DESIGNING PARTICLE SIZING AND PACKING FOR FLOWABILITY AND SINTERED MECHANICAL STRENGTH

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Processing of particulate systems (loose powders, slurries, pastes) is determined by particle packing, hence particle size distribution and particle morphology. These characteristics also greatly affect many properties and the performance of bodies consolidated from powders (dry and sintered powder compacts). However, the particle requirements for consolidated powders are frequently opposed to those for loose powder systems. Refractory concretes provide a unique example of this antagonism: fresh castables require easy flow for improved workability and casting; set and sintered castables require low porosity and high mechanical strength. More than a century's work has been dedicated to finding the best compromise solution, from Academia (thorough explanations and comprehensive models) and industry (competitive practical solutions) alike, from the spherical particle packing models of Furnas and Andreasen to the development of the latest generation ultra-low cement castables. Still, it is difficult to define the requisites for an adequate new formulation and the last resort is simple adjustment of older ones, based on rule of thumb or virtue of experience. In this work, alumina powders in various commercially available size fractions, together with the "Lisa" software (Elkem Materials) and the statistical design of mixture experiments and response surface methodologies (Statistica—StatSoft Inc.), were used to prepare various powder mixtures which were characterized for packing density, size distribution modulus, flowability and after sintering properties, in order to investigate the relationships between these variables. The optimized all-alumina castable was found to require 47.5 wt.% of a fine size matrix with high flowability, which provides the necessary flow bed for 52.5 wt.% of coarse aggregates (Table 1), and presented a fresh flowability index above 106% and a sintered modulus of rupture above 52MPa.

Table 1: Optimum size composition for self-flowability and high mechanical strength.

Alumina matrix [wt%]			Alumina aggregate (T60) [wt%]		
CT3000SG	<25µm (T60)	<63µm (T60)	1–3 mm	0.5–1 mm	0.2–0.6 mm
28.5	9.5	9.5	11.375	11.375	29.75

The optimization of matrix, aggregate (Figure 1) and matrix-aggregate proportion, subjected to different property requirements brought to light the relationships between Andreasen size distribution modulus (q), specific surface area (SSA) and maximum paste thickness (MPT). The prevailing mechanisms were investigated for three fundamental processing steps, namely, dry powders, fresh paste and consolidated dry body. A graphical interpretation is provided.

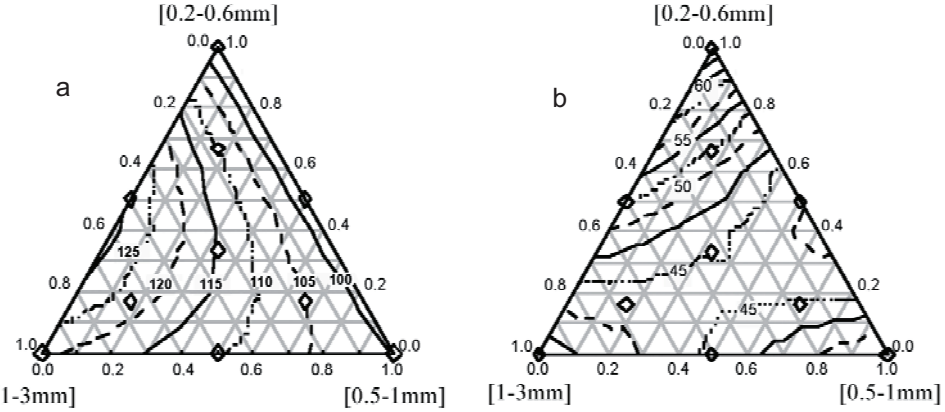

Fig. 1: Aggregate properties contour plots: a) Flowability Index [%]; b) Mechanical strength [MPa].