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Studies on Synthesis and Mechanical Properties of Calcium Sulfoaluminate Cements by Using Marble Waste Powder as a Raw Material

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Abstract- **In this study, two types of Calcium Sulfoaluminate (CSA) cement clinkers were synthesized from reagent-grade chemicals among them one is 15% of partial replacement with Marble Waste Powder (MWP). Raw materials are blended with ultra pure water and blended raw ingredients were collected in alumina crucibles after drying in an oven and then fired in an electric high temperature muffle furnace at 1250°C for 2 hours soaking time. After completion of firing, the synthetic clinkers were ground into fine powder form through ball mill and tested for mechanical properties such as Specific Gravity, Standard Consistency, Initial and Final Setting Times, Soundness, Workability and Compressive Strength.**

Index terms - Synthesis, Mechanical Properties, CSA Cement, Marble Waste Powder (MWP).

Notations- $C_4A_3\$$:Tetracalcium Trialuminate Sulphate (Yeelimite), C_2S:Dicalcium Silicate, CA:Calcium Monoaluminate, $C_{12}A_7$:Mayenite, C$:Calcium Sulphate, C_4AF:Tetracalcium Aluminoferrite, C:Free Lime.

I. INTODUCTION

Cement is an essential component of the construction industry. Modern world cannot develop without it. The Calcium Sulfoaluminate (CSA) cements are currently receiving a lot of interest, because their manufacture produces less CO_2 than Ordinary Portland Cement (OPC) and also the beneficial use of industrial wastes as raw materials.

Zhang and Wang [1] state that the Ettringite or CSA Cements are of high alumina cement that first came to prominence in the 1970's. Sulfoaluminate cement was developed by introducing $C_4A_3\$$ and it is known as klein's Compound.

Carmen Martín-Sedeñoa et al [2] was discussed the laboratory production of three aluminum-rich BSA clinkers with nominal mineralogical compositions in the range C_2S (50–60%), $C_4A_3\$$ (20–30%), CA (10%) and $C_{12}A_7$ (10%).

Belz et al [3] derived special cements based on CSA, can be successfully synthesized at a laboratory scale from raw mixes containing Limestone, Bauxite, fluidized bed combustion (FBC) bottom and/or Fly ash heated at 1200°C - 1300°C.

Glasser Zhang [4] examined and compared to Tricalcium silicate (Ca_3SiO_5), which releases 0.578g of CO_2 per gram of the cementing phase when made from Calcite and Silica, whereas CSA clinker releases only 0.216g of CO_2 per gram of cementing phase when made from Limestone, Alumina and Anhydrite. The firing temperature used to produce CSA clinker is typically 1250°C, about 200°C lower than that used for Ordinary Portland Cement (OPC) clinker. In addition, this type of clinker is easier to grind than OPC clinker.

Chena and Juenger [5] state that the potential problem facing the widespread adaption and production of CSA cement is the cost and availability of raw materials such as Bauxite, Limestone and Iron Oxide. Therefore, it is desirable to find alternative raw materials to keep costs competitive. If the raw materials are waste products of other industries, the environmental benefit of CSA cement becomes even greater than simply a reduction in energy usage, since the cement becomes a useful repository for waste materials that would otherwise enter landfills.

Objective of present study is the use of MWP as a raw material for production of CSA-MWP sample and compared with reference CSA-Ref sample.

II. MATERIALS AND METHODS

In this study, two types of CSA cement clinkers (CSA-Ref & CSA-MWP) were synthesized based on potential target phase clinker compounds estimated by modified Bogue compounds method [6] is shown in Table 1, which produces better mechanical performances.

Table 1. Potential Target Phase Clinker Compounds.

Mineral Compound	$C_4A_3\$$	C_2S	C$	C_4AF	C
Wt %	42.70	37.27	12.6	7.60	0

The CSA-Ref sample prepared with reagent-grade chemicals of Calcium Oxide (96% CaO; Merck), Silica Oxide (95% SiO_2; Merck), Aluminum Oxide (98% Al_2O_3; Merck), Ferric Oxide (93% Fe_2O_3; Qualigens), and Calcium Sulphate Dihydrate (99% $CaSO_4.2H_2O$; Merck). The other sample CSA-MWP prepared with the same reagent-grade chemicals along with replacement of 15% MWP. The MWP was collected from local marble (Jaipur Origin) stone dressing plant at Tirupati, Chittoor District, AP, India and the chemical compositions of MWP were shown in Table 2.

Table 2. The Chemical compositions of MWP.

Chemical Compound	Composition in wt %
CaO	49.00
SiO_2	1.69
Al_2O_3	1.05
Fe_2O_3	0.20
MgO	6.70

The proportioned raw materials shown in Table 3 were blended with ultra pure water (1:2 ratios) by using an aluminum mixi jar for 1 hour at 100 rpm. The blended solutions were transferred to ceramic crucibles and dried in a laboratory oven at 103°C for 24 hours. The resulted materials were crushed into fine powder by using a mortar and pestle. This powder samples were collected in alumina crucibles and then submitted for firing in an electric high temperature muffle furnace at 1250^0C for 2 hours soaking time. After completion of firing, the synthetic clinkers were ground into fine powder form through ball mill and tested for mechanical properties such as Specific Gravity, Standard Consistency, Initial and Final Setting Times, Soundness, Workability and Compressive Strength.

Table 3. The raw material proportions of samples in wt%.

Chemical Compound	Sample Name			
	CSA-Ref (Reagent - grade)	CSA-MWP		
		Reagent - grade 1	MWP (15 %) 2	Total 1+2
CaO	40.50	33.15	7.35	40.50
Al_2O_3	23.00	23.00	0.15	23.15
$CaSO_4$	21.00	21.00	--	21.00
Fe_2O_3	2.50	2.50	0.03	2.53
SiO_2	13.00	12.5	0.25	12.75
MgO	--	--	4.47	4.47

III. RESULTS AND DISCUSSIONS

Tests conducted according to BIS 12269:1987 for measurement of mechanical properties of CSA cement powder samples. The results of mechanical properties of CSA clinkers were shown in Table 4.

The specific gravity of both CSA-Ref and CSA-MWP samples were observed same and noted as 3.15 and it is also compatible for specific gravity of OPC.

The standard consistencies were observed as 22% and 24% for CSA-Ref and CSA-MWP samples respectively. The observed standard consistency shows that it requires the amount of water to produce plastic mix.

Initial setting times were observed as 9 min and 11 min for CSA-Ref sample and CSA-MWP sample respectively. The observed initial setting times indicates that both samples set rapidly (flash set) and it is said to be Rapid set cements [7].

Table 4. Mechanical properties of CSA cement samples.

Properties	Cement sample details	
	CSA-Ref	CSA-MWP
Specific gravity	3.15	3.15
Standard Consistency, %	22	24
Initial Setting Time, min	9	11
Final Setting Time, min	24	27
Soundness, mm	1.50	2.00
Workability of Mortar, w/c Ratio	0.42	0.50

Initial setting times were observed as 9 min and 11 min for CSA-Ref sample and CSA-MWP sample respectively. The observed initial setting times indicates that both samples set rapidly (flash set) and it is said to be Rapid set cements [7].

The final setting times were observed as 20 min and 24 min for CSA-Ref and CSA-MWP samples respectively this indicates that hardening of cement paste was completed in short time.

The observed values of soundness were 1.5 mm and 2.0 mm for CSA-Ref and CSA-MWP samples respectively. This indicates that CSA samples were less expansive.

The 1, 3, 7, 21 and 28 days moist curing ages of cement mortar cube compressive strength (Shown in Fig 1) were measured on 50x50x50 mm cubes. The workability (w/c ratios) was kept 0.42 and 0.50 for CSA-Ref and CSA-MWP samples respectively. Compressive strength on all ages of curing days the strength increases steadily and significantly for both samples of CSA-Ref and CSA-MWP.

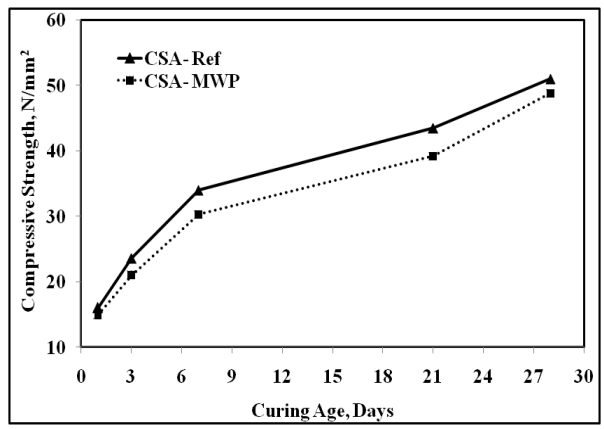

Fig 1. Compressive Strength results of Samples.

IV. CONCLUSIONS

CSA clinkers were produced successfully at lower temperature (1250^OC) compared to OPC driving to reduces energy consumption and lower CO_2 emissions because of low lime requirement.

Present study, the CSA-MWP sample synthesized from optimum utilization materials of 15%, indicating that the adapted Target Phase Clinker Compounds can effectively predict mechanical properties Clinkers.

The flash set represents Rapid Set Cement and it makes it is uniquely suited for all applications as needed.

Compressive strength on all ages of curing days the strength increases steadily and significantly for both samples of CSA-Ref and CSA-MWP.

Finally, the use of high CaO (49%) containing waste material such as MWP reduces the use of expensive raw materials such as reagent grade CaO, thereby reducing cost and the environmental impact of cement manufacturing.

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