PERFORMANCE OF CALCINED COMMON CLAY AS PARTIAL REPLACEMENT TO CEMENT IN SELF-COMPACTING CONCRETE

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Extended Abstract

Segregation resistance of SCC is usually achieved by increasing the proportion of fines and reducing the coarser particles (powder type SCC mix design). This necessitates the use of a high proportion of cement in this method of SCC production [1]. Although, an effort is on-going to produce cement with reduced clinker factor while at the same time maintaining the same level of strength and durability as achieved with Portland cement (OPC) without any substitution [2]. The first giant stride made is the production and standardization of Portland limestone blended cement. With this type of cement, the clinker factor can be substituted with up to 35 wt.% ground limestone powder (LP) [3] without an adverse effect on strength and durability.

The mechanism of LP reaction in cement base paste is both with the aluminate phases in the cement or the aluminium-rich supplementary cementitious materials (SCM) and portlandite. It is therefore prudence to incorporate the blend of LP and aluminium-rich SCM (e.g. calcined clays) as a partial substitution to the clinker phase [4]. This formed the bases for the production and use of limestone-calcined clay cement. The most commonly used clay for this purpose is kaolinite-rich. This clay has some other industrial attractions making its use in concrete more costly. Therefore, establishing the potentials of other clays not rich in kaolinite as partial replacement to cement in SCC production is suitable.

CEM I 42.5 R conforming to DIN EN 197-1 [3] was partially substituted by 15 wt.% LP to form a Portland limestone blended cement. The blended cement was further substituted with a calcined common clay (CC) at 20 and 40 wt. %. Sand with maximum grain size of 4 mm, bulk density of 2.87 g/cm3 and having 7.6 wt.% passing sieves 0.125 was used as fine aggregate (FA). Gravels with a bulk density of 2.68 and about 2.7 wt. % passing sieves 0.125 was used as coarse aggregate (CA). Aggregates fractions lower than 0.125 were sieved out. The empirical design method of Okamura et al. [1] for SCC was adopted to obtain the proportioning of the constituents for the SCC from the paste and mortar. The proportioning of the SCC is shown in Table 1.

Table 1: Paste and SCC mix designation

Mix designation	*Constituents [m^3/m^3]*						
	OPC	*LP*	*CC*	*FA*	*CA*	*Water*	*SP [wt. % of OPC]*
SCC-00CC	0.167	0.029	-	0.289	0.323	0.172	0.60
SCC-20CC	0.133	0.024	0.039	0.289	0.323	0.172	0.70
SCC-40CC	0.100	0.018	0.078	0.289	0.323	0.172	0.90

Slump flow was used to evaluate the filling ability of the SCC, while the J-ring test with 16 re-bars was employed to assess the blocking tendency of the SCC. The viscosity of the SCC was determined using the V-funnel test. The mechanical and durability properties of SCC were assessed at 28 days of curing. 150 x 300 mm cylinders were used for testing compressive strength and modulus of elasticity. The depth of chloride penetration was determined on 100 x 50 mm cores drilled and slices from 150 x 150 mm cubes. For the porosity and TG measurements, a self-consolidating paste was produced and cured at a climatic condition of 20 °C/65 % relative humidity until testing. For the TG measurement, binder hydration was stopped by solvent exchange method and the samples dried in a ventilated oven at 60 °C for 12 h. About 300 mg of the powder was heated between room temperature to 1000 °C at a rate of 2 K/min, under a nitrogen atmosphere using Netzsch STA 449 F3 Jupiter equipment. Porosity was measured on approximately 1 mm^3 specimens using Thermo Fisher mercury intrusion porosimeter Pascal 140 and 440.

Table 2 shows the effect of binder substitution with CC on slump flow, V-funnel time, and blocking tendency of the SCC. An increasing SP dosage is required to achieve the targeted SCC average slump flow when CC is used as binder substitute. The viscosity of the system with CC is relatively high and it deformed slowly compared to the system without CC (T_{500} results). With adjusted dosages of SP, binder substitution with CC has no significant effect on the blocking tendency of the SCC.

Table 2: Fresh properties of SCC

Specimens	*Slump flow [mm]*	*T_{500} [s]*	*V-funnel time [s]*	*J-ring [mm]*
SCC-00CC	700	3.0	15	3.5
SCC-20CC	740	4.3	22	4.7
SCC-40CC	760	6.1	24	3.2

A compressive strength of 70 MPa was obtained for the SCC without CC. Cement replacement with up to 40 wt. % has no significant effect on its 28 days compressive strength. The modulus of elasticity followed the same train as depicted in Table 3. The combined effect of pore size refinement and microstructural densification at 28 days of hydration provided by CC led to increased resistivity of SCC produced with CC as a cement substitute. Consequently, the depth of chloride penetration and the coefficient of migration is less in the SCC system with CC as shown in Table 3. These findings are in line with the influence of metakaolin on compressive strength and modulus of elasticity of SCC [5, 6].

Table 3: Mechanical and durability properties of SCC

Specimens	Compressive strength [MPa]	Modulus of elasticity [GPa]	Chloride penetration depth [mm]	Chloride migration coefficient [m^2/s]
SCC-00CC	70.0	34.4	21.5	$13.8*10^{-6}$
SCC-20CC	70.3	34.9	18.5	$8.0*10^{-6}$
SCC-40CC	71.0	35.5	16.5	$4.7*10^{-6}$

The use of CC as partial replacement to binder for SCC production increased the viscosity of the SCC and slightly influenced its 28 days compressive strength. More so, CC refined the porosity of SCC and reduced the depth of chloride penetration. The outcomes of the study revealed the suitability of using CC as a partial replacement to Portland limestone blended cement for the production of SCC.

References

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