INFLUENCE OF METAKAOLIN AND GGBS IN TERNARY BLENDED CONCRETE WITH RECYCLED COARSE AGGREGATE

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Abstract - *As the infrastructure development increasing, there is the need of more amount of aggregates. But there is the shortage and depleting quality of aggregates, the recycled aggregates can be the good replacement. In this project there is the replacement of recycled aggregates, available from the demolition waste is with natural aggregate in some percentage is done. There is also the use of metakaolin and ground granulated blast furnace slag in concrete to modify the strength, workability and durability characteristics of concrete. Detailed investigation will be carry out in term of compressive, split tensile and durability property with acid attack, sulphate attack, sorptivity, and water permeability of concrete prepared with Recycled Coarse Aggregate for M25 grade of concrete. The results showed that for the concrete when the addition of metakaolin and GGBS induced the workability, strength and durability increases. From the study it is concluded that 35% RCA replacement with 10% MK and 40% GGBS in ternary is the optimum replacement and give same or better performance than control concrete.*

***Key Words*: Recycled Aggregate, Metakaolin (MK) & Ground Granulated Blast Furnace Slag (GGBS)**

1. INTRODUCTION

For last few years the cost of aggregates are increased tremendously and quality of aggregate is also depleting year by year. To meet the global demand of concrete in the future, it becoming a more challenging task to find suitable alternatives of sand and gravel for preparing concrete. On the other side, sustainable waste management is another major problem faced by the countries all over the world. Using of the waste concrete as coarse aggregate in new construction reduce dumping place, decrease energy consumption, provide economy and protect environment.

Recycled aggregate (RA) mainly differs from natural aggregate (NA) as it is composed by two different materials: NA and residue old cement mortar attached. Old mortar properties have a negative influence on recycled aggregate concrete (RAC) quality such as reduction of the strength and durability due to the increased concrete porosity and a weak aggregate-matrix interfacial bond.

In this research work, the performance of concrete prepared with recycled aggregate improved by using mineral admixtures. Metakaolin and ground granulated blast furnace slag are used as the mineral admixtures to be replaced with the cement. So there is the ternary blended concrete prepared with metakaolin and GGBS blend into cement and recycled aggregates replaced with natural aggregate.

The objective of this study is to investigate strength and durability property of concrete containing 20,35 & 50% RCA replaced with NCA and ternary blended cement containing constant 10% metakaolin and 20,30 & 40% GGBS. Total 10 number of combinations prepared with control mix and the property of concrete was compared to control mix.

2. EXPERIMENTAL PROGRAMM

2.1 Materials

In this study, commercially available recycled coarse aggregate of 10mm and 20 mm size, metakaolin and GGBS used. There properties are as follows:

2.1.1 Cement, MK and GGBS

Cement was used in this work is accordance with IS: 12269-2013 OPC 53 grade. Metakaolin was used as per Indian standard draft code CED 2(7921) and GGBS as per IS: 12089-1987. The properties of all are shown as below;

Table 1 Cement, MK & GGBS properties

Contents	Cement	MK	GGBS
SiO_2 (%)	20.1	54.9	35.26
CaO (%)	63.5	0.06	38.77
Al_2O_3	4.9	41.7	8.2
Fe_2O_3	3.6	1.07	1.23
MgO	1.2	0.84	4.1
TiO_2	-	0.36	-
MnO_2	2.9	-	11.7
Loi	1.7	1.03	0.74
Specific Gravity	3.15	2.44	2.77
Color	grey	white	off-whitish
Bulk density (kg/cc)	830	900	1060

2.1.2 Properties of Aggregates

The properties of recycled coarse and natural coarse aggregates are shown below;

Physical properties	NCA 20mm	NCA 10mm	RCA 20mm	RCA 10 mm
Water Absorption	0.97	0.91	5.2	6.12
Sp. Gravity of Agg.	2.82	2.78	2.57	2.28
Elongation Index	12.34	11.96	11.32	11.32
Flakiness Index	10.7	12.74	12.53	12.11

2.1.3 Concrete Mix Design

A normal mix design of M25 as per IS: 10262-2009 was prepared. The water cement ratio for the concrete maintained at 0.50 without chemical admixture. The mix design of concrete as shown below;

Table 3 Concrete Mix design

Grade	M25
Cement	383.16
Water	191.56
Fine Aggregates	691.6
Coarse Aggregate (>20 mm)	684.7
Coarse Aggregate (<20 mm)	456.46
W/C ratio	0.5

2.1.4 Concrete Mix Proportions

For the research work, the concrete mix proportion or combinations are shown below;

Table 4 Concrete Mix Proportion

Sr. no	Mixes	Recycled Coarse Aggregate replacement (%)	Metakaolin replacement with cement (%)	Blast furnace slag replacement with cement (%)
1	CM	0	0	0
2	R20G20	20	10	20
3	R20G30			30
4	R20G40			40
5	R35G20	35	10	20
6	R35G30			30
7	R35G40			40
8	R50G20	50	10	20
9	R50G30			30
10	R50G40			40

2.1.5 Testing Procedure

For recycled aggregate concrete and control mix the following tests are performed. For workability of concrete slump test as per IS guidelines performed. To compare the strength parameters the compressive strength of cube at 7 and 28 days and split tensile strength of cylinders at 7 and 28 days were performed. For evaluating the durability properties of concrete there are acid resistance test, sulphate resistance test, sorptivity and water permeability performed.

Compressive strength test performed on cube of 150*150*150 mm size after 7 and 28 days of curing. While, split tensile strength performed on cylinder of size 150 mm dia. and 300 mm height after 7 and 28 days curing.

For acid and sulphate resistance test of concrete, there was concrete cubes of size 150*150*150 mm casted and cured for 28 days. After curing they were immersed in 5% concentrated sulphuric acid (H_2SO_4) solution for acid attack and sodium sulphate (Na_2SO_4) solution for sulphate attack for 28 days. Effect of solution can evaluated by visual inspection, change in mass after 14 and 28 days and loss of compressive strength after 28 days measured.

For sorptivity test ASTM 1585 guidelines were followed and concrete specimens of 100 mm dia. and 50 mm height were prepared. After 28 days of curing they are coated by epoxy on the side surface. For calculate the capillary water absorption the weight of specimen measured on 0,1,2,5,10,20,30 & 60 minutes.

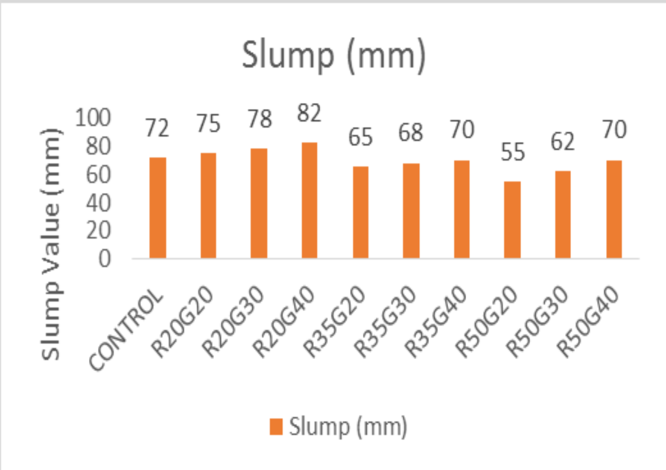
Water permeability test performed as per the railway concrete code. The size of specimens are 150 mm dia. and 150 mm height. After 28 days of water curing the specimens are put in water permeability mechanism and the test performed for 96 hours. First 48 hours of test 1 bar pressure, later 24 hours 3 bar pressure and later 24 hours 7 bar pressure given to water chamber. After the test the depth of water penetration measure using vernier scale for concrete.

3. TEST RESULTS AND DISCUSSION

3.1 Slump Test

Figure 1 shows the results of slump test of concrete. As the figure shows that with the increase of recycled aggregate content the slump value decreases but the GGBS content increases the slump value increases. The best slump result obtained for R20G40 mix.

Figure 1 Slump Test Results



3.2 Compressive & Split Tensile Strength Test

Figure 2 & 3 shows the compressive and split tensile strength results performed at 7 and 28 days. As the figure shows that with increase of replacement of RCA the strength decreases due to the poor interfacial transition zone (ITZ) between new mortar and old mortar attached to old concrete aggregate. That leads to low bond strength between cement paste and aggregate and the strength decreases. However inclusion of MK and GGBS replacement in cement causes dense microstructure of concrete and fill the porosity on old aggregate surface.

At 7 days the strength of concrete containing ternary is decreasing due to MK pozzolonic reaction was not completed while the GGBS pozzolonic reaction starts after 7 days. So, as per the figure the fruitful results obtained at 28 days due to pozzolonic reaction started and that covert slaked lime into C-S-H gel and the concrete strength increases. Same thing happens with split tensile strength test at 7 and 28 days.

R35G40 shows the similar strength so that was the optimum replacement of RCA is 35% and 40% of GGBS.

Figure 2 Compressive Strength

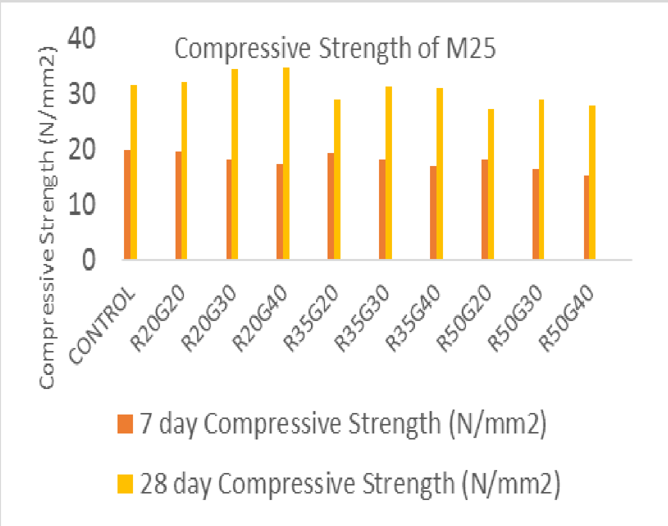
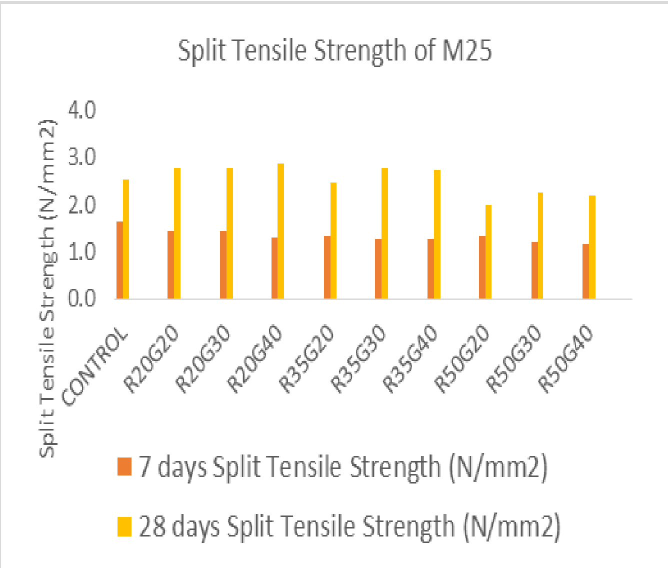


Figure 3 Split Tensile Strength



3.3 Acid Resistance Test

Figure 4 & 5 shows the change in mass and reduction in compressive strength of concrete respectively. As the figure shows that the resistance to acid attack increases with increase the GGBS content in concrete and decrease with RCA content increases. The compressive strength also shows the same variation.

Figure 4 Change in mass in Acid attack

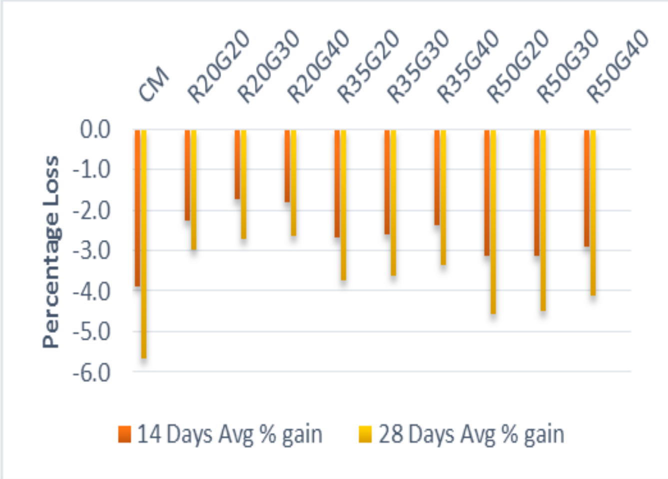
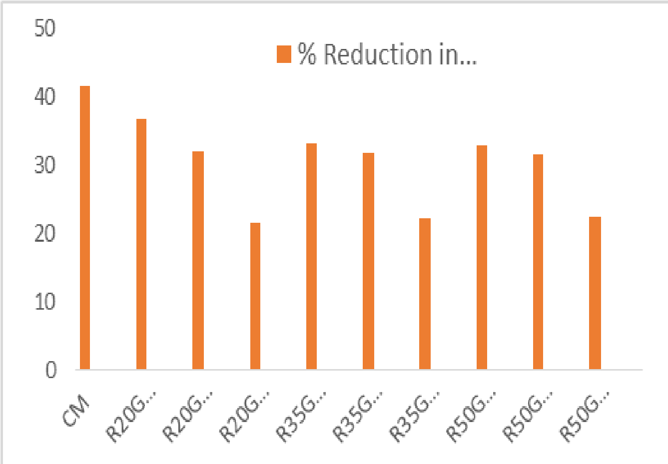


Figure 5 Loss in strength in Acid attack



3.4 Sulphate Resistance Test

Figure 6 Change in mass in sulphate attack

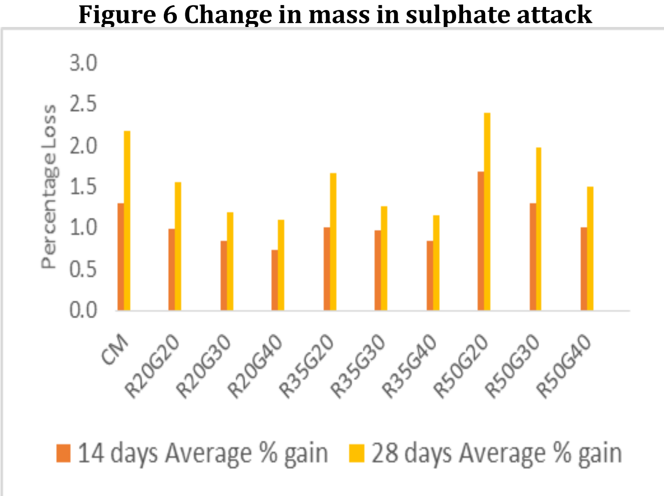


Figure 7 Loss in strength in sulphate attack

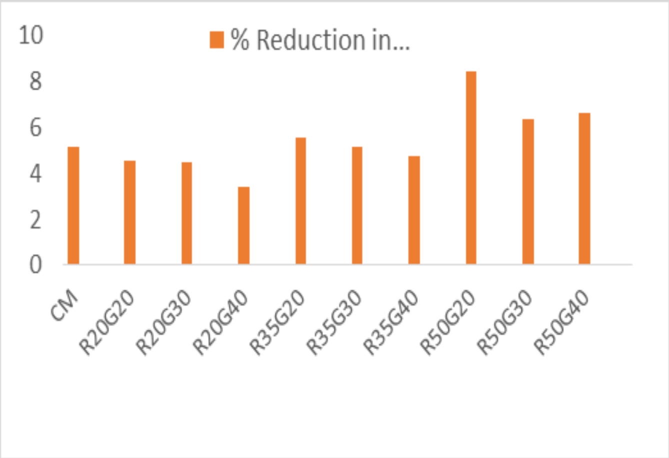
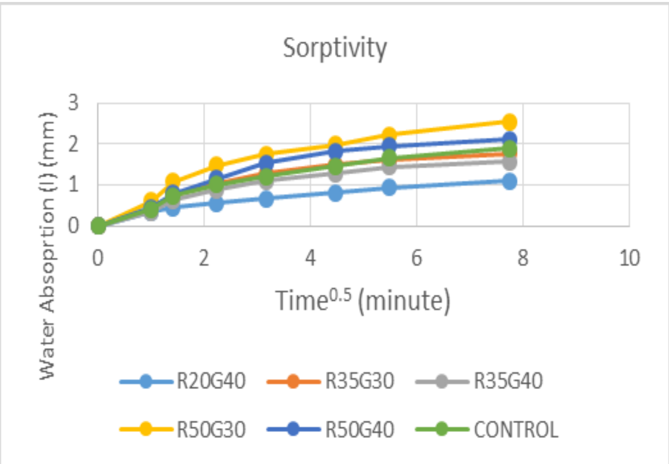


Figure 6 & 7 shows the change in mass and reduction in compressive strength respectively. As the figure shows that the resitance to sulphate attack is incresed of the concrete due to influence of metakaolin and GGBS. They both are very good resistance to sulphate attack but the recycled aggregate presence make concrete porous and sulphate attack seen at 50% RCA replacement.

3.5 Sorptivity

Figure 8 shows the line chart of cumulative water absorption of concrete to square root of time. The chart gives the value of sorptivity. From the figure we can see that the water absorption of the concrete decreases in ternary blend upto 35% RCA replacement.

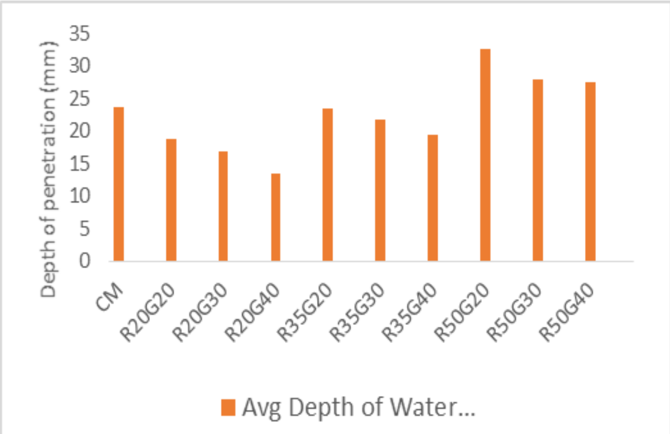
Figure 8 Sorptivity



3.6 Water Permeability Test

Figure 9 shows the results of water penetration depth of various combinations. As per the criteria of test the depth of penetration greater than 25 mm called the porous concrete. As the figure shows that the 35% RCA replacement with 40% GGBS ternary shows the same or better performance. More than 35% replacement of RCA leads to porous concrete and more water penetration depth.

Figure 10 Water Permeability Test



4. CONCLUSIONS

Objective of this study is to maximum replacement of recycled aggregates into concrete with optimum GGBS and MK content in ternary. Based on the study the following conclusions are drawn;

1. The quality of concrete decrease with the increase of replacement of recycled aggregate.
2. With the use of Metakaolin and GGBS in ternary blend, the effect of recycled aggregate is compensated and took to the performance of control concrete.
3. Workability tests results shows that the GGBS increase the workability and the RCA replacement of 20% and GGBS 40% gives the maximum value of slump.
4. Compressive strength test results at 7 day shows that there is the low strength of concrete for all

combination compare to the control mix. For 28 days the results increases due to the pozzolonic reaction took place due to GGBS and metakaolin. RCA maximum replacement is at 35% with GGBS 30% gives optimum value.

5. At 7 day splitting tensile strength of concrete is low than control but at 28 days it's better than control concrete up to RCA 35% replacement.
6. Acid and Sulphate attack results shows that RCA replacement at 35% and GGBS replacement at 40% gives similar or better performance to concrete in term of change in mass and loss in compressive strength.
7. Sorptivity and water permeability test also shows that the optimum replacement is R35G40.

So, it can be conclude that the recycled coarse aggregate replacement with natural coarse aggregate restricted to 35% with ternary blended cement containing 10% metakaolin and 40% ground granulated blast furnace slag (GGBS) to get the concrete with similar or better performance than control concrete.

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