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Research paper

Strength Characteristics of Ternary Mix of Cement in Light Weight Concrete

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Abstract

The main aim of this study is to decrease the density and the dead load of the structure by using Light weight concrete (LWC). In this study Pumice aggregate was replaced with the conventional coarse aggregate. To enhance the strength of the concrete, cement was partially replaced with mineral admixtures, Ground Granulated Blast Slag (GGBS) and Metakaolin (MK). The constant replacement level of cement with 30% GGBS and 15% Metakaolin was followed for all the mixes. The natural aggregate has been replaced with pumice from 10% to 50% in the increment of 10%. A total of six combinations were cast. Hardened properties of the concrete were evaluated by conducting compressive strength (100 mm x 100 mm x 100 mm cubes), split tensile strength (cylinder of size 100 mm x 200 mm). In order to enhance the strength properties, cement has been replaced with GGBS and MK at certain replacement levels. The strength properties of light weight concrete samples and the conventional concrete samples were carried out.

Keywords: *GGBS; Metakaolin; Pumice; Light weight concrete; Strength characteristics.*

1. Introduction

In order to reduce the density and the dead load of the structure, light weight concrete is used. Earlier researchers suggested the replacement of various kinds of light weight aggregates results in the light weight concrete. To make it structurally strong and to reduce the pollution created by the production of cement, Supplementary Cementitious materials are used. Pumice, Expanded clay, Expanded shale, Perlite, vermiculite, coconut shell, palm oil shell, sugarcane shell are some of the alternatives which can be used as aggregates in the concrete. Ground granulated blast slag(GGBS), Metakaolin(MK), Silica Fume, Rice husk ash, Sugarcane ash are some of the alternatives which can be replaced with cement to attain light weight concrete (LWC). LWC results in good thermal resistivity and can be used as thinner sections which reduce the dead load. LWC used at foundation is cost effective.

The optimum replacement of GGBS in cement of M35 grade was 20% referring to only compressive test [1]. The ternary blended concrete with GGBS and micro silica yields the optimum mix when 30% of GGBS was replaced [2]. When ternary blended was carried out with GGBS and Metakaolin the optimum replacement gained at 30% by the result of compressive strength [3]. For M50 concrete when concrete was replaced with 30% and 50% the optimum replacement percentage obtained was 50% [4]. When ternary blended cement was done by MK and GGBS the referral percentage of MK adopted was 10% [5]. The constant percentage of Metakaolin at 5% was adopted and with bagasse ash ternary blended concrete was studied and they referred the optimum percentage of replacement of MK was at 10% or below 10% [6].

Regarding the strength properties the strength of the concrete partially replaced with pumice stone found to be decreased [7]. The relative strength was high when the Metakaolin was replaced at 10% [8]. The properties and features of pumice were studied in earlier research [9-12].

1.1 Research Significance

The main objective of this paper was to obtain light weight concrete by partially replacing pumice with natural coarse aggregate. To enhance the strength properties, ternary blended cement was used by replacing the cement with Ground granulated blast slag and Metakaolin. The strength properties of the different mix combinations and the control concrete was studied.

2. Materials and Methods

2.1 Materials Used

The materials used to carry out this study are as follows. The cement used in this study was Ordinary Portland cement (OPC) of grade 43 confirming BIS IS 8112: 2013 has specific gravity of 3.15. Ground granulated blast slag (GGBS) with specific gravity 2.6 and Metakaolin (MK) with specific gravity 2.64 was used in this study. The materials were purchased from ASSTRA CHEMICALS in Chennai. Locally available river sand with specific gravity 2.74 passing through 4.75 mm were used as fine aggregate as per IS 2386-1 1963. Pumice was used as the light weight aggregate material which has the dry bulk density of 48 kg/m³. The specific gravity of pumice is 0.85 and the nominal size is 20 mm. Pumice has been partially replaced with the naturally available coarse aggregate with specific gravity of 2.8. The quantity details for all the mixes were described in terms of kg/m³ in table 1. “R” indicates the replacement percentage of pumice with natural coarse aggregate. The materials used as partial replacement are shown in fig 1.

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Table 1: Quantity details for all the mixes

MIX	CEMENT (kg/m³)	GGBS (kg/m³)	MK (kg/m³)	FA (kg/m³)	CA (kg/m³)	PUMICE (kg/m³)
CONTROL	437.7	-	-	710	1111	-
R10	274.2	108.09	54.76	710	1000.33	34.52
R20	274.2	108.09	54.76	710	888.8	69.04
R30	274.2	108.09	54.76	710	777.7	103.56
R40	274.2	108.09	54.76	710	666.6	138.1
R50	274.2	108.09	54.76	710	555.5	112.6



a) Pumice



b) Metakaolin



c) GGBS

Fig. 1: Partially replaced materials

2.2 Methods

The basic properties like specific gravity were found out for all the materials used in this study.

The dry bulk density for the pumice aggregate was found out to be 48 kg/m³. The grade of concrete adopted was M30. The ternary blended cement was used by replacing Ground granulated blast slag (GGBS) by 30% and Metakaolin by 15%. The pumice was replaced from 0% to 50% in the increment of 10% for each mix. The wet density as per ASTM C138 2009 and the dry density as per ASTM C642 1997 were found out for all the mixes. The cubes were cast to determine the compressive strength and the cylinders were cast to determine the split tensile strength. The specimens were moist cured for a period of 28 days. The tests were carried out after 28 days of curing. The specimen details are shown in table 2.

Table 2: Specimen details

TYPE OF SPECIMEN	AREA (mm x mm)	NO OF SPECIMENS
CUBES	100 x 100	18
CYLINDER	100 X 200	12

3. Results and Discussion

3.1 Bulk Density

The density of the concrete samples eventually got decreased when the pumice has been replaced with natural coarse aggregate. The density of the specimens before curing and the density of the specimens after 28 days of curing are listed in table 3. The percentage reduction in density of the specimens before curing from R10 to R50 was at 7.2%, 4.35%, 16.7%, 28.2% and 36.2%. Similarly the percentage reduction in density of the specimens after 28 days of curing was 5.44%, 7.6%, 13.15%, 16.34% and 18.87%. The graphical comparison of the bulk densities is represented in figure 2. Similar results regarding density were reported in earlier research [9].

Table 3: Density of the specimens before and after curing (Cubes)

S.NO	SPECIMEN	AREA(mm²)	WEIGHT BEFORE CURING(KG)	WEIGHT AFTER CURING (KG)
1	CONTROL	100 X 100	1.380	2.57
2	R10	100 X 100	1.280	2.430
3	R20	100 X 100	1.320	2.374
4	R30	100 X 100	1.150	2.232
5	R40	100 X 100	0.990	2.15
6	R50	100 X 100	0.880	2.085

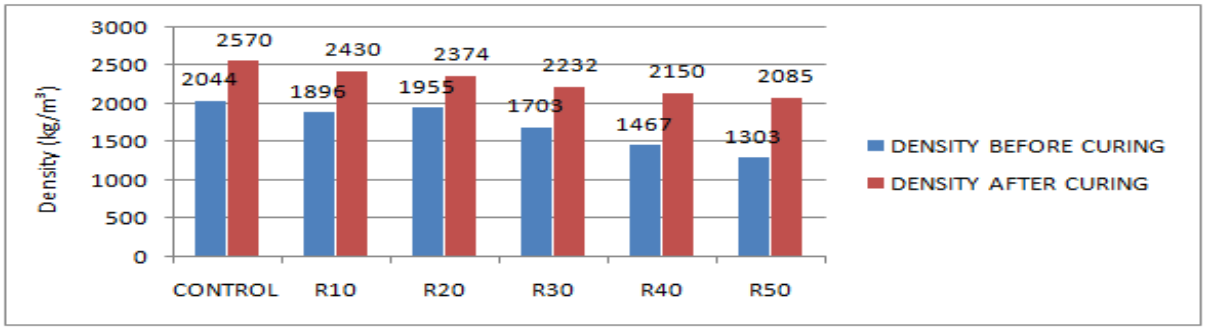
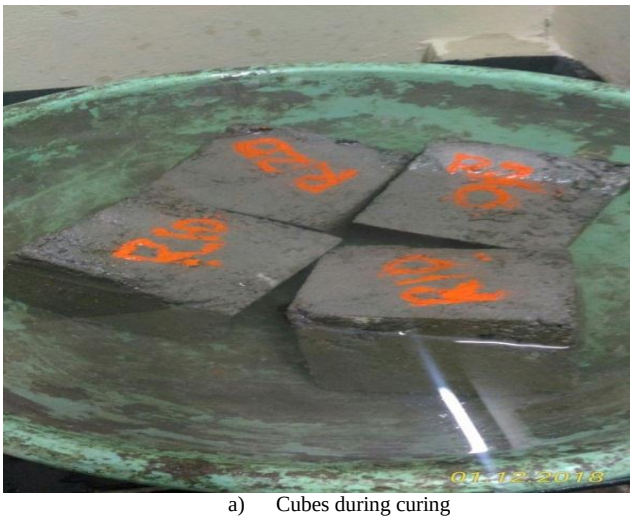


Fig. 2: Comparison of density before and after curing of the specimens

3.2 Compressive Strength

The compressive strength test was done in CTM, which has the loading capacity of 3000 KN as per IS 516 1959 [16]. After 28 days of curing the cube specimens were dried and tested until the failure load.

For each mix average of 3 cubes were taken for the stress calculation. The specimens during casting and testing are shown in figure 3. The load and stress details are represented in the table 4.



a) Cubes during curing



b) Cube during testing

Fig. 3: Specimens during curing and testing

Table 4: Compressive test results

S.NO	SPECIMEN	AREA (mm^2)	COMPRESIVE LOAD (KN)	COMPRESSIVE STRESS (N/mm^2)
1	CONTROL	100 X 100	382.9	38.29
2	R10	100 X 100	292.3	29.23
3	R20	100 X 100	261.9	26.19
4	R30	100 X 100	261.2	26.12
5	R40	100 X 100	229.5	22.95
6	R50	100 X 100	214	21.40

The percentage difference in the compressive strength compared to the control concrete is graphically represented in the figure 4.

Earlier studies found that the optimum replacement level of GGBS in cement was 20%, for achieving required compressive strength [1]

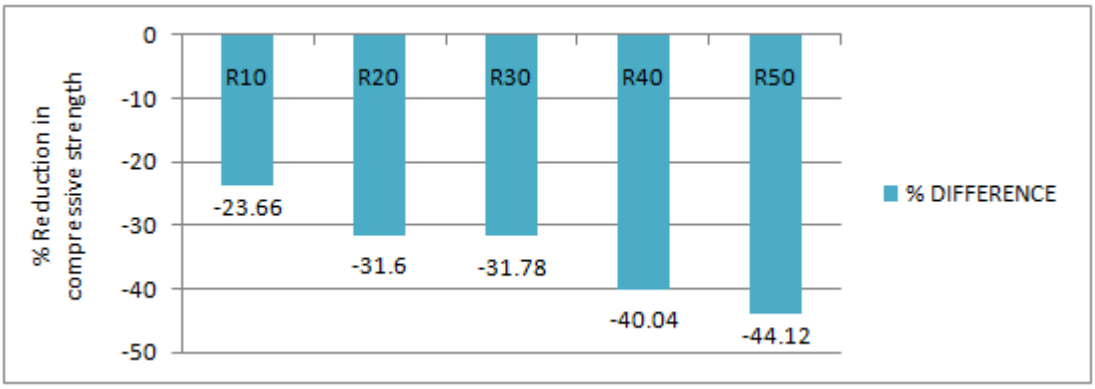


Fig. 4: Graphical representation of the percentage reduction in the compressive strength.

3.3 Split Tensile Strength

The split tensile strength test was conducted using CTM of loading capacity 3000 KN as per IS 516 1959 [16]. The test was done after the cylindrical specimens was moist cured for 28 days.

For each mix combinations the cylinder specimen was tested. The specimens during curing and testing are shown in figure 5. The load and the stress details are listed in the table 5



Fig. 5: Cylindrical specimens during curing and testing. A) Cylinder during curing
B) Cylinder during testing

Table 5: Split Tensile Test Results

S. NO	SPECIMEN	AREA (mm²)	LOAD (KN)	STRESS (N/mm²)
1	CONTROL	100 X 200	97.4	3.1
2	R10	100 X 200	52.5	1.67
3	R20	100 X 200	70.2	2.2
4	R30	100 X 200	61.1	1.94
5	R40	100 X 200	55.9	1.8
6	R50	100 X 200	51.5	1.64

The percentage reduction in split tensile strength of all the combinations compared to the control concrete is graphically represented in figure 6.

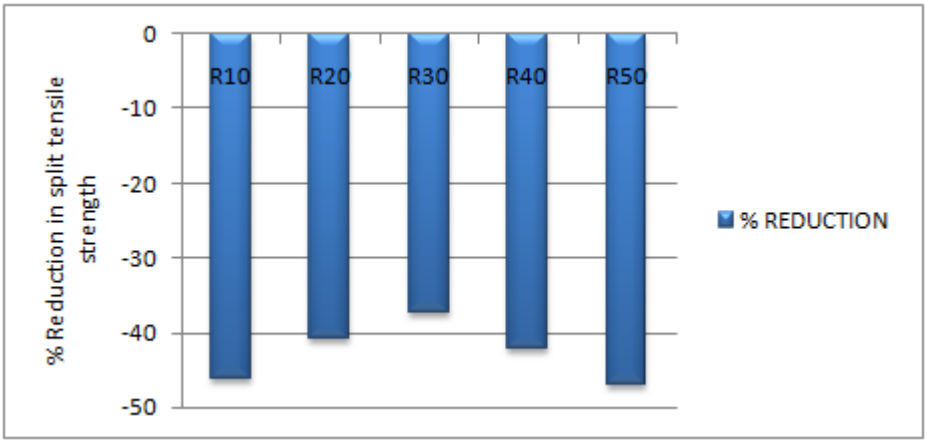


Fig. 6: Graphical representation of the percentage reduction in split tensile strength.

Both the compression and tensile test showed that the optimum mix was R30, which apart from achieving less density also resulted in less reduction in strength compared to conventional mix. Similar results were repoted in earlier study [2]. It was found

that the ternary blended concrete with GGBS and micro silica yielded the optimum mix when cement was replaced with 30% of GGBS.

4. Conclusion

The conclusions arrived from the ternary blend of cement in light weight aggregate concrete are,

1. Replacement of pumice from 10% to 50% showed a considerable reduction in bulk density in both state (before curing and after curing) compared to the control concrete.
2. The workability of the concrete for all the mix combinations is low. Addition of super plasticizer is recommended.
3. The compressive strength and the split tensile strength of the concrete got reduced when replacement of pumice is incremented from 10% to 50%
4. The percentage reduction in compressive strength is high in R40 mix compared to R30. Taking density and strength as parameters R30 mix can be used as the optimum mix and further tests can be carried on.

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