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Properties of Concrete with Coal Washery Rejects Partial Replaced as Coarse Aggregates

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Abstract: *The demand of natural aggregates is rapidly becoming high day by day in the construction industry. Various attempts are being made to find substitutes for natural aggregates. In India, about 70% of electricity is produced by combustion of good quality coal. In the process of coal washing, large quantities of impure coal are being rejected and causing disposal problems. These rejected impure coals are called as Coal Washery Rejects (CWR). To maintain the environmental sustainability, an attempt has been made in the present study to use new material CWR as partial replacement of coarse aggregate in concrete. In this study, coarse aggregates are partially replaced by CWR at different levels (0% - 40%). The Compressive strength , Split tensile strength ,Bond, and. Durable properties RCPT, Drying shrinkage, Water absorption, porosity, of concrete were resolved at various curing periods and contrasted with M25 evaluation of conventional concrete (CC).*

I. INTRODUCTION

Research concerning the usage of by-merchandise and modern squanders to amplify the homes of concrete has been persevering with for a long time. In the past due decade, the endeavors have been made to make use of industry by using-merchandise, for instance, fly ash, silica fume, ground granulated blast furnace slag (GGBFS), glass cullet, and so forth., in the commonplace tendencies. The capability use of modern by products in concrete as incomplete aggregate substitution or as midway cement substitution, contingent upon their synthetic organization and molecule length. The utilization of those substances in concrete emerges because of herbal necessities, inside the sheltered switch of those via merchandise.

Huge attention is being focused across the earth and protective of ordinary assets and reusing of squanders materials. Really several industries are turning in a noteworthy variety of items which be part of scrap (buildups). In the maximum current 20 years, a ton of works concerning the utilization of some kinds of urban squanders in constructing materials industrials system were allotted. Numerous professionals had been reached out to pay attention new varieties of squanders to discover profoundly precise viewpoints. The expansion of squanders, apart from the herbal advantages, likewise creates remarkable outcomes for the properties of specific items.

Aggregates are the primary element of cement regarding round 70-80% of its extent and straightforwardly influencing the clean and difficult residences. The accessibility of top pleasant totals is draining little by little due to massive improvement in Indian development industry. Concrete being the most important guy made cloth applied in the world is frequently requiring tremendous nature of totals in considerable volumes. A need turned into felt to apprehend capability option wellspring of general to satisfy the destiny improvement choice of Indian development enterprise

Indian coal is thought to be of low quality since it contains fiery remains as high as 45%, high dampness content (4–20%), low sulfur content (0.2–0.7%), and low calorific qualities (between 2500–5000 kcal/kg) (IEA, 2002). High slag content in the coal supplied to the force pants postures natural issues as well as results in poor plant execution and high cost for Operation and Maintenance and fiery debris transfer. In this manner, coal washing is essential from monetary and environment perspective. The present introduced limit of washeries for coal is around 131.24 million-tons per annum for both coking and non-coking coal (Energy Statistics, 2013). The era of rejects from washeries in Coal India Limited (CIL) in 2004-05 was 2.44 Mt. Amassed load of washry rejects up to March'05 was 18.15Mt. The Coal Washry Rejects

(CWR) are the major natural peril amid the procedure of Coal Washing. Transfer of this tremendous amount of rejects in a domain benevolent way represents a genuine issue. As of late, the reject from the washry has been reused by smoldering it again in fluidized bed based evaporator to raise steam for Power era. CIL has set up 7nos of 10 MW each FBC based force plants utilizing washry rejects at different areas. Expense of era from these plants shifts from Rs.2.5 to Rs.3.5 per kWh because of operation of these plants in confinement mode at low PLF. The utilization of rejects would bring about sparing of 0.2 Mt crude coal for every year.

II. LITERATURE REVIEW

K. RAJESH KUMAR AND SALINI concluded that from the results it is seen that the concrete mixes with partial replacement of CWR have attained lower values of compressive, splitting tensile and flexural strength properties at all ages as compared to that of conventional concrete. The lower value of crushing and impact strength of CWR is mainly attributed to the decrease in compressive, splitting tensile and flexural strength properties of CWR based concrete mixes.It is observed that the strength properties have been decreased marginally for the concrete mixes CWR_20 and CWR_30. The 28 day compressive strength of the concrete mixes CWR_20 and CWR_30 are comparable to that of M 25 grade of CC.The further increase in replacement of CWR decreased the strength properties significantly as in the case of the concrete mixes CWR_40 and CWR_50.Hence, it can be recommended to use CWR at 30% partial replacement of coarse aggregate in order to attain the desired values of CC.
(1997) as a substitution of coarse total in cement was rakish molded with honeycombed surface composition. The precise state of steel slag total can develop extremely solid interlocking properties.

The Flakiness Index (FI) of the steel slag total is particularly lower than those for the dolerite and quartzite totals (Anastasiou and Papayianni 2006). The measure of earth bump and friable material substance in steel slag is impressively lower than in normal totals (Almusallam et al. 2004). Anastasiou and Papayianni (2006) assessed a few physical properties of pounded steel slag to be utilized as aaggregates as a part of cement. The creators reasoned that the assessed total properties of steel slag are in the middle of the cutoff points of the guidelines and in the best classes. Steel slag has higher scraped area resistance and lower squashing esteem than normal totals. Then again, the particular gravity and water retention limit of steel slag are higher than those of ordinary totals. The porosity of a common steel slag reported by Manso et al. (2004) is 10.5 %. EAF-steel slag totals have incredible imperviousness to fracture (Papayianni and Anastasiou 2010). The surface composition of steel slag is rougher than that of limestone total (Xue et al. 2006; Ahmedzade and Sengoz 2009). The checking electron micrograph of EAF-slag shows the nearness of numerous pores on its surface. Steel slag has higher mass thickness than characteristic totals (Al-Negheimish et al. 1997). A sufficient reviewing of steel slag is important to acquire better execution from cement containing steel slag as total (Manso et al. 2006). Contingent upon the cooling procedure, the molecule size of steel slag may change. Air-cooled steel slag comprises of expansive estimated granules and some powder (Wang et al. 2010). The high substance of free lime (free-CaO) and periclase (MgO) is the adverse component against utilizing different steel slags as total in cement. The substance of free lime (free-CaO) and periclase (MgO) in EAF-slag is significantly lower than in BOF-slag. As steel slag contains extensive materials like CaO and MgO, to be utilized as a part of solid slag is by and large treated. Maturing or weathering of slag, steam and autoclave curing of slag are for the most part performed to lessen extensive oxide substance (Chen et al. 2007; Faraone et al. 2009; Lun et al. 2008; Pellegrino and Gaddo 2009). As most of the steel slag contains free CaO and MgO, investigations are for the most part performed to assess the free CaO and MgO content in the slag and soundness of steel slag aggregate.

III. MIX DESIGN

MIX DESIGN OF M 25 GRADE CONVENTIONAL CONCRETE

This section describes the steps for calculation of M 25 grade conventional concrete mix proportions as per IS 10262 (2009) and IS 456 (2000).

A1 Stipulations for proportioning

a) Grade designation : M 25

b) Type of cement :OPC 53 grade (IS 12269)
c) Maximum nominal size of aggregate : 20 mm
d) Exposure conditions : Moderate
e) Minimum cement content : 300 kg/m^3
d) Maximum water-cement ratio : 0.5
f) Workability : 75 mm
g) Type of aggregate Crushed angular
h) Maximum cement content : 450 kg/m^3
i) Method of placing : Compaction
j) Degree of supervision : Good

A2 Test data for materials

a) Cement
i) Specific gravity : 3.15
ii) Compressive strength at 28 days : 57 MPa
b) Coarse aggregate (20 mm and 10 mm)
i) Specific gravity : 2.6
ii) Water absorption : 0.3%
iii) Free (surface) moisture : Nil
iv) Sieve analysis : Refer 3.1.4
c) Fine aggregate
i) Specific gravity : 2.6
ii) Water absorption : 1.0%
iii) Free (surface) moisture : Nil
iv) Sieve analysis : Refer 3.1.5
v) Grade of zone : Zone II

A3 Target mean strength for mix proportioning

$$f'_{ck} = f_{ck} + 1.65\, s$$

Where, f'_{ck} = Target mean compressive strength at 28 days (MPa)
f_{ck} = Characteristic compressive strength at 28 days (MPa) and
s = Standard deviation
From Table 1 of IS 10262 (2009), standard deviation, s = 4 N/mm^2

Therefore, target mean strength, f'_{ck}= 25 + (1.65 x 4) = 31.6 MPa

A4 Selection of water-cement ratio

From the Figure 2 of IS 10262 (1982), water-cement ratio = 0.53
From the Table 5 of IS 456 (2000), maximum water-cement ratio = 0.5
Therefore, adopt water-cement ratio = 0.5 (lower of the above two values)

A5 Selection of water content

From the Table 2 of IS 10262 (2009), maximum water content for 20 mm aggregate = 186 litre (25 to 50 mm slump range).
Estimated water content for 75 mm slump = 186 + [(3 x 186) / 100]
= 192 litre/m^3

A6 Calculation of cement content

Water-cement ratio = 0.5
Cement content = (192 / 0.5) = 384 kg/m^3
From the Table 5 of IS 456 (2000), minimum cement content for moderate condition and M 25 grade concrete is 300 kg/m^3.
Therefore, adopt cement content = 384 kg/m^3 (higher of the above two values)

A7 Proportion of coarse aggregate and fine aggregate content

From the Table 3 of IS 10262 (2009), volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone III) for water-cement ratio of 0.5 is 0.64
In the present case water-cement ratio is 0.5, hence no correction is required in the volume of coarse aggregate.
Therefore, volume proportion of coarse aggregate = 0.64

A8 Mix calculations

The mix calculations per unit volume of concrete are described as follows:
a) Volume of concrete = 1000 litre/m^3
b) Volume of cement = (384 / 3.15) = 121.9 litre/m^3
c) Volume of water = (192 / 1) = 192 litre/m^3

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d) Volume of all in aggregates = Volume of concrete – (volume of cement + volume of water)
= 1000 – (121.9 + 192) = 686.1 litre/m^3
e) Volume of coarse aggregate = 686.1 x 0.64 = 439.1 litre/m^3
f) Volume of fine aggregate = 686.1 – 439.1
= 247 litre/m^3
g) Mass of coarse aggregate = (Volume of coarse aggregate) x (specific gravity of coarse aggregate)
= 686.1 x 2.6
= 1142 kg/m^3
h) Mass of fine aggregate = (Volume of fine aggregate) x (specific gravity of fine aggregate)
= 247 x 2.6
= 642.2 kg/m^3

A9 Adjustment of mix proportions

Aggregates are assumed in saturated surface dry condition (SSD).
Quantity of water absorbed by coarse aggregate = (0.3/100) x 1142 = 3.426 kg/m^3
Therefore, dry weight of coarse aggregate i.e., weight of coarse aggregate in field condition = 1142 – 3.426 = 1138.57 kg/m^3 ≈ 1139 kg/m^3.
Similarly, quantity of water absorbed by fine aggregate = (1/100) x 642.2
= 6.422 kg/m^3
Therefore, dry weight of coarse aggregate i.e., weight of fine aggregate in field condition = 642.2 – 6.422 = 635.778 kg/m^3 ≈ 636 kg/m^3.
Adjusted water content = 192 + 3.426 + 6.422 = 201.85 kg/m^3 ≈ 202 kg/m^3

A10 Actual quantities of mix proportions

The duly adjusted actual quantities of mix proportions are described below. In the mix, 20 mm and 10 mm coarse aggregates are blended in 60:40 proportion by percentage weight of total aggregate. Mix proportion of cement, fine aggregate and coarse aggregate by weight is given by 1 : 1.66 : 2.97.

Cement	:	384 kg/m^3
Water	:	202 kg/m^3
Coarse aggregate	:	1139 kg/m^3
20 mm	:	683.4 kg/m^3
10 mm	:	455.6 kg/m^3
Fine aggregate	:	636 kg/m^3

IV. TEST RESULTS

Table 1: Mix Proportions Of Constituent Materials Of Concrete Mixes

Mix type	Cement kg/m^3	Water l/m^3	20 mm kg/m^3	10 mm kg/m^3	CWR 20 mm kg/m^3	Sand kg/m^3
CWR_0	384	192	683	456	0	636
CWR_10	384	192	615	456	68.5	636
CWR_20	384	192	546	456	137	636
CWR_30	384	192	478	456	205	636

TABLE 2: SLUMP CONE VALUES

Mix	Slump in mm
M1	68
M2	74
M3	76
M4	85
M5	91
M6	102

TABLE 3 COMPACTION FACTOR TEST

Mix	Compaction factor
M1	0.92
M2	0.95
M3	0.92
M4	0.92
M5	0.92

TABLE 4 COMPRESSIVE STRENGTH OF CONCRETE

MIX TYPE	COMPRESSIVE STRENGTH(MPa)		
	28days	56 days	90days
CWR-0	34.12	36.02	38.72
CWR-10	33.41	35.89	38.69
CWR-20	33.07	35.87	38.65
CWR-30	32.98	35.86	38.64
CWR-40	28.65	30.81	32.16

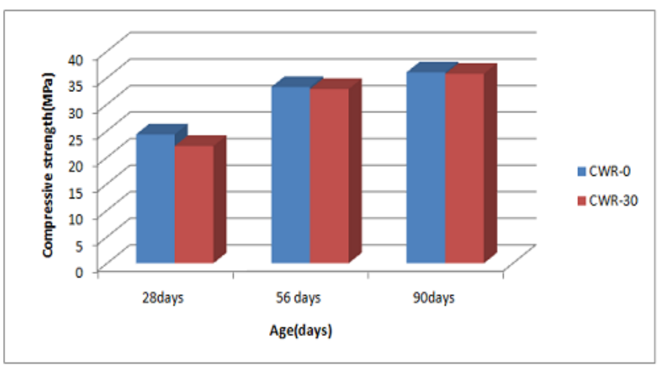

FIG .1 COMPRESSIVE STRENGTH V/S AGE

TABLE 5 SPLITTING TENSILE STRENGTH OF CONCRETE

MIX TYPE	SPLIT TENILE STRENGTH(MPa)		
	28days	56 days	90days
CWR-0	3.54	3.89	3.94
CWR-30	3.49	3.75	3.89

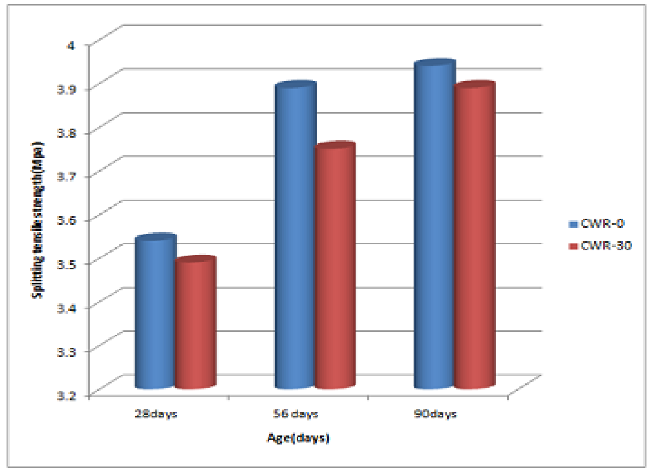

FIG 2 SPLIT TENSILE STRENGTH V/S. AGE

V. CONCLUSION

Based on the test results, the following conclusions are drawn:

1. From the results it is seen that the concrete mixes with partial replacement of CWR have attained lower values of compressive, splitting tensile, bond strength, and MOE properties at all ages as compared to that of conventional concrete.

2. The lower value of crushing and impact strength of CWR is mainly attributed to the decrease in compressive, splitting tensile and Bond and MOE properties of CWR based concrete mixes.

3. It is observed that the strength properties have been decreased marginally for the concrete mixes CWR_20 and CWR_30. The 28 day compressive strength of the concrete mixes CWR_20 and CWR_30 are comparable to that of M 25 grade of CC.

4. The further increase in replacement of CWR decreased the strength properties significantly as in the case of the concrete mixes CWR_40 and CWR_50.

5. Hence, it can be recommended to use CWR at 30% partial replacement of coarse aggregate in order to attain the desired values of CC.

6. It is observed that from the durable properties, the values of RCPT (Rapid chloride permeability test) is observed MODERATE compared with conventional concrete.

7. It is observed that, The values of water absorption is less when compared with conventional concrete at all ages of the curing periods.

8. From the results of porosity it is observed that the porosity values are little more when compared with conventional concrete.
9. From the drying shrinkage values it is observed that the values of drying shrinkage is less when compared with the conventional concrete.

FUTURE WORK

Based on the investigation of this project, the future work includes:

● Study on durability properties of CWR based concrete mixes.
● Keeping in view of the availability of natural resources and environmental aspects, it is recommended to replace some percentage of sand with bottom ash CWR based concrete mixes and study all hardened and durability properties.
● Study on micro level properties of CWR based concrete mixes.

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