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INFLUENCE OF TEMPERATURE ON COMPRESSIVE STRENGTH OF WASTE GLASS CONCRETE

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Abstract: Concrete is a composite material thus it is very essential to study its thermal properties. This study depicts the effect of elevated temperature on the residual compressive strength of concrete containing Waste Glass (WG). Five concrete mixes (S1, S2, S3, S4, and S5) were prepared at different replacement levels of WG (0%, 10%, 20%, 30%, and 40%) with fine aggregates. The temperature was increased to 150^0C. The temperature was also increased to 300^0C and then 600^0C for two and half hour duration in the muffle furnace. In present study, sixty cubes were casted (with three cubes for each testing condition) and cured for 28 days. At 150^0C, it was observed that there was slight loss in strength for all concrete mixes. While during the elevation of temperature up to 600^0 strength loss was very critical for control as well as WG concrete. In nutshell, it can be concluded that the replacement of fine aggregates with WG does not improve the strength properties of concrete at elevated temperature.
Keywords: Waste Glass, Compressive Strength, Concrete, Elevated Temperature, Workability.

INTRODUCTION

Concrete basically is defined as a composite material, obtained by the mixing of raw materials like cement, sand and aggregates in ratio as specified in the mix. Today, with the advancement of technology in pre-stressed concrete, concrete and reinforced concrete structures, demand of concrete is increasing day by day. This ultimately effects the utilization of raw materials. Natural sand is one of the major constituent of the concrete, used as a fine aggregate. As the use of fine aggregate (sand) in concrete is increased, this will affect the natural resources. Like, with the use of river sand as a fine aggregate, this will lead to the exploitation of river bed, lowering the water table, erosion of land near the river and damaging the bridge structures. In order to eradicate this problem, utilization of many waste products is need of the day's timing as it changes the unsustainable to sustainable development by two ways. To begin with, it utilizes the waste materials and reduces the disposal problem of waste. Secondly, it will help to mitigate the problem of digging of sand,

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thus minimizing the problem of degradation of land. Many of industrial waste such as Waste Glass (WG), Coal bottom ash, Blast furnace slag, Copper slag etc. cause a waste disposal crisis. If fine aggregates are replaced by waste glass of specific size with definite ratio, it will decrease the utilization of fine aggregate. Waste glass is non bio-degradable, thus land filling with waste glass is non sustainable.

Glass is produced in various forms like container glass, flat glass, bulb glass, tube glass etc. All type of these glasses has their limited life, thereby creating environmental problem during their disposal. Thus, we can use WG as fine aggregates by slight modification in their size and shape. Based on the chemistry of glass, it can be divided into various categories like vitreous silica, alkali silica, soda lime glass, borosilicate glass, lead glass and aluminosilicate glass etc. however, soda lima glass is mainly used for the manufacturing of containers, jars and sheets. In waste glass, soda lime glass is approximately about 80% and mainly consists of SiO_2 (73%). The main problem regarding the utilization of WG as aggregate is chemical reaction that takes place between alkali in concrete pores and silica in glass. In small size fine glass particles this reaction is not detected (Cornaldesi *et al*, 2005). Therefore this reaction can be overcome by fining the size of waste glass particles.

Concrete structures are massive durable structures. During their life time, they may be exposed to high temperature for instance in nuclear reactor, furnaces or sometimes buildings exposed to fire etc. The non-uniform high temperature of aggregates is the major cause of spelling of aggregates; this is mainly due to internal pressure of aggregates. Apart from this, expansion in cement paste is also observed due to their chemical composition. As temperature is increased, due to loss of water from the cement paste free calcium hydroxide will turns in to calcium oxide. This concrete after coming in contact with moisture again forms calcium hydroxide again. This continuous change in volume of concrete may cause cracks in concrete structures, ultimately change the durability as well as strength of concrete structure (Husem, 2006). Glass is a unique material because glass cullet has different thermal properties like their temperature remains same for next 24 hours. Therefore the present research will investigate the properties of concrete at elevated temperature inclusion with WG.

MATERIALS USED

Cement and aggregates

Ordinary Portland cement of 43 grade meeting the requirement of BIS: 8112:1989 was used for the preparation of concrete specimens. It was stored in cement stores to protect from moisture. Fine aggregates were collected from Chakki River Pathankot. As per BIS: 383-1970, it falls in grading zone II. It was brown in color with specific gravity 2.71. Coarse aggregates of comprising machine crushed stones of size 10mm and 20mm, with equal proportion were collected from Pathankot quarry. All desired properties were calculated in accordance with BIS: 383-1970. These were gray in colour with specific gravity as 2.65.

Water

Water is an important constituent of concrete as it is responsible for chemical reaction with cement. In this study, tap water was used for casting cubes. It was free from organic matter, silt, oil, and acidic material as per BIS: 456-2000.

Waste Glass

Waste glass was collected from various places which included container glass, bulb glass and flat glass. Thereafter, it was fined through Loss Angles Abrasion Machine. The physical properties of glass were calculated after sieving through 4.75-mm sieve. They were angular and irregular in shape and size with specific gravity as 2.65.

LABORATORY TESTING PROGRAM

Mix design and specimen preparation

In this research, five concrete mixes were prepared. First mix was designated as control mix (S1), designed as per BIS 10262:2009. Water cement ratio of each mix was kept constant (0.55). Remaining four mixes were prepared by replacing fine aggregates with WG (0 to 40% @ increment of 10%). Water content, cement content and coarse aggregates were constant in all five mixes. Sixty concrete cubes of sizes 100mm x 100mm x 100mm were casted for each mix, from three samples were used for each testing condition. Mix proportions are given in Table 1.

Table 1: Mix proportions of concrete mixes

Mix	WG (%)	Cement (Kg/m^3)	Fine Aggregates (Kg/m^3)	Waste Glass (Kg/m^3)	Coarse Aggregates (Kg/m^3)	Water (L/m^3)
S1	0	358.47	728.20	0	1113.77	197.16
S2	10	358.47	655.38	73.17	1113.77	197.16
S3	20	358.47	582.56	146.34	1113.77	197.16
S4	30	358.47	509.74	219.51	1113.77	197.16
S5	40	358.47	436.92	292.68	1113.77	197.16

Workability of concrete

Workability of fresh concrete samples was determined by using slump test. As replacement level of waste glass increased slump value was also increased, thus indicating the increase in workability with replacement.

Compressive Strength of concrete

After casting, all sixty cubes were cured in simple water. After 28 days, they were dried for two hours at normal temperature. When surface become dry, they were placed in muffle furnace for temperature assessment. They were heated for two and half hours to 150^0C, 300^0C and 600^0C respectively for uniform temperature distribution across them. After that furnace was turned off and samples were cooled to room temperature. Compression test was conducted under Universal Testing Machine (UTM) of 9000kN capacity as per BIS 516-1959.

RESULTS AND DISCUSSION

Workability

Workability of all five mixes was calculated. Slump value of concrete mixes increased with the increase in replacement level of WG with sand. As the percentage of waste glass increased from 0% to 40%, their slump value increased from 110 mm to 133 mm as given in Table 2 and illustrated by Figure 1. The cardinal cause behind this incline is poor water absorption of waste glass as compared to sand. There is a huge incline in workability at 30% replacement.

Table 2: Slump values of concrete

Mix	WG (%)	Slump (mm)
S1	0	110
S2	10	112
S3	20	117
S4	30	127
S5	40	133

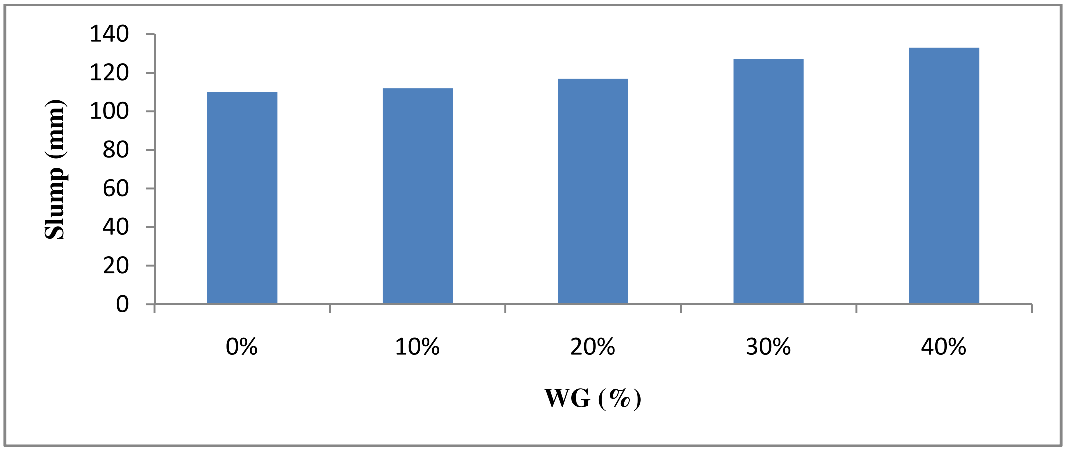

Figure 1: Slump values of concrete mixtures

Compressive Strength

Compressive strength of all five mixes at Room Temperature (R.T) and after heating 150^0C, 300^0C and 600^0C is given in Table 3 and illustrated by Figure 2. The percentage loss in strength is given in Table 4. In all concrete mixes, with the rise in temperature strength starts decreasing. Concrete mix containing 20% waste glass shows higher loss in strength as compared to other mixes at all temperature.

Table 3: Compressive strength of concrete mixtures at different temperature range

Mix	Compressive strength (N/mm^2)			
	Room Temperature (R.T)	150^0	300^0	600^0
S1	29.35	26.71	24.66	11.45
S2	29.14	26.19	23.63	11.30
S3	28.64	25.86	23.34	10.88
S4	27.58	24.24	23.33	10.97
S5	26.91	23.62	22.01	10.62

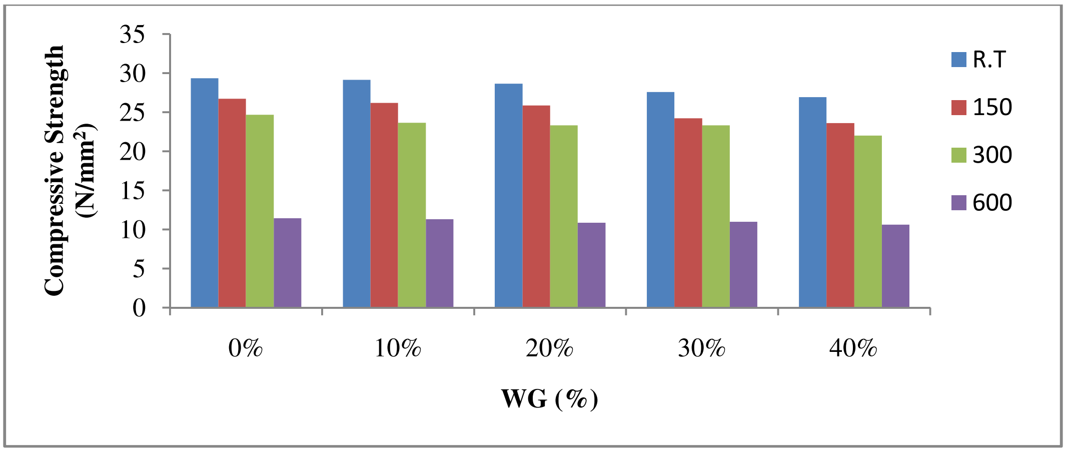

Figure 2: Compressive strength of concrete mixes at different temperature range

There was not a significant change in compressive strength up to 150^0, while after 150^0 as the temperature is increased to its double value(300^0) concrete starts showing the effects of elevation in temperature. At 600^0, there was a huge decline in strength approximately about 60% from room temperature. This is mainly due to evaporation of water from concrete on heating. As water evaporates, bonding between cement paste and aggregates gets lost due to internal pressure. Moreover expansion of cement paste and contraction of aggregates is also one of the main reasons behind this decline in strength.

Table 4: Percentage loss in compressive strength at different temperature range

Mix	Percentage loss in compressive strength		
	R.T - 150^0	R.T - 300^0	R.T - 600^0
S1	9.0	15.9	60.9
S2	10.1	18.9	61.2
S3	9.7	18.5	62.0
S4	12.1	15.4	60.2
S5	12.2	18.2	60.5

CONCLUSIONS

- The compressive strength of concrete with or without waste glass reduces as the temperature starts growing.
- It is also observed that there was a highest loss in compressive strength in mix (S2) containing 20% of waste glass at all elevated temperature conditions.
- Thermal properties of waste glass do not have significant effect on the compressive strength of concrete.

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