Particle Packing

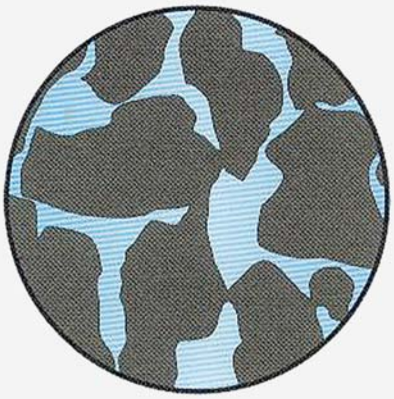
Any castable may be described as a mixture of aggregates and a matrix that has the ability to set. It is obvious that almost infinite variations exist concerning raw materials and proportioning of both, aggregates and matrix.

Amongst a number of key factors that control the properties of the castables, Particle Size Distribution (PSD) is one of the most important.

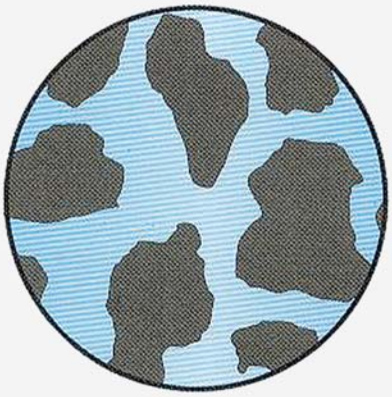
By controlling the particle size distribution of a castable, dense packing can be achieved. Dense packing minimises the amount of water needed for casting, which will result in low porosity and high strength properties in the product.

To gain full benefit of the PSD technology, it is advisable to use a computer-based tool that gives a graphic representation of experimental compositions.

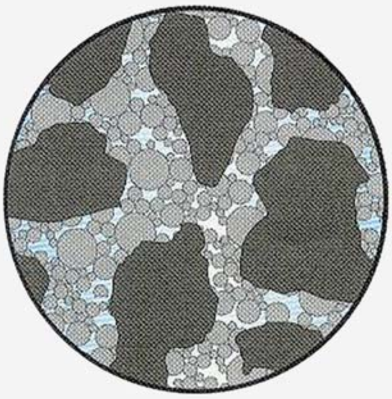
In order to explain how particle packing influences the flow properties of a castable, some basic principles should be considered:



Vibra flow is obtained when there is just enough water to fill the voids. However, the aggregates remain in contact, and external energy must be applied to make the coarse particles and matrix move.

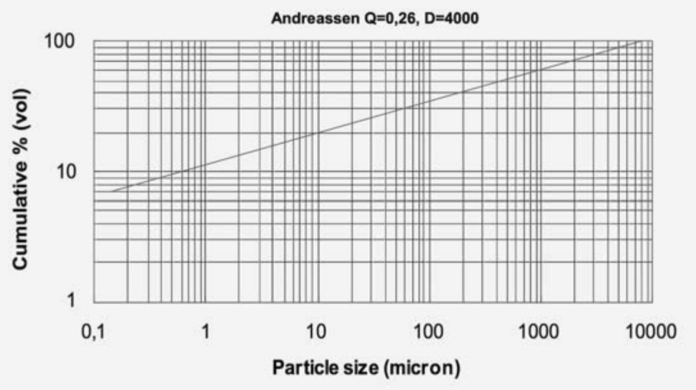


Free flow is attained upon addition of more water, or more matrix fines. The aggregate particles become separated, and no external energy is needed to obtain flow.

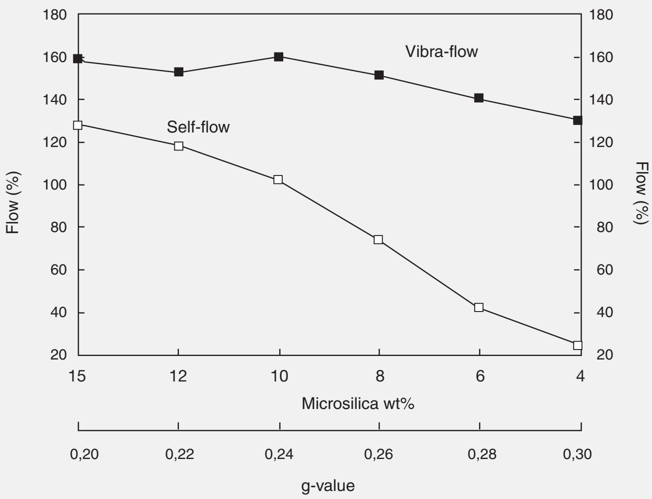


Controlled Particle Size Distribution (PSD) allows smaller particles to fill the voids between the aggregates, and desired flow properties may be achieved at reduced water additions.

Increasing the microsilica content will lower the q-value and thus improve flow



If the Andreassen model is visualised in a double logarithmic plot, it appears as a straight line with q as slope. By computer simulations, is has been shown that 0% voids (i.e. 100% packing) is theoretically possible if q is equal to or less than 0.37.[2]



The Andreassen Model

Theories on particle packing may be used to determine the optimum particle size distribution. One of the most commonly used is the Andreassen model, proposed in 1931:

$$CPFT = [d/D]^q$$

CPFT: Cumulative Percent Finer Than (volume)
d: Particle size
D: Maximum particle size
q: Distribution coefficient (q-value)

Castable Design

Through extensive experimental testing, we found that if a castable is designed to follow the Andreassen model, the q-value may be used to predict its flow properties (provided a deflocculated system and constant water addition). For castables with maximum particle size 4mm, we found that vibra flow is constant when the q-value is lower than 0.30, and good free flow is obtained when the q-value is lower than 0.25.[3]

The q-value is strongly influenced by the amount of superfines. Increasing the microsilica content will lower the q-value and thus improve flow.[4]

Particle Packing & Flow

At Elkem Materials we have developed a software package that gives you the power to design castables. Together with extensive laboratory testing and documentation, LISA (Language Independent Size Distribution Analyser) provides the basis for accurate design of vibratable and self-flowing castables. LISA can be downloaded from our web page www.refractories.materials.elkem.com.

References:

1) A.H.M. Andreassen and J. Andersen: Kolloid Z. 50 (1930) p. 217–228.
2) D.R. Dinger and J.E. Funk: Interceram 41 (1992) 5, p. 332–334.
3) B. Myhre, A.M. Hundere: «The use of particle size distribution in development of refractory castables», in Proc. XXV ALAFAR Congress in San Carlos de Bariloche, Argentina, Dec. 1–4, 1996.
4) B. Myhre, K. Sunde: «Alumina based castables with very low contents of hydraulic compound-Part 1», in Proc. UNITECR '95, Kyoto, p. 11 / 309–316.

For more information, please contact us:

Elkem AS, Materials
P.O. Box 8126
NO-4675 Kristiansand – Norway
www.refractories.elkem.com

Telephone: +47 38 01 75 00
Telefax: +47 38 01 49 70
e-mail: refractories.materials@elkem.no

Elkem Materials