certain extent due to its pozzolanic activity. Therefore, this research study aims to introduce glass powder as a partial cement replacement and increasing the pozzolanic reactivity of glass within the concrete matrix, and then it highlights the positive impacts on the environment by reducing the quantities of a dumped solid waste of glassy products.

ENVIRONMENTAL IMPACT

Due to significant emphasis on increasing sustainability and environmental protection, there is also a need to take this into account in construction practices. The building and construction sector were responsible for 36% of the final energy consumption and 39% of energy and carbon dioxide (CO2) emissions associated with the process in 2018. Of this, 11% was due to the production of building materials and products such as steel, cement and glass. Cement production is an energy intensive process that accounts for 5% of the industrial energy consumption and 3% of the total energy consumption worldwide. Moreover, the production of one tonne of cement generates about

0.9 tonnes of CO2 by decarbonisation, which is released into an environment .

2.AIM AND OBJECTIVES

The overall objective of this research is to study the effect of the partial cement replacement by glass powder on both physical and mechanical characteristics of the concrete mix. This can be achieved by the following:

- Identify the influences of adding waste glass on the fresh properties of concrete mixes such as compressive strength test and capillary absorption test.
- Study the influence of partial cement replacement by glass powder on hardened properties of concrete mixes including compressive strength.
- Determine the optimum portion of glass powder to be added as a partial replacement of cement.
- Study the effect of different curing temperatures and temperature cycles on both physical and mechanical properties, and durability of concrete with glass powder.

As of late, Glasses and its powder has been utilized as a development material to diminish ecological issues. The coarse and fine glass aggregates could cause ASR (alkali-silica-reactions) in concrete , however the glass powder could stifle their ASR tendency, an impact like supplementary cementations materials (SCMs). Along these lines, glass is utilized as a substitution of supplementary cementitious materials.

THESIS FRAMEWORK

Chapter 1: Introduction: this chapter deals with the brief idea of thesis and importance of present study.

Chapter 2: Literature review: this chapter deals with the past work done on the project and reviw given by different people.

Chapter 3: Experimental work and Material used: This chapter includes the type of material I have used, their properties and various tests performed for finding their properties along with the experimental work.

Chapter 4: Methodology : this part describes the mix design involved ,how to obtain the samples and also deals with the different types of tests performed on the samples.

Chapter 5: Results and Discussions: This chapter has all the detailed graphs and the test results.

These graphs and the test results are thoroughly discussed in this chapter.

Chapter 6: Conclusion: After the study the conclusion is included in this chapter. At last we have references of the thesis.

3. LITERATURE REVIEW

Many works have been done to explore the benefits of using pozzolanic materials in making and enhancing the properties of concrete. One of the most attractive alternatives to waste disposal is waste recycling because of the limited area of landfills and due to its high cost of disposal. The utilization of waste products in concrete is an economical alternative, which concrete will become cheaper, furthermore minimizing the waste disposal cost.

Today a lot of research is ongoing into the replacement of Portland cement by waste materials and manufacturing products. These materials are known as Supplementary Cementitious Materials (SCM). For example, Silica fume (SF), Pulverized Fly Ash (PFA) and Ground Granulated Blast

Furnace Slag (GGBS). As well, waste Glass Powder (GP) has the potential as (SCM)

Shayan (2002) studied and carried out to examine the usefulness for the employment of waste glass in concrete in many forms. It concluded that positive impact in terms of concrete valueadding and cost recovery produced by the use of glass powder form in concrete. It was found that cement or aggregate could be replaced by 30% GP in concrete without damaging effects at the long-term age.

Bignozzi, et al., conducted to investigate using glass waste with various chemical composition as supplementary cementing materials. They concluded that both the pozzolanic progress and/or alkali-silica reactions are very dependable on the chemical composition of glass, which is the main responsible at developing the reactions conditions. It was also concluded that Glass waste is classified as a new source of pozzolanic addition for the production of sustainable cement.

M.D.A. Thomas, M.H.Shehata et al. have studied the ternary cementitious blends of Portland cement, silica fume, and fly ash offer significant advantages over binary blends and even greater enhancements over plain Portland cement.

Sandor Popovics has studied the Portland cement-fly ash - silica fume systems in concrete and concluded several beneficial effects of addition of silica fume to the fly ash cement mortar in terms of strength, workability and ultra-sonic velocity test results.

Jan Bijen have studied the benefits of slag and fly ash added to concrete made with OPC in terms of alkali-silica reaction, sulphate attack.

L. Lam, Y.L. Wong, and C.S. Poon studied entitled Effect of fly ash and silica fume on compressive and fracture behaviours of concrete had concluded enhancement in strength properties of concrete by adding a different percentage of fly ash and silica fume.

Tahir Gonen and Salih Yazicioglu studied the influence of binary and ternary blend of mineral admixtures on the short and long term performances of concrete and concluded many improved concrete properties in fresh and hardened states.

Mateusz Radlinski, Jan Olek and Tommy Nantung in their experimental work entitled Effect of mixture composition and Initial curing conditions on the scaling resistance of ternary concrete have found out the effect of different proportions of ingredients of ternary blend of binder mix on scaling resistance of concrete in low temperatures.

S.A. Barbhuiya, J.K. Gbagbo, M.I. Russeli, P.A.M. Basheer studied the properties of fly ash concrete modified with hydrated lime and silica fume concluded that addition of lime and silica fume improves the early days' compressive strength and long term strength development and durability of concrete.

Shalabi, Ibrahim Asi carried out Research work in Use of low CaO unprocessed steel slag in concrete as fine aggregate.Their conclusion is that regarding the compressive and tensile strengths of concrete steel slag is more advantageous for concretes of lower strengths.

O. Boukendakdji, S. Kenai, E.H. Kadri, F. Rouis carried out Research work in Effect of slag on the rheology of fresh self-compacted concrete. Their conclusion is that slag can produce good self-compacting concrete.

Shaopeng Wu, Yongjie Xue, Qunshan Ye, Yongchun Chen carried out Research work in Utilization of steel slag as aggregates for stone mastic asphalt (SMA) mixtures. Their conclusion is that The test roads shows excellent performances after 2 -years service, with abrasion and friction coefficient of 55BPN and surface texture depth of 0.8 mm.

Tahir Gonen, Salih Yazicioglu carried out research work in the influence of mineral admixtures on the short and long term performance of concrete, hence concluded that silica fume contributed to both short and long term properties of concrete, where as fly ash shows its beneficial effect in a relatively longer time. As far as the compressive strength is concerened, adding of both silica fume and fly ash slightly increased compressive strength, but contributed more to the improvement of transport properties of concrete.

M. Maslehuddin, Alfarabi M. Sharif, M. Shameem, M. Ibrahim and M.S Barry carried out experimental work on comparison of properties of steel slag and crushed limestone aggregate concretes, finally concluded that durability characteristics of steel slag cement concrete were better than those of crushed limestones aggregate concrete. Some of physical properties were better than of crushed lime stones concrete.

J. G. Cabrera and P. A. Claisse carried out experimental work on Oxygen and water vapour transport in cement pastes, hence concluded that the flow of oxygen is described by the Darcy equation, but the flow of water vapour is not. The different mechanisms of transmission cause the transmission rates for oxygen to be spread over a far greater range than those for water vapour with some of the SF samples almost impermeable to oxygen. containing silica fume as a partial replacement for cement, greatly contributes to strengthening the bond between the cement paste and aggregate. It was also demonstrated that super plasticizer in combination with silica fume plays a more effective role in mortar mixes than in paste mixes. This can be attributed to a more efficient utilization of super plasticizer in the mortar mixes due to the better dispersion of the silica fume.

Jigar p. patel carried out experimental work on broader use of steel slag aggregate in concrete, hence concluded that durability of steel slag aggregates concrete under freeze-thaw environment was the main goal in this research, as there was a belief that the steel slag aggregates have expansive characteristics and would cause cracking in concrete.

4.SUMMARY

The several number of literature reviews shows the importance glass waste research. Some carried out the experimental work on oxygen and water vapour transport in cement pastes, and finded out the oxygen flow but not the flow of water vapour. The various researches also included the influence of mineral admixtures on the short period and the long period of concrete performance. The researches also include the effect of flyash and silica fume on the compressive and the fracture behaviors on concrete.

5. METHODOLOGY

A design mix of M30 was received for the current investigation. The primary blend MC1 is control blend having just cement as blinder. The MCG arrangement had glass powder as substitution of cement. The compressive strength test were led to screen the quality improvement of concrete containing 15% and 30% of these pozzolana as cement substitution. The molecule size impact of glass powder concentrated by utilizing glass powder of size (150-100)μ and (50-100)μ.

Capillary absorption test is led to consider the impact of alkali aggregate reactions.

- The tests were conducted in two series.
- In first Series 30 % of pozzolana were used as partial replacement of cement.
- In second series 15% of pozzolana were used as partial replacement of cement.
- Eleven numbers of standard cubes (150x150x150 mm) were cast to measure the compressive strength after 07 days and 28 days. Two cube were retained to measure capillary absorption after 07 days and 28 days respectively.

To study the characteristics following tests were conducted :

Normal consistency

1) Normal consistency of different binder mixes determined by using the procedure referring to IS 4031: part 4 (1988):
2) 300 gram of sample coarser than 150μ sieve is taken.
3) Approximate percentage of water added to sample and mixed methodically for 2-3 minutes.
4) After applying oil to the surface of mould, paste was filled in the vicat's mould and was placed under the needle of vicat's apparatus.
5) Release quickly the needle allowing it to sink in the paste and note down the penetration reading when the needle becomes stable.
6) If the penetration reading is less than 5 to 7 mm, prepare the paste again with more water and repeat the above procedure until the needle penetrates to a depth of 5 to 7 mm.
7) The percentage of the water with which the above situation is satisfied is called normal consistency.

For each series, five-set were cast to determine compressive strength. Each set comprises of eleven standard cubes out of which nine cubes were cast to measure the compressive strength after 07days and 28 days. The size of the cube is as per the IS code 10086 – 1982.

6. Procedure:

- The sample was dried in oven at 105oC until constant mass was obtained.
- Sample was cool down to room temperature for 6hr.
- The side of the sample was coated with paraffin to attain unidirectional flow.
- The sample was exposed to water on one side by placing it on a pan filled with the water.
- The water in the pan was kept about 5mm above the base of the specimen as shown in the figure below.
- The weight of the sample was measured at 15 and 30 minutes intervals.
- The capillary absorption coefficient (k) was calculated by using formula:

k= Q/A* sqrt (t)

where, Q= amount of water absorbed A = cross sectional area in contact with water t = time

7.WORKABILITY OF CONCRETE

The final output results for different sample groups regarding slump values for fresh concrete are listed in table 4.1 The slump test was also conducted after 15 minutes to measure the slump loss from the time of original batching.

The results show that the workability increases gradually by the increase of glass powder content. The increase in workability can be attributed to the presence of more free water in the mix as the amount of the glass powder increases, which the ratio of water to cement content increase linearly as a function of GP content where as the slump after 15 minutes decreased due to the use of free water in the formation of hydrate products.

EXPERIMENTAL WORK AND MATERIAL USED

Materials

The materials used in this present work are glass powder, Ordinary Portland cement(43 grade).

Glass Powder

The glass powder used in the present study is brought from Indian market. This material replaces the cement in mix proportion. Particle size distribution graph and XRD analysis of glass powder were done and shown in Fig.4.2 and Fig.4.3 respectively.

Ordinary Portland Cement

The OPC(43 grade) used in the present work is of Ultratech brand. This is used as main binder in the mixes.

Fine Aggregate

Naturally available sand from river bed is used as fine aggregate in the present work. The most common constituent of sand is silica, usually in the form of quartz, which is chemical inert and hard. Hence used as a fine aggregate in concrete. The sieve analysis of sand is shown in table 4.2.

As per IS383 the sand falls under zone 2.

Coarse Aggregate

The coarse aggregate, available in structural engineering lab of the civil engineering department. The sieve analysis of 20mm and 10mm downsize is shown in and sieve analysis in respectively.

4.6 MIX DESIGN CALCULATION

The mix design for M30 grade of concrete is described below in accordance with Indian Standard Code IS: 10262-2019.

TARGET STRENGTH FOR MIX PROPORTIONING:

Characteristic compressive strength at 28 days: fck = 30 Mpa

Assumed standard deviation (Table 2 of IS 10262:2019): s = 5 Mpa

Target average compressive strength at 28 days: ftarget = fck + 1.65s =38.25 Mpa

SELECTION OF WATER- CEMENT RATIO:

From Table 5 of IS: 456-2000, maximum water-cement ratio = 0.50

Water-cement ratio taken = 0.45

SELECTION OF WATER CONTENT:

Maximum water content per cubic metre of concrete (refer Table 4 of IS: 10262- 2019):

Wmax = 186 kg (for 50 mm slump).

Table 4.7 **Maximum Water Content As Per IS 10262 2019**

S.No 1	Nominal num Size aggregate 2	Water ıt (kg) 3
i)	10	208
ii)	20	186
iii)	40	165

Since, the slump was less than 50 mm, no adjustment was required.

CEMENT CONTENT CALCULATOIN:

Mass of water per cubic metre of concrete = 186 kg.

Mass of cement per cubic metre of concrete = 186/0.45 = 413 kg.

Minimum cement content = 320 kg/m^3 (for severe exposure condition, Table 5 of IS 456:2000)

Maximum cement content = 450 kg/m^3 (Section 8.2.4.2 of IS 456:2000), hence selected cement content is ok.

PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT:

Volume of coarse aggregate per unit volume of total aggregate,

As per (Table 5 of IS: 10262-2019) = 0.62

(Corresponding to 20 mm size aggregate and Zone II fine aggregate for water-cement ratio of 0.50).

As the water-cement ratio is lowered by 0.05, the proportion of volume of coarse aggregate is increased by 0.01 (Section 5.5.1 of IS: 10262-2019).

Hence the corrected volume of coarse aggregate per unit volume of total aggregate = (0.62+0.01) = 0.63

Therefore, volume of fine aggregate per unit volume of total aggregate = 1-0.63 = 0. 37.

MIX CALCULATIONS:

I Volume of concrete = 1 m^3

II Volume of cement = mass of cement/sp gravity X 1000

$= 413 / (3.05 \times 1000) = 0.135\ m^3$

III Volume of water = mass of water /sp gravity X 1000

$186/1000 = 0.186\ m^3$

IV Volume of all aggregates = $1 – (0.135 + 0.186) = 0.679\ m^3$

V Coarse aggregate mass = g x volume of coarse aggregate X specific gravity of coarse aggregate x 1000

$= 0.63 \times 0.679 \times 2.7 \times 1000 = 1155\ kg/m^3$

VI Fine aggregate mass = g X volume of fine aggregate X specific gravity of fine aggregate X 1000

$= 0.37 \times 0.679 \times 2.65 \times 1000 = 666\ kg/m^3$

MIX PROPORTIONS

For a batch of 3 cubes of 150 mm side, the volume of concrete required = $(0.15)^3 \times 3 \times 1.2 = 0.0122\ m^3$

(taking into account 20 % extra for losses)

Cement required = 0.0122 x 413 = 5.04 kg

Fine aggregate required = 0.0122 x 666 = 8.12 kg

Coarse aggregate required = .0122 x 1155 = 14.091 kg

Water required = .0122 x 186 =2.26

8.RESULTS AND DISCUSSIONS

Where, MC= pure cement,

GP= glass powder

DESIGN	07 days n2)	28 days n2)
MC1	21.03	25.33
MCG21	13.77	14.67
MCG22	15.11	19.57

The results of compressive strength testing of laboratory-cured cubes are presented in Table 5.2(a) and Table 5.2(b) for First series with 30% cement replacement and Second series with 15% cement replacement respectively. The strength values reported are the average of three test results.

Compressive Strength of series after 07 days and 28 days were tabulated below: Table 5.2(a)

First Series: 30% Replacement Of Glass Powder

DESIGN	07 days n2)	28 days n2)
MC1	21.03	25.33
MCG11	12.88	14.57
MCG12	14.22	17.05

Where, Where, Mix MC1= Only OPC cement

Mix MCG11= cement+ 30% glass powder (150-100) micron Mix MCG12= cement + 30% glass powder (<100) micron

Second Series: 15% Replacement Of Glass Powder Table 5.2(b)

Where, Mix MC1= Only OPC cement

Mix MCG21= cement+ 15% glass powder (150-100) micron

Mix MCG22= cement + 15% glass powder (100-50) micron

Graph Comparison Of 30% replacement And 15% Replacement Of Glass Powder

Fig 5.1 **Compressive Strength Of Mixes With 30% Replacement**

Fig 5.2 Compressive Strength Of Mixes With 15% Replacement

CONCLUSION

The aim of the study was to assess the possibility of using a glass powder made from post-consumer waste glass (food, medicine, and cosmetics packaging, including mostly bottles) in concrete that is difficult to recycle and is stored in large quantities in landfills. The three different contents of glass cullet with a sharp edge(powdered) and rougher surface texture were carried out as a replacement for mixes in mortar. It was 15 and 30 wt.% of glass powder(mostly of the green glass cullet). Based on the results of this experimental investigation, the following key conclusions can be drawn:

1. Waste glass, if ground finer than 100μm shows a pozzolanic behavior.
2. The smaller particle size of the glass powder has higher activity with lime resulting in higher compressive strength in the concrete mix.
3 . Compared to fly ash concrete, finer glass powder concrete had slightly higher early strength as well as late as strength.
4. The coefficient of capillary absorption test also indicates that incorporation of finer glass powder improves durability.
5. Glass powder of size 150μm - 100μm exhibit initiation of alkali-aggregate reaction. The presence of ettringite confirms this.

6. The results obtained from the present study shows that there is great potential for the utilization of best glass powder in concrete as replacement of cement.

7. The fine glass powder can be used as a replacement for expensive materials like silica fume and fly ash.

8. It can be concluded that 30% of glass powder of size less than 100μm could be included as cement replacement in concrete without any unfavorable effect .

Based on the above, it seems that the increase in mechanical properties of mortar/concrete with the addition of glass sand is probably resulting from the pozzolanic activity. This will be the subject of further research, in which tests for other types of cement, other types of glass waste and its mixes, and different contents and the size of the aggregate particle, with particular emphasis on long-term fatigue tests are planned to be carried out.

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