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Comment on "Thermo-mechanical behaviour of low cement castables derived from mullite aggregates synthesised from beach sand sillimanite"

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Low Cement Castables (LCC) is commercially available in the market since the 1970's. The features and characteristics of LCC are well known [1,2]. A recent work [3] report the properties of LCC, based on 6% of Calcium Aluminate Cement (CAC) commercially produced by us and 6% fumed silica. The properties of LCC reported in Ref. [3] are far from those reported in the literature and discrepancies are in the following areas:

- Apparent porosity (AP) as well as Bulk Density (BD) reported here are anomalous for LCC. The authors have reported BD at 110 °C and 800 °C for LCC 2.6 and 1.4 gm/cc, respectively (Fig. 4) [3]. The authors also report an increase in porosity from ~18% for 110 °C dried sample to ~38% for the samples cured at 800 °C, which for properly designed LCC are 10% and 14%, respectively [4].
- The Cold Crushing Strength (CCS) as function of treatment temperature is reported in Fig. 3 [3]. The authors report a CCS of ~20 MPa for the castable dried at 110 °C and the same for the castable treated at 1000 °C drops to ~17 MPa. The authors have justified this observation as a normal phenomenon in refractory castable and have attributed the same to "breaking down of the hydraulic bond" in the LCC. The CCS at 110 °C for commercial grade 70% alumina LCC, based on the same cement produced by us, is 70 MPa and no reduction in CCS is observed when the product is treated at elevated temperature [4].
- Fig. 5 [3] reports the Hot Modulous of Rupture (HMOR) of the castables pretreated at different conditions. The HMOR of "Prefired" samples is ~18 MPa, whereas the CCS of the same specimen is ~20 MPa. The H MOR at 1200 °C is expected to be equal to C MOR. CCS to Cold MOR ratio as reported by the author [3] thus is ~1, which, in general, is in the range of 5–6 [5].

In this context it is prudent to analyse the bonding mechanism for LCC and the reasons for strength development in LCC. Appropriate particle size adjustment and incorporation of ultrafine particles, like micro-silica, are the key to proper designing of LCC. The particle site distribution (PSD) of the aggregates plays a dominant role and manufactures of LCC maintain the PSD as per well-known available models [6–8].

The use of micro-silica, in combination with appropriately selected dispersant or superplasticizer, has excellent micro-filler, i.e. water reducing, effects in LCC. The micro-silica replaces water and air, which otherwise occupy minute void space between the finer aggregates. Cations such as Ca^{2+} and Al^{3+}, generated due to CAC hydration, act as flocculants in this dispersed system and cause rapid agglomeration of aluminous cement and refractory fine particles, which is the cause of fast loss of workability of LCC. It is hypothesised that pozzolanic reactions yield C–A–S–H (zeolitic structure). C_2ASH_8 (gehlenite hydrates), pseudo-zeolitic structure and C–S–H hydrate, though no pozzolonic phase has been identified by X-ray diffraction (XRD). Additionally, in LCC hydrated calcium aluminate phases also are not identified by XRD. The bonding system of LCC is primarily due to agglomeration, instead of hydraulic reaction, and is called "agglomerate bond" [9]. Prior to the development of LCC, the bonding phase of hydrated castables was hydration products of CAC and thus, a drop in CCS is observed in the 800–1100 °C range due to dehydration of hydrated calcium aluminate phases. Low cement castables with ultra-fine material, like

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micro-silica, are different from hydraulically bonded conventional castable where no such reduction in CCS is observed. Owing to efficient packing of the aggregate in appropriately designed LCC, the AP at no temperature exceeds 18%.

The reasons, we speculate, for extremely poor CCS and high porosity of the LCC, based on our CAC, reported in Ref. [3] are

- Improper dispersion of fumed silica
- Erroneous dosage of deflocculant
- Selection of improper grade of fumed silica
- Improper aggregate grading
- High aggregate porosity

Any of the above or their combination would yield product with such low BD and high porosity as has been reported in Ref. [3]. High porosity, in turn, would cause low CCS of castable [10].

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