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PERFORMANCE CHARACTERISTIC OF SUSTAINABLE TERNARY CEMENTS

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Abstract: Cement production leads to an emission of approximately 0.87 ton of CO_2 for each ton of cement produced, which accounts for 7-8% of global CO_2 emissions. To minimize these emissions, various alternative materials or waste products from other industries having pozzolanic or cementitious properties are used. Development of blended cement consisting of Portland cement along with two different SCMs (Supplementary cementitious Materials) has been increased in past two decades. Use of combination of Slag-Fly Ash and Calcined Clay-Limestone based Portland cement has increased in recent times. In the view of the above, present study is focused on, composite cement (Slag-Fly Ash-Portland Cement) and limestone calcined clay cement (Calcined Clay-Limestone-Portland cement), having clinker content as low as (50%). Further, concrete specimens were cast at two different water to cement ratio and various properties of concrete such as compressive strength, porosity and sorptivity were assessed. The performance of ternary cement produced by adding two different SCMs with high clinker replacement showed equivalent performance as of Portland Pozzolana Cement.

Keywords: CO_2 emission; Low Clinker Cement; Porosity;

1. Introduction

Extensive availability of the concrete makes it most used construction material in the world. Carbon dioxide is emitted from cement plant because of calcination of raw materials and burning of fossil fuels [1]. Increased production will lead to further rise in the carbon dioxide emission from the cement industry, having a significant impact on global warming. Supplementary Cementitious Materials (SCMs) are being used as clinker replacement. Depending upon latent hydraulic or pozzolanic property the SCMs undergoes reaction on addition of water. Hydraulic SCMs can react of its own in presence of water whereas pozzolanic SCMs undergoes reaction in presence of calcium hydroxide produced from the hydration of cement. SCMs helps to improve durability and mechanical properties of concrete [2]. Another, important material which does not possess any pozzolanic or hydraulic property but reacts in presence of alumina to give carboaluminates to fill up more space in concrete and thus impart strength i.e. limestone [3].

Quality, limited quantity, and variability restricts the usage of SCMs in cement as clinker replacement. This problem of SCMs can be resolved by using combination of SCMs with any filler. Using blend of SCMs will help to mitigate the shortcomings of other SCMs at the same time improving resistance of concrete and reducing the CO_2 emission by increased clinker substitution.

In India recently a draft Indian Standard code on usage of ternary cement made from the blend of OPC, slag and Fly ash has been proposed. Slag being hydraulic in nature reacts faster in early age along with cement whereas Fly ash pozzolanic reaction contributes in later stage of strength development by filling up the pore space initially occupied by the water [4]. Another blend comprising of OPC, calcined clay and limestone can be used to get high clinker replacement with minimal change in concrete properties as compared to OPC. Recently, a wide interest has been generated on the research of calcined clay limestone blend cement commonly known as LC^3. The pozzolanic reaction of calcined clay with CH produced from hydration of cement, reaction of limestone with alumina of calcined clay and cement creates a synergetic effect in the system [5].

In this study mechanical and pore structure properties of concrete made using this two type of cements OPC-Slag-Fly Ash (CC1) and OPC-Calcined Clay-Limestone (CC2) are studied.

2. Methodology

2.1 Materials

OPC required for the production of two blends was produced by grinding clinker in a laboratory scale ball mill. Slag, Fly ash, limestone, calcined clay and gypsum was procured from western region of India. The composition of the blends produced is given in Table 1. The quantity of gypsum to be added was decided by sulphate optimization carried out using isothermal calorimetry. Interblending of the raw materials in ball mill in known proportion was carried out to get a homogeneous mix.

Table 01. Percentage composition of raw materials

	Clinker	Calcined Clay	Lime stone	Fly ash	Slag
CC1	50	-	-	15	31
CC2	50	31	15	-	-

*4 % gypsum was added in both the system.

2.2 Experiments

2.2.1 Sample preparation

Concrete was cast with both the blends at two different water to cement ratio of 0.35 and 0.45. The concrete mix design was finalized according to guidelines provided in Indian Standard IS 10262 (2009) [6]. Crushed rock was used as coarse aggregate whereas river sand was used as fine aggregate. 15x15x15 cm3 cubes were cast to measure the compressive strength whereas cylinders of diameter 10 cm and height of 20 cm was cast to measure pore structure characteristics of the concrete. Poly carboxyl ether based admixture was used at the time of casting to get a flowable mix. After casting, the specimens were left in the mould for 24 hours. Thereafter, concrete specimens were demoulded and kept underwater for curing till 28 and 120 days.

2.2.2 Compressive Strength

The compressive strength of the concrete was measured on the cubes at the end of 28 and 120 days of curing. Three different cubes were tested on each age.

2.2.3 Porosity

The porosity of both the blends after 120 days of curing was determined according to guidelines provided in ASTM C642.

2.2.4 Sorptivity

Water absorption characteristics of concrete by sorption was measured by the method described in ASTM C1585.

3. Results

3.1 Compressive Strength

The compressive strength of the concrete measured is given in Table 2.

Table 02. Compressive strength of concrete (Mpa)

	28 days		**120 days**	
w/c	**0.35**	**0.45**	**0.35**	**0.45**
CC1	37.33	27.93	41.74	29.30
CC2	47.11	32.74	55.05	35.07

3.2 Porosity

Porosity was measured on the concrete cylindrical samples. After the end of 120 days of curing regime, the cylinders were cut into disc having height of 5±0.2 cm. The porosity results of the blends casting using ternary cement is shown in Table 3.

Table 03. Porosity (% voids)

	w/c	
	0.35	0.45
CC1	6.22	9.08
CC2	6.30	6.79

3.3 Sorptivity

The sorption characteristics of the concrete sample was measured on cylindrical disc samples as described in above section. The results of primary absorption by concrete samples is given in Table 4.

Table 04. Water Absorption (10^{-2} mm/sec$^{1/2}$)

	w/c	
	0.35	0.45
CC1	0.0109	0.031
CC2	0.0169	0.021

4. Discussion

The compressive strength result of CC2 is more than as compared to CC1 and at par with OPC concrete made at same water to cement ratio. Increase in strength is observed in concrete samples after 120 days of curing. The lower strength of CC1 mix can be attributed to lower reactivity of Fly ash in the cement. In CC2 system formation of carboaluminates restrict the decomposition of ettringite to monosulfate. This occupy more space filling capacity and thus impart strength to the concrete. The porosity of both the systems at lower water to cement ratio is despite of lower strength in CC1 blend. The porosity of CC1 blend is higher as compared to CC2 blend at higher water to cement ratio, which is evident from low strength of CC1. The sorptivity results also follow the similar trend. At lower water to cement ratio the sorption in CC2 blend is higher because of more pore refinement due to pozzolanic reaction and carboaluminates phase formation thus more suction.

5. Conclusions

Performance characteristic of composite cement made by using combination of blends was studied.

- Composite cement containing calcined clay and limestone seems to perform better in terms of mechanical properties as compared to blend containing slag and Fly Ash.
- The porosity and sorption of concrete made using both the blends are almost similar. With CC2 blend showing better characteristics at lower water to cement ratio.
- Synergetic effect of limestone and calcined clay imparts strength and refined pores in the system.

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