Institute Of Refractories Engineers

How Refractories Are Put Together

IRE Training Day

November 2018

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Batching and Mixing Overview

- Aggregate Processing
- Aggregate Characterisation – sizes
- Blending
- Density of Aggregates
- Product Production

- Castable Example

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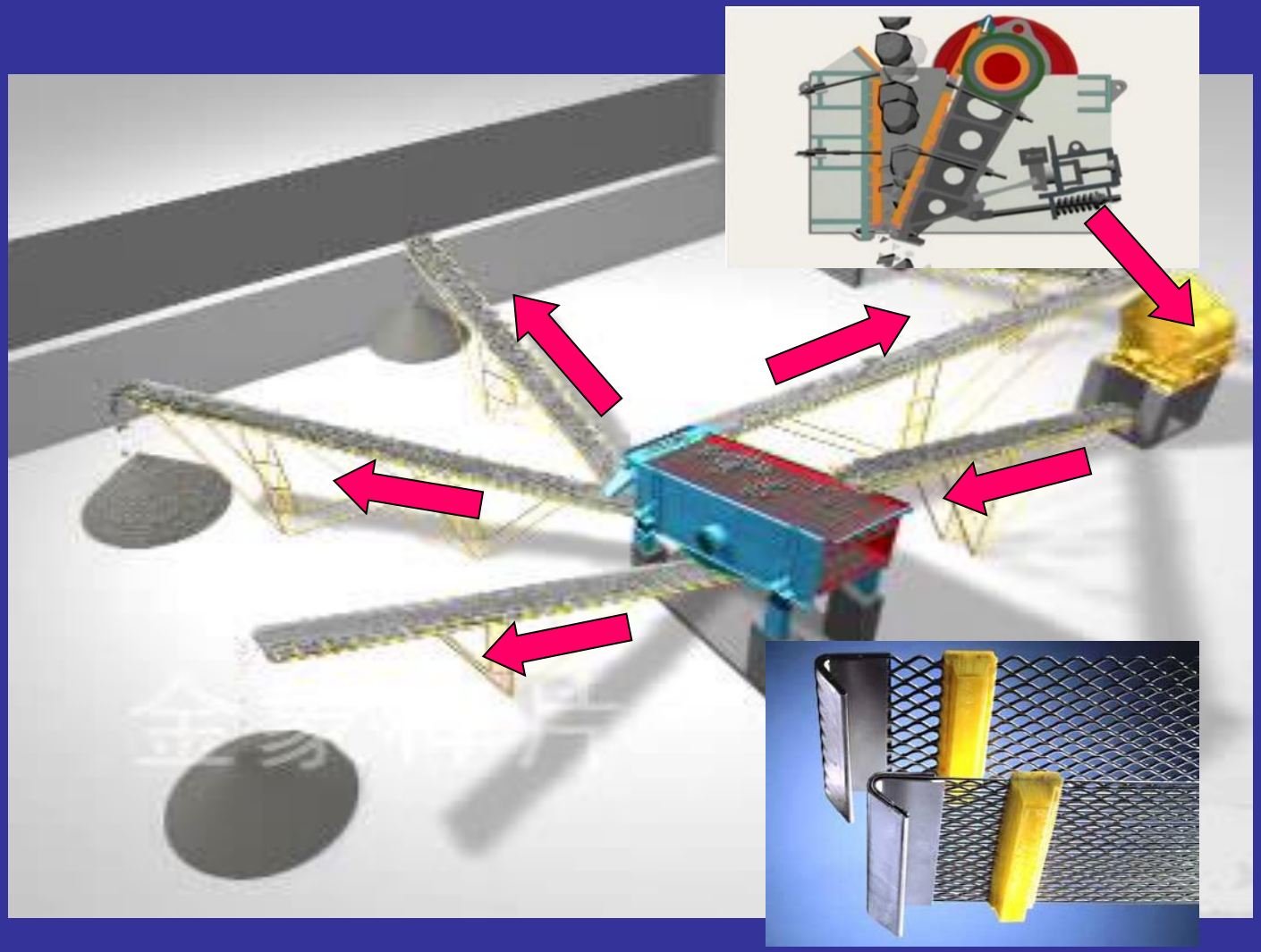
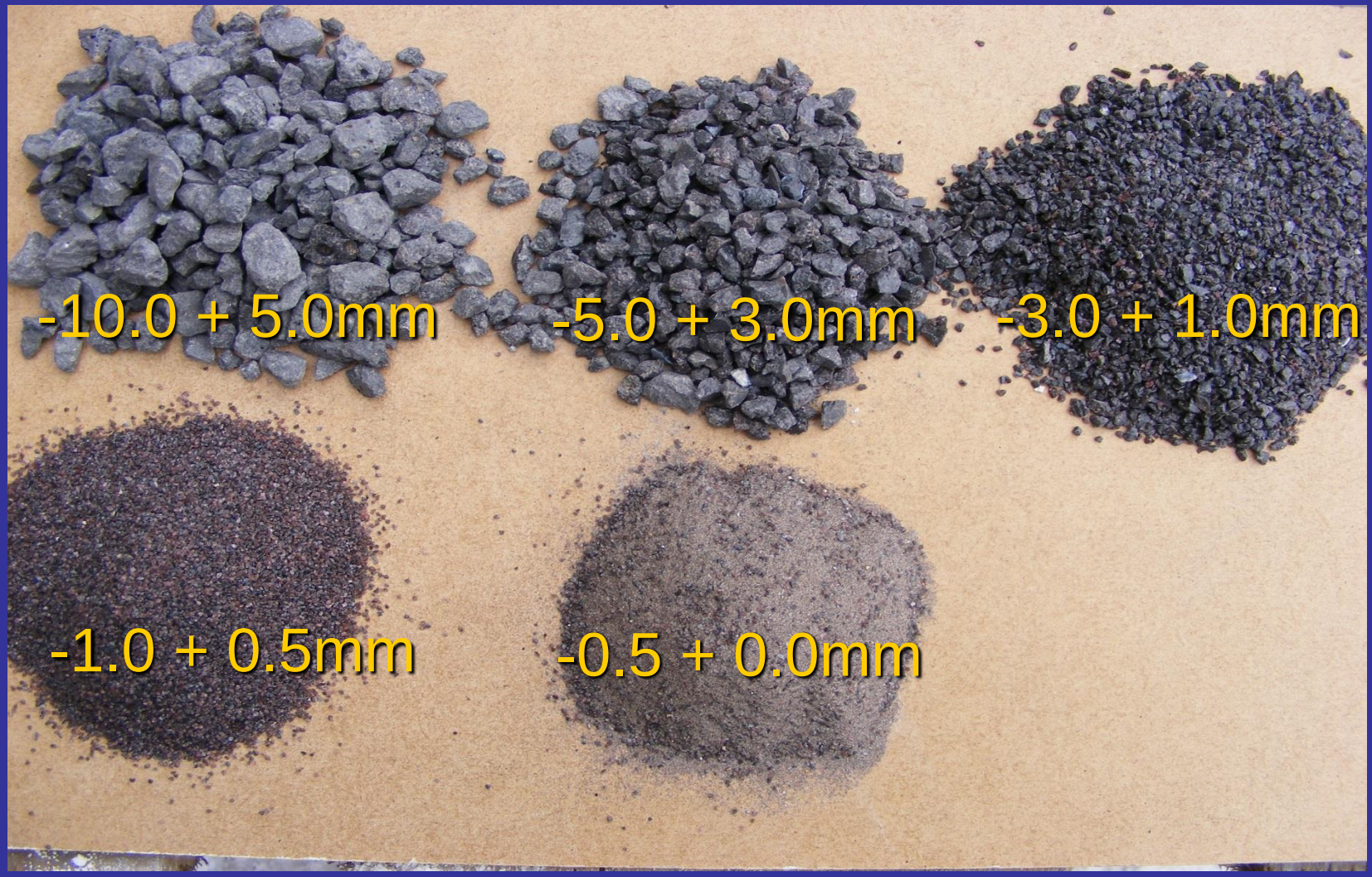
- Crushing and Grading
- Refractory Aggregates
  - Size
  - Shape
  - Density

Batching and Mixing
Crushing and Grading

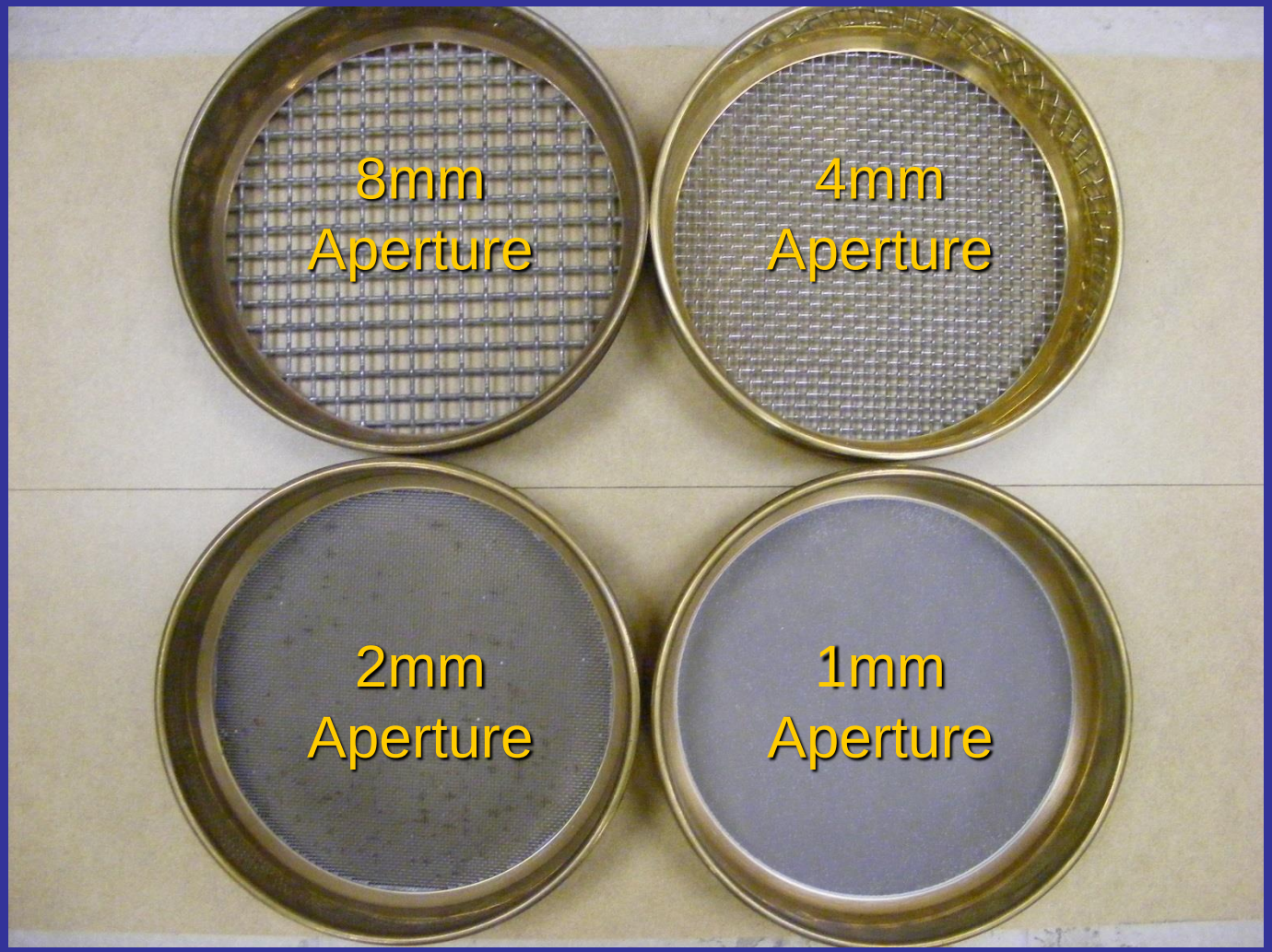


Crushing and Grading

Batching and Mixing
Aggregate Size



Batching and Mixing
Grain Size – Typical Sieve Sizes



Batching and Mixing
Aggregate Characterisation

Sieve Analysis (% retained)

Sieve Size (mm)	Brown Fused Alumina				
	-10.0 + 5.0	-5.0 + 3.0	-3.0 + 1.0	-1.0 + 0.5	-0.5 + 0.0
9.500					
8.000	24.0				
4.000	74.0	45.0			
2.800	2.0	55.0	2.0		
2.000			15.0		
1.000			80.0		
0.500			3.0	98.0	2.0
0.300				2.0	27.0
0.250					11.0
0.125					30.0
0.075					15.0
-0.075					15.0

Batching and Mixing
Fillers and Binders

Cement	< 45μm
Calcined Alumina	< 30μm
Reactive Alumina	≈ 10 – 0.1μm
Mineral Clay	< 1μm
Volatilised Silica	≈ 1 – 0.1μm
Carbon Black	< 0.1μm

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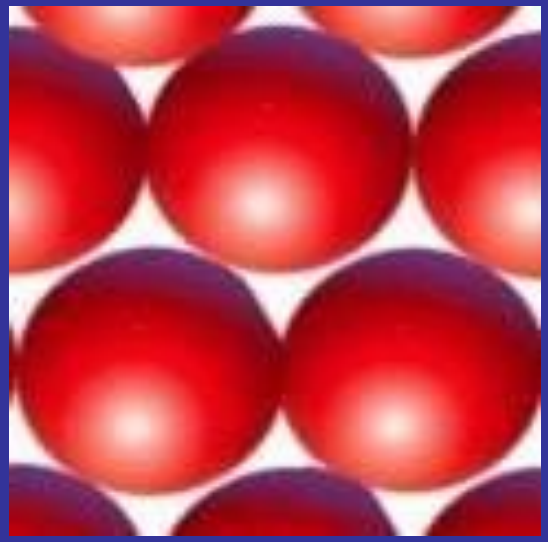
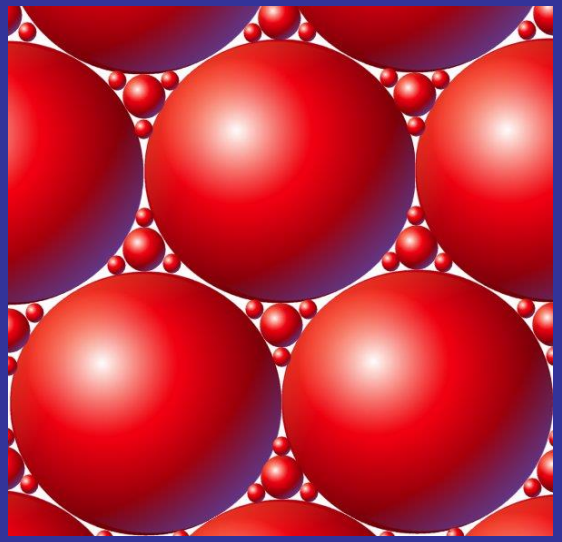
- Ideal Particle Packing
- Practical Particle Packing
- Mathematical Model

Batching and Mixing
Packing of Spheres



Ideal Packing of Spheres
(in one plane)

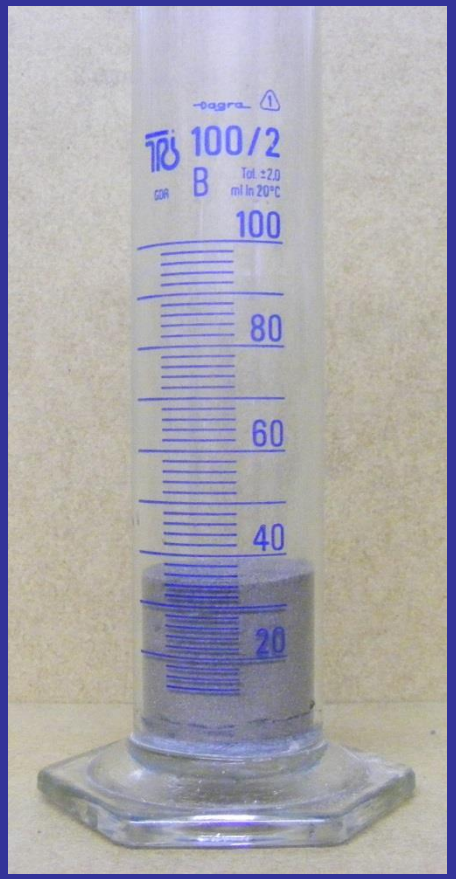
Voids are filled
using progressively
smaller particles



In this case, the mathematical model used to calculate the quantity and size of progressively smaller particles needed to achieve maximum density assumes that all the particles are spherical and are the same density

Batching and Mixing
Raw Material Grain Shape

Batching and Mixing
Raw Material Density



100g
Zircon Sand

100g
Fused Alumina

100g
Chamotte

Batching and Mixing
Raw Material Density

10g
Perlite

Batching and Mixing
Andreasen Distribution

$$X = 100 \left(\frac{d}{D}\right)^{q}$$

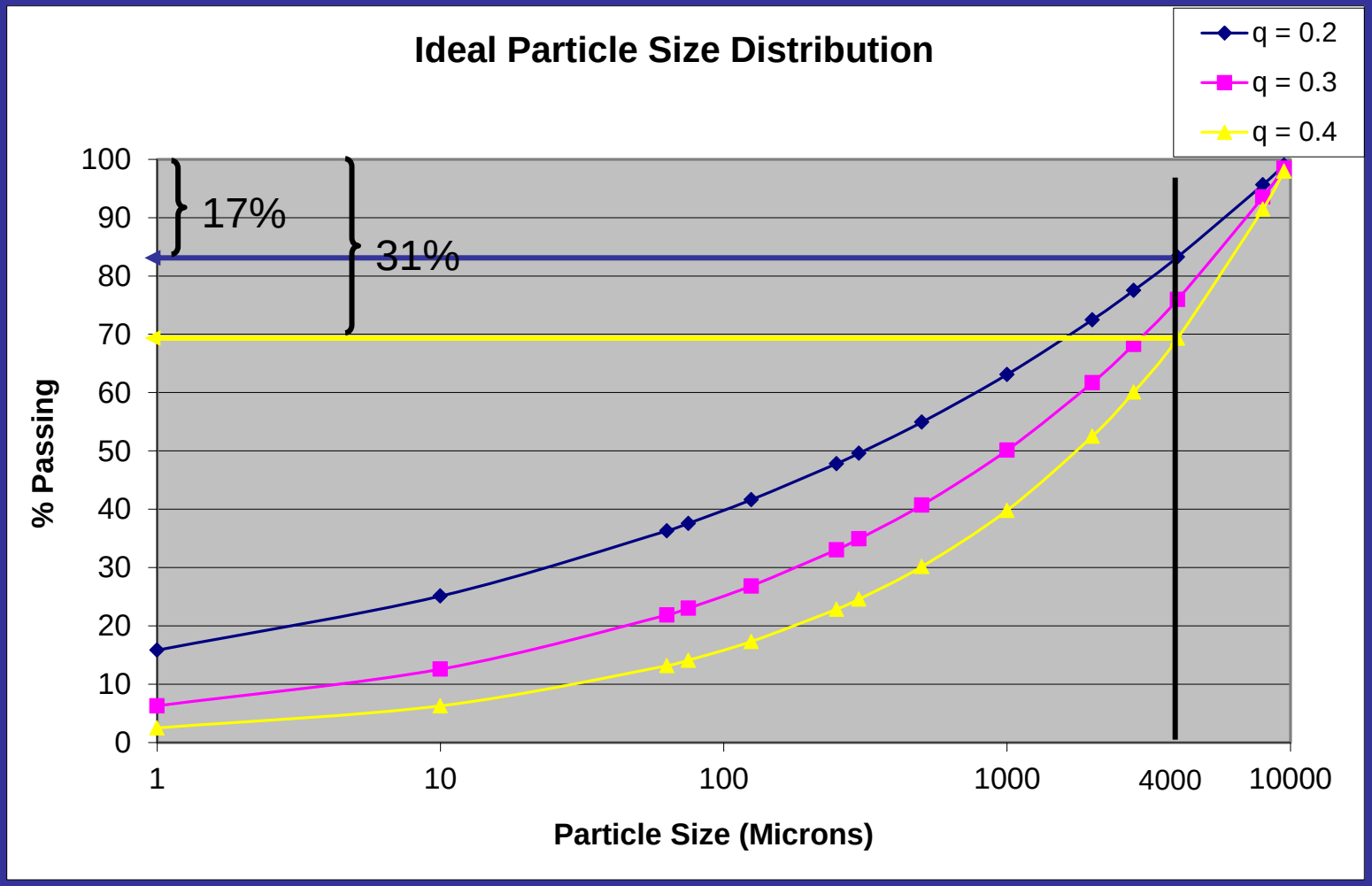
Where

X = % passing size d

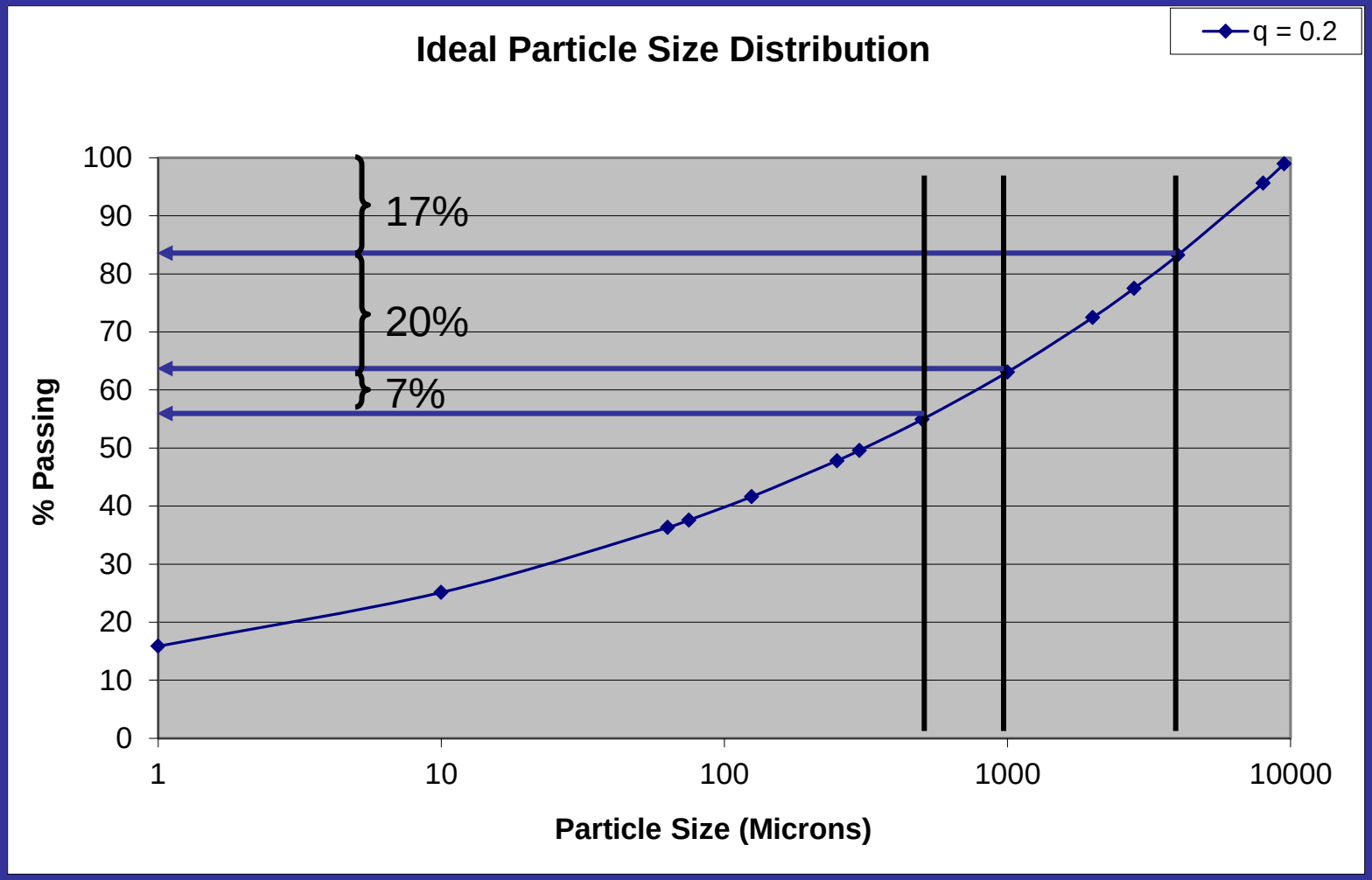
D = Diameter of largest particle

q = Variable to control the relative proportion of fine and coarse particles (distribution modulus)

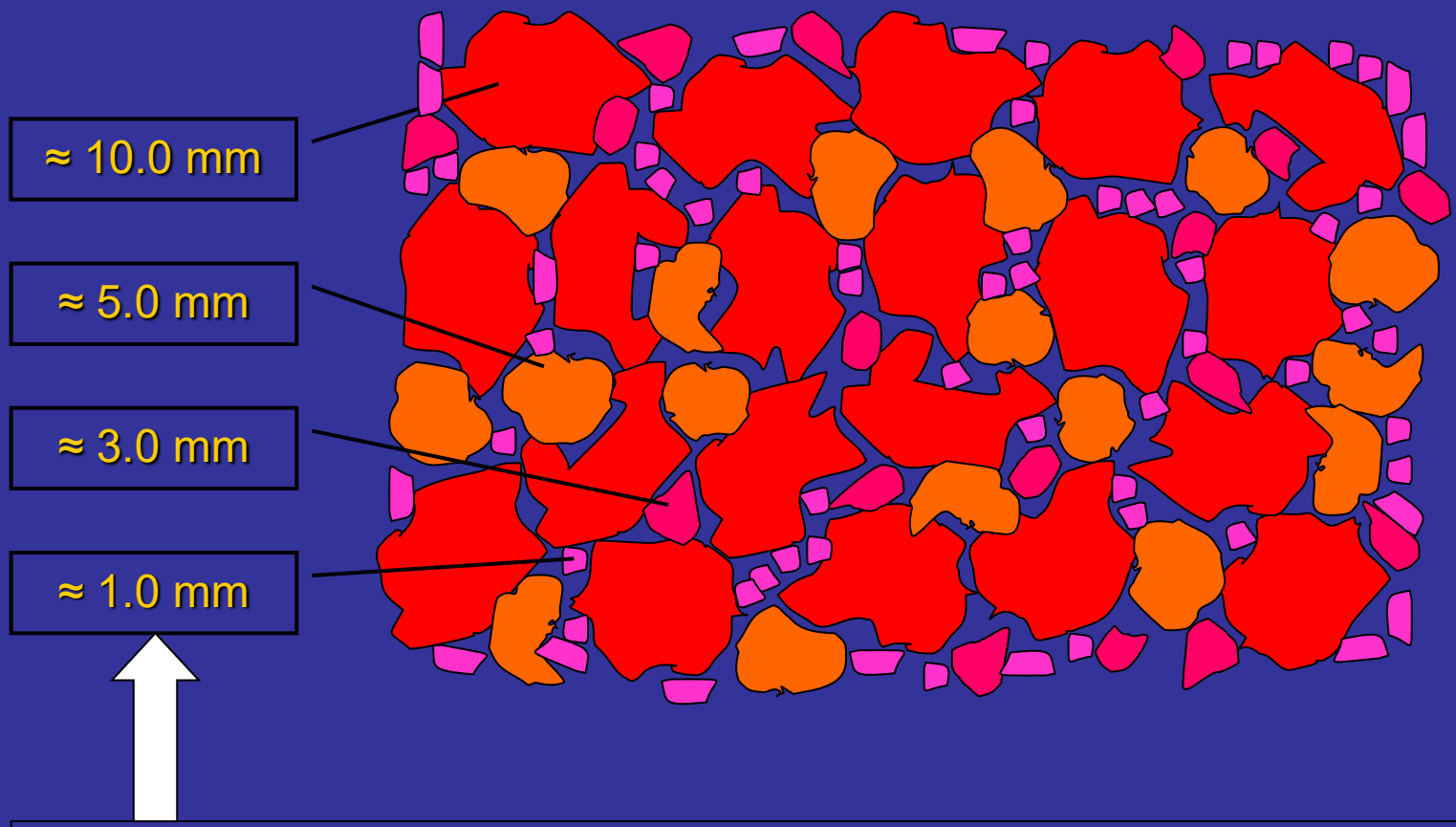
Batching and Mixing
Andreasen Distribution Curves



Batching and Mixing
Andreasen Distribution Curves



Batching and Mixing
Particle Packing



If this fraction were Zircon Sand at 1.5 x the density of Fused Alumina we would have to add 1.5 times as much by weight to fill the voids.

Batching and Mixing
Refractory Mix

- Simple Refractory Mix

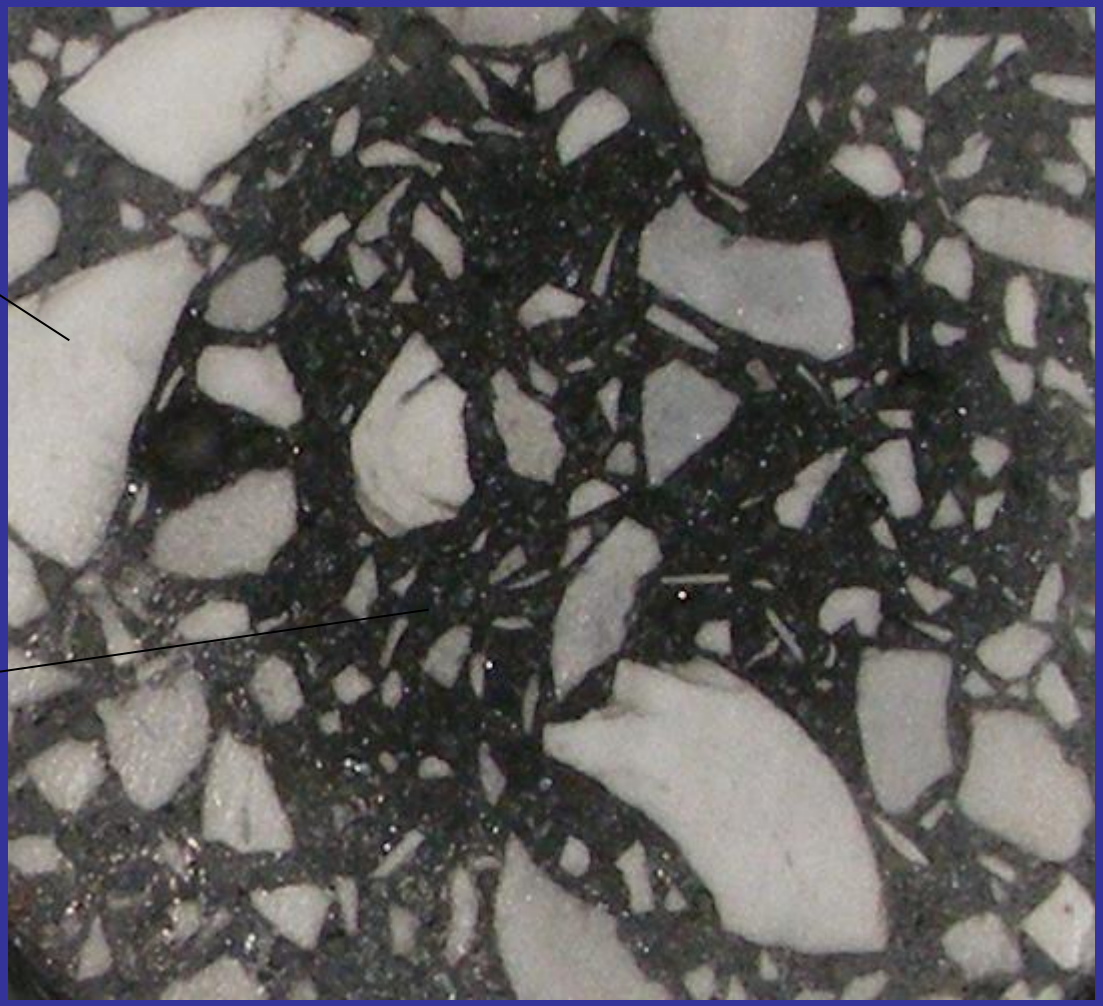
		%
Fused Alumina	-10+5	25.0
Fused Alumina	-5+1	20.0
Fused Alumina	-1+0	25.0
Calcined Alumina	-	15.0
Volatilised Silica	-	5.0
Cement	-	10.0
Additives	-	+0.1

Batching and Mixing
Simple Mix

Batching and Mixing
Manufacture and Installation

Aggregate

Matrix



Batching and Mixing
Materials Available

- There are 100’s of different Aggregates available to produce the various mix compositions used.
- There are also 100’s of Additives available which impart the required properties to the refractory mix.
- The combination of Aggregates, Additives and Production Process give the required texture to the Refractory mix.

Batching and Mixing
Refractory Production

Accurately Weighed Aggregates and Additives

Mixing Operation

Castable

Gunning

Taphole Clay

Mortar

Batching and Mixing
Summary

- Natural and synthetic aggregates are crushed and used as graded product.
- Aggregates are blended with fillers and binders in specific proportions to achieve required properties and texture.
- Composition is specifically designed for a given application.
- Production operation could be simple ‘dry mixing’ or ‘wet mixing’ to produce mouldables, taphole clay or mortars.

Castable Composition, Mixing And Testing

Blast Furnace Runner Castables

- Required Properties
- Composition
- Testing

Blast Furnace Runner Castables Properties

- Mix at low water additions
  - Reduced porosity
  - Improves strength
  - Helps dry-out
- Resist erosion of molten iron
- Resist attack by molten slag

Blast Furnace Runner Castable Composition

Alumina -10+5mm Alumina -5+3mm Alumina -3+1mm Alumina -1+0.5mm Alumina -0.5mm	50 to 60% of the mix	Main body of the castable • Strength • Erosion resistance
Silicon Carbide -3+1mm Silicon Carbide -1+0.5mm Silicon Carbide -75µm Silicon Carbide -10µ	20 to 30% of the mix	Body & Matrix of the castable • Slag resistance
Calcined Alumina Reactive Alumina	≈ 10% of the mix	Matrix of the castable • Strength
High Alumina Cement	= 2% of the mix	Initial Strength
Carbon	≤ 2.5% of the mix	Iron/Slag resistance
Metallic Powders Al / Si / B_4C	≤ 4% of the mix	Drying / Strength / Ox resist'
Volatilised Silica	< 2% of the mix	Flow & Strength
Additives	< 0.5% of the mix	Wetting / Setting
Plastic Fibres	≈ 0.05% of the mix	Drying

Runner Castables Testing

Runner Castables
Mixing

Runner Castables
Flow Test

Runner Castables
Flow Test

How Refractories Are Put Together

Trough Castables

Thank you for your attention

Dave Pickard