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EFFECT OF GLASS ON STRENGTH OF CONCRETE SUBJECTED TO SULPHATE ATTACK

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ABSTRACT

Quantities of waste glass have been on the rise in recent years due to an increase in industrialization and the rapid improvement in the standard of living. Unfortunately, the majority of waste glass is not being recycled but rather abandoned, and is therefore the cause of certain serious problems such as the waste of natural resources and environmental pollution. This paper has attempted to provide concise information of strength of concrete containing waste glass powder when subjected to sulphate attack. Cement replacement by glass powder in the range 5% to 40% in increments of 5 percentages has been studied. Replacement of 20% cement by glass powder was achieved higher strength when concrete was subjected to sulphate attack

Key Words: waste glass powder, Strength, Sulphate attack,

1. INTRODUCTION

Utilization of waste glass is very important for human development because huge amount of glass waste produce by human increases the need of land to get rid Use up precious landfill space, decreasing possible area that can be used for landfills of other waste increasing the need to establish new expansive landfills ,lactates and gas releases from the landfill site degrade communities living condition and harmful to human health ,location of most recycling plants are built within low income neighborhoods because of cheap labor and strict regulation may affect respiratory system if breath in pollutants. Case-local residents at Mercedes Arumbula claimed that the neighborhood and kids have developed asthma once the plant was built in their community ,Glass is non-biodegradable (remains in our environment and do not decompose easily by itself therefore do not have significant environmental and social impact could result in serious impact after disposal. Table no. 1 gives the chemical composition of the cementing materials. The particle size distribution of the glass powder and cement are shown in figure 1.

Irrespective of the nature of their products, almost all industries produce waste. Effective disposal of wastes therefore is a challenging task. In olden days, solid wastes were used as landfills in low-lying areas. Waste disposal in landfill sites however are unsustainable in the end. Industrial wastes like fly ash, silica fume, blast furnace slag etc. and other wastes of plastics, glass, tiles and agriculture are causing environmental pollution. Recycling of wastes is therefore emerging as an important component of technology for contributing towards sustainability

Wastes are produced by the industries irrespective of the nature of their products. Disposal of wastes is a challenging task for industries. Industrial wastes like fly ash, silica fume, blast furnace slag and other wastes like plastics, glass and agricultural wastes are causing environmental pollution. The concrete industry to some extent is making use of these industrial wastes in the production of concrete. Generally, wastes like fly ash, silica fume and blast furnace slag in concrete act as pozzolana and replace a part of cement. Pozzolanic reaction adds to the strength of concrete and also results in saving of cement. Waste glass when ground to a very fine powder shows pozzolanic properties as it contains high SiO_2 and therefore to some extent can replace cement in concrete and contribute in strength development.

Glass is an amorphous solid that has been around in various forms for thousands of years and has been manufactured for human use since 12,000 BCE. The status of glass as a liquid, versus a solid, has been hotly debated. The short story is that glass is a super cooled liquid, meaning that it is rigid and static but does not change molecularly between melting and solidification into a desired shape. Glass is one the most versatile substances on Earth, used in many applications and in a wide variety of forms, from plain clears glass to tempered and tinted varieties, and so forth. Glass occurs naturally when rocks high in silicates melt at high temperatures and cool before they can form a crystalline structure. Obsidian or volcanic glass is a well-known example of naturally occurring glass, although it can also be formed by a lightning strike on a beach, which contains silicate-rich sand. Early forms of glass were probably rife with impurities and subject to cracking and other instability, but examples of glass beads, jars, and eating materials first appeared in ancient Egyptian culture. When manufactured by humans, glass is a mixture of silica, soda, and lime. Other materials are sometimes added to the mixture to “frost” or cloud the glass or to add color. The elements of glass are heated to 1800° Fahrenheit (982° Celsius). The resulting fused liquid can be poured into molds or blown into various shapes, and when cooled, glass is a strong, minimally conducting substance that will not interact with materials stored inside. As a result, glass is frequently used in scientific laboratories to minimize inadvertent chemical reactions and to insulate power lines.

Table 1 Chemical composition of cementing materials

Composition (% by mass)/ property	Cement	Glass powder
Silica (SiO2)	20.2	72.5
Alumina (Al_2O_3)	4.7	0.4
Iron oxide (Fe_2O_3)	3.0	0.2
Calcium oxide (CaO)	61.9	9.7
Magnesium oxide (MgO)	2.6	3.3
Sodium oxide (Na_2O)	0.19	13.7
Potassium oxide (K_2O)	0.82	0.1
Sulphur trioxide (SO_3)	3.9	-
Loss of ignition	1.9	0.36
Fineness % passing (sieve size)	97.4(45 μm)	80 (45 μm)

2. LITERATURE REVIEW

The concrete industry has been making use of industrial wastes like fly ash, silica fume, blast furnace slag as pozzolana by replacing a part of cement.[1] While Pozzolanic reaction adds to the strength of concrete, and the utilization of these materials brings about economy in concrete manufacture. It has been estimated that several million tons of waste glasses are generated annually world wide[2]. The key sources of waste glasses are waste containers, window glasses, windscreen, medicinal bottles, liquor bottles, tube lights, bulbs, electronic equipments, etc. Only a part of this waste glass can be recycled. A majority of the waste glass remains unutilized.

Waste glass is a major component of the solid waste stream in many countries and is generally used in landfills[3]. As an alternative, however, waste glass could be used as a concrete aggregate, either as a direct replacement for normal concrete aggregates (low value) or as an exposed, decorative aggregate in architectural concrete products (high value). Expansive alkali silica reactions (ASR) can occur between glass particles and cement paste, particularly in moist conditions and high alkali cements. This reaction can occur whenever aggregates contain reactive silica. However it is now well known that by controlling cement alkali level and moisture, the reaction can be mitigated [4, 6]. Research has shown that the waste glass can be effectively used in concrete either as aggregate or as pozzolana. Waste glass when ground to a very fine powder shows pozzolanic properties. Therefore, glass powder shows pozzolanic properties. Therefore, glass powder can partially replace cement and contribute to strength development. Finely ground glass has the appropriate chemical composition including SiO_2 to react with alkalis in cement

(Pozzolanic Reaction) and form cementitious products that help contribute to the strength development[5].

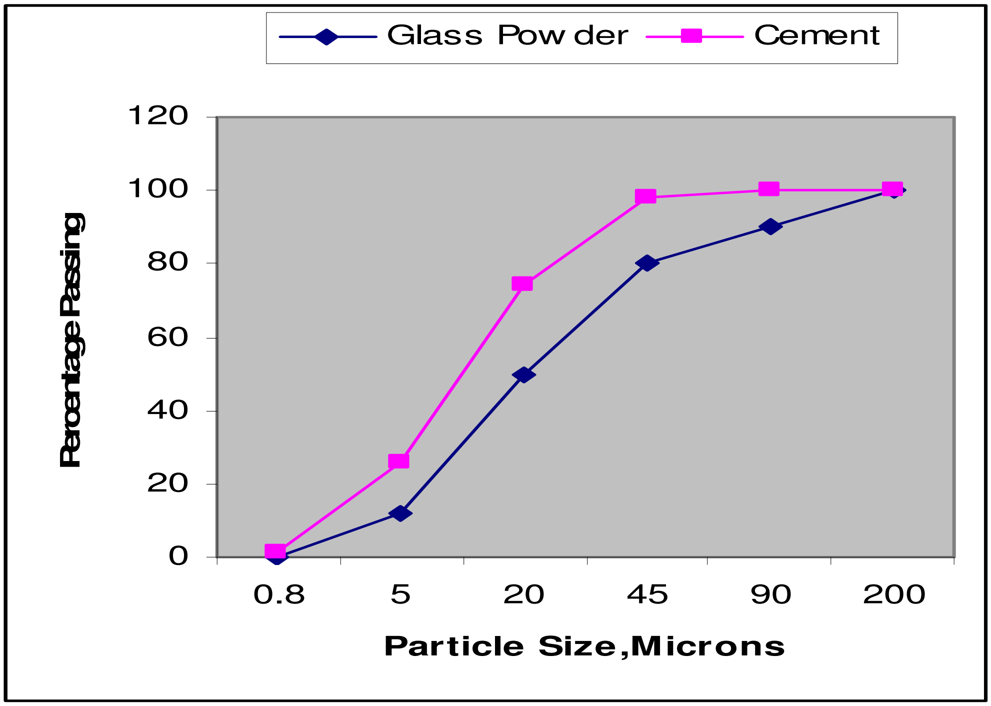

Figure 1. Particle Size Distributions of Cementitious Materials

3. RESEARCH SIGNIFICANCE

Recycling, disposal and decomposing of waste glass possesses major problems for municipalities everywhere, and this problem can be greatly eliminated by re-using waste glass as cement replacement in concrete. Moreover, there is a limit on the availability of natural aggregate and minerals used for making cement, and it is necessary to reduce energy consumption and emission of carbon dioxide resulting from construction processes, solution of this problem are sought thought usages of waste glass as partial replacement of Portland cement. Replacing cement by pozzolanic material like waste glass powder in concrete, not only increases the strength and introduces economy but also enhances the durability. Sulphates of sodium, magnesium and calcium are present in alkaline soils and water. Sulphates react chemically with product of hydration causes expansion .Therefore, the action of sulphates in concrete containing waste glass powder needs to be investigated

4. EXPERIMENTAL PROGRAMME

In this experimentation, an attempt has been made to find out the effect of Sulphate attack on the properties of concrete produced by replacing the cement with waste glass powder in various percentages ranging from 5% to 40% in increments of 5% (0%,5%, 10%,15%, 20%,25%, 30%,35% and 40%.) Ordinary Portland Cement (OPC) 43 grade, locally available sand and coarse aggregates were used in this experiments. The sand used was a Zone II had the specific gravity of 2.62. The specific gravity of the coarse aggregate was 2.93. The coarse aggregate used were of 20 mm and down size. To impart workability to the mix, a superplasticiser from a reputed company was used with the dosage of 2% by weight of cement. The glass powder was obtained by crushing waste glass pieces in a cone crusher mill. The 600-micron passing fraction was used for the experimentation. Chemical composition of glass powder and cement is shown in Table 1.

Mix design carried out form M20 grade of concrete by IS 10262: 2009 yielded a mix proportion of 1:2.35:4.47 with water cement ratio of 0.50[41] Specimens were prepared according to the mix proportion and by replacing cement with glass powder in different proportion.

To find out the effect of Sulphate on compressive strength, specimens (of dimensions 150 x 150 x 150 mm) and on flexural strength, specimen (of dimension 150 x150x 700 mm) were cast tested using a compressive testing machine (CTM) of capacity 2000KN as per IS 516:1959 [42]

To find out the effect of Sulphate attack, the cube specimen of dimension 150 x 150 x150 mm were used. The specimen was immersed in a 5% MgSo4 solution for 7, 28, and 90 days.

5. TEST RESULTS

Table 2, 3, 4 and figures 2, 3, 4 summarize the results obtained from MgSo4 experiment conducted over 7 days, 28 days, and 90 days. These Tables shows the compressive strength of concrete produced by replacing cement with glass powder. Table 5 and figure 5 shows the result of Variation of flexural strength of concrete with cement replacement by glass powder for 7, 28 and 90 days

Table 2 Overall results of compressive strength with and without subjecting to sulphate attack for 07 days

Percentage replacement of cement by glass powder (%)	Concrete without subjecting to Sulphate attack		Concrete subjected to Sulphate attack for 07days		Percentage decrease of compressive strength when subjected to Sulphate attack
	Compressive Strength (MPa)	Percentage increase or decrease in compressive strength w.r t. ref.mix.	Compressive Strength (MPa)	Percentage increase or decrease in compressive strength w.r t. ref.mix.	
0(Ref.mix)	21.05	-------	20.62	--------	2.04
05	22.28	+6	21.83	+6	2.01
10	23.27	+11	22.57	+9	3.00
15	24.86	+18	24.36	+18	2.01
20	27.3	+30	26.75	+30	2.01
25	23.72	+13	23.00	+12	3.03

30	17.62	-17	17.09	-17	3.00
35	16.04	-24	15.71	-24	2.05
40	12.93	-39	12.67	-39	2.01

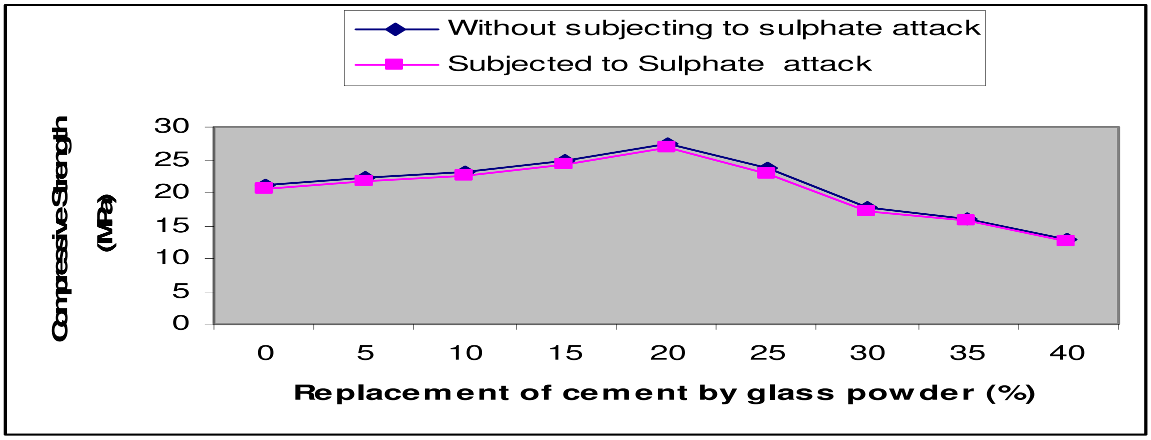

Figure 2. Variation of compressive strength of concrete with cement replacement by glass powder and when subjected to Sulphate attack for 7 days

Table 3 Overall results of compressive strength with and without subjecting to sulphate attack for 28 days

Percentage replacement of cement by glass powder	Concrete without subjecting to Sulphate attack		Concrete subjected to Sulphate attack for 28 days		Percentage decrease of compressive strength when subjected to Sulphate attack
	Compressive Strength (MPa)	Percentage increase or decrease in compressive strength w.r t. ref.mix.	Compressive Strength (MPa)	Percentage increase or decrease in compressive strength w.r t. ref.mix.	
0(Ref.mix)	27.05	------	25.45	--------	5.91
05	28.58	+6	27.15	+7	5.00
10	29.77	+10	28.10	+10	5.61
15	31.56	+17	30.00	+18	4.94
20	33.50	+24	31.85	+25	4.92
25	30.52	+13	29.01	+14	4.94
30	24.22	-10	23.20	-9	4.21
35	22.44	-17	21.55	-15	3.96
40	19.03	-30	18.25	-28	4.1

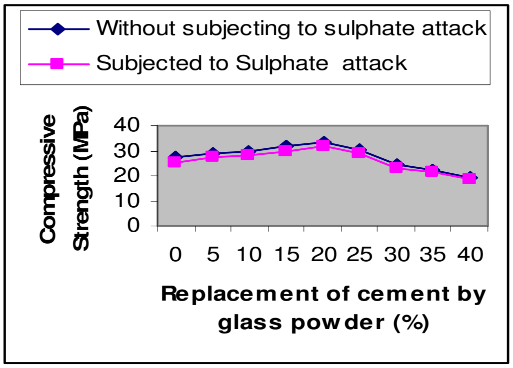

Figure 3. Variation of compressive strength Of concrete with cement replacement by glass Powder and when subjected to sulphate attack For 28 days.

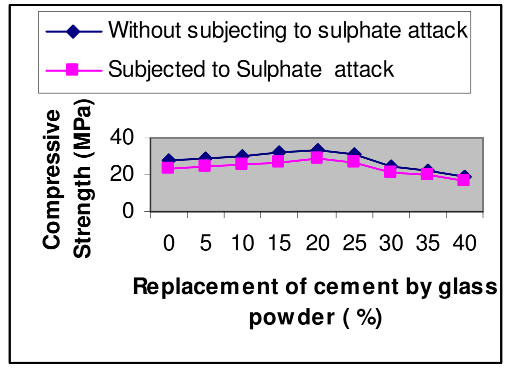

Figure 4. Variation of compressive of concrete with cement replacement by glass powder and when subjected To sulphate attack for 90 days.

Table 4. Overall results of compressive strength with and without subjecting to sulphate attack for 90 days

Percentage replacement of cement by glass powder	Concrete without subjecting to sulphate attack		Concrete subjected to sulphate attack		Percentage decrease of compressive strength when subjected to chloride attack
	Compressive Strength (MPa)	Percentage increase or decrease in compressive strength w.r t. ref.mix.	Compressive Strength (MPa)	Percentage increase or decrease in compressive strength w.r t. ref.mix.	
0(Ref.mix)	27.33	------	22.80	-------	16.57
05	28.87	+6	24.22	+6	16.10
10	30.08	+10	25.65	+11	14.72
15	31.85	+17	27.18	+19	14.66
20	33.86	+24	28.86	+27	14.76
25	30.82	+13	26.30	+15	14.66
30	24.44	-11	21.60	-5	11.62
35	22.72	-17	19.70	-14	13.29
40	19.25	-30	16.88	-26	12.31

Table 5 Overall results of flexural strength of concrete with cement replacement by glass powder

Percentage replacement of cement by glass powder	**Flexural strength (N/mm²) [07days]**	**Percentage increase or decrease in flexural strength with respect to reference mix**	**Flexural strength (N/mm²) [28 days]**	**Percentage increase or decrease in flexural strength with respect to reference mix**	**Flexural strength (N/mm²) [90 days]**	**Percentage increase or decrease in flexural strength with respect to reference mix**
0(Ref.mix)	2.40	-	3.50	-	3.60	------
05	2.45	+2	3.62	+4	3.64	+2
10	2.78	+16	3.78	+8	3.82	+7
15	2.85	+19	3.95	+13	4.00	+12
20	3.05	+22	4.17	+20	4.21	+17
25	2.90	+21	4.00	+15	4.05	+13
30	2.82	+18	3.90	+12	3.92	+9
35	2.42	+1	3.57	+2	3.60	0
40	2.32	-4	3.41	-3	3.45	-5

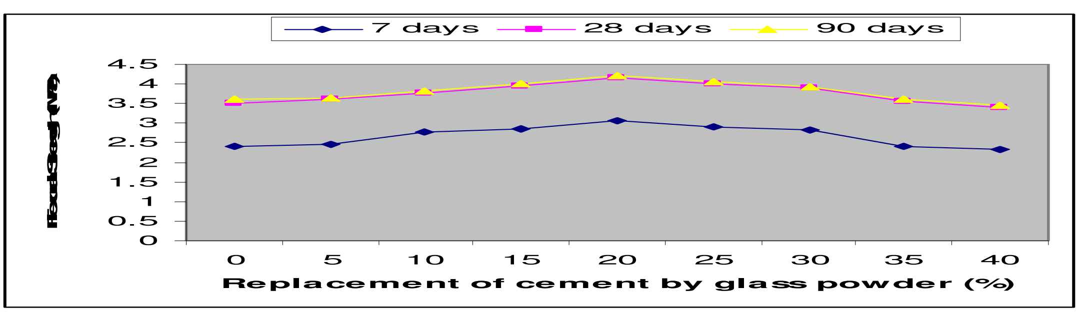

Figure 5. Variation of flexural strength of concrete with cement replacement by glass powder for 7, 28 and 90 days

6. DISCUSSION ON TEST RESULTS

An increasing trend in strength was observed with increasing replacement of cement with glass powder up to 20%. The highest percentage increase in the compressive strength was about 30% and flexural strength was about 22% at 20% replacement level. When the cement replacement level was increased beyond 20%, the compressive strength decreased.

. The increase in strength up to 20% replacement of cement by glass powder may be due to the pozzolanic reaction and filling the voids giving rise to a dense concrete microstructure as a result waste glass powder offers resistance against expansive forces caused by sulphates and the penetration of sulphate ions into the concrete mass. However, beyond 20%, apparently, the dilution effect takes over and the strength starts to drop. Thus, it can be concluded that better resistance to sulphate attack for concrete can be expected with 20% replacement of cement by glass powder.

The maximum strength development appeared at the same replacement level of 20% of cement by glass powder. Replacement of cement by glass powder by more than 20% decreased the compressive strength. In the 07 days experiment, the lowering in strength due to sulphate attack was in the range of 2% to 4% while that in the 28 days experiment was in the range of 3 % to 6%. In addition, in the 90 days experiment was in the range of 11 to 17 %. The sample with 20% glass content had 30 %, 25. % and 27% more strength than the control sample in 07days, 28 days and 90 days experiments respectively. This means that the concrete produced with 20% of glass powder showed more resistance to sulphate attack.

It is observed that there was a reduction in strength of concrete produced by replacing cement by glass powder when such concretes were subjected to sulphate attack. This may be due the sulphate may react with the products of hydration and cause expansion which results in micro cracks and these cracks may be responsible for reduction in strength.

Thus, it can be concluded that the strength properties are affected when concrete produced by replacing cement by glass powder is subjected to sulphate attack.

CONCLUSIONS

Based on experimental observations, the following conclusions can be drawn:

1. Higher strengths were achieved when 20% cement was replaced by glass powder in concrete.
2. Reduction in strength of concrete produced by replacing cement by glass powder when such concrete were subjected to Sulphate attack
3. Waste glass powder in appropriate proportions could be used to resist Sulphate attack

4 Considering the strength criteria, the replacement of cement by glass powder is feasible.

5 It is recommended that the utilization of waste glass powder in concrete as cement replacement is possible

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