CEMENTITIOUS MATRIX COMPOSITES (CMC) WITH MANUFACTURED COAL ASH AGGREGATES (MCAA)

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Abstract

Bulk utilization of coal ash as repository in light weight cementitious matrix composites using both peat ash as a binder and Manufactured Coal Ash Aggregates (MCAA) is an effective means of achieving carbon neutrality . MCAA are lighter in weight than conventional granite aggregates and can be used for production of structural grade concretes. Coalash is pozzolanic and capable of utilizing both heat and calcium hydroxide generated during hydration process of portland cement. Hence it has been used as partial cement replacement materials (CRM) as per the codes.

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1. INTRODUCTION

Use of Peat Ash , M sand and Manufactured Coal Ash aggregates in development of Structural grade light weight concrete yielded 28 days compressive strength of 55 MPa sufficient for use in precast construction.

Peat ash is used as partial replacement material (CRM). Technical feasibility of bulk utilization of Peat Ash has been studied by several researches(1,2) however there is apprehension among field engineers about usage of peatash in construction practice. Also CA conversion into aggregates using waste heat would lead to bulk utilisationvis-a-vispelletisation and sintering.CA based aggregates (CAAS) are lighter than normal granitic aggregates and facilitate production of light weight concretes.28days compressive strength of 35 MPaas been reported by other researchers(1,2). However structural light weight concrete of 55 MPa is required by several agencies including Indian Railways.

2. EXPERIMENTAL WORK

Characterisation of concrete ingredients and mix details are shown in table 1 to 5. Superplasticiser (glenium) dosage of 0.4%by weight of cementitious material was used. Proper mixing was ensured using a drum type laboratory concrete mixer.More than 160 mm slump obtained indicatessuperior workability.The cohesive mix was vibrated and compacted in moulds**.**

3. TEST RESULTS AND DISCUSSION

For each test a five specimens were cast for statistical integrity.

3.1 Characteristics of MCAA (Table 4)

Oblate dimension: The MCAAs produced were in the range of about 4.75 to 20 mm.

Sphericity and Angularity Number: The MCAASproduced wereoblate spheroids. With voids content of 28% and AN value of -5 which is not acceptable as sphere hence the assumption of solid content 67% and void content of 33% as per BS:812 part 1:1975 is not realistic. The ratio of solid volume to the total bulk volume of absolute spherical mix is reported as 0.74 by Lerrard (1999) which provides a void content of 26%. AN values of MCAAs were found to be 3 and 7 for 20 and 10 mm mono size respectively. The MCAAS exhibit high spherecity giving rise to lower surface area per volume, contributing to reduction in water demand which is the ruling parameter of workable mix.

Rodded density: Bulk densityof oven dried state aggregateis 968kg/m3 which is below half that for granitic aggregates and loose sate density is 890kg/m^3.

Relative density(RD): Apparent RD for particles is 1.49 where as for conventional ones have 2.62 to 2.85. Apparent RD depends on packed matrix micro structure indicated by receptability. Apparent RD of solids of MCAA showed large variation. Therefore meticulous selection of RD value depends on fluid/ moisture content during computation of individual contents .

Capillary pore humidity: About 17% of saturated water absorption is found. This value is several times larger compared to the granitic aggregates. The hydration of binder paste leads to loss of humidity in capillary pores.

Water pick up rate: The extensively porous MCAAs pick up 66% of total water in first 8 mins of contactwhich is a requisite factor for computation of volume of water used during mixing process.

Aggregate Crushing Load:MCAAs are relatively weaker than conventional aggregates such as pulverized cobble,granitic pieces which show 4.7 to 5.4 and 8.9 to 9.8 KN crushing loads respectively where as 4.6 to 5.8 for MCAA is obtained. Thus MCAAS in composites act as adulterants with lesser resistance to load gain compared to Cementitious Matrix part of the system. This also has been found by researchers (Satish Chandra et al,2003) who have suggested atleast twice the expected mortar strength in concrete.

MCA aggregate crushing value: Crushed cobble, granitic pieces were subjected to aggregate crushing value test(ACV) in a compression testing machine and percent passing through 2.86mm sieve were 33%,42% and 47% for MCAA , crushed cobbles and granitic pieces respectively this means a superior relative performance by SFAA .

3.2 Concrete Properties

Oven dried Density: Oven dried density of 1800 to 1905kg/m^3 and water saturated densityof 1948 to 2015kg/m^3 were obtained.

Compressive strength: Concrete developed using MCAA showed compressive strengths of 39 to 59MPa. Thus production of minimum structural grade concrete as per codal provision is facilitated by use of MCAAC. Compressive strengths of concrete after oven drying showed 5% to 18% more than specimens which were saturated. However, the gap reduced with augmented MCAA content.Light Weight Aggregates (LWA) have pores without connectivity which hold the water due to which compressive strengths for water saturated conditions is increased. Any part reduction in strength is eliminated because of moisture presence. This is similar as in the case of LWAConcrete.

3.3 Inter relationship between UCS(Unconfined Compressive Strength) of MCAA and Cementitious Mortar

(a) Logarithmic empirical equationis proposed by researchers (Satish Chandra 2003) (Chalmers University Sweden) as follows:

$$\text{Log}(f_{con}) = V_{la}\{\text{Log}(f_{la})\} + V_{cm}\{\text{Log}(f_{cm})\} \quad (1)$$

Where f_{con} =Strength of concrete,
f_{la}= strength of light weight aggregate,
f_{cm}= strength of cementitious mortar,
V_{la}, V_{cm} = Volume fraction of LWA and cement mortar, in concrete;

$$V_{la} + V_{cm} = 1 \quad (2)$$

matrix strength f_{cm} is estimated by considering of fluid binder ratio and UCS for the givencementitious material and also tests were conducted on mortar portion of concrete. following equation is used for obtaining the strength of LWA(F_{LA})

$$F_\rho = \text{Strength of LWA} = a*10*(b*\rho/1000), \quad (3)$$

where, a, b=constants for given aggregate and ρ = particle density of aggregate kg/m3.

a) The equation is reliable due to the validated value of 28 day UCS is close to the computed value. However constants 'a' and'b' need special attention despite suggested values by satishchandra. Crushing load and aggregate strength relation as not been documented in literature. Short and Kinniburgh 1963 had suggested the contribution of aggregate to concrete strength determination with a series of tests on concrete with different weight % ofaggregates and cement mortars of different strengths.

b) Chen's method : Chen defined the dividing strength as the concrete strength beyond which failure occurs through the aggregate. Dividing strength ofcomposite 35MPa was recorded for a particle density of 1500 to 1700kg/m^3 and mortar matrix strength of 57.5 MPa. Concrete strength containingMCAA was found to be between 38 and 50 MPa. Hence 28 days strength of 39 to 59 MPA obtained compares well for mortar matrix strength of 57.5MPa

Rate of strength development: Formula as per SP: 24 BIS, 1982:

$$f_{ct}=(f_{c28})(t)/[4.7+\{0.833\}(t)] \quad (4)$$

With usual notations
f_{ct}=Compressive strength at time 't',
f_{c28}= 28 d compressive strength,
t=age in days.

The above equation gives an under estimated value for the strength in MCAA concretes. This is because the test data for ratio fc7/fc28 gives 84 to 97.8 %. The inoculent in the mortar matrix is weaker than the matrix and hence aggregate strength and mortar strength equilibrium occurs at early curing period which reduces gradually as function of mortar concrete synergy. Cracks steer through the aggregates which is quite different from natural aggregates where the crack propagation is found to be around the aggregate. In case of natural aggregates strength is greater than the mortar.The porous nature of concretes using MCAAC shows no definite transitional zone of high porosity and rich calcium hydroxide starting from aggregate phase to matrix phase. However transition zone has been reported to exist in cementious composites with granitic and basaltic aggregates leading to concrete fracture in the weaker zone.

4. CONCLUSION

1. The explanatory study shows the MCAA as a potential candidate for developing structural grade concretes of higher strength
2. MCAAs are porous and lighter in nature having bulk density of 890kg/m^3 which is less than half of granitic aggregates.
3. Apparent specific gravity of MCAA in oven dried condition is 1.49 indicating that it is a light weight aggregate .
4. MCAA concretes have high slumps of more than 150 mm at fluid binder ratios of 0.36.this is explained by oblate spheroid shape of these aggregates.
5. Mortar matrix strength is much more than the inoculent strength and hence line of failure passes through the aggregate take place during compression test
6. Line of failure passes through the aggregates which is quite different in case of granitic aggregates, where it passes around the aggregates
7. Early curing of concrete gives the equilibriumstrength and hence the concrete developed has lesser strength than in case of natural granite aggregate concrete.

Table 1 Properties of Cement

SLNO	PROPERTY	
1	Type	Ordinary Portland Cement
2	Specific gravity	3.15
3	Fineness,m^2/Kg	245
4	Setting time a) Initial setting time, min b)final setting time, min	 110 295
5	Compressive strength, MPa	55

TABLE 2 Properties of Peat ash

SL NO	PROPERTY	
1	Specific gravity	2.38
2	Fineness, m^2/kg	474
3	Soundness by Autoclave test Expansion of specimens, %	0.026

Table 3 Properties of M sand

SLNO	PROPERTY	
1	Specific gravity	2.622
2	Bulk density Kg/m^3	1656
3	Fineness modulus	3.34
4	Water absorption,%	2.10
5	Moisture content,%	2.15

Table 4 Properties of Manufactured Coal Fly ash aggregates.

SL NO	PROPERTY	
1	Sieve analysis	20mm and down
2	PH	7.38
3	Crushing value ,%	47
4	Los Angeles Abrasion value,%	21
5	Specific gravity	1.49
6	**Water absorption,%** 10 min 30 min 60 min 2 hours 4 hours 24 hours 48 hours(saturated condition)	 9.9 10.2 10.8 10.9 11 17 17.2
7	**Oven dried condition** Apparent specific gravity % moisture content Loose bulk density ,Kg/m^3 Voids ratio,Vv/Vs(loose)	 1.21 0 660 0.89
8	**Air dry condition** Apparent specific gravity % moisture content Loose bulk density ,Kg/m^3 Voids ratio,Vv/Vs(loose)	 1.212 0.10 661 0.89
9	**Saturated surface dry condition(SSD)** Apparent specific gravity % moisture content Loose bulk density ,Kg/m^3 Voids ratio,Vv/Vs(loose)	 1.50 20.1 705.3 0.89

Table 5 Mix proportions:

SL NO	MIX	CEMENTITIOUS MATRIX (C+PA)	FA	CA	F/B	COMPRESSIVE STRENGTH ,MPA
1	MCAA1	(0.9+0.1)	1.18	0.60	0.35	58
2	MCAA2	(0.8+0.2)	1.21	0.65	0.35	55.5
3	MCAA3	(0.7+0.3)	1.31	0.70	0.35	53

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