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PERFORMANCE STUDIES ON WASTE GLASS POWDER IN SELF COMPACTING CONCRETE

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Abstract— ***The goal of promoting sustainable materials in construction industries increased the interest in use of recycled materials. One such type of recycled material which can provide sustainability towards environment is 'waste glass powder' (WGP). The waste glass powder obtained from fine grinding of crushed containers and building materials can be used as the partial replacement for cement. The present paper studied the effect of replacement of cement by waste glass powder in terms of physical, mechanical (compressive strength, split tensile strength and flexural strength) and durability (sorptivity) properties of self compacting concrete. The parameters of the study include grade of concrete (M_{20} and M_{40}), level of replacement of WGP (0%, 10%, 20%, 30% and 40% by weight of cement). The study concluded that the increase in level of replacement of WGP upto 20% improved the mechanical and durability properties.***

Keywords— ***Waste Glass Powder; Self Compacting Concrete; Sustainability; Compressive strength; Sorptivity;***

I INTRODUCTION

Sustainable development can simply be referred to as the prudent use of resources; and a major key feature of sustainable development is creating sustainable ways of preserving the environment with focus on reducing greenhouse gas (GHG) emissions, energy saving and preserving the natural resources. In addition, it was emphasized by that the construction industry is one of the major user of the natural resources and contributes a large part of worldwide CO_2 emissions [1,2]. For example, cement production is highly energy consuming and a major producer of carbon dioxide emissions to the atmosphere. However, opined that utilizing industrial by products and solid wastes by the construction industry can help sustain the environment in two ways; first, reusing waste materials that could have been a major concern to the environment by occupying scarce land spaces; and secondly, minimizing environmental degradation through depletion of the natural resources [3,4].

Waste glass in broken forms constitutes a major part of waste byproducts from both the industry and domestic, and previous studies mentioned that waste glass represents an urgent environmental challenge all over the world due to the non-biodegradable nature of the glass materials resulting in serious environmental pollutions. Hence, an alternative option offered to solve the menace of glass wastes on the environment is to reuse or recycle them. Some ways of recycling waste glass for other usage were explained in the studies carried by several authors. According to them, waste recycling will help to conserve the earth's natural resources, minimizes the land fills paces, and saves energy and capital resources. [5,6]

Self-compacting concrete is largely used in construction industry these days. So, developing Self-compacting concrete (SCC) will be beneficial. Self-compacting concrete is considered as a concrete which can be placed and compacted under its self-weight with little or no vibration effort, and which is at the same time, cohesive enough to be handled without segregation or bleeding [7,8].

II EXPERIMENTAL PROGRAMME

The experimental programme is designed to know the effective dosage of waste glass powder to replace the cement quantity in SCC mixes, in according to that strength and durability properties of SCC mixes is to be determined. To this Nan Su method of simple mix design is adopted for developing SCC, initial trial mixes were carried in laboratory and then mixes were modified accordingly as per EFNARC [14] to achieve optimum mix proportions satisfying fresh properties , and also economy. The proportions arrived for two mixes A and B is given in Table 1.

The final selection of recommended test methods was based mainly on their relation to one or more of the key properties of SCC (filling ability, passing ability, and resistance to segregation) as well as on reproducibility and repeatability [9,10]. The selection process involved consideration of the outcome of an extensive experimental program in laboratory conditions and on site together with the general advantages and disadvantages of each method (cost, portability, simplicity of operation, and other practical aspects).The key rheological parameters 'plastic viscosity' and 'yield value' mainly determine the filling ability of SCC; the slump flow and T50 tests demonstrate the best correlation with these, as well as having acceptable to good repeatability and reproducibility. Fresh properties for two mixes with different dosages of WGP are given in Table 2.

MATERIALS:

a) Cement: Ordinary Portland cement used was conforming to IS: 12269[11]. The initial and final setting times were 40 min and 560 min.

b) Supplementary Cementitious Materials (SCM): Fly ash was used as mineral admixture in all the mixes. In addition to fly ash, for Mix A, Silica fume was also used to achieve the required strength.

c) Fine Aggregate: Natural river sand with a maximum size of 4.75 mm conforming to Zone-2 according to IS: 383 [12] was used as fine aggregate. The specific gravity and bulk density were 2.65 and 1.45 g/cm^3 respectively. The Fineness modulus was 2.56.

d) Coarse Aggregate: Crushed granite was used as coarse aggregate. The coarse aggregate used was 20mm nominal size, well graded aggregate according to IS: 383[12] . The specific gravity was 2.8 and the bulk density was 1.5 g/cm^3. The Fineness modulus was 7.3.

e) Water: Potable water was used in the experimental work for both mixing and curing the specimens.

f) Waste glass powder (WGP): used in this study was obtained from waste mixed colour glass sourced from dumpsites and waste collection centers within Warangal. Before crushing, the waste glasses were thoroughly washed with water and air dried to remove every form of impurities and dirt (Fig 1a). To activate the pozzolanic behaviour and suppressed the alkali-silica reaction, the waste glass was crushed and ground to required degree of fineness using a mill crusher and sieved through a 0.075 mm sieve openings to achieve a consistent particle sizes as shown in Fig. 1(b).

Figure 1: Shows the waste glass pieces and crushed into powder form

Table:1 Mix Proportions for Mix A and Mix B

SI. NO	Material	Mix A kg/m^3	Mix B kg/m^3
1	Cement	276	358
2	Fine Aggregate	961	1020
3	Coarse Aggregate	808	918
4	Water	200	156
5	Flyash	150	120
6	SP	8.50	9.23

Table: 2 Fresh Properties of Self-Compacting Concrete with different dosages of WGP for Mix B

	EFNARC RANGE [14]	PLAIN SCC	With WGP	With WGP	With WGP	With WGP
		0%	10%	20%	30%	40%
SLUMP FLOW(mm)	550-850	750	730	720	715	700
T 50 (sec)	2-5	3.69	3.72	3.92	4.15	4.5
J-RING (mm)	0-10	5.00	7.00	8.00	9.00	9.00
L-BOX	0.8-1.0	0.94	0.90	0.87	0.82	0.80
V-FUNNEL (Sec)	6-12	7.12	7.83	8.34	9.7	11.21
V 5min (sec)	9-15	9.34	10.16	10.65	11.23	13.65

III TEST METHODS

i) Mechanical Properties: The cube specimens of size 150 x 150 x 150 mm for compression and cylinder of size 150 diameter and 300 mm height is considered for split tensile strength and also prisms of size 100 x 100 x 500 are cast and tested in a standard compression testing machine of capacity 200 T. as per IS 516 [15]. The maximum load applied on the specimen was recorded to determine the hardened properties.

ii) Sorptivity test: Sorptivity measures the rate of penetration of water into the pores in concrete by capillarity suction. After curing, the specimens of each batch were taken and side surfaces were sealed to keep in contact with water up to a depth of 5 mm from bottom. To determine the absorption of water, weights of specimens are taken at regular intervals. The test was conducted as per Hall's method [16] .The sorptivity was obtained by using the following expression:

$$\frac{\Delta w}{A * \sqrt{t}} = S$$

Where ΔW = the amount of water absorbed in (g);

A = the cross-section of specimen that was in contact with water (mm^2);

t = time (min);

S = the sorptivity coefficient of the specimen (mm/min$^{0.5}$).

iii) Acid Attack test: The chemical resistance of the SCC with WGP was studied through chemical attack by immersing concrete cubes in 5% concentration Hydrochloric acid (HCL) solution. Being alkaline in nature, concrete cubes are susceptible to get attacked during contact with chlorides. The components of cement products were broken down leaving weak reaction materials in the form of loose materials on mortar surface. After 28days of curing period, the specimens of each batch were taken and their surfaces were cleaned with a soft nylon brush to remove weak reaction products and loose materials from the specimen. The strength of concrete specimens is measured after 28 days immersion in HCL solution. The decrease in the strength of specimens represents in prone to acid attack

IV RESULTS AND DISCUSSION

a) Hardened Properties of WGP for two mixes A and B

Figure 1 and Table 3 shows the hardened properties of Mixes A and B with different percentage replacements of cement with waste glass powder (WGP). From Figure1 it is clearly observed that the percentage replacement of WGP is beneficial at the level of 20% when compared with other dosages. On the Other hand it is clearly identified that by replacement of cement with WGP gains the strength at different levels, this may due to usage of less particle size WGP compared to cement particles , due to this the reaction of WGP with cement is rapid in early stages. The reason for the attribution of strength is mainly due to the presence of reactive silica in WGP which helps to form secondary C-S-H gel in concrete at early stages of hydration cement with water. After 28 days curing of specimens, the compressive strength of WGP-20% is more and attained about 14.3% increased compressive strength in Mix B. on the other hand for Mix A similar behaviour is observed in all the cases, when compared conventional concrete specimens. Table 3 shows the split tensile and Flexural strength for Mixes A and B with different WGP replacements, it is evident that the replacement of cement with WGP is beneficial by the strength properties. From table 3 its clear observed that the optimum dosage of WGP replaced with cement is 20%.

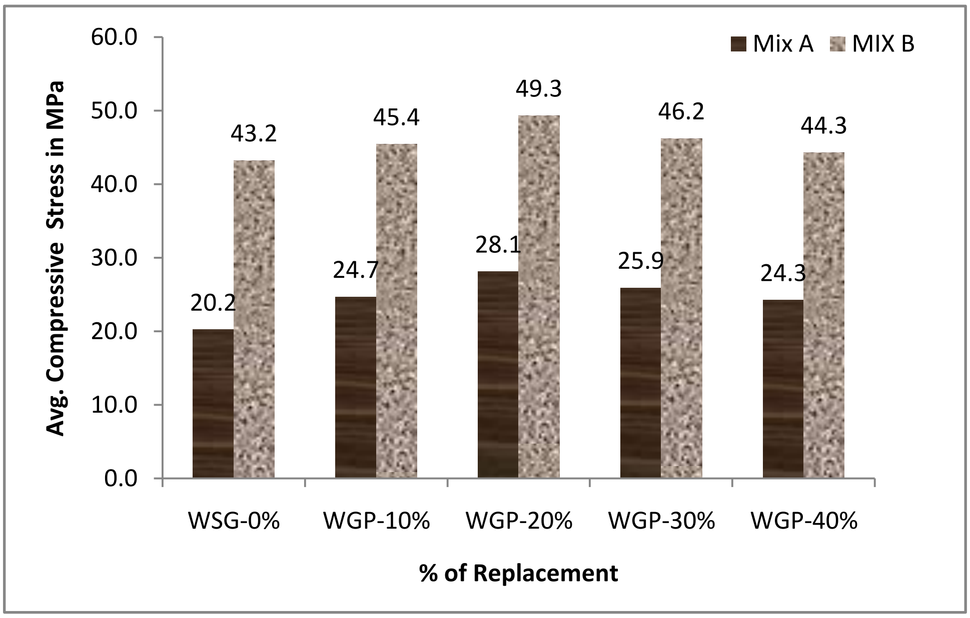

Figure 2: Average Compressive Strength Vs percentage replacement of WGP for Mix A and Mix B

Table 3 Split Tensile Strength and Flexural Strength of Mixes A and B With different dosages of WGP

S NO	Split Tensile Strength for Mix A (MPa)	Split Tensile Strength for Mix B (MPa)	Flexural Strength For Mix A (MPa)	Flexural Strength For Mix B (MPa)
WGP-0%	2.62	4.32	3.14	4.67
WGP-10%	3.20	4.54	3.47	4.76
WGP-20%	3.65	4.73	3.74	4.94
WGP-30%	3.36	4.62	3.56	4.73
WGP-40%	3.15	4.43	3.44	4.62

b) Sorptivity test results for Mixes A and B with different dosages of WGP

Figures 3 and 4 shows cumulative water absorption versus squrt (t) for Mixes A and B, from the figures it is observed that the specimens of WGP has less sorptivity coefficient compared to conventional concrete specimens. Mix A specimens have more sorptivity coefficient value than Mix B as the Mix A is lower grade (20MPa) and Mix B specimens are of medium grade (40 MPa), due to the presence of more amount of water content in Mix A ;leads to more amount of voids which allows to percolate water into the concrete. From the test results it is concluded that the specimens which had contributed more strength at hardened stage absorbed less water through the action of capillary suction. The specimens with replacement of cement with WGP are beneficial in terms of strength and permeability. Similar behaviour is observed in both the Mixes A and B with WGP-20%specimens. It is beneficial in terms of strength and permeability point of view, on the other it is clear that the replacement of Cement with WGP has beneficial which can decrease the wastage of construction industry and helps in contribution to environment in terms of sustainability. Further durability studies where carried to strength the strength and sorptivity.

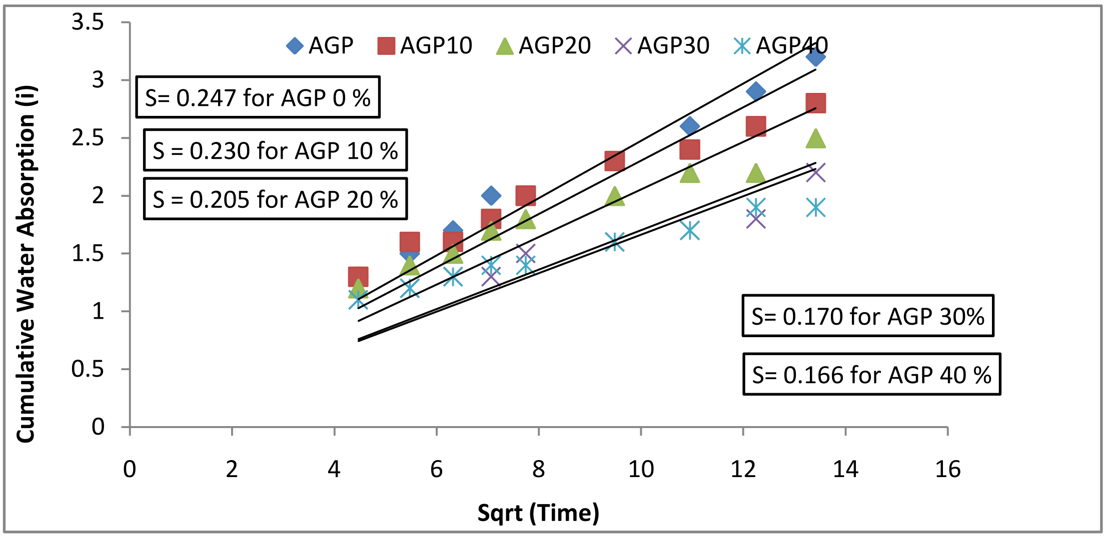

Figure 3: Cumulative Water Absorption Vs Sqrt (Time) for Mix A with WGP

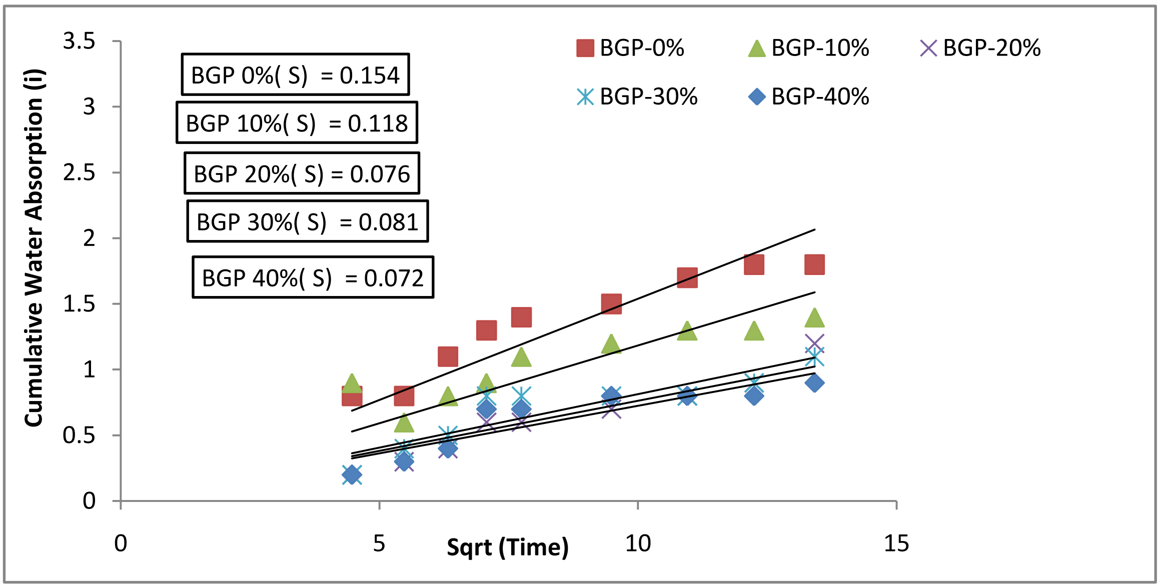

Figure 4: Cumulative Water Absorption Vs Sqrt (Time) for Mix A with WGP

c) Acid Attack Test Results for Mixes A and B

Figure 5 shows the acid strength loss factor for Mixes A and B with replacement cement with different dosages of WGP. From the figure it is observed that the specimens with WGP have less strength loss compared to 100% cemented based specimens. It is evident that the specimens of WGP-20% has less strength loss compared to all other dosages of WGP, whereas it is clear that from the strength, permeability and acid attack with 20 percent replacing of cement with WGP is beneficial for both Mixes A and B. From the overall test results it is concluded there is huge amount of beneficial with WGP for cement manufacturing industry which can further decrease the cement manufacturing and decease in the global warming on the other hand dumping of waste glass is huge problem to construction sector, so by using of WGP in construction can solve the problem. Further studies should be strengthened by conducting micro structural analysis.

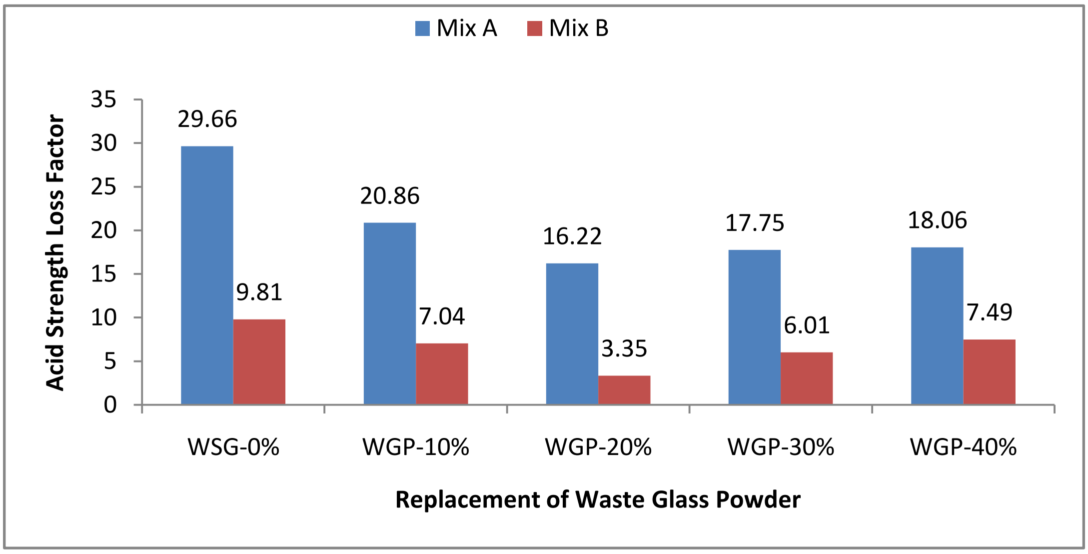

Figure 5 Acid Strength Loss Factor Vs Percentage Replacement of WGP for Mixes A and B

V. CONCLUSIONS

From the experimental studies conducted on the usage of waste glass powder as a partial replacement to cement, the following conclusions are obtained.

1. Increased level of replacement decreased the flow properties; however the obtained results are within EFNARC specifications.
2. The mechanical studies viz: Compression, Split Tensile and Flexural Strength properties are enhanced with 20% replacement of waste glass powder with Cement.
3. There is an increase of about 14% compressive strength in WGP-20% specimens when compared to WGP-0% specimens for both Mixes A and B.
4. Sorptivity results clearly predicted that the specimens with WGP-20% have attained less sorptivity coefficient compared conventional concretes.
5. Acid strength loss factor is less for WGP based specimens when compared to the conventional concrete.
6. The durability studies (Sorptivity, Acid Attack) depicted the high performance behaviour with 20% replacement level.
7. It can be concluded from strength and durability studies that the performance of SCC can be enhanced with partial replacement of WGP.
8. The macro level behaviour should be strengthened by microstructural studies (SEM, XRD, TGA, DTA, XRF IR).

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