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Strength Aspects of Concrete by Partially Replacing Cement by GGBS and Coarse Aggregate by Waste Ceramic Tiles

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Abstract:- Worldwide concrete is that the most generally used construction material. The recognition of concrete is attributable to it's locally available ingredients. However, high consumption of raw materials by the infrastructure sector leads to severe shortage of building materials and therefore leads to environmental damage. The challenge for civil engineers is to encourage the usage of high performance materials and merchandise manufacture at affordable price with minimum environmental hazard. In this study, GGBS (Ground Granulated Blast Furnace Slag) and waste ceramic tiles are used as a partial replacement of cement and coarse aggregate respectively. Strength properties of M30 concrete were studied with 25% constant replacement of cement by GGBS and coarse aggregate by waste ceramic tiles with varying percentages 5% to 30% with an interval of 5%. The strength aspects studied included compressive strength, split tensile strength and flexural strength. The results showed the use of 25% cement replaced with GGBS had similar properties as conventional concrete. Waste ceramic tiles up to 25 percentage replacement of coarse aggregate provides greater strength properties than the conventional concrete and 30% ceramic tile mix also gave the similar strength as conventional concrete.

Keywords:- *Waste Ceramic Tiles, M-Sand, GGBS, Compressive Strength , Split Tensile Strength And Flexural Strength.*

I. INTRODUCTION

Concrete is a widely used construction material with ingredients as Portland cement, aggregates and water in its most common form. Concrete is the most used man-made material on this planet. It is a low-cost material and advantageous for the construction of any type of structure. Aggregates which used in making concrete are chemically inert solid particles of selected sizes, held together by the cement paste which when hardens to gain strength. cement acts as the binder to aggregates. Aggregates in concrete are of two types namely fine and coarse based on their sizes. They can be natural gravel, crushed rock, artificially prepared heavy or light weight material, available in various shapes, sizes and qualities. Being cement as the most expensive ingredient in making a concrete, it is desirable to minimize the quantity of cement and maximize the quantity of aggregate without affecting its strength in concrete production. Generally, in a normal concrete, almost 75 to 85% of the volume are aggregates that makes the cost of concrete relatively low.

Developmental activities such as construction of buildings etc. largely consume precious natural resources. This leads to faster depletion of natural resources on one side and resulting increase in the cost of construction of structures on the other side. It is important to search for suitable other viable materials which could be used either as a substitute or as a partial replacement to the conventional ingredients of concrete.it will help in saving existing natural resources to a possible extent and reduce environmental impact and the future generation will be benefited.

In this aspect, use of waste materials in concrete is a good practice provided materials satisfy the standards of quality. Consumption of broken tiles or waste tiles as coarse aggregates in concrete manufacturing can be made practical in the field of sustainable concrete. A vast quantity of tiles gets broken or wasted in tile industries and on mega construction projects. Commonly these wastes are disposed into environment consequently being a burden without any commercial return. Besides, huge money is being spent for the waste disposal reasons without any benefit and also leads to environmental pollution. Similarly, GGBS being a byproduct of iron industry has been proven as a good mineral admixture. By these we should realize that addition of industrial wastes or byproducts in concrete as a supplement material generally reduces the construction cost and does maintain the properties of concrete. In addition, properly processed waste materials have proven to be effective as construction materials that readily meet the design specifications.

II. LITERATURE REVIEW

Usmi S et.al, (2016) [1] studied properties of M25 grade concrete with cement replaced partially by GGBS by 10% to 60% with 10% increments and a constant value of 30% coarse aggregate replaced by construction waste.40% cement replaced with GGBS was found to be the optimum mix. Workability also was improving when GGBS quantity increased.

Parminder Singh et.al, (2015) [2] experimented waste ceramic tiles as replacement of 5%,10% and 20% coarse aggregates in concrete.M20, M25 & M30 mixes were studied. For M20 grade concrete, up to 20% replacement of coarse aggregate with tiles was possible, but for higher grades (M25 & M30) strength decreased with increase in the quantity of tiles but it was comparable with control mix. The use of waste tiles in concrete was proved effective for the selected grades studied in this paper.

III. OBJECTIVES

- To do design proportion for M30 grade of concrete.
- To study the performance of fresh & hardened concrete with partial replacement of coarse aggregate with waste ceramic tiles by variation of 0%, 5%, 10%, 20%, 25% & 30% and 25% constant replacement of cement with GGBS and M-sand as fine aggregate by conducting different tests for:
  - Workability
  - Compressive Strength
  - Split Tensile Strength
  - Flexural Strength

IV. MATERIAL PROPERTIES

Materials used here for the current study were cement, M-sand, coarse aggregates, GGBS, waste ceramic tiles (WST), chemical admixture and water. Chemical admixtures were used to improve workability of concrete.

A. Cement

Cement used for all specimens was Birla Super ordinary Portland cement of 53 grade conforming to IS: 12269:2013.

TABLE 1. Physical Properties of Cement

Properties	Values Obtained
Standard consistency	32%
Specific Gravity	3.14

B. Fine Aggregate

M-sand was used as fine aggregate. Properties were conforming to IS:383-1970 zone II.

TABLE 2. Physical Properties of M-Sand

Properties	Values Obtained
Specific gravity	2.489
Fineness Modulus	3.72
Water Absorption	1.5%

C. Coarse Aggregate

Coarse Aggregate used was conforming to IS:383-1970. The size of aggregate was 20mm maximum.

TABLE 3. Physical Properties of Coarse Aggregate

Properties	Values Obtained
Specific gravity	2.553
Fineness Modulus	3.72
Water Absorption	0.37%
Shape	Angular
Impact Value	17.45%(strong)

D. Waste Ceramic Tiles

Waste ceramic tiles of size 20mm maximum and 12.5mm minimum were used. For this study the tiles were hand crushed and sieved for the size. IS: 2386(part1) guidelines had been used. The sieves analysis was done for combined aggregates conforming to the specifications of IS: 383-1970 (reaffirmed 2007) for graded aggregates.

TABLE 4. Physical Properties of Waste Ceramic Tiles

Properties	Values Obtained
Specific gravity	2.31
Fineness Modulus	2.31
Water Absorption	5.2%
Shape	Angular
Impact Value	15.56%(strong)

Fig.1 Broken Waste Ceramic Tiles

E. GGBS

Granulated Blast Furnace Slag is a byproduct of iron manufacturing industry. While using iron ore, coke and limestone as the raw materials, the molten slag formed has a composition of about 30% to 40% $SiO2$ in this 40% CaO which is close to the chemical formula of Portland cement.

TABLE 5. Physical Properties of GGBS

Properties	Values Obtained
Standard consistency	31%
Specific Gravity	3.09

Fig.2 GGBS

F. Water

Tap water available in the laboratory was used for mixing ingredients of concrete and for specimen curing.

G. Chemical Admixture

Super Plasticizer ECMAS HP902 was used in this work which mainly improves the workability of concrete without affecting its strength properties.

V. MIX DESIGN AND NOMENCLATURE

Mix design was done to achieve M30 grade concrete as per IS: 10262-2009 recommendations. As per the design mix obtained here was 1: 2.25: 3.13 with a water-cement ratio of 0.45.

TABLE 6. Mix quantities for M30 grade concrete

Materials	**Quantity in kg/m^3**
cement	350
Fine aggregate	3.72
Coarse aggregate	1.5%
Water	140

M1 - Conventional Concrete
M2 - 25% GGBS & 0% WCT
M3 - 25% GGBS & 5% WCT
M4 -25% GGBS & 10% WCT
M5 -25% GGBS & 15% WCT
M6 -25% GGBS & 20% WCT
M7 -25% GGBS & 25% WCT
M8 -25% GGBS & 30% WCT

VI. TESTS CONDUCTED AND RESULTS

The specimens used were 150mmx150mmx150mm cubes for compressive strength test, cylinders of 150mm diameter x 300mm height for split tensile strength and 100mmx100mmx500mm prisms for flexural strength. They were tested after 7 and 28 days of water curing. Prisms were tested after 56 days of water curing. Fresh concrete was tested for workability by slump cone test.

A. Slump Test

Fresh concrete is tested for its consistency by slump test before it sets. It is an important parameter to check the acceptability of concrete mixes. Slump cone test is conducted to check the workability of freshly made concrete, therefore the ease with which concrete can be worked up on. Clause 7 of Is:456 2000 gives the required slump value in mm. The test results are shown in Fig. 3. It was observed that addition of GGBS increased workability.M2 mix showed more workability than M1. Addition of ceramic tiles decreased workability. But there was not much variation in the values. Water absorbing nature of tiles, its flakiness and glazy surface may be affecting its bonding properties. Superplasticizer dosage of 0.8% was maintained to get the required workability.

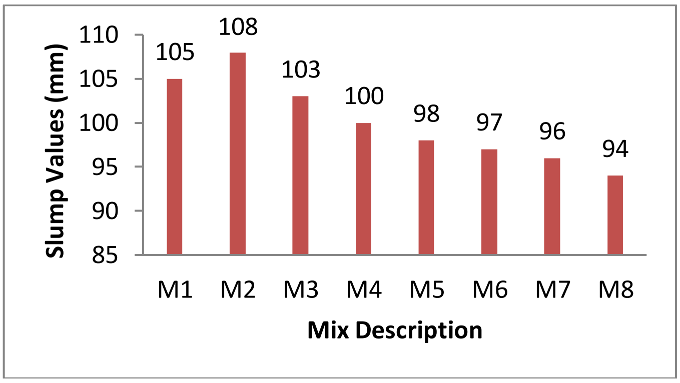

Fig.3 Slump Values

B. Compressive Strength

Compressive strength of concrete is a function of many factors such as water-cement ratio, cement quality & strength, quality of other materials, and quality control during production of concrete etc. Cubes were tested using compression testing machine. The results are shown in Fig.4.

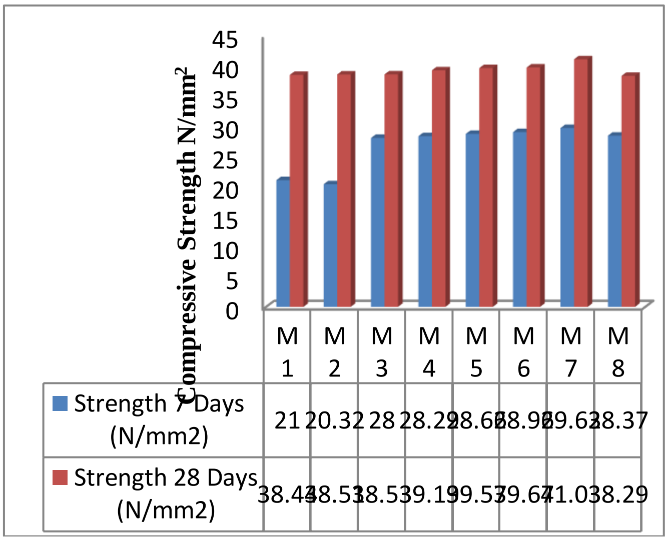

Fig.4 Compressive Strengh at 7 & 28 days

M2 mix showed lesser strength compared to M1 at 7 days, but at 28 days it achieved target strength. As replacement percentage of waste ceramic tiles increases the strength increased up to 25% (M7) replacement of coarse aggregate, after this the strength decreased slightly. The optimum percentage obtained at M7 mix and its strength was 41.03N/mm^2 which was 6.7% greater than that of conventional concrete of 38.44N/mm^2 at 28 days. Even

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though M8 mix had shown a reduction in strength compared to optimum mix M7, it has achieved near to target strength at 28 days. Up to 25% replacement, the bonding between materials had arrived adequately for the strength gain. Ceramic tiles used in this investigation were in a presaturated state so that added water while mixing could be effectively used for hydration.

C. Split Tensile Strength

The cylinders of standard size 150mm x 300mm were tested in Compression Testing Machine. The results are given in Fig.5.

The split tensile strength for conventional concrete(M1) was obtained as 1.84 N/mm^2 at 7 days and 3.49 N/mm^2 at 28 days. The split tensile strength of M2 mix increases from 2.26 N/mm² to 3.74 N/mm² from 7 to 28 days. From M3 to M7 mix proportions the strength increases from 3.79 N/mm² to 4.55 N/mm² for 28 days. The strength obtained for M7 proportion is 30.3% greater than the conventional mix proportion. Split tensile strength gain has gradually increased as the replacement % increases from 5% to 25% (i.e., from M3 to M7 mix) and after that for M8 mix proportion the strength decreased slightly. Up to 25% replacement, the bonding between materials has arrived adequately for the strength gain.

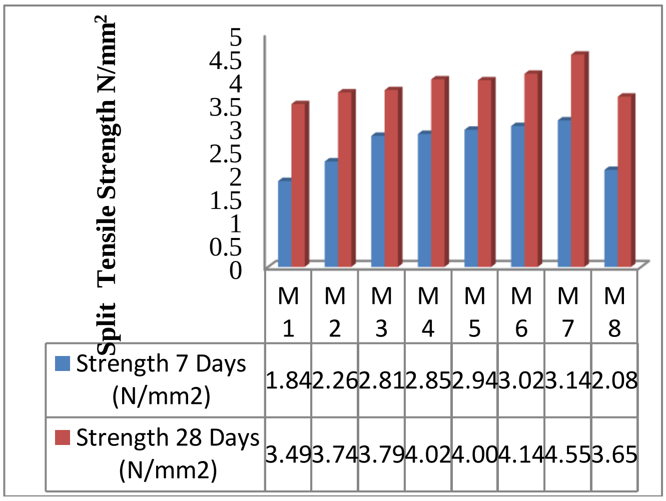

Fig.5 Split Tensile Strengh at 7 & 28 days

D. Flexural Strength

The flexural strength of concrete was carried out in Universal testing machine (UTM). The test was conducted after 56 days of curing. The results are shown in Fig. 6.

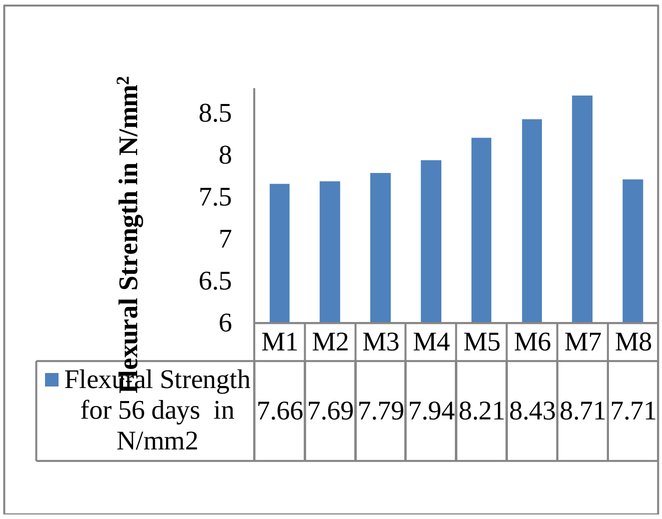

Fig.6 Flexural Strengh at 56 days

Flexural tensile strength was seen increasing up to the M7 mix proportion and then for M8 mix, it decreased slightly as shown in the graph. Flexural strength of CC (7.66N/mm^2) and M2 (7.69N/mm^2) mixes had almost the same strength. The Flexural strength increased from 7.66 N/mm^2 to 8.71N/mm^2 for M1 to M7. It meant that the strength increased up to M7 mix then there was a slight decrease in the strength. The optimum mix was M7.

VII. CONCLUSION

1. For all mix proportions with Waste Ceramic Tiles (from M3 to M8) the slump decreased slightly but within required limit. The combination of GGBS and waste ceramic tiles is effective in the concrete mix with constant amount of Superplasticizer. The admixture dosage of 0.8% was maintained for getting the required slump.
2. Compressive Strength of M2 (25% GGBS) increased by 16.38% compared to conventional concrete at 28 days. As GGBS being a mineral admixture, which requires time to gain the strength, there is a chance of increased later stage strength also.
3. The optimum percentage obtained at M7 mix proportion and its compressive strength was 41.03N/mm^2 which is 6.7% greater than that of conventional concrete 38.44N/mm^2 at 28 days.
4. Even though M8 mix had shown a reduction in compressive strength compared to optimum mix M7, it had also achieved near to target strength at 28 days.
5. The split tensile strength for conventional concrete was obtained as 1.84 N/mm^2 at 7 days and 3.49 N/mm^2 at 28 days.

6. The split tensile strength of M2 mix increases from 2.26 N/mm² to 3.74 N/mm² from 7 to 28 days. From M3 to M7 mix proportions the strength increases from 3.79 N/mm² to 4.55 N/mm² for 28 days. The strength obtained for M7 mix proportion is 30.3% greater than the conventional mix proportion which was the optimum.
7. The split tensile strength for replaced concrete obtained was more than that of normal mix, indicating addition of GGBS and waste ceramic tiles increased tensile strength.
8. Flexural strength of CC ($7.66 N/mm^2$) and M2 ($7.69 N/mm^2$) mixes had almost the same strength at 56 days of curing.
9. Flexural tensile strength was seen increasing up to the M7 mix proportion and then for M8 mix, it decreased slightly.
10. The combination of 25% cement replaced by GGBS and 25% coarse aggregate replaced by waste ceramic tiles had given satisfactory results comparing strength parameters.
11. As an extension of this work, durability of the same concrete can be done by various tests and the use of these ingredients can be proved effective for construction practice.

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