Influence of Alccofine on Semi-Light Weight Concrete under Accelerated Curing and Conventional Curing Regimes

P. Parthiban, J. Karthikeyan

***Abstract*—**This paper deals with the performance of semi-light weight concrete, prepared by using wood ash pellets as coarse aggregates which were improved by partial replacement of cement with alccofine. Alccofine is a mineral admixture which contains high glass content obtained through the process of controlled granulation. This is finer than cement which carries its own pozzolanic property. Therefore, cement could be replaced by alccofine as 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, and 70% to enhance the strength and durability properties of concrete. High range water reducing admixtures (HRWA) were used in these mixes which were dosed up to 1.5% weight of the total cementitious content (alccofine & cement). It also develops the weaker transition zone into more impermeable layer. Specimens were subjected in both the accelerated curing method as well as conventional curing method. Experimental results were compared and reported, in that the maximum compressive strength of 32.6 MPa was achieved on 28th day with 30% replacement level in a density of 2200 kg/m^3 to a conventional curing, while in the accelerated curing, maximum compressive strength was achieved at 40% replacement level. Rapid chloride penetration test (RCPT) output results for the conventional curing method at 0% and 70% give 3296.7 and 545.6 coulombs.

***Keywords*—**Alccofine, compressive strength, RCPT, wood ash pellets.

I. Introduction

LIGHT weight concrete (LWC) is most widely used in especially in long span bridges and in high rise buildings due to its low density, good vibrating resistance and high thermal insulation [7], [8]. The unit weight of LWC was 20% lesser than the normal weight concrete which also retains the adequate strength. It reduces the members' size and overall cost of the structure [5], [7]. It was reported that LWC has better impermeability, higher frost resistance and it also removes the risk of alkali-aggregate reaction [5], [7], [8]. The passing of harmful ions takes place when the light weight concrete contains high porosity. These result in debar passivation and corrosion which cause the adverse effect on durability of structures [6]. Autogenous deformation gets reduced by using light weight aggregates [2]. The penetration of chloride ions in the LWC can be reduced by using mineral admixtures [3]. Therefore, in this research, alccofine, an ultrafine mineral admixture is used to replace the cement for the preparation of semi-LWC with high resistance against the harmful ions.

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II. Materials Used

A. Cement

In this research, OPC 53 grade cement conforming to IS 12269-2013 was used [14]. The specific gravity of various materials is shown in Table I.

TABLE I
SPECIFIC GRAVITY VALUES

Description	OPC	Sand	Fly Ash	Wood Ash	Alccofine
Specific gravity	3.16	2.80	2.5	2.0	2.8

B. Fly Ash

Class F Fly ash was utilized. It is collected from Mettur thermal station, Tamil Nadu which is conforming to ASTM C 618.

C. Fine Aggregate

Locally available river sand was used which is classified under zone III in accordance with IS 383:2016. The fineness modulus and specific gravity were found to be 2.5 and 2.7, respectively. The sieve analysis of fine aggregate is shown in Table II and Fig. 1

TABLE II
SIEVE ANALYSIS OF FINE AGGREGATES

S. No	Sieve Size (mm)	Retained weight (g)	Cumulative weight retained (g)	Percentage Retained %	Passing %	Grading Limits as per IS 383-2016
1	4.75	0	0	0	100	90-100
2	2.36	90	90	1.8	98.2	85-100
3	1.18	282	372	7.44	92.56	75-100
4	0.6	1002	1374	27.48	72.52	60-79
5	0.3	2761	4135	82.7	17.3	12-40
6	0.15	865	5000	100	0	0-15

D. Coarse Aggregate

Artificially made coarse aggregate (pellets) is prepared from the wood ash particle using pelletization technique. A drum type pelletizer of 650 mm diameter and 220 mm depth with an inclined blade positioned at an angle of 45 degrees was used. Wood ash particles were grounded into fine powder in a ball mill for 15 minutes before the process of making pellets. During pelletization, water was introduced into the rotating drum in terms of spraying. Due to this fact, fine particles get agglomerated and made into a small pea like

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substances called pellets. Sieve analysis, specific gravity, water absorption and bulk density were found to be 7.5, 1.8, 27% and 1140 Kg/m^3 respectively. The sieve analysis of coarse aggregate is shown in Table III and Fig. 2.

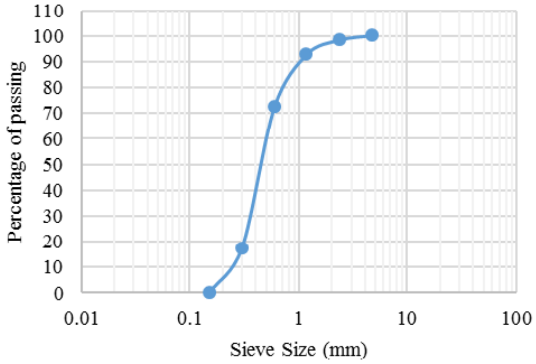

Fig. 1 Sieve Analysis of Fine Aggregate

TABLE III
SIEVE ANALYSIS OF COARSE AGGREGATES

S.No	Sieve Size (mm)	Retained weight (g)	Cumulative weight (g)	Percentage Retained %	Passing %
1	12.5	2.812	2.812	56.24	43.76
2	10	1.128	3.94	78.8	21.2
3	8	1.06	5	100	0

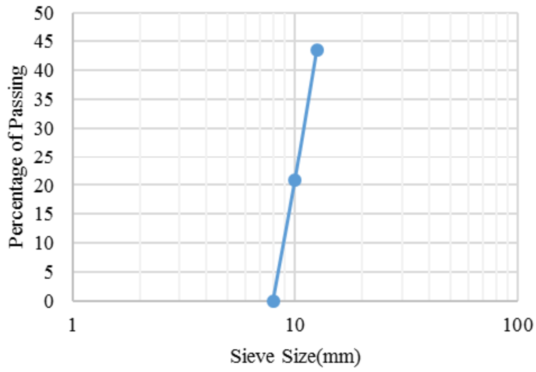

Fig. 2 Sieve Analysis of Coarse Aggregate

E. Water

Potable water is used for making pellets, concrete and also for curing the specimens.

F. Super Plasticizer

Super plasticizer is a brown solution, based on sulphonated naphthalene was used in the concrete mixtures which is conforming to IS 9103-1999 with a specific gravity of 1.2 [4].

G. Wood Ash

The residue left out after the burning of wood chips, barks and trunks is termed as wood ash. In this research, wood ash is collected from the dryers of modern rice mills; specifically obtained from tamarind tree barks [13]. The specific gravity of wood ash is found to be 2.0. Fig. 3 shows the XRD results of wood ash.

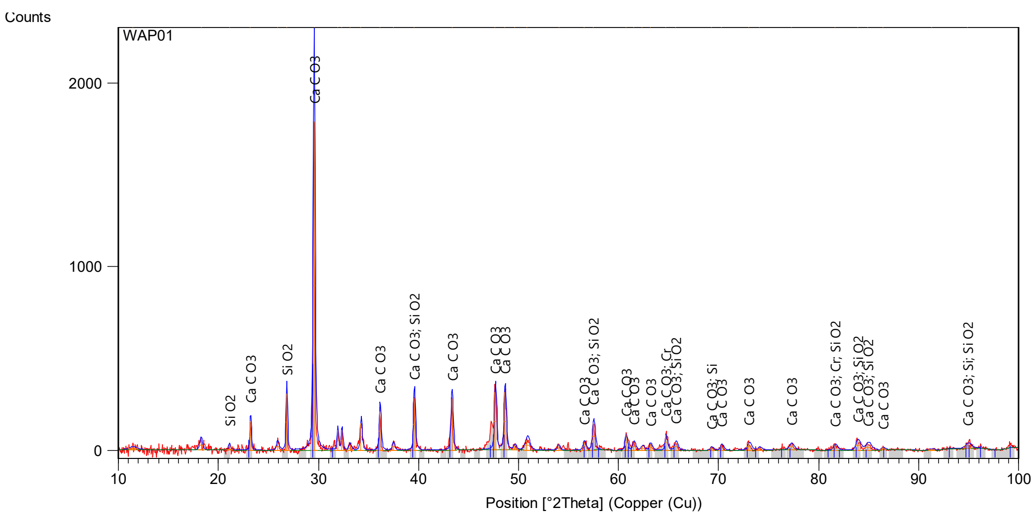

Fig. 3 XRD pattern of wood ash particles

H. Alccofine

Alccofine 1203, low calcium silicate based mineral admixture, is used in accordance with IS 1727-1967 [9] as a replacement of cement to enhance the performance of concrete as well as reduces the hydration of cement. Table IV shows the chemical analysis of alccofine [16].

TABLE IV
CHEMICAL ANALYSIS OF ALCCOFINE 1203

Chemical composition	SiO_2	Al_2O_3	Fe_2O_3	CaO	SO_3	MgO
%	33.7	22.0	1.6	34.3	0.12	6.1

III. MIX PROPORTION

Optimizing the mix design for semi-LWC using this artificially made pellet is a complicated task, due to its high water absorption capacity and porosity. It leads to do several trial mixes in the laboratory and the final proportion of optimized mix design with a maximum cement content of 450 Kg/m^3.

TABLE V
MIX DESIGN

Cement (Kg/m^3)	Fine Aggregate (Kg/m^3)	Coarse Aggregate (Kg/m^3)	Water (Kg/m^3)	Super Plasticizer (Kg/m^3)
450	915.176	622.155	153.3	6.75

In the optimized mix, cement content was replaced by alccofine admixture as 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, and 70% to enhance the strength and durability properties of semi-LWC. For each replacement, 12 No's of specimens has been cast. Specimens cast in 100 × 100 × 100 mm moulds were removed after 24 hours. Six specimens were placed in accelerated curing tank for 3 ½ hours in accordance with IS 9013-1978 using boiling water method (Accelerated Curing Method) and the rest of six specimens were subjected to ordinary curing tank for 28 days. After completion of curing period, specimens were taken out and subjected to compressive test.

IV. TESTING

A. Test on Wood Ash Pellets

The strength of wood ash pellets was determined by loading diametrically under compression. The test set up was shown in Fig. 4. Minimum 10 Nos of pellets were tested to find the average crushing value. The crushing value of pellets is determined by CBR apparatus using (1):

$$\sigma = 2.8p/\pi X^2 \tag{1}$$

where σ is the crushing strength (MPa), P is the fracture load (N), X is the distance between two plates. The results were shown in Table VI.

TABLE VI
CRUSHING STRENGTH OF PELLETS

S. No	X(cm)	P(kN)	σ(MPa)
1.	0.8	0.274	3.82
2.	0.8	0.333	4.64
3.	0.8	0.225	3.13
4.	0.8	0.252	3.51
5.	0.8	0.319	4.44
6.	0.7	0.216	3.93
7.	0.8	0.273	3.80
8.	0.5	0.1	3.57
9.	0.8	0.166	2.31
10.	0.7	0.252	4.59

B. Compression Test

Compression test was conducted on 100 × 100 × 100 mm specimens in accordance with IS 516: 1959 [11]. Characteristic compressive strength was made on accelerated cured specimens after 3 ½ hrs under 100 °C and conventional cured specimens after 28 days were observed.

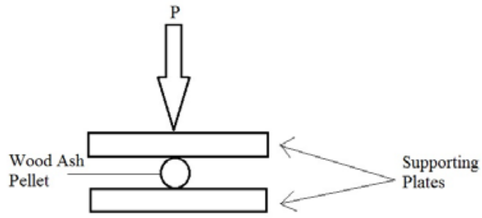

Fig. 4 Crushing strength setup of individual pellet

C. RCPT

This test is conducted on the concrete specimens by applying the electric charges to evaluate the penetration of chloride ions. In this experiment, potential difference of 60 V dc is passed through the 100 ×50 mm cylindrical specimens for 6 hours as per ASTM C1202-17 [15]. The RCPT apparatus is shown in Fig. 5. Finally, the total amount of charge passed through the specimens is calculated using (2) and the results are related with the resistance of concrete to the chloride ion penetration.

$$Q = 900\,(I_0 + 2I_{30} + 2I_{60} + \ldots\ldots + 2I_{300} + 2I_{330} + I_{360}) \tag{2}$$

where, Q= charge passed (coulombs) Io = current (amperes) immediately after voltage is applied, and It = current (amperes) at t min after voltage is applied.

Fig. 5 RCPT apparatus

V. RESULTS AND DISCUSSION

A. Influence of Wood-Ash Pellets in Semi-LWC

Wood ash pellets were prepared by using pelletization process. The raw materials used to prepare pellets were wood ash (60%), fly ash (20%) and cement (20%). Wood ash is a main ingredient, taken part in the production of pellets. Fly ash (class F) plays a vital role to enhance the performance of pellets. Cement acts as a binding material. The specific gravity and bulk density of wood ash pellets were comparatively low, when compared with the conventional type aggregates. Therefore, it reduced the density of concrete by 10% while comparing with normal concrete. Due to the observance of porosity nature of this wood ash pellets leads to act as an internal curing agent and also enhances the early age hydration of interfacial transition zone [1].

B. Influence of Alccofine on Semi-LWC

Alccofine is an ultrafine material, which has its own pozzolanic property. It maintains the workability of concrete at low water-binder (w/b) ratio and also improves the strength and durability of concrete at all ages.

C. Fresh Concrete Properties

For light weight aggregate concrete, thicker grout should be made because it has lower density, lighter particle packing load, smaller vertical pressure. Higher thickness of grout will avoid aggregates floating. Therefore, the designed slump should be maintained in the range of 150-180 mm [10]. Influence of rounded woodash aggregates, literally increases the workability of concrete. When alccofine percentage was increased up to 45% replacement level, the slump got increased from 170-220 mm, later it decreases to 170 mm at 70% replacement level.

D. Compressive Strength

The compressive strength of semi-LWC in the range of 24.3-29.5 MPa at 3 ½ hours in boiling water method is shown in Table VII and Fig. 6. In normal curing method, it is in the range of 25.2-32.6 MPa at 28 days as shown in Table VIII and Fig. 7. All compressive strength values of normal curing method were 1.2-23.5% greater than corresponding values of boiling water method. The alccofine replacement rate was optimized as 30% in normal curing method, and in boiling water method, it shows 40% replacement level. Therefore, the higher compressive strength was achieved from normal curing method as compared with boiling water method. Because of low strength light weight aggregates, the compressive strength can be increased by replacing mineral admixture [12] and also, the strength of the transition zone gets increased.

TABLE VII
COMPRESSIVE STRENGTH VALUES OF SPECIMENS UNDER ACCELERATED CURING

S.No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
% alccofine	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Average Compressive strength (MPa)	24.3	24.3	24.6	24.6	25.7	26.7	25.2	28.5	29.5	28.3	28.0	26.8	27.0	25.7	24.9

TABLE VIII
COMPRESSIVE STRENGTH VALUES OF SPECIMENS UNDER NORMAL CURING

S.No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
% alccofine	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Average Compressive strength (MPa)	28.4	29.6	30.9	32.1	32.2	32.4	32.6	30.8	30.1	29.9	29.7	28.4	27.6	26.8	25.2

E. RCPT

Decreasing the porosity of the concrete will improve the resistivity of it. The compactness of the concrete can be increased by adding ultra-fine materials to it. Alccofine plays a major role in the performance improvement and reduction of pores in the concrete. When increasing the percentage of alccofine, the conductivity of concrete gets gradually decreased. RCPT results depend on the w/b ratio of concrete while going lower w/b ratio, it shows good resistivity against the chloride ion penetration. For conventional concrete, the conductivity value shows 3297 coulombs and for 70% replacement of alccofine, the conductivity gets decreased to 545.4 coulombs.

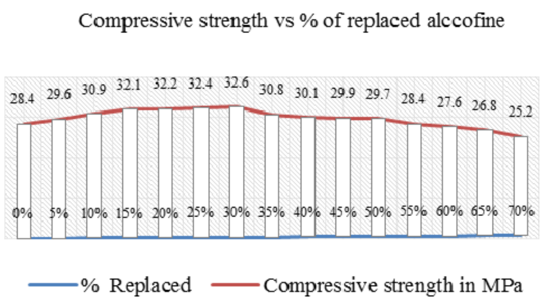

Fig. 6 Normally Cured Specimens

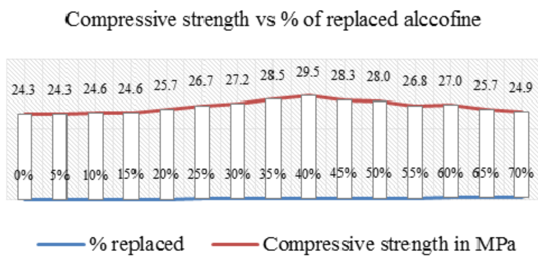

Fig. 7 Accelerated Cured Specimens

VI. CONCLUSION

From the test results, the following conclusions were drawn:

1. From the compressive strength results, for boiling water method, the values are in the range of 24.3- 9.5 MPa. For normal curing method, the values are in the range of 25.2-32.6 MPa. Normal curing method shows better performance than boiling water method, when mineral admixture is added because the influence of alccofine is good in normal curing method.
2. At fixed w/b ratio of 0.34, the design slumps of alccofine replacement concrete maintained in the range of 170-220 mm.
3. The RCPT value is good at 70% alccofine replacement, because of increasing fineness in the concrete, leading to the reduction of porosity.
4. From the test results, it is proven that the low strength concrete may give high durability. Therefore, it should not depend on the strength of the concrete.

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