STUDIES ON UTILIZATION OF WASTE GLASS POWDER IN CONCRETE MAKING

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ABSTRACT: This work examines the possibility of using Glass powder as a partial replacement of cement for new concrete. The global cement industry contributes about 7% of greenhouse gas emission into the earth's atmosphere. Among the greenhouse gases; CO_2 contributes about 65% of global warming. Cement industry is one of the major contributors of CO_2 emission. Consequently, efforts have been made in the concrete industry to use waste materials as partial replacement of coarse or fine aggregates and cement. Waste glass is one materials when ground to a very fine powder shows pozzolanic properties which can be used as a partial replacement for cement in concrete. In this paper, an attempt has been made to find out the strength of concrete containing waste glass powder as a partial replacement of cement for concrete. For this, finely powdered waste glasses are used as a partial replacement of cement in concrete and compared it with conventional concrete. Glass powder was partially replaced cement by 5%, 10%, 15%, 20%, 25%, 30%, 35%, and 40% and tested for its compressive, split tensile and flexural strength at 7 days, 28 days of age and were compared with those of conventional concrete. From the results obtained, it is found that glass powder can be used as cement replacement material up to 20 % and beyond 20%, the strength decreases.
KEYWORDS: Glass powder, Admixture, Compressive Strength, Flexural Strength, Split tensile Strength.

I. INTRODUCTION

Concrete is the world's most consumed man-made material. To produce 1 ton of Portland cement, 1.5 tons of raw materials are needed. These materials include good quality limestone and clay. Therefore, to manufacture 1.5 billion tons of cement annually, at least 2.3 billion tons of raw materials are needed. Over 5-million BTU of energy is needed to produce one tone of cement. Concrete solidifies and hardens after mixing with water and placement due to a chemical process known as hydration. The water reacts with the cement, which bonds the other components together, eventually creating a stone-like material. Concrete is used to make pavements, architectural structures, foundations, and motor ways/roads, bridges/overpasses, parking structures, brick/block walls and footings for gates, fences and poles. Concrete is an artificial material in which the aggregates both fine and coarse are bonded together by the cement when mixed with water. Concrete has unlimited opportunities for innovative applications, design and construction techniques. It's great versatility and relative economy in filling wide range of needs has made it is very competitive building material. With the advancement of technology and increased field of applications of concrete and mortars, the strength workability, durability and other characters of the ordinary concrete need modifications to make it more suitable for all situations. Added to this is the necessity to combat the increasing cost and scarcity of cement. Under these circumstances the use of admixtures is found to be an important alternative solution. Regular concrete is the lay term describing concrete that is produced by following the mixing instructions that are commonly published on packets of cement, typically using sand or other common material as the aggregate, and often mixed in improvised containers. This concrete can be produced to yield a varying strength from about 10 MPa (1450 psi) to about 40 MPa (5800 psi), depending on the purpose, ranging from blinding to structural concrete respectively. Many types of pre-mixed concrete are available which include powdered cement mixed with aggregate, needing only water.

NEED FOR PRESENT INVESTIGATION

Over decades, attempts have been made to obtain concrete with certain desired characteristics such as high compressive strength, high workability, and high performance and durability parameters to meet the requirement of complexity of modern structures. The properties commonly modified are the heat of hydration, accelerate or retard setting time, workability, water reduction, dispersion and air-entrainment, impermeability and durability factors. Though a lot of research is focused in the last decade on use of various admixtures in producing concrete, very little information is available on glass powder concrete. This new admixture has got lot of potential for use in concrete. Hence, there is need to study the strength and workability characteristics of glass powder as admixture in concrete. An admixture is a material other than water, aggregates, or cement that is used as an ingredient of concrete or mortar to control setting and early hardening, workability, or to provide additional cementing properties.

GLASS POWDER:

Glass is a non-crystalline amorphous solid that is often transparent and has widespread practical, technological, and decorative usage in, for example, window panes, tableware, and optoelectronics. Scientifically, the term "glass" is often defined in a broader sense, encompassing every solid that possesses a non-crystalline (that is, amorphous) structure at the atomic scale and that exhibits a glass transition when heated towards the liquid state. The most familiar, and historically the oldest, types of glass are "silicate glasses" based on the chemical compound silica (silicon dioxide, or quartz), the primary constituent of sand. The term glass, in popular usage, is often used to refer only to this type of material, which is familiar from use as window glass and in glass bottles. Different waste glass powders are shown in Figure 1. Below.

Figure 1. Different Waste Glass Powders

Of the many silica-based glasses that exist, ordinary glazing and container glass is formed from a specific type called soda-lime glass, composed of approximately 75% silicon dioxide (SiO2), sodium oxide (Na2O) from sodium carbonate (Na2CO3), calcium oxide, also called lime (CaO), and several minor additives. A very clear and durable quartz glass can be made from pure silica, but the high melting point and very narrow glass transition of quartz make glassblowing and hot working difficult. In glasses like soda lime, the compounds added to quartz are used to lower the melting temperature and improve workability, at a cost in the toughness, thermal stability, and optical transmittance.

Many applications of silicate glasses derive from their optical transparency, which gives rise to one of silicate glasses' primary uses as windowpanes. Glass will transmit, reflect and refract light; these qualities can be enhanced by cutting and polishing to make optical lenses, prisms, fine glassware, and optical fibers for high-speed data transmission by light. Glass can be colored by adding metallic salts, and can also be painted and printed with vitreous enamels. These qualities have led to the extensive use of glass in the manufacture of art objects and in particular, stained windows. Although brittle, silicate glass is extremely durable, and many examples of glass fragments exist from early glass-making cultures. Because glass can be formed or moulded into any shape, and also because it is a sterile product, it has been traditionally used for vessels: bowls, vases, bottles, jars and drinking glasses. In its most solid forms it has also been used for paperweights, marbles, and beads. When extruded as glass fibre and matted as glass wool in a way to trap air, it becomes a thermal insulating material, and when these glass fibres are embedded into an organic polymer plastic, they are a key structural reinforcement part of the composite material fibre glass. Some objects historically were so commonly made of silicate glass that they are simply called by the name of the material, such as drinking glasses and reading glasses. In science, porcelains and many polymer thermoplastics familiar from everyday use are glasses too. These sorts of glasses can be made of quite different kinds of materials than silica: metallic alloys, ionic melts. From the literature it is observed that the effect of adding Glass Powder to concrete is to improve the properties of concrete. The use of Glass Powder as an admixture will have an impact on the durability and the thermal insulation. The other benefit of addition of Glass Powder is to minimize the risk of the Environmental Pollution. The use of recycled glass as aggregate greatly enhances the aesthetic appeal of the concrete. Recent research findings have shown that concrete made with recycled glass aggregate have shown better long term strength and better thermal insulation due to its better thermal properties of the glass aggregates.

OBJECTIVE OF WORK: The main objective of the present investigation is to find the suitability of glass powder as a partial replacement to cement. For this, finely powdered waste glasses are used as a partial replacement of cement in concrete and compared it with conventional concrete.

II. MATERIALS USED

Experiments were conducted on concrete prepared by partial replacement of cement by waste glass powder of particle size 75μm.The the waste glass powder was replaced by 5%, 10%, 15%, 20%, 25%, 30%, 35%, and 40%of the binder and the mix design was prepared. In all mixes the same type of aggregate i.e. crushed granite aggregate; river sand and the same proportion of fine aggregate to total aggregate are used. For each mix, 6 cubes of size 150 x 150 x 150 mm and 6 cylinders of 150 mm diameter & 300 mm height and 6 flexural beams of size 500 x 100 x 100 mm were cast and tested. The test programmed consisted of conducting Compressive tests on Cubes, Split Tensile tests on Cylinders and Flexural strength on beams.

CEMENT: Cement is a well-known building material and has occupied an indispensable place in construction works. Different varieties of cements are available in the market and each type is used under certain conditions due to its special properties. The cement commonly used is Portland cement, and the fine and coarse aggregates used are those that are usually obtainable, from nearby sand, gravel or rock deposits. In order to obtain a strong, durable and economical concrete mix, it is necessary to understand the characteristics and behavior of the ingredients. 53 grade OPC is used in this work

AGGREGATES: Aggregates are generally cheaper than cement and impart greater volume stability and durability to concrete. The aggregate is used primarily for the purpose of providing bulk to the concrete. To increase the density of the resulting mix, the aggregate is frequently used in two or more sizes. The aggregates provide about 75% of the body of the concrete and hence its influence is extremely important. Aggregate was originally viewed as an inert, inexpensive material dispersed throughout the cement paste so as to produce a large volume of concrete. In fact, aggregate is not truly inert because it's physical, thermal and, sometimes, chemical properties influence the performance of concrete, for example, by improving its volume stability and durability over that of the cement paste. From the economic viewpoint, it is advantageous to use a mix with as much aggregate and as little cement as possible, but the cost benefit has to be balanced against the desired properties of concrete in its fresh and hardened state.

WATER: Generally, cement requires about 3/10 of its weight of water for hydration. Hence the minimum water-cement ratio required is 0.35. But the concrete containing water in this proportion will be very harsh and difficult to place. Additional water is required to lubricate the mix, which makes the concrete workable. This additional water must be kept to the minimum, since too much water reduces the strength of concrete. The water-cement ratio is influenced by the grade of concrete, nature and type of aggregates, the workability and durability. If too much water is added to concrete, the excess water along with cement comes to the surface by capillary action and this cement-water mixture forms a scum or thin layer of chalky material known as laitance this laitance prevents bond formation between the successive layers of concrete and forms a plane of weakness. The excess water may also leak through the joints of the formwork and make the concrete honeycombed. As a rule, the smaller the percentage of water, the stronger is the concrete subject to the condition that the required workability is allowed for.

GLASS POWDER: Glass is one of the oldest man-made materials. It is produced in many forms such as packaging or container glass, flat glass, and bulb glass, all of which have a limited life in their manufactured forms and therefore need to be recycled so as to be reusable in order to avoid environmental problems that would be created if they were to be stockpiled or sent to landfills. Quantities of waste glass have been rising rapidly during the recent decades due to the high increase in industrialization and the considerable improvement in the standards of living, but unfortunately, the majority of these waste quantities are not being recycled but rather abandoned causing certain serious problems such as the waste of natural resources and environmental pollution. Recycling of this waste by converting it to aggregate components could save landfill space and also reduce the demand for extraction of natural raw material for construction activities. Glass powder of different grades is shown in the following Figure 2.

Figure 2. Glass powder in different grades

Theoretically, glass is a fully recyclable material; it can be recycled without any loss of quality. There are many examples of successful recycling of waste glass: as a cullet in glass production, as raw material for the production of abrasives, in sand-blasting, as a pozzolanic additive, in road beds, pavement and parking lots, as raw materials to produce glass pellets or beads used in reflective paint for highways, to produce fiber glass. In this study, finely powdered waste glasses are used as a partial replacement of cement in concrete and compared it with conventional concrete. Concrete mixtures were prepared with different proportions of glass powder ranging from 5 to 40% with an increment of 5% and tested for compressive strength after 7, 28 and 90 days of Table below lists some of approximate compositions and the corresponding uses of various common forms of glass. Waste glass available locally was collected and made into glass powder. Glass waste is very hard material. Before adding glass powder in the concrete it has to be powdered to desired size. In this study glass powder ground in ball mill/ pulverizer for a period of 30 to 60 minutes resulted in particle sizes less than size 150 µm and sieved in 75 µm. The physical, chemical properties and chemical composition are presented in the table 1,2 & 3.

Table 1.Physical properties of glass powder

S.NO	PHYSICAL PROPERTIES OF GLASS POWDER	
1.	Specific gravity	2.6
2.	Fineness Passing 150µm	99.5
3.	Fineness Passing 90µm	98

Table 2. Chemical properties of glass powder

S.NO	PHYSICAL PROPERTIES OF GLASS POWDER	
1.	pH	10.25
2.	Colour	Greyish white

Table 3. Chemical Composition of glass powder

S.NO	CHEMICAL PROPERTIES OF GLASS POWDER	% BY MASS
1.	SiO_2	67.330
2.	Al_2O_3	2.620
3.	Fe_2O_3	1.420
4.	TiO_2	0.157
5.	CaO	12.450
6.	MgO	2.738
7.	Na_2O	12.050
8.	K_2O	0.638
9.	ZrO_2	0.019
10.	ZnO	0.008
11.	SrO	0.016
12.	P_2O_5	0.051
13.	NiO	0.014
14.	CuO	0.009
15	Cr_2O_3	0.022

III. METHODOLOGY

To evaluate the strength characteristics in terms of compressive, split tensile and flexural strengths, a total of 9 mixes were tried with different percentages of Glass powder (0, 5, 10, 15, 20, 25, 30, 35 & 40%) In all mixes the same type of aggregate i.e. crushed granite aggregate; river sand and the same proportion of fine aggregate to total aggregate are used. The relative proportions of cement, coarse aggregate, sand and water are obtained by IS - Code method. M20 is considered as the reference mix. For each mix, 6 cubes of size 150 x 150 x 150 mm and 6 cylinders of 150 mm diameter & 300 mm height and 6 flexural beams of size 500 x 100 x 100 mm were cast and tested. The test programmed consisted of conducting Compressive tests on Cubes, Split Tensile tests on Cylinders and Flexural strength on beams at 7 and 28 days. All the materials used in this investigation i.e. cement, fine aggregate, coarse aggregate, and glass powderwere mixed thoroughly manually. Care has to be taken in mixing to avoid balling effect. For all test specimens, moulds were kept on table vibrator and the concrete was poured into the moulds in three layers by tamping with a tamping rod and the vibration was effected by table vibrator after filling up moulds. The moulds were removed after twenty four hours and the specimens were kept immersed in clean water tank. After curing the specimens in water for a period of 7 days, 28 days the specimens were taken out and allowed for drying under shade before testing.

IV. RESULTS AND DISSUSSION

TEST RESULTS:

This section provides the results obtained from various tests conducted in this work. The different results obtained from Compressive Strength test for 7 days, 28 days, and Split Tensile Strength tests for 7 days, 28 days, and Flexural Strength test for 7 days, 28 days are presented in tables 4, 5 and 6. Also the variations of strengths with percentage glass powder are graphically represented in the following Figures from 3 to 8.

COMPRESSIVE STRENGTH:

Table 4.Compressive strength in concrete with age

PERCENTAGE REPLACEMENT OF GLASS POWDER(GP)	COMPRESSIVE STRENGTH, MPa	
	7 Days	28 Days
0 % GP	14.97	23.04
5 % GP	15.30	23.54
10 % GP	16.07	24.73
15 % GP	16.25	25.01
20 % GP	16.32	25.12
25 % GP	15.91	24.48
30 % GP	15.07	23.41
35 % GP	15.07	23.19
40 % GP	14.95	23.01

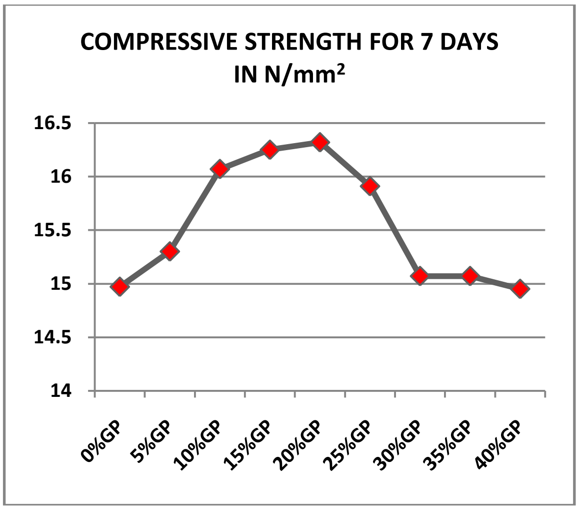

Figure 3. Variation of Compressive strength with % Glass Powder(GP) for 7 days

The variation of compressive strength with percentage glass powder is shown in Figure 3 and 4 for 7day and 28 days curing respectively. In the above Figure 3 there is an increase in compressive strength up to 20% replacement of glass powder and beyond that, increasing percentage of glass powder decreases the compressive strength. So 20% replacement of glass powder is found to be optimum for 7 days compressive strength.

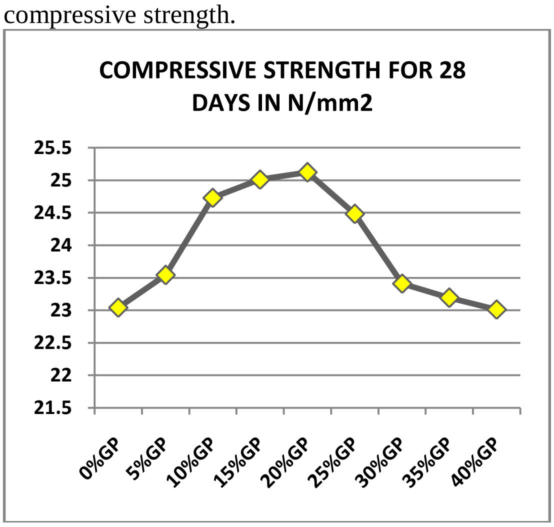

Figure 4. Variation of Compressive strength with % Glass Powder(GP) for 28 days

From the above figure 4, it is observed that there is an increase in compressive strength up to 20% replacement of glass powder and beyond that increasing percentage of glass powder decreases the compressive strength. Hence 20% replacement of glass powder is found to be optimum for 28 days compressive strength.

FLEXURAL STRENGTH

The variation of Flexural strength with percentage glass powder is shown in Figure 5 and 6 for 7day and 28 days curing respectively and presented in table 5.

Table 5.Flexural strength in concrete with age

PERCENTAGE REPLACEMENT OF GLASS POWDER	FLEXURAL STRENGTH, MPa	
	7 Days	28 Days
0 % GP	2.41	3.98
5 % GP	2.43	3.51
10 % GP	2.49	3.60
15 % GP	2.51	3.62
20 % GP	2.51	3.63
25 % GP	2.48	3.58
30 % GP	2.41	3.50
35 % GP	2.41	3.49
40 % GP	2.40	3.47

In the above figure 5, there is an increase in flexural strength up to 20% replacement of glass powder and beyond that increasing percentage of glass powder decreases the flexural strength. So 20% replacement of glass powder is optimum for 7 days flexural strength.

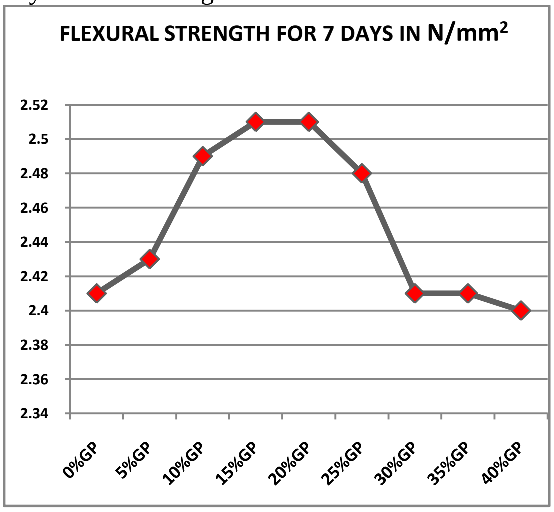

Figure 5. Variation of Flexural strength with % Glass Powder(GP) for 7 days

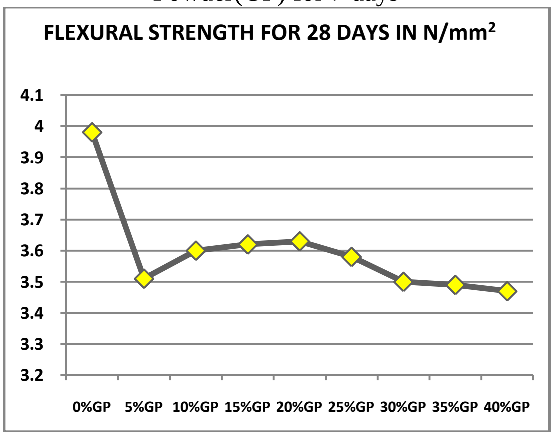

Figure 6. Variation of Flexural strength with % Glass Powder(GP) for 28days

From the figure 6, it was understood that flexural strength is lower when glass powder added, compared to conventional (0% GP) concrete. In above figure 6, there is an increase in flexural strength up to 20% replacement of glass powder and beyond that increasing percentage of glass powder decreases the flexural strength. So 20% replacement of glass powder is optimum for 28 days flexural strength.

SPLIT TENSILE STRENGTH

The variation of Split Tensile strength with percentage glass powder is shown in Figure 7 and 8 for 7day and 28 days curing respectively and presented in table 6.

Table 6. Split Tensile strength in concrete with age

PERCENTAGE REPLACEMENT OF GLASS POWDER	SPLIT TENSILE STRENGTH, MPa	
	7 Days	28 Days
0 % GP	1.50	2.10
5 % GP	1.60	2.22
10 % GP	1.61	2.24
15 % GP	1.65	2.30
20 % GP	1.66	2.31
25 % GP	1.41	2.22
30 % GP	1.40	2.18
35 % GP	1.40	2.20
40 % GP	1.30	2.21

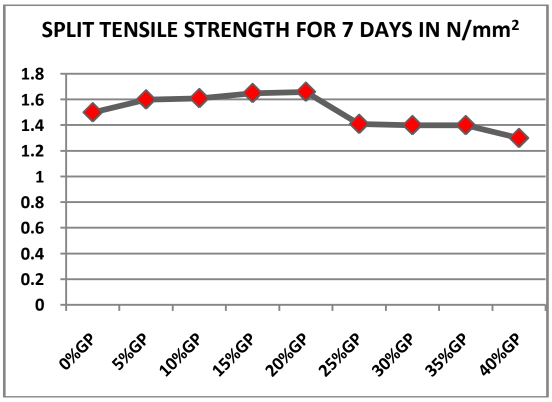

Figure 7. Variation of Split tensile strength with % Glass Powder(GP) for 7 days

In above figure 7, there is an increase in split tensile strength up to 20% replacement of glass powder and beyond that increasing percentage of glass powder decreases the Split tensile strength. So 20% replacement of glass powder is optimum for 7days Split tensile strength.

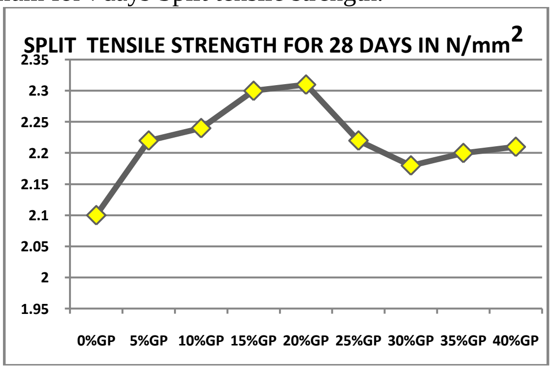

Figure 8. Variation of Split tensile strength with % Glass Powder(GP) for 28 days

In above figure 8, there is an increase in split tensile strength up to 20% replacement of glass powder and beyond that increasing percentage of glass powder decreases the split tensile strength. So 20% replacement of glass powder is optimum for 28days Split tensile strength.

V. CONCLUSIONS

Based on experimental observations, the following conclusions are drawn:
Waste Glass powder can be effectively utilized in concrete making and hence reduces the cement costs and pollution problem.

- Compressive strength increases with an increase in percentage of glass powder up to 20% replacement of cement and beyond 20% strength decreases.
- Flexural strength is low when glass powder is added to concrete.
- Flexural strength also increases with increase in percentage of glass powder upto 20% replacement and of cement beyond 20% strength drops down.
- Split tensile strength increases with an increase in percentage of glass powder up to 20% replacement of cement and beyond 20% strength decreases.
- Considering the strength criteria, the replacement of cement by glass powder is feasible. Therefore we can conclude that waste glass powder can be used as a partial replacement to cement up to 20%.

Scope for further studies:
The workability, durability and other aspects of concrete can be studied under varied environmental conditions.

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