

Blended Cements

John Kline

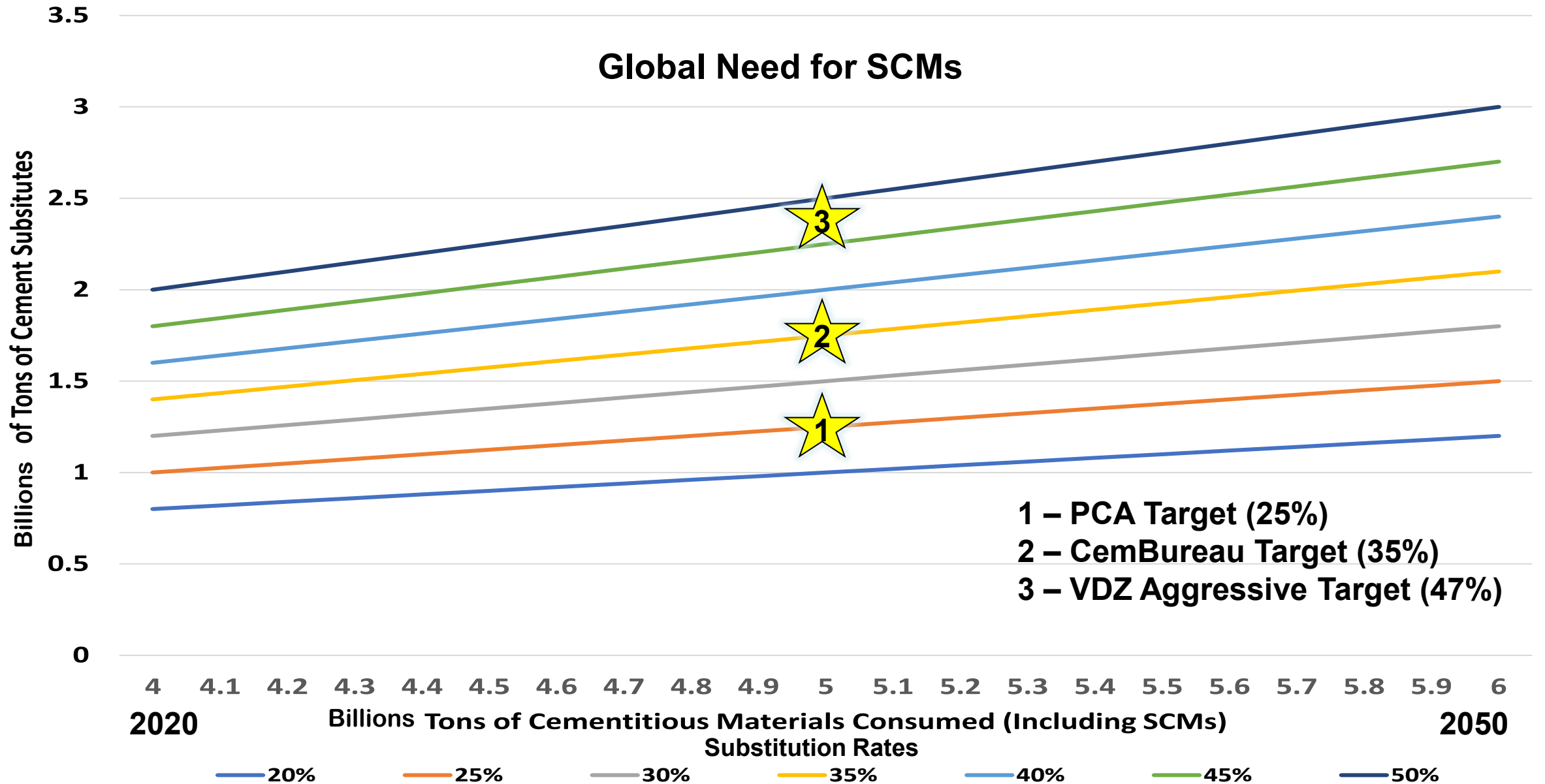
West Coast Cement Industry Conference

Provo, Utah

October 2023

Required Cement Substitute Volumes

Global Need for SCMs

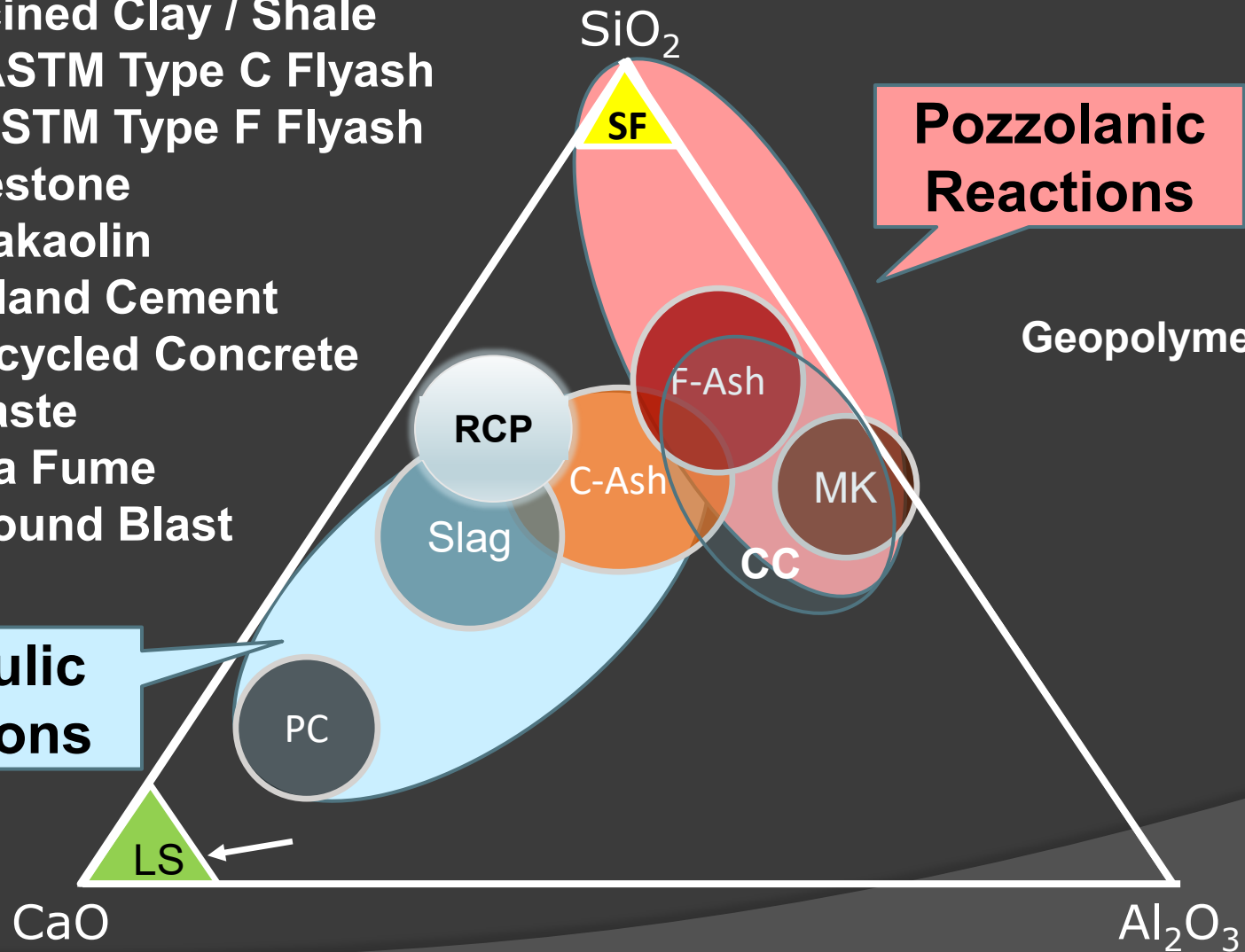


Most Important Binder Materials

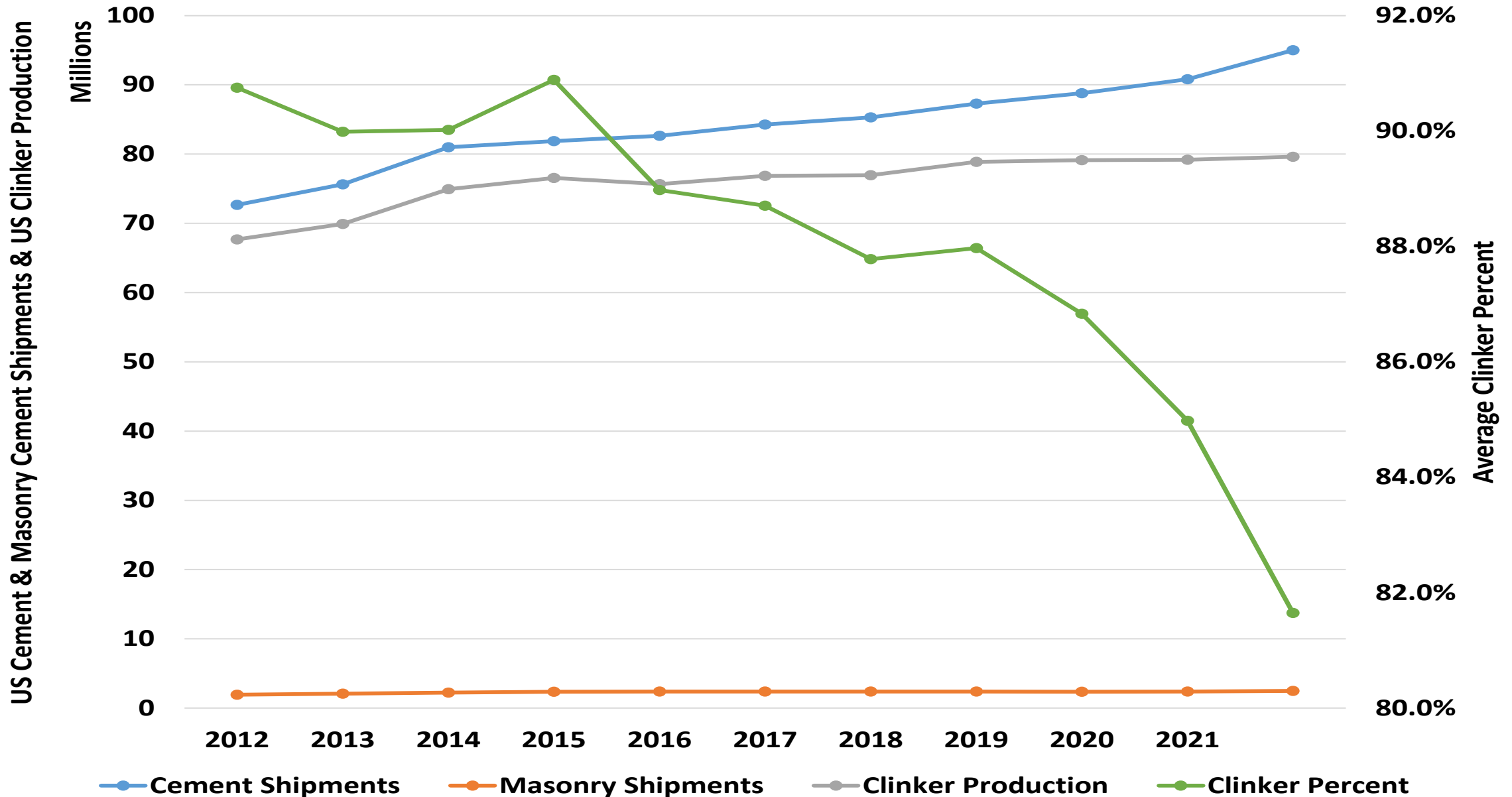
Legend

- CC – Calcined Clay / Shale
- C-Ash – ASTM Type C Flyash
- F-Ash – ASTM Type F Flyash
- LS – Limestone
- MK – Metakaolin
- PC – Portland Cement
- RCP – Recycled Concrete Paste
- SF – Silica Fume
- Slag – Ground Blast Furnace

Hydraulic Reactions

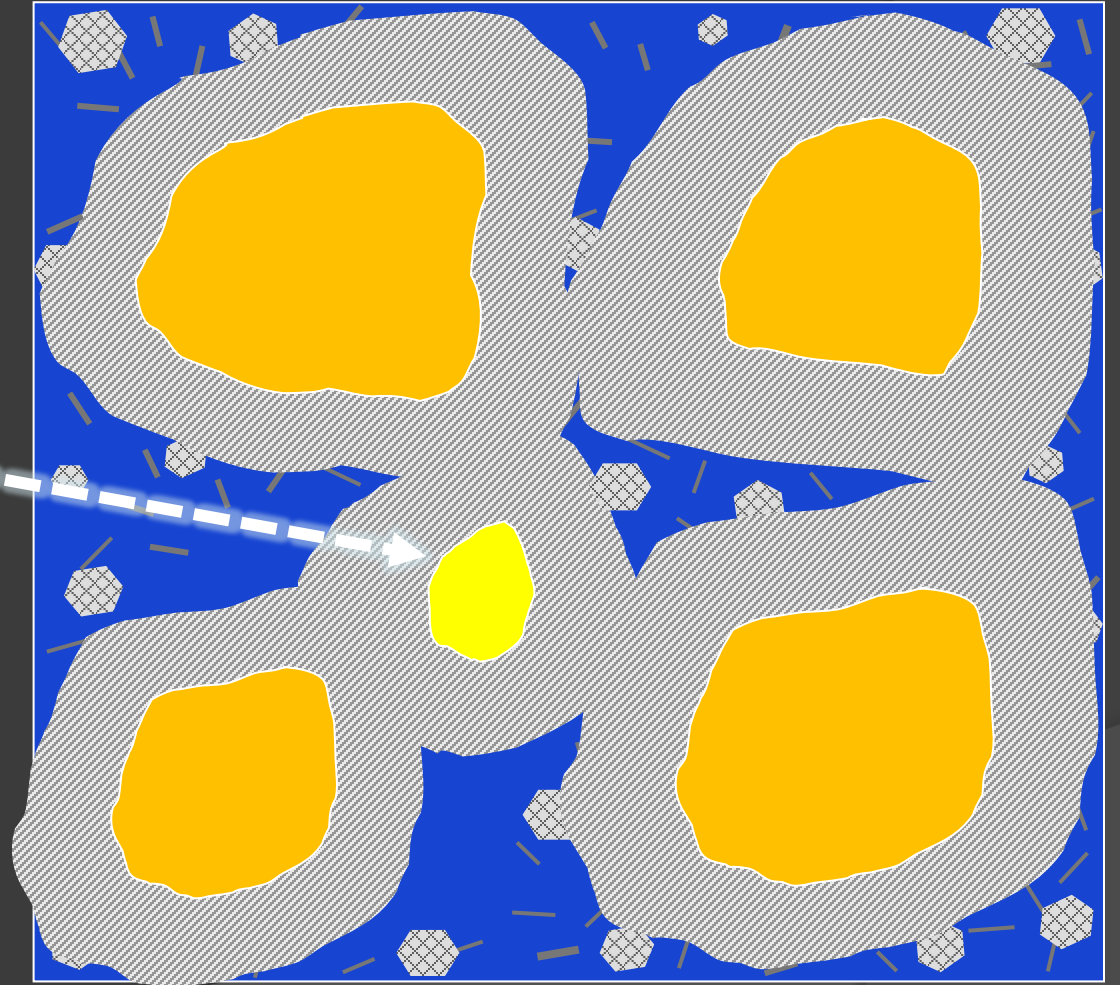


Cement to Clinker Ratio Evolution

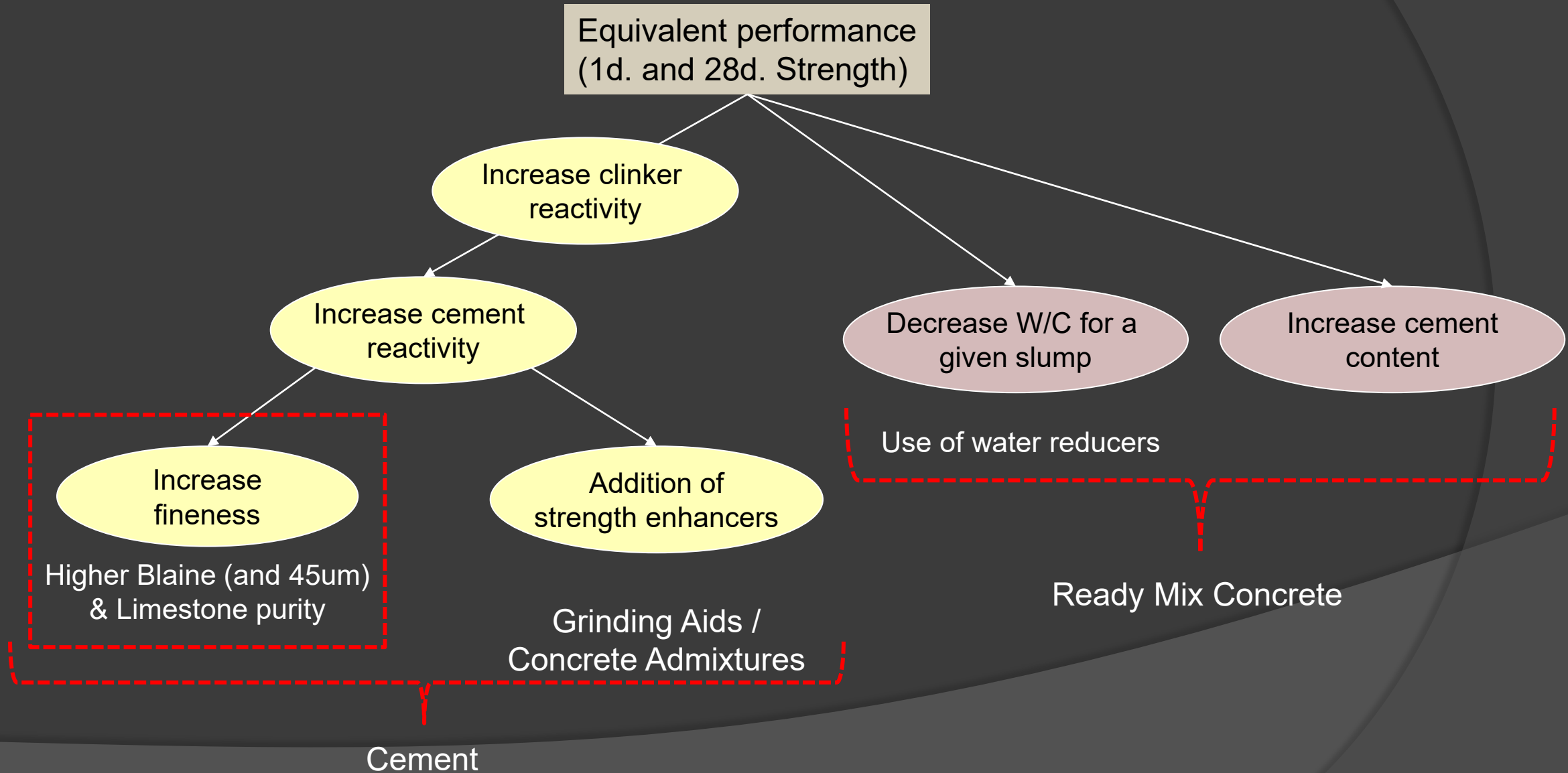


How Limestone Works

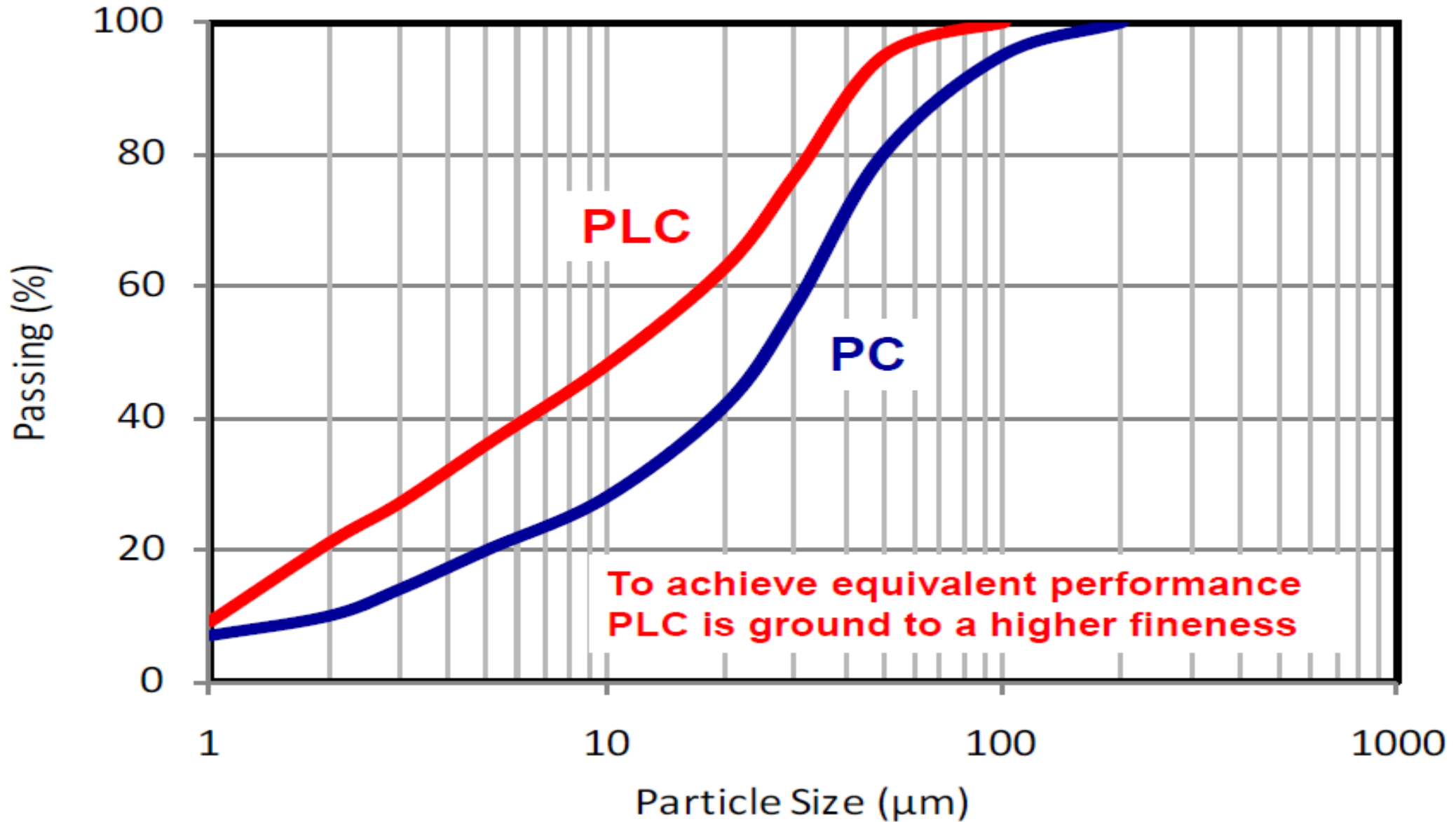
- ◎ Particle packing
 - Improved particle size distribution
- ◎ Nucleation
 - Surfaces for precipitation
- ◎ Chemical reactions
 - Only a small amount

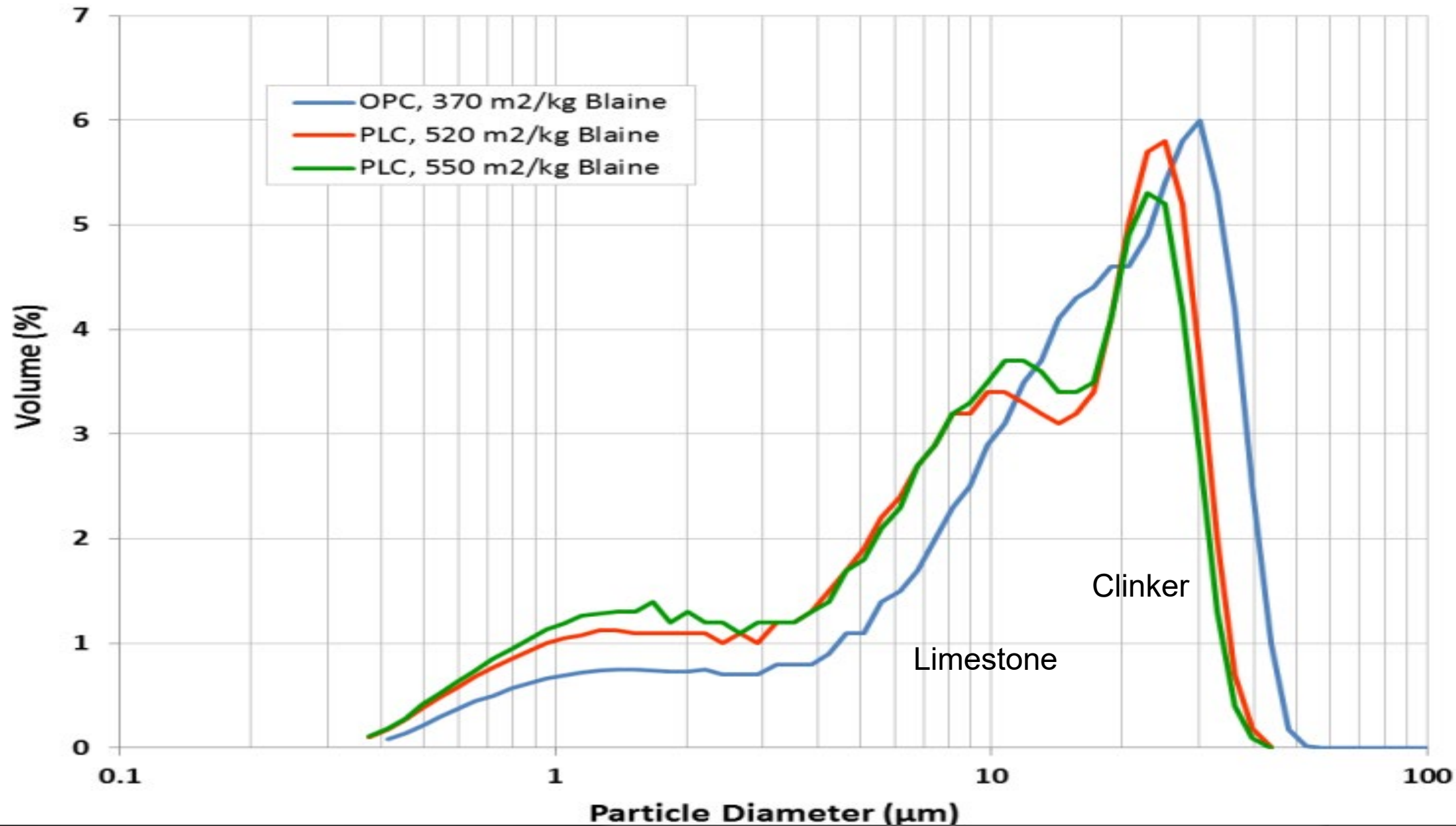


How can we get equivalent performance?



Fineness PLC vs. PC

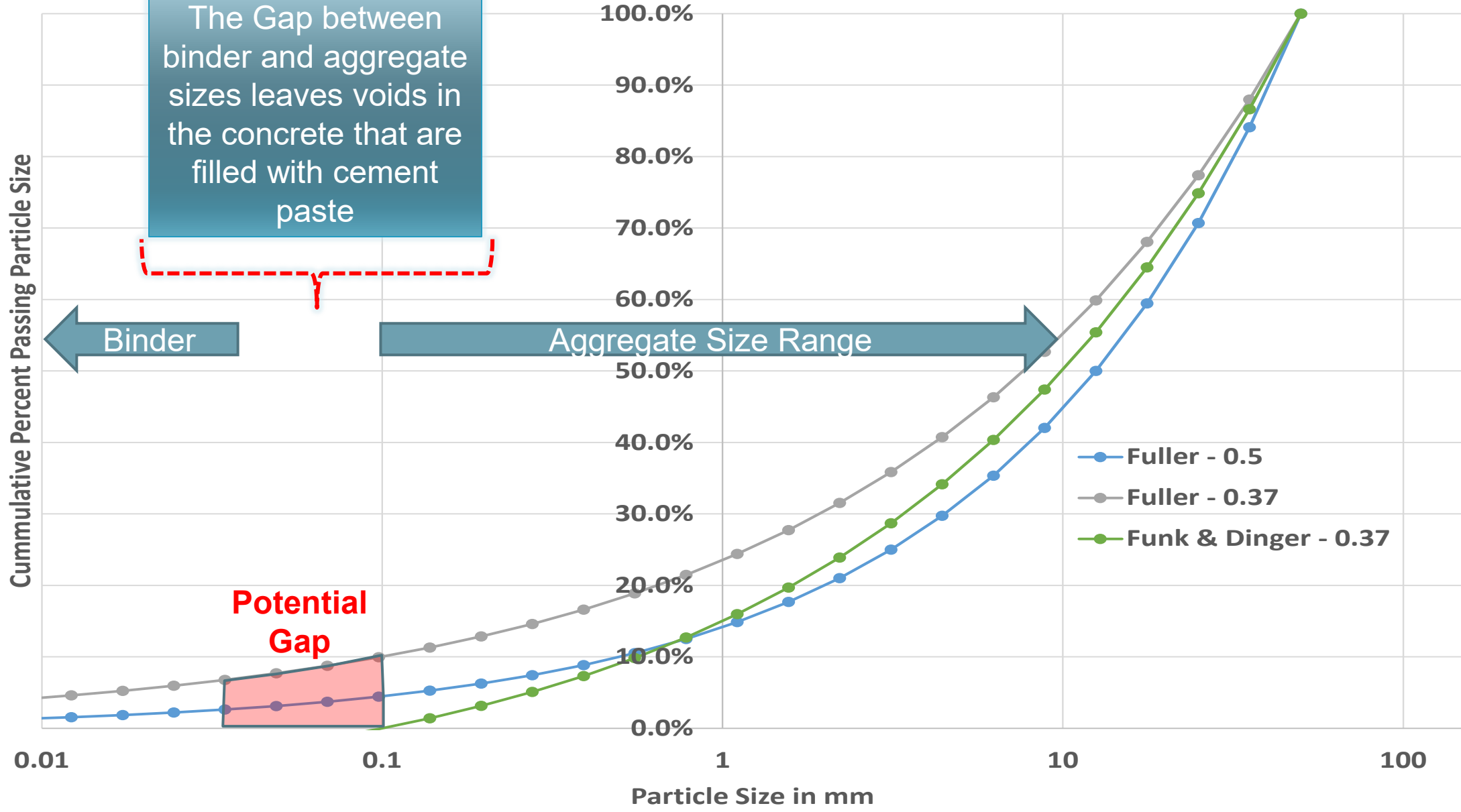




How Do We Recover Production Loss

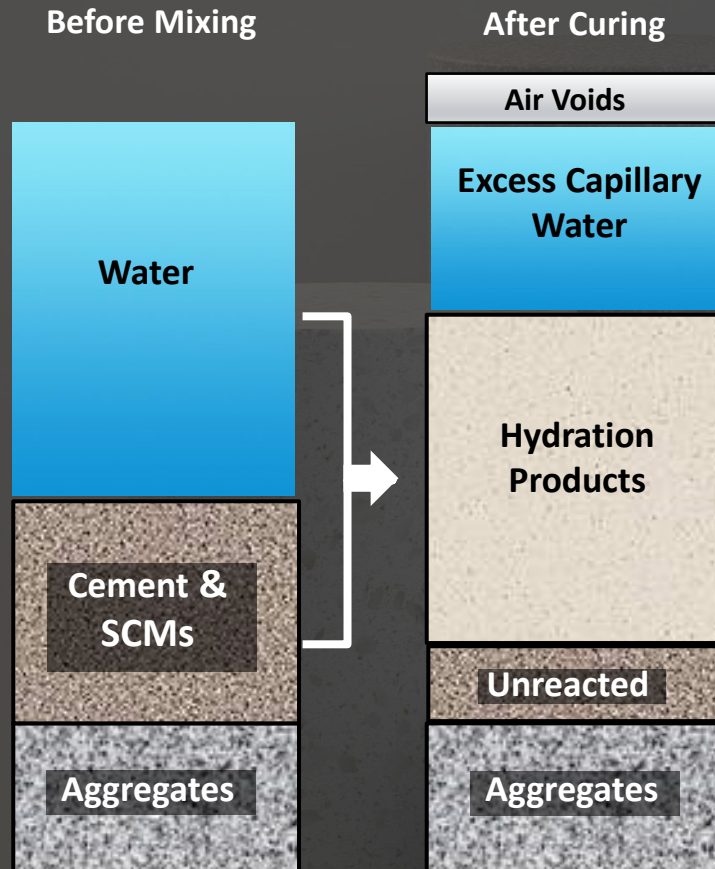
- ⦿ Grinding circuit optimization
 - Mill audits
 - Enhanced instrumentation / expert systems / AI
 - Third generation / high efficiency separators
- ⦿ Pre-crushing of clinker
 - Optimize existing clinker crushing / clinker size reduction
 - Install additional crushing ahead of the cement mill
- ⦿ Optimization of clinker reactivity
 - More strength with coarser grind
- ⦿ Grinding aid optimization
 - For cement mill performance
 - For strength enhancement

Particle Packing Density

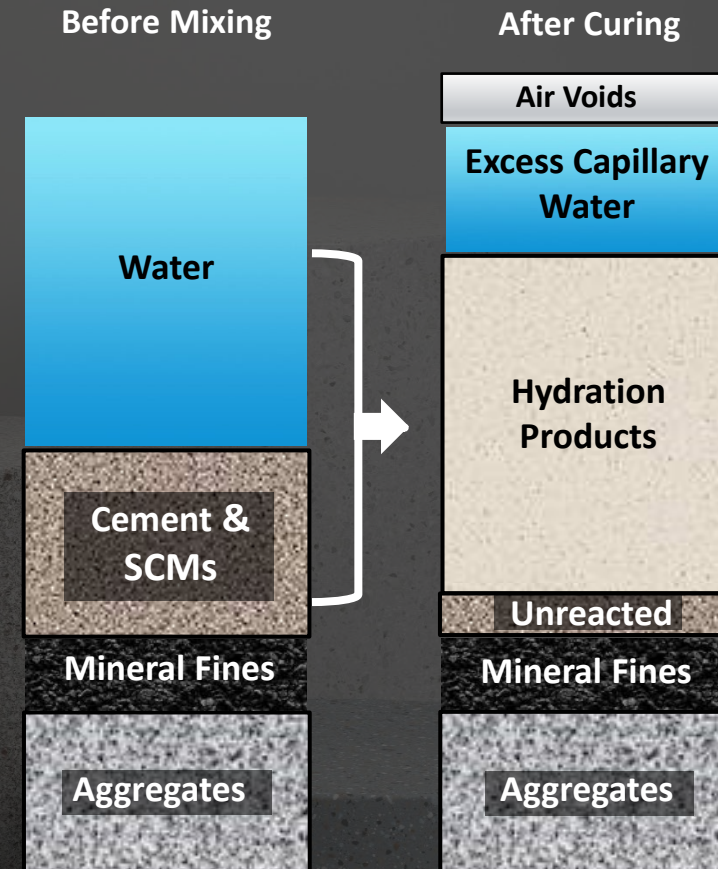


Concrete Ingredients Before and After Curing

Traditional Mix



“Roman Cement” Mix



Particle Size Optimization

Salt Lake City Pilot Project in Cooperation with Geneva Rock



Particle Size Optimization

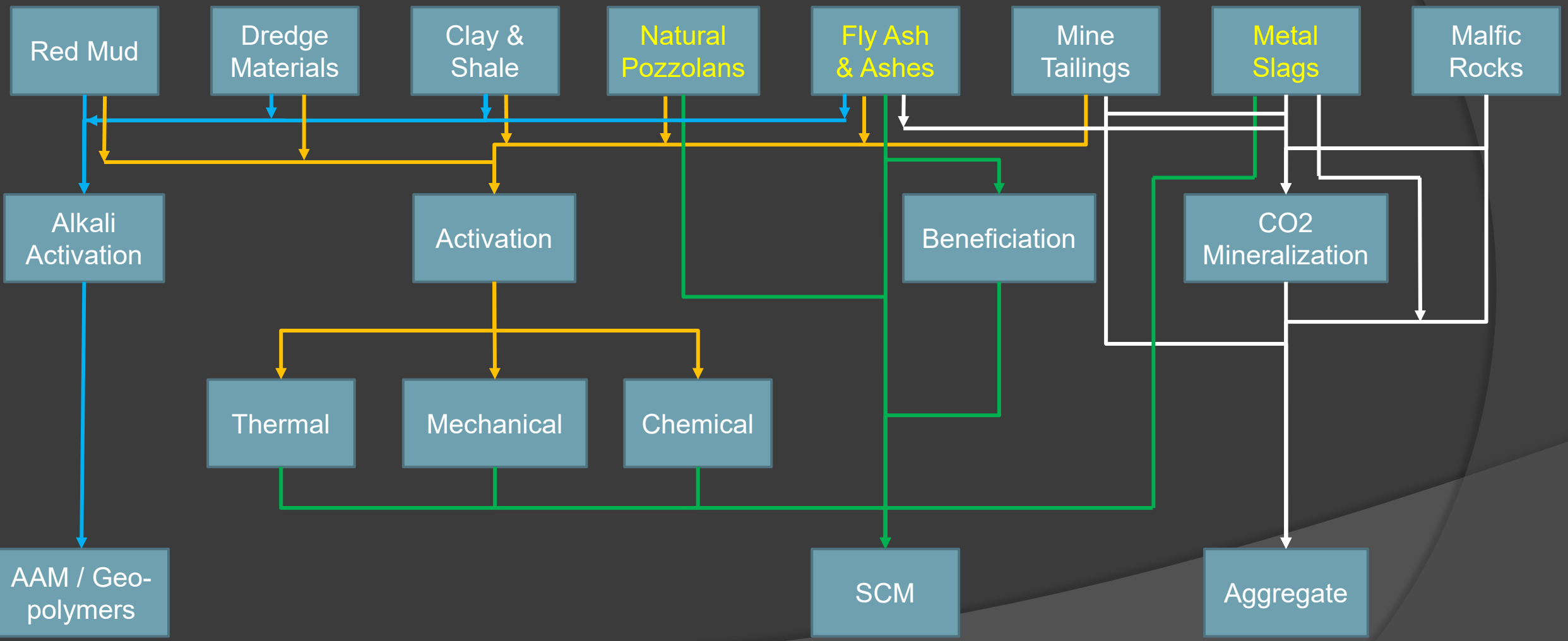
Salt Lake City Pilot Project in Cooperation with Geneva Rock

- **Concrete Pad For Electric Bus Recharging Station**
 - 110 cubic yards
 - Based on 4000 psi (27.5 MPa) air entrained mix design of Geneva Rock
 - Cement (1L) = 489 lb/yd³
 - Fly ash = 122 lb/yd³
 - Total Cementitious = 611 lb/yd³
 - Roman Cement redesigned mix
 - Cement (1L) = 391 lb/yd³ (20% reduction)
 - Fly ash = 104 lb/yd³ (15% reduction)
 - Total Cementitious = 495 lb/yd³
 - Inert mineral fines = 150 lb/yd³

End

The Large Volume Options (Global)

- **Limestone – Unlimited, limited by area**
- **Clay – Unlimited, limited by area**
- **Natural Pozzolans – Unlimited, limited by area**
- **Fly Ash ~ 750 mn tons**
- **Granulated Blast Furnace Slag ~250 mn tons**
- **Air Cooled Blast Furnace Slag ~100 mn tons**
- **Steel Slag ~ 250 mn tons (Outside specifications)**
- **Bottom Ash ~ 250 mn tons (Outside specifications)**
- **Mine Tailings ~ 30-60 bn tons**
- **Red Mud ~175 mn tons**
- **Dredged Materials >500 mn m³**
- **MSW & CDW ~2 bn tons (more for alternative fuel)**
- **Recycled Concrete Fines - ?**



Performance Indicators from Selected Sustainability Reports

Cement Roadmap Indicators (CSI)	Sustainability Report Year	Thermal energy consumption per tonne of clinker GJ / tonne	Electricity intensity of cement (kWh/t cement)	Alternative Raw Materials in Cement	Alternative fuels total % (1)	Biomass fuel usage %	Clinker to cement ratio	Tonne CO2 emissions net per tonne cement	2030 Pledge
2DS Targets	2050	3.1	79		NA	30%	60.0%	0.370	
LafargeHolcim	2021	3.520	-	13.0%	13.0%	8.0%	70.1%	0.553	0.475
Heidelberg	2021	3.590	-	11.8%	26.4%	11.2%	72.9%	0.565	0.400
Cemex	2021	4.023	122	11.0%	29.2%	10.7%	75.2%	0.591	20%
Ultratech	2020/2021	3.034	78.5	18.4%	3.1%	0.5%	72.3%	0.597	0.557
Votorantim	2021	3.000	109	9.2%	22.4%	12.1%	74.9%	0.597	0.520
CRH	2021	3.782	-	11.9%	25.3%	7.3%	78.4%	0.586	0.520
Buzzi	2021	4.106	122	9.0%	27.8%	7.1%	80.2%	0.633	-
Siam cement	2021	3.466	-	8.4%	7.7%	12.2%	74.2%	0.623	20%
Taiheyo	2021	3.321	106.4	15.8%	12.2%	2.0%	82.4%	0.675	>20%

2DS 2 degree scenario – original industry targets set by the IEA

Use of SCMs

- Rest of World
- In the Cement Plant
 - Clinker (>5%)
 - Limestone (<35%)
 - Gypsum (<5%)
 - Slag (<95%)
 - Fly Ash (<35%)
 - Other Pozzolans (<35%)
- At the Ready Mix Plant
 - Chemical additives
 - Silica Fume
 - Meta Kaolin
- US & Canada
- In the Cement Plan
 - Clinker (~85%)
 - Limestone (<15%)
 - Gypsum (<5%)
 - Mineral Additives (5%)
 - Slag (20% or 100%)
- At the Ready Mix Plant
 - Slag
 - Fly Ash
 - Other Pozzolans
 - Chemical Additives
 - Silica Fume
 - Meta Kaolin

Supplemental Cementitious Materials

- ◎ Traditional SCMs
 - Slag
 - Fly Ash
 - Pozzolans
- ◎ New SCMs
 - Calcined Clay
 - Harvested Fly Ash
 - Bottom Ash
 - Recycled Concrete Paste
 - Other metal slags
- ◎ Drivers for SCM use
 - Cost
 - CO2 emissions reductions
 - “Green” Products

Clinker Reactivity & Limestone Cement

Plant	Type	Blaine [cm ² /g]	Strength [psi]	Reactivity
Plant A	I/II	4110	6600	1.61
	IL	4500	6240	1.39
Plant B	I	3810	6706	1.76
	IL	4730	6354	1.34
Plant C	I/II	3843	6013	1.56
	IL	4580	5525	1.21
Plant D	I/II	4080	5985	1.47
	IL	5160	6239	1.21

Reactivity defined as 28 day mortar strength / Blaine (cm²/g)

