Study on Mechanical Properties of Blended UHPC using Recycled Glass Powder and Sugar Cane Bagasse Ash

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ABSTRACT

Ultra High Performance Concrete(UHPC)) is a special concrete known to have better strength, durability and performance than normal concrete. It combines fibre reinforced concrete, self-compacting concrete, and high performance concrete. It consists of ordinary Portland cement, supplementary cementitious materials, micro steel fibers, fine aggregates, water reducing superplasticizers and water. UHPC consumes double the amount of cement than normal concrete and is costly. Cement manufacturing is a major contributor of carbon dioxide, a greenhouse gas. Sugar cane Bagasse Ash is an agro waste obtained from burning sugar cane waste obtained after extracting its juice. Sugar cane Bagasse Ash has good pozzolanic properties. Recycled Glass Powder is obtained by grinding glass waste into fine powder and shows better strength in hardened state concrete. The addition of sugar cane bagasse ash and recycled glass powder as cement replacement materials showed an increase in strength of blended UHPC mixture. Blended UHPC was found to be cost effective than normal UHPC.

Keywords: SCBA, UHPC, RGP

1 Introduction

UHPC has differing use like bridge structure, retrofitting, tall constructions etc. This actual is a blend of SCC, FRC and HPC. UHPC subsists of Ordinary Portland Cement, Supplementary cementitious matters (Micro Silica, GGBS), Fine soil, Micro steel fibers and High Range Water Reducing Admixtures. The use of UHPC is restricted on account of allure over use of money and extreme cost.

Cement is ultimate widely expended building material used in hardened result manufacturing. Cement production leads to a large amount of carbon dioxide and greenhouse gas issuance. Cement result demands a many of water such as rock formed from sediment and earth. UHPC consumes double the amount of cement than common factual. Even though the cover content is lowered by including additional cementitious matters in it, the cement use is in large for UHPC.

Researchers are focusing on replacing the cement use in concrete. To reduce the cement consumption, bio-waste and industrial wastes are being encouraged. Sugar cane Bagasse Ash (SCBA) is bio-waste obtained from burning bagasse obtained after extracting sugar juice from sugar factory. Since silica oxide is primary component of bagasse ash, many researchers have noted its potential application in concrete. The design and responsible management of a healthy constructed environment while taking into account ecological and resource efficiency is known as sustainable construction practice. According to studies, glass has a chemical makeup and phase that is similar to that of conventional SCMs. It is plentiful, has a potential economic worth, and is frequently landfilled.

A factor which may have attributed to its lack of acceptance in Indian markets is the high expense that comes with it when compared with conventional concrete. This high cost is due to the addition of cement,

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super plasticizers, and fibres, which enables UHPC to behave like strong concrete. At the same time, it provides benefits that conventional concrete could not. As a consequence, it is necessary to figure out if UHPC should be chosen despite its high cost. The current research examined the prospects of producing sustainable concrete with recycled glass powder and sugar cane bagasse ash. Finally, analysis of cost was done, taking into account the advantages that blended UHPC provides over normal UHPC.

2 Materials and Methodology

2.1 Materials Used

The materials used in this study were Ordinary portland cement (OPC 53), supplementary cementitious material such as micro silica, sand (M-Sand), Sugar Cane bagasse Ash (SCBA), Recycled Glass Powder(RGP), micro steel fibers, superplasticizer (HRWRA) and potable water.

2.1.1 Ordinary Portland cement

OPC 53 grade cement of Chettinad is chosen due to its high initial strength as per the guidelines of IS 12269:1987. The physical properties of the cement is demonstrated in Table 1.

Table 1: *Physical properties of Cement*

Test	Obtained value
Fineness test	5%
Consistency	32%
Specific gravity	3.136
Initial setting time	30min

2.1.2 Silica fume

Densified micro silica or silica fume of size lesser than 150micron was chosen as supplementary cementitious materials for the concrete as per IS 3401:1992. The fineness was 5%. Figure 1 shows the image of silica fume.

Figure 1: *Silica fume*

2.1.3 Fine M-Sand

Fine sand of size lesser than 600micron was chosen as fine aggregates so as to reduce maximum pores in concrete. Figure 2 shows the image of M-Sand.

Figure 2: *M-Sand*

2.1.4 Sugar cane bagasse ash

Sugar cane bagasse collected from sugarcane mill was dried and partially burnt in boilers at around 800 ◦ C to obtain it. Figure 3 shows the image of SCBA

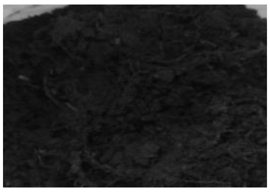

Figure 3: *SCBA*

2.1.5 Recycled glass Powder

The Recycled glass powder of size lesser than 90 micron was used in this study. The image of recycled glass powder is shown in Figure 4.

Figure 4: *Recycled Glass Powder*

2.1.6 Micro steel fibers

Brass coated micro steel fibers of 12mm length and 0.25mm diameter with a tensile strength of 2850 Mpa was chosen. Figure 5 shows the image of brass coated micro steel fiber.

Figure 5: *Brass coated micro steel fibers*

2.1.7 High Range Water reducing Admixture

For satisfy the flowability conditions and its workability, a polycarboxylate ether based superplasticizer named Escocrete M70 was chosen. Figure 6 shows the image of the High Range Water Reducing Agent.

Figure 6: *High Range Water Reducing Agent*

2.1.8 Water

Normal tap water was chosen.

2.2 Mix Proportion

The mix proportion was determined as per modified ACI 211.1 method. The binders of UHPC containing ordinary Portland cement and micro silica were dry mixed initially. Following this fine sand and micro steel fibers were added. Three quarters of the mixture of water and admixture added to the dry mix and was hand mixed for about 10 to 12 minutes. Later the remaining water mixture was added and mixed until the required flow was obtained. Water to Binder ratio of 0.25 was chosen for mix design. The cement has been replaced partially with recycled glass powder and Sugarcane bagasse ash. The replacement percentage is fixed as 5% for Recycled glass powder and the replacement percentage was varied for sugarcane baggage ash in different mixes. There are five Mixes with different proportion replacements as shown in table 2.

Table 2: *Replacement percentage in different concrete*

Mix Designation	Mix type	RGP	SCBA
Mix 1	Normal UHPC	0%	0%
Mix 2	Blended UHPC	5%	0%
Mix 3		5%	2%
Mix 4		5%	4%
Mix 5		5%	6%

2.3 Test Methods

2.3.1 Compressive Strength Testing

For determining the compressive strength cube shaped specimens with each 150mm sides were casted and water cured under normal room temperature conditions. A digital compressive strength testing machine with a loading capacity of 3000 kN was used to provide uniaxial compressive force. Compressive strength was determined on cubes respectively at the age of 7, 14 and 28 days. Figure 7 shows the setup for the compression testing of the concrete.

Figure 7: *Compressive strength test of Conventional UHPC*

2.3.2 Split tensile strength

For determining the split tensile strength of blended UHPC, cylindrical specimens were casted and cured in water under normal room temperature conditions. Digital compressive strength testing machine with a capacity of 2000 kN was used to test tensile strength of the concrete. Split tensile strength was determined on cylinders respectively at the age of 7, 14 and 28 days. Figure 8 shows the setup for testing the tensile strength of the concrete.

Figure 8: *Split tensile strength of blended UHPC using recycled glass powder and sugar cane bagasse ash (Mix2)*

2.3.3 Flexural Strength

Beam specimens having size 100×100×400mm were casted and cured in water under normal temperature conditions for 28 days. A flexural strength testing machine was used to determine the flexural strength of the specimens. Figure 9 shows the setup for flexural strength test.

Figure 9: *Flexural strength test of blended UHPC using Recycled glass powder and sugar cane bagasse ash (Mix 4)*

3 Results and Discussions

3.1 Fresh Properties

The slump flow is 760mm for normal UHPC. The slump flow increases with addition of Recycled Glass Powder (RGP). The slump flow decreases with the addition of Sugarcane Bagasse ash (SCBA). The slump flow of those mixes are shown in Table 3. The slump increases with increase with the addition of Recycled Glass powder which shows that it absorbs less water and improves the workability of the concrete. The slump flow begins to reduce on adding sugar cane bagasse ash as it absorbs more water from the concrete. The slump begins to reduce by increasing addition of sugar cane bagasse ash.

Table 3: *Slump flow test results*

MIX	SLUMP FLOW (mm)
Mix 1	760
Mix 2	770
Mix 3	745
Mix 4	710
Mix 5	670

3.2 Strength Results

3.2.1 Compressive strength results

The compressive strength for normal UHPC is 65.69 N/mm^2. The compressive strength results were higher with an average strength of 78.11 N/mm^2 for Mix 4 which contains 5% recycled glass powder and 4% of sugar cane bagasse ash compared to normal UHPC mix and other blended UHPC mixes for 7,14 and 28 days as demonstrated in the following chart.

The strength results increase with increase in proportion replacement upto Mix 4. Beyond this, the compressive strength result decreases with increase in replacement percentages of Sugar cane bagasse ash. The strength increased by 19.07% for Mix 4 as compared to normal UHPC in Mix 4. This increase in strength is due to high pozzolanizity and pore filling effect of Recycled glass powder and sugar cane bagasse. Figure 10 shows the graphical representation of the obtained result for compressive strength test.

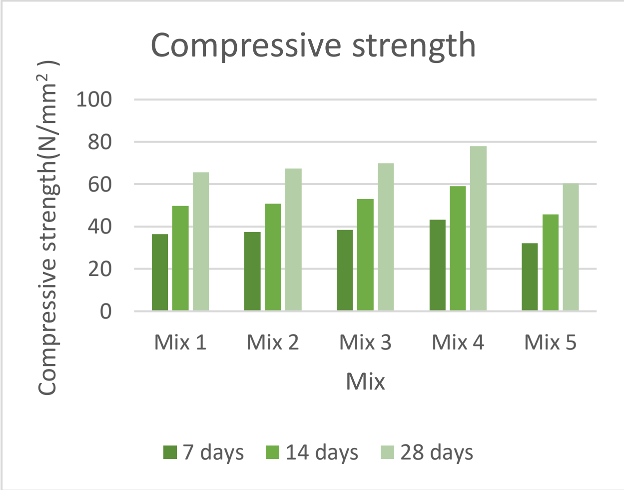

Figure 10: *Compressive strength of different mixes*

3.2.2 Split tensile strength results

The split tensile strength for normal UHPC is 6.7 N/mm². The split tensile strength results were higher with an average strength of 8.04 N/mm² for Mix 4 which contains 5% recycled glass powder and 4% of sugarcane bagasse ash compared to normal UHPC mix and other blended UHPC mixes as demonstrated in the figure 11 for 7,14 and 28 days. The strength results increase with increase in proportion replacement. upto Mix 4. Beyond this, the split tensile strength result decreases with increase in replacement percentage. The split tensile strength increased by 20% for Mix 4 as compared to normal UHPC in Mix 4. This increase in strength is due to high pozzolanizity and pore filling effect of Recycled glass powder and sugar cane bagasse.

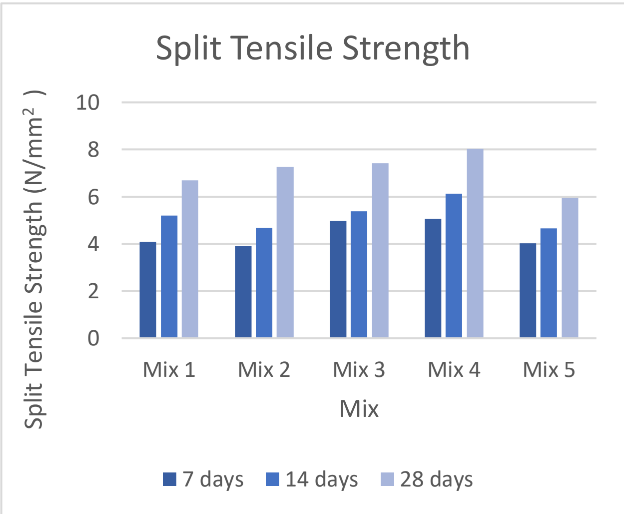

Figure 11: *Split tensile strength of different*

3.2.3 Flexural strength results

The flexural strength of normal UHPC was 8.69 N/mm². The flexural strength results were higher with an average strength of 9.7 N/mm² for Mix 4 which contains 5% recycled glass powder and 4% of sugarcane bagasse ash compared to normal UHPC mix and other blended UHPC mixes as demonstrated in the following chart for 28 days. The strength results increase with increase in proportion replacement upto Mix 4. Beyond this, the results decreases with increase in concrete. Figure 12 shows the graphical representation of the result obtained for flexural strength test.

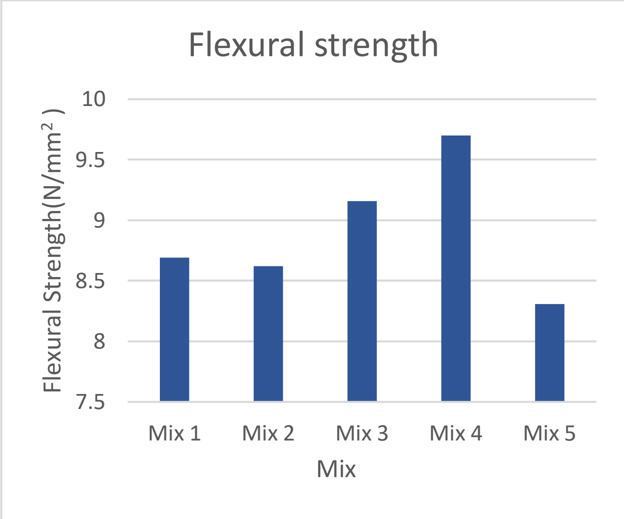

Figure 12: *Flexural strength of different mixes*

3.3 Cost Analysis

The optimum strength is obtained for Mix 4 replacing cement with 5% RGP and 4% SCBA. The cost of individual materials of normal UHPC for 1m^3 of concrete has been shown in the Table 4. The individual cost percentage of each materials in normal UHPC is shown in Fig.13.

Table 4: *Rate of components of normal UHPC mix for 1m^3 of concrete.*

Materials	Quantity(Kg)	Amount(Rs.)
Cement	434	3645
Silica fume	160	304
sand	324	848
water	143	0
HRWRA	11.96	1913
Steel fiber	9.86	1479
TOTAL AMOUNT		Rs. 8189/-

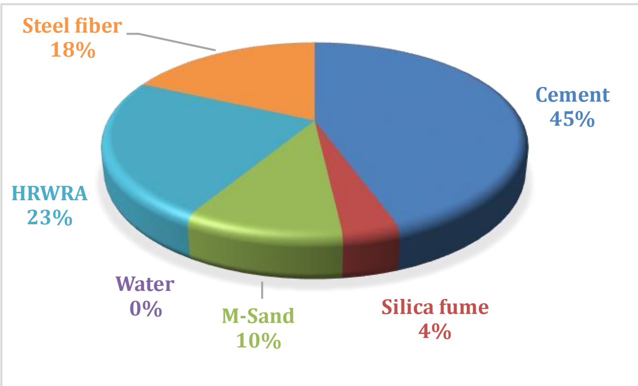

Figure 13: *Percentage of material cost for normal UHPC for 1m^3 of concrete*

The cost of individual materials of blended UHPC for 1m^3 of concrete (Mix 4) has been shown in the following Table 5. The individual cost percentage of each material in normal UHPC is shown in Fig.14.

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Table 5: *Rate of components of blended UHPC mix for 1m^3 of concrete.*

Materials	Quantity (Kg)	Amount (Rs.)
Cement	394	3317
Silica fume	160	304
SCBA	17.36	14.75
RGP	21.7	54.25
sand	324	848
water	143	0
HRWRA	11.96	1913
Steel fiber	9.86	1479
TOTAL AMOUNT		Rs. 7931/-

The difference in cost of normal UPHC and blended UHPC is Rs. 258.5 for 1m^3 concrete.

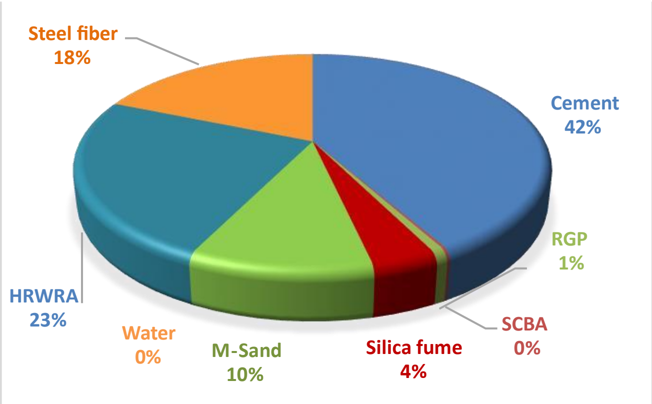

Figure 14: *Percentage of material cost for blended UHPC for 1m^3 concrete (Mix 4)*

4 Conclusions

- The workability increased with the addition of Recycled Glass Powder but decreases with addition of Sugar Cane Bagasse Ash.
- The mechanical properties results are higher for UHPC blended with 5% Recycled Glass Powder and 4% Sugar cane Bagasse Ash compared to nominal mix and other replacements.
- The total cement consumption can be reduced by 9% in UHPC.
- The use of sustainable materials in UHPC increases the sustainability of UHPC and reduces the total cement consumption.
- The blended UHPC mix is 3% less costlier than normal UHPC.

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