Limestone
Calcined
Clay
Cement

LOW CARBON LOW COST LOW CAPITAL

Influencia del proceso en la fabricación del cemento LC3

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EcoSolutions sustainable habitat

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CENTRO DE INVESTIGACIÓN Y DESARROLLO DE ESTRUCTURAS Y MATERIALES

EPFL
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Guion de la presentación

» Introducción general al proceso productivo
» El impacto de la molienda de cementos ternarios
» La sulfatación de sistemas cementicios con arcillas calcinadas
» Corrección de álcalis en sistemas cementicios con arcillas calcinadas
» Reporte de prueba industrial de molienda en Cuba
» Consideraciones sobre normas

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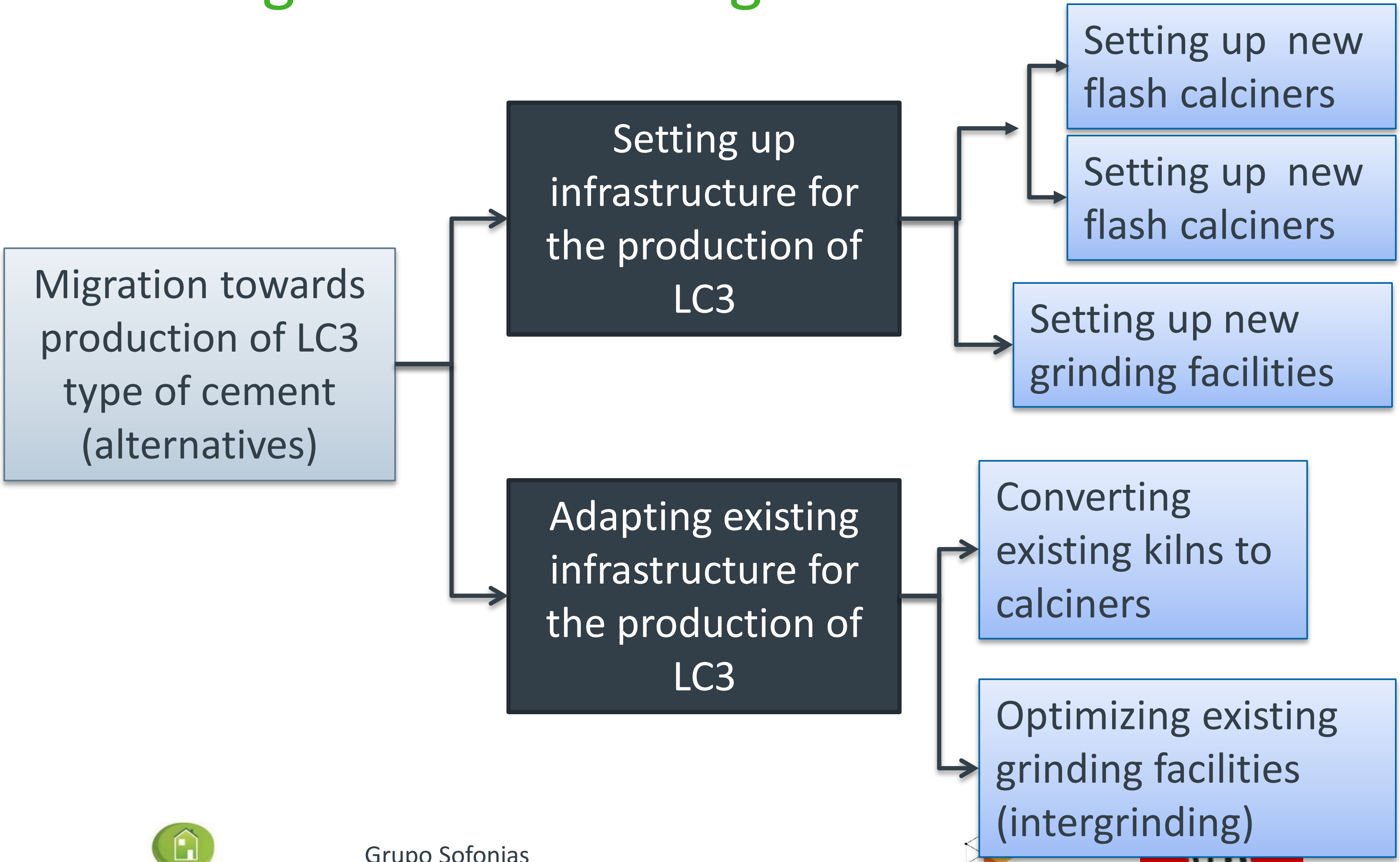
¿Cómo migrar a la tecnología LC3?



Migration towards production of LC3 type of cement (alternatives)

Setting up infrastructure for the production of LC3

Setting up new flash calciners

Setting up new flash calciners

Setting up new grinding facilities

Adapting existing infrastructure for the production of LC3

Converting existing kilns to calciners

Optimizing existing grinding facilities (intergrinding)

Opciones de calcinadores

	Ventaja	**Desventaja**
Hornos rotatorios de clinquer convertidos (generalmente de proceso húmedo)	Bajo costo de inversión	Baja eficiencia energética Poca flexibilidad uso combustibles No control color
Hornos rotatorios diseñados específicamente para calcinación de arcillas (Dynamis/IPIAC)	Costos de inversión atractivos Tecnología confiable (30+ años de uso) Sistema control color Alta productividad	Costos de mantenimiento altos
Calcinadores flash	Alta eficiencia energética Buen uso del espacio	Alto costo de inversión Baja productividad
Hornos de cama fluidizada	Alta homogeneidad de tratamiento térmico	No hay tecnología disponible a nivel comercial

Opciones de molienda

	Ventaja	**Desventaja**
Molinos de bolas de circuito abierto	Bajo costo de inversión Tecnología conocida	Hipermolienda de materiales finos. Pobre control de finura
Molinos de bolas de circuito cerrado	Tecnología conocida Mejor control de finura resultante	Hipermolienda de materiales finos.
Molinos de rodillos verticales	Alta eficiencia energética Posibilidad de lograr DTP específicas Alta productividad	Alto costo de inversión

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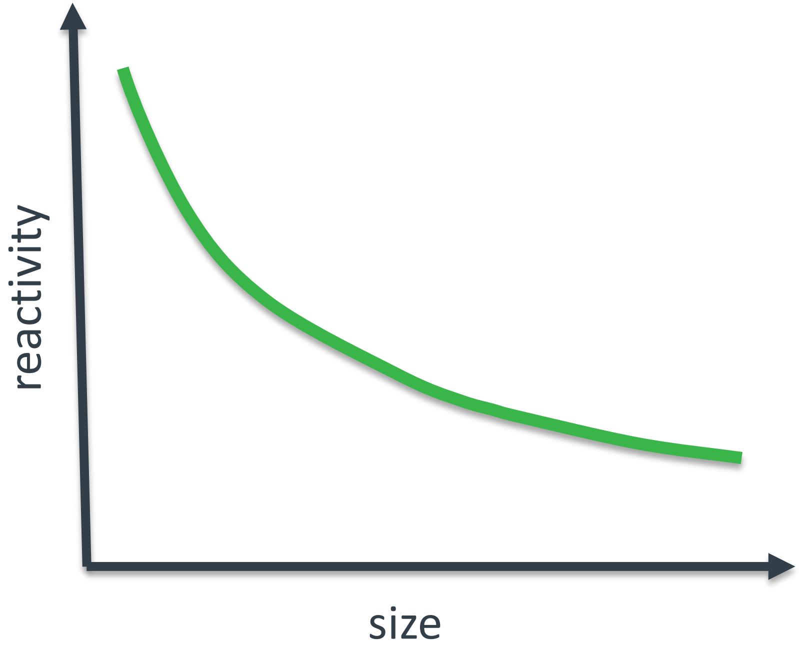
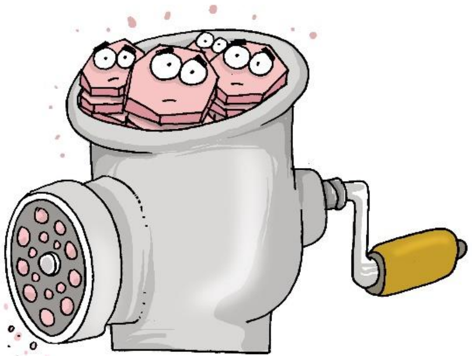
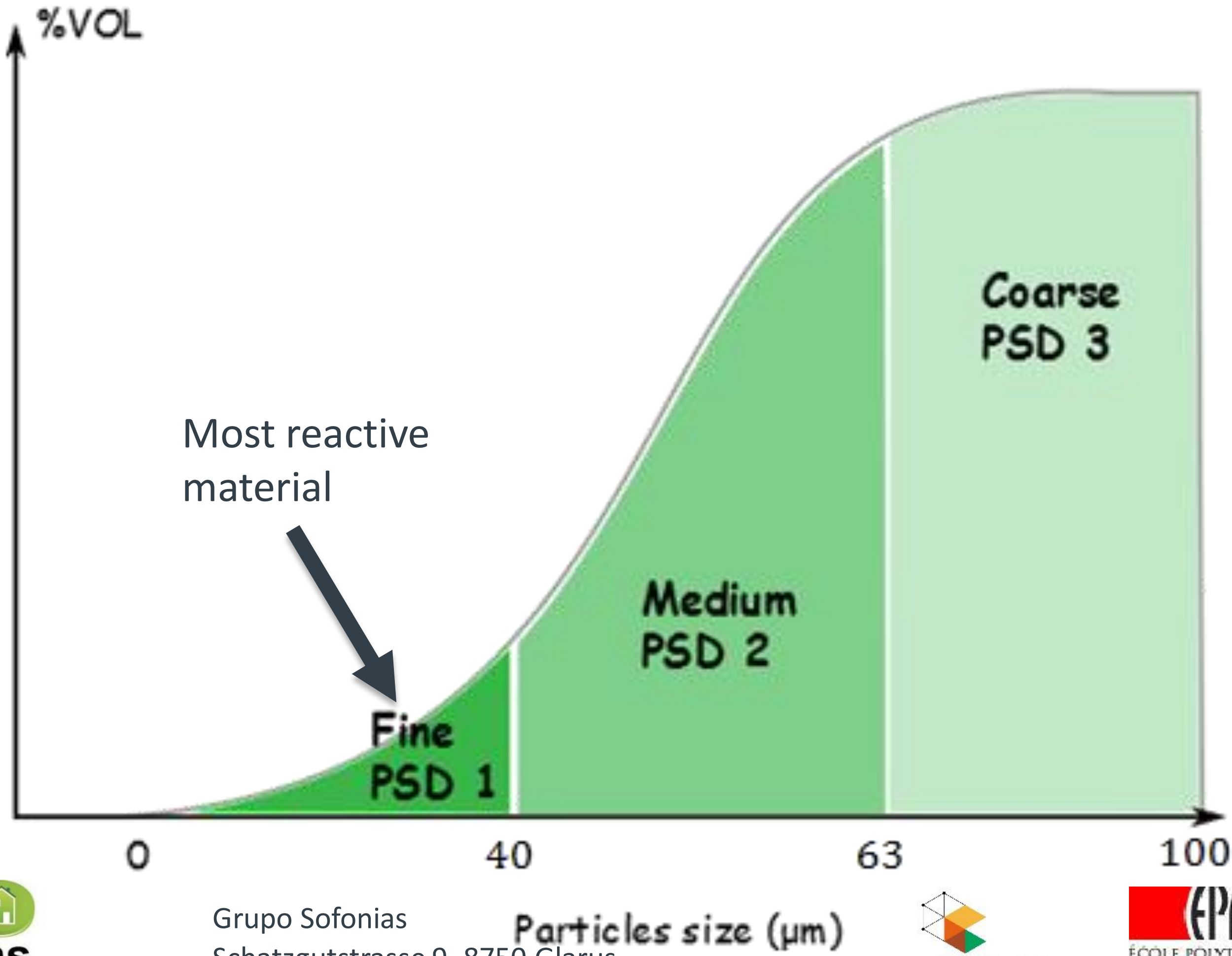
Why grind cement?

- Clinker in normal form is only marginally reactive due to its low specific surface
- Calcined clays have a high degree of agglomeration which needs to be broken down.
- Grinding the material guarantees the reduction in size and the increase of specific surface and thus reactivity



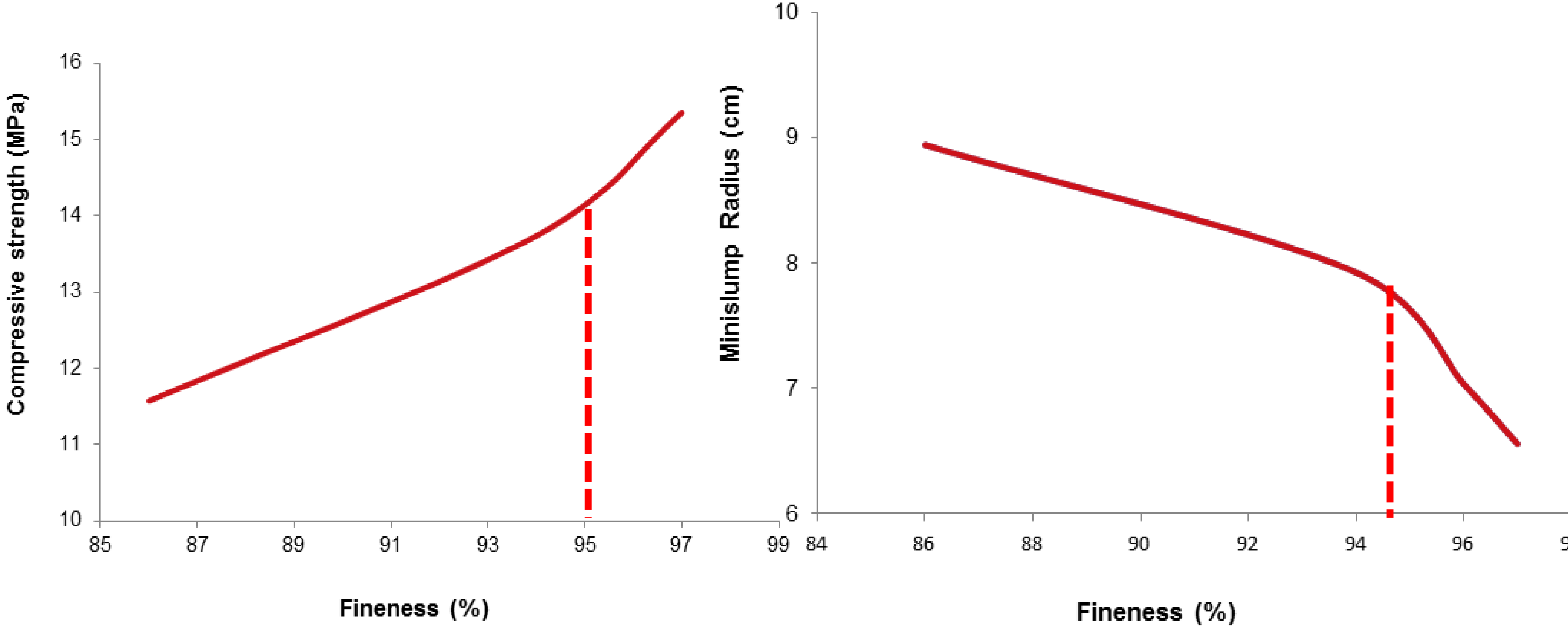


Particle size distribution for cement



Most reactive material

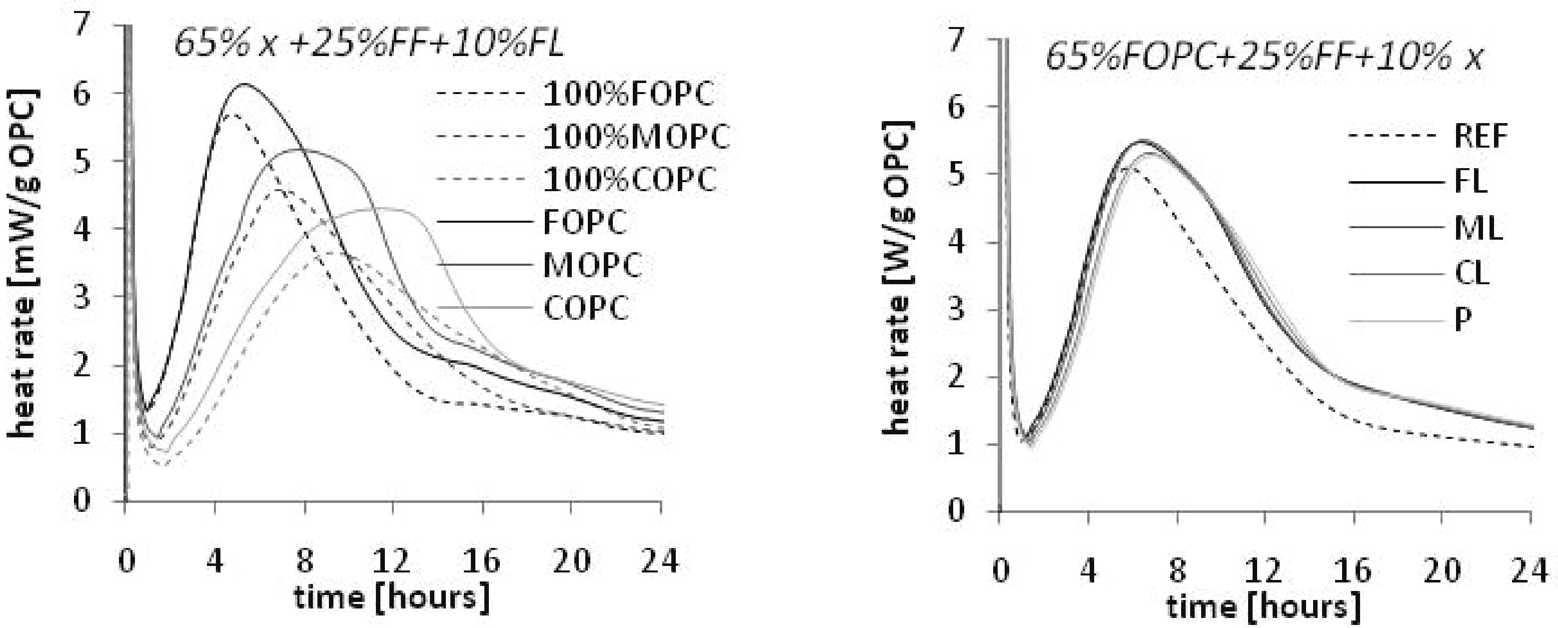
Strength vs. rheology



Fineness vs strength

Fineness vs workability

Fineness of cement components



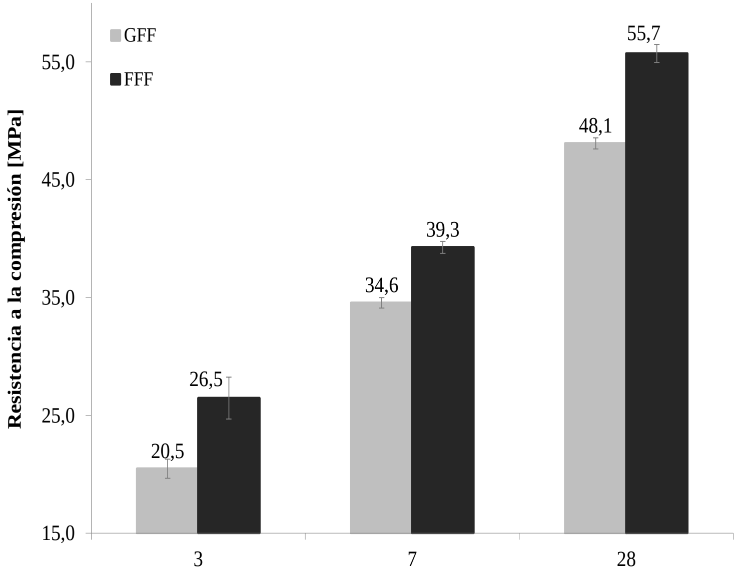
Grinding tests with ternary blends with flyash and limestone

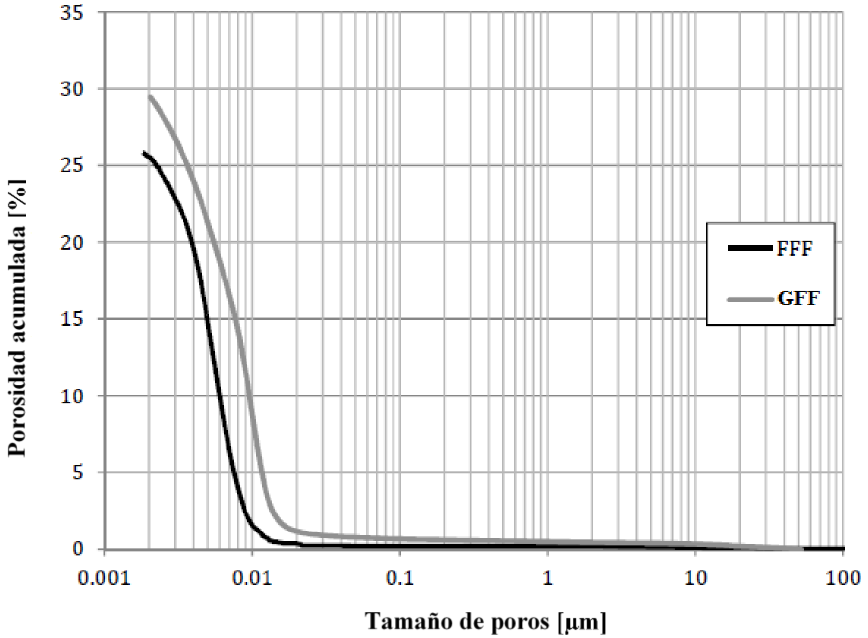
K. De Weerdt et al. / Cement and Concrete Research 41 (2011) 279–291

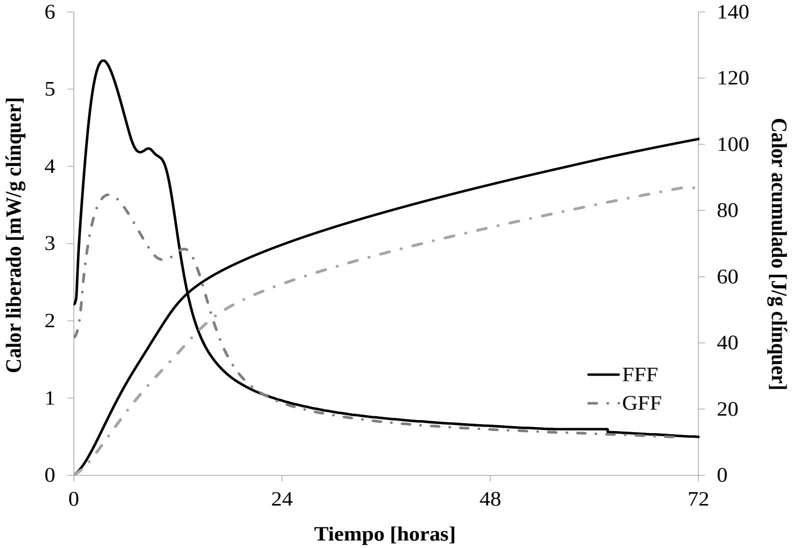
Experimental design: grinding

Material	Fraction; PSD (µm)								
	D_{v10}	D_{v50}	D_{v90}	D_{v10}	D_{v50}	D_{v90}	D_{v10}	D_{v50}	D_{v90}
	Fine			**Medium**			**Coarse**		
Clinker (CK)	2,4	17,0	41,8	6,8	43,4	78,6	16,5	77,0	119,6
Calcined clay (CC)	-	-	-	0,4	6,5	53,8	-	-	-
Limestone (LS)	1,4	3,8	9,5	4,0	51,6	78,4	4,0	108,7	197,1

Influencia de finura del clínquer

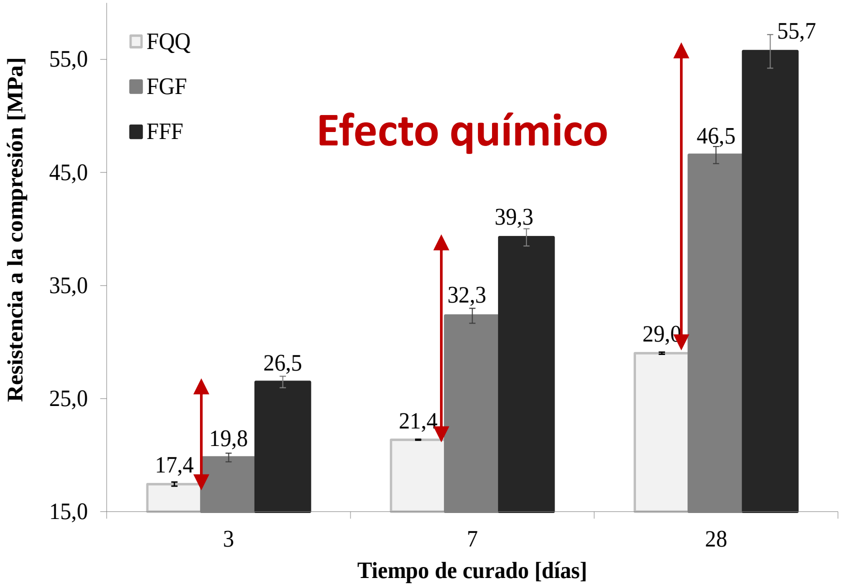




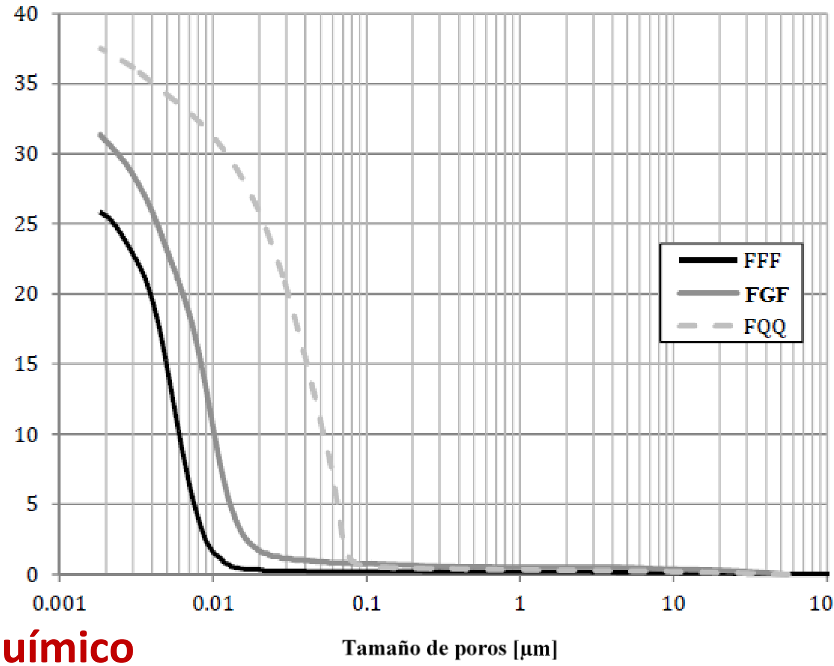


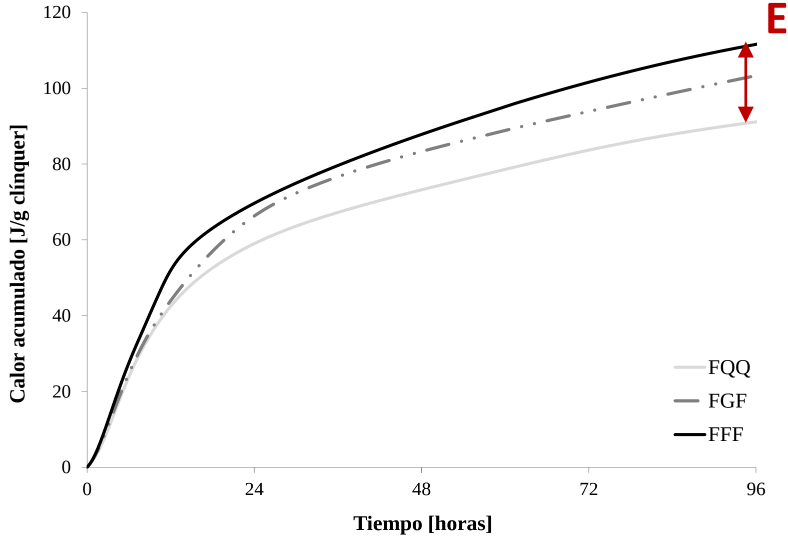
- Mayor influencia en la resistencia a las edades tempranas
- Mayor calor liberado = mejor hidratación de partículas de clínquer
- Mayor refinamiento de la estructura de poros y porosidad total

Influencia de la finura de la arcilla calcinada



Efecto químico

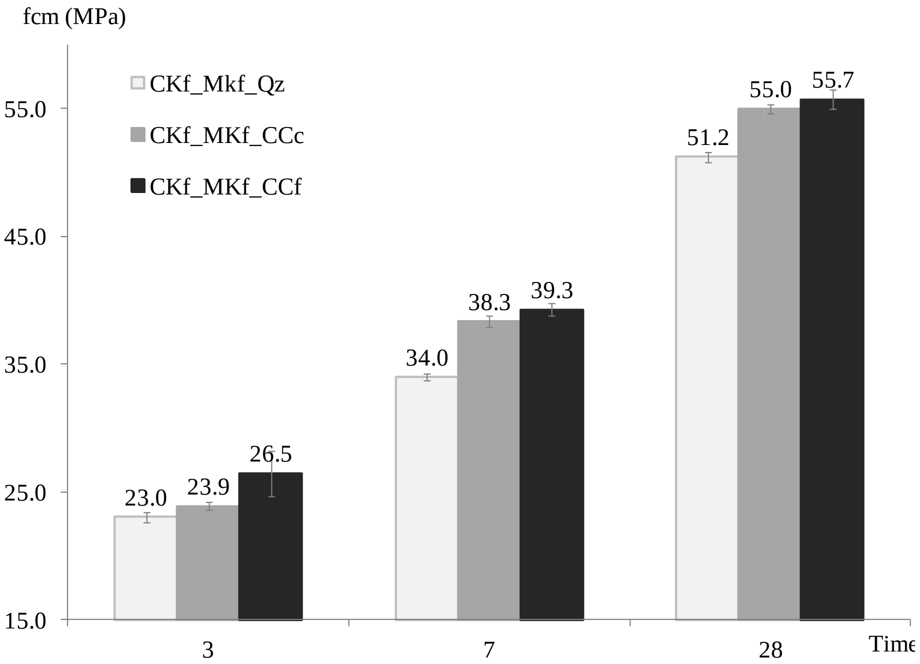


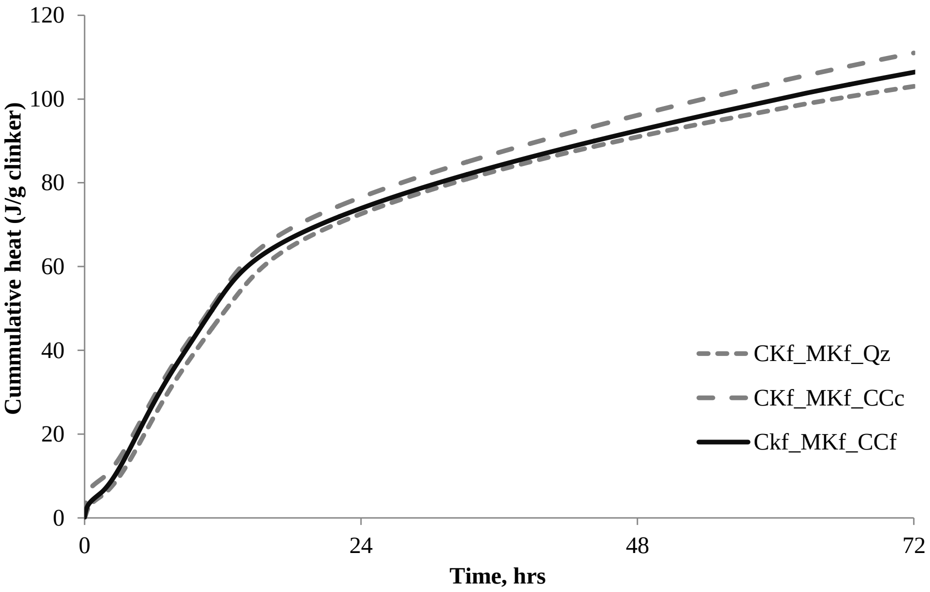


Efecto químico

- Finura arcilla favorece la nucleación heterogénea de los silicatos de calcio
- Reacción puzolánica mayor después de los 3 días
- Efecto de puzolanas en refinamiento de la estructura de poros (8 – 9 veces)

Influencia de la finura de la caliza

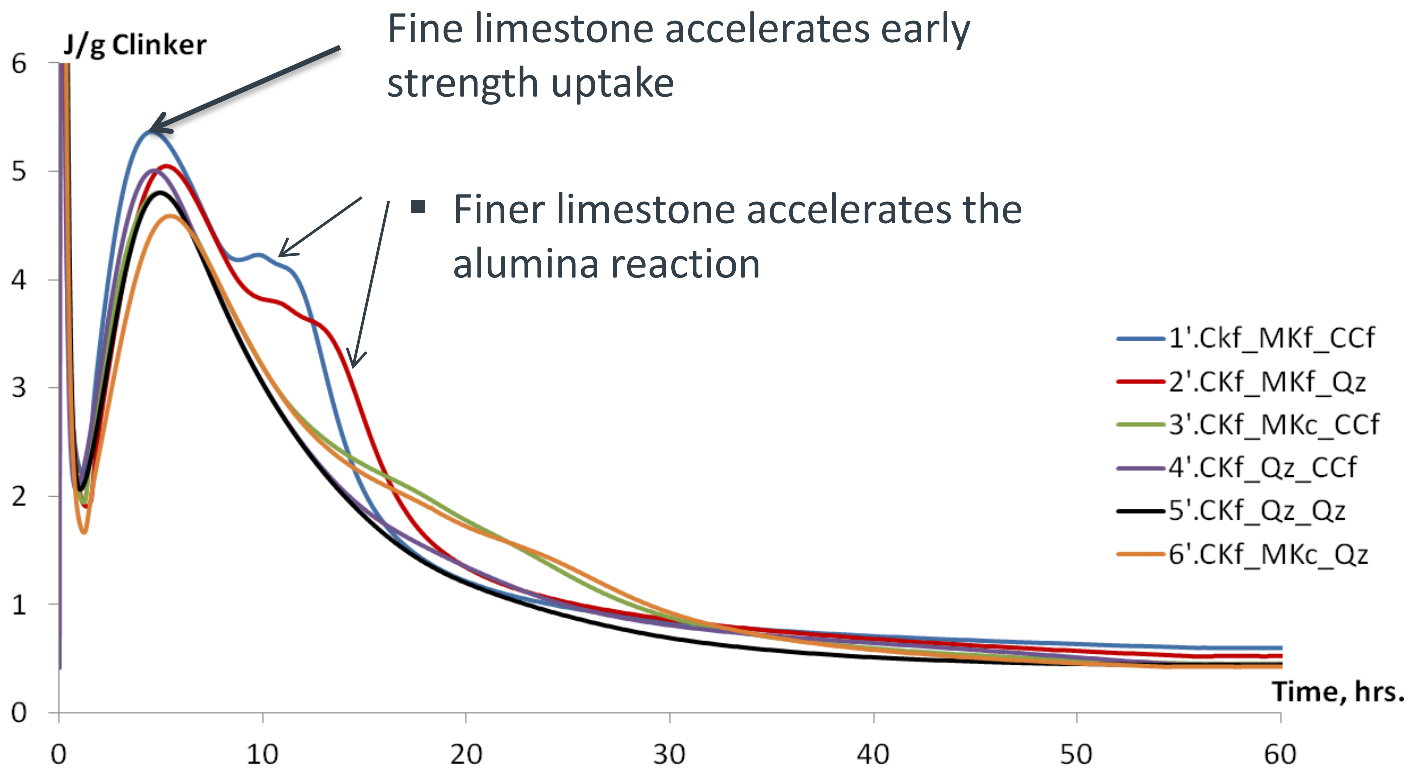




La finura de la caliza no tiene una mayor influencia sobre la hidratación del sistema, aun molida muy finamente…

Slide L. Vizcaíno, 2013

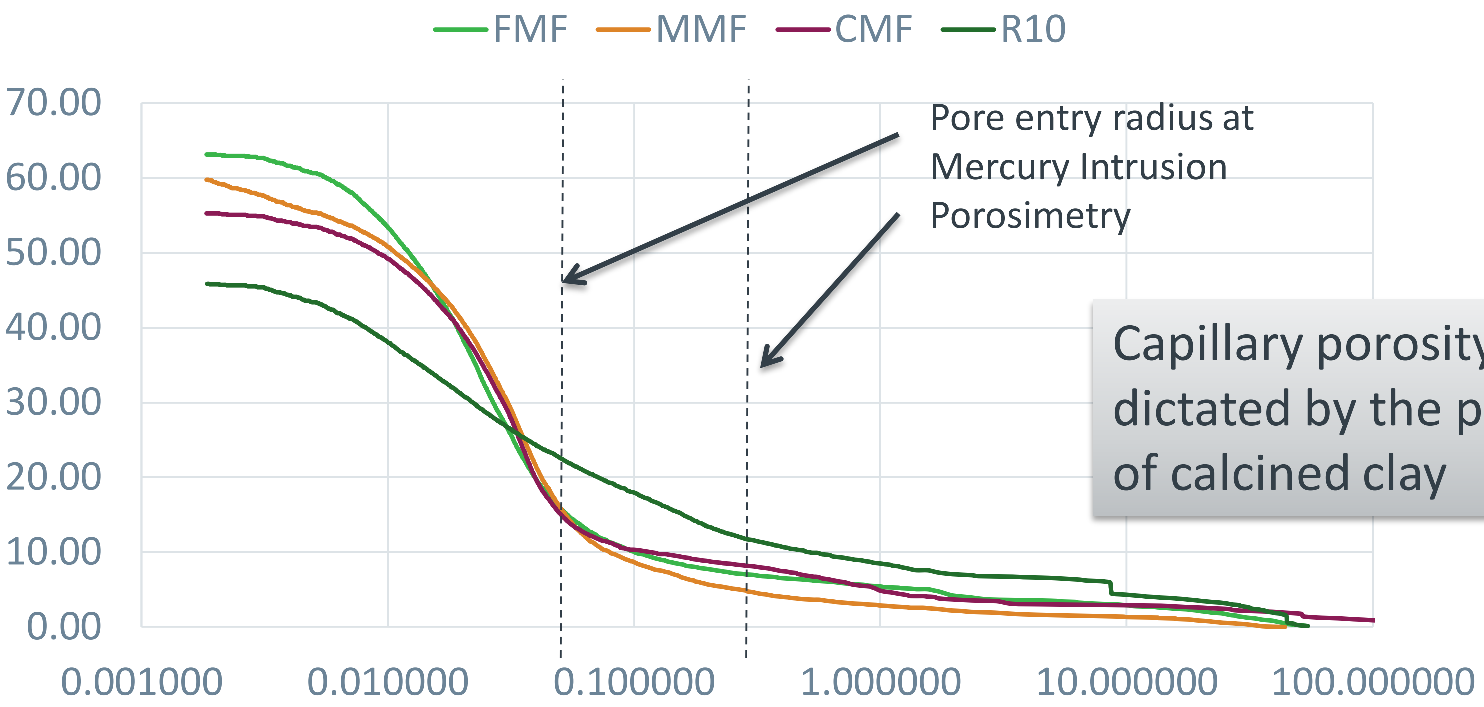
Impact of fineness of different components



Fine limestone accelerates early strength uptake

- Finer limestone accelerates the alumina reaction

Impact on the pore structure



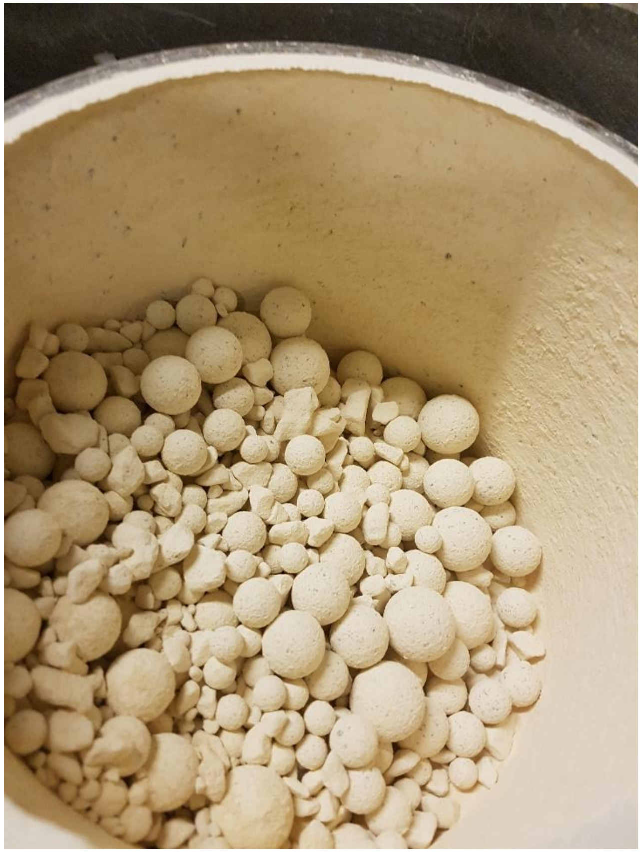
Pore entry radius at Mercury Intrusion Porosimetry

Capillary porosity is dictated by the presence of calcined clay

Efectos de la co-molienda

Franco Zunino, EPFL, 2018

Calcined clay after 2h



Limestone after 2h

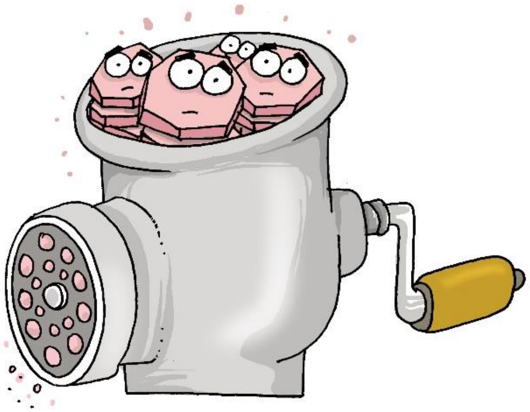
Intergrinding multi-component cements

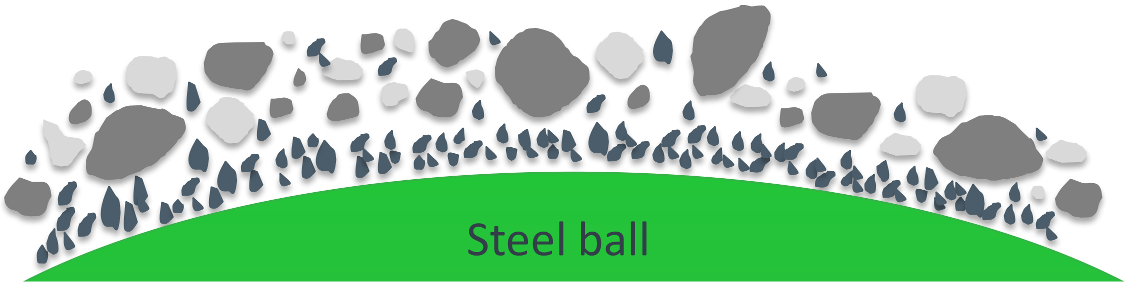
- Electrically charged calcined clay particles stick to the steel balls and prevent clinker from further grinding
- Calcined clay and limestone as a result end up ground in excess

Clinker

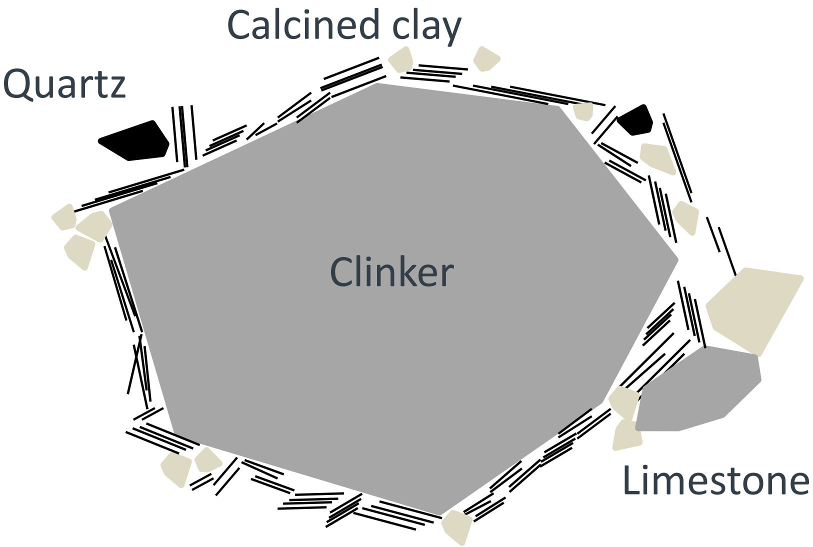
Calcined clay

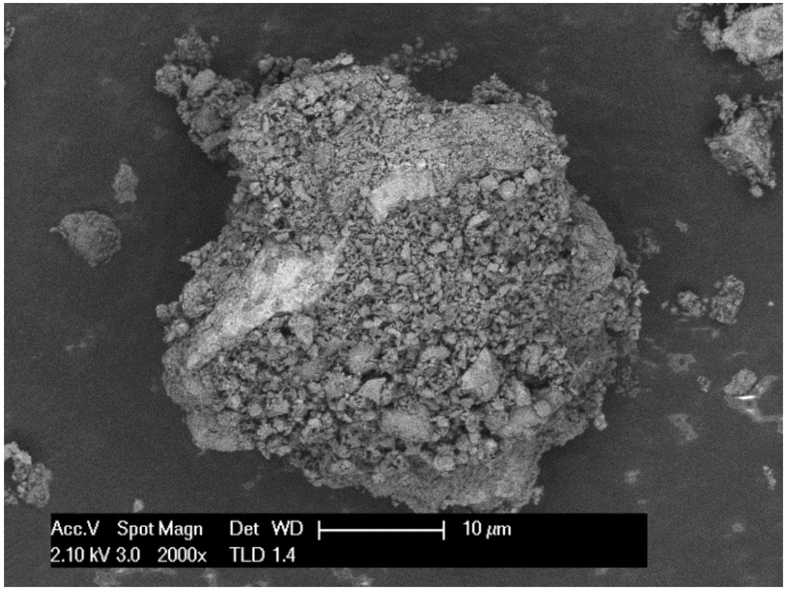
Limestone





Intergrinding multi-component cements





Undergrinding of clinker

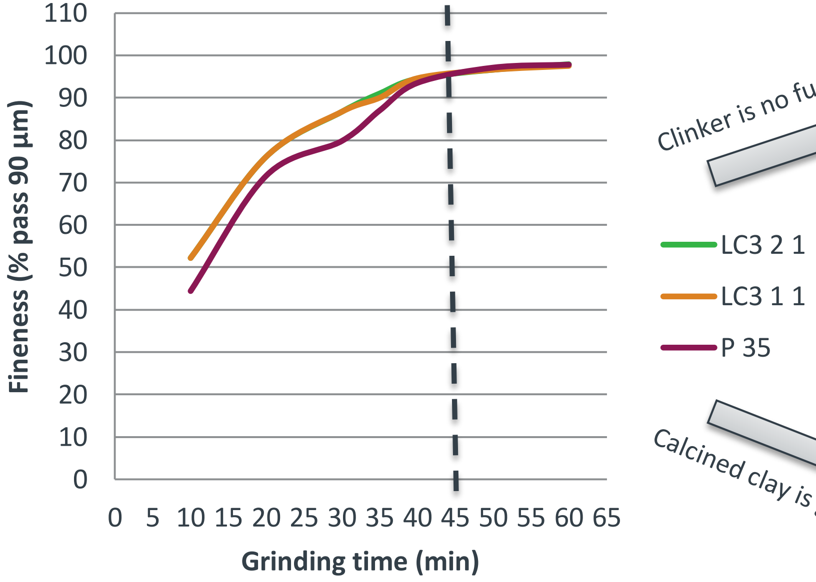
Separator gauge was set for around 10% of cement retained at 90 µm sieve (coarser than normal practice)

Most material retained at 90 µm (9%) sieve was coarse clinker

Coarser Clinker (over 90 µm

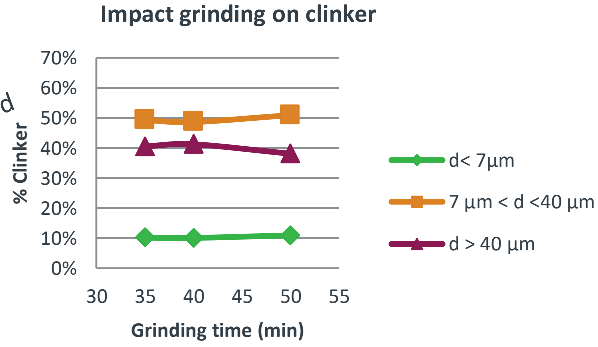
Finer the Rest

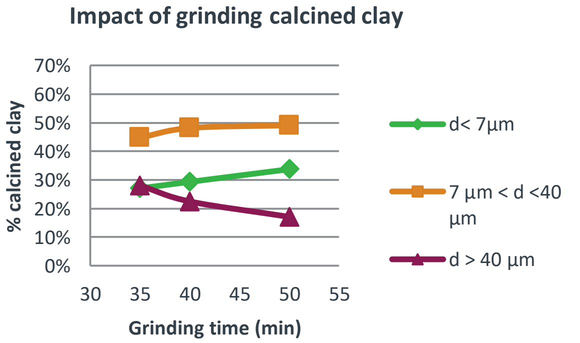
Materiales mas duros sobre-muelen a los más suaves



Clinker is no further ground

Calcined clay is ground finer





Benefits and Value of Cement Additives

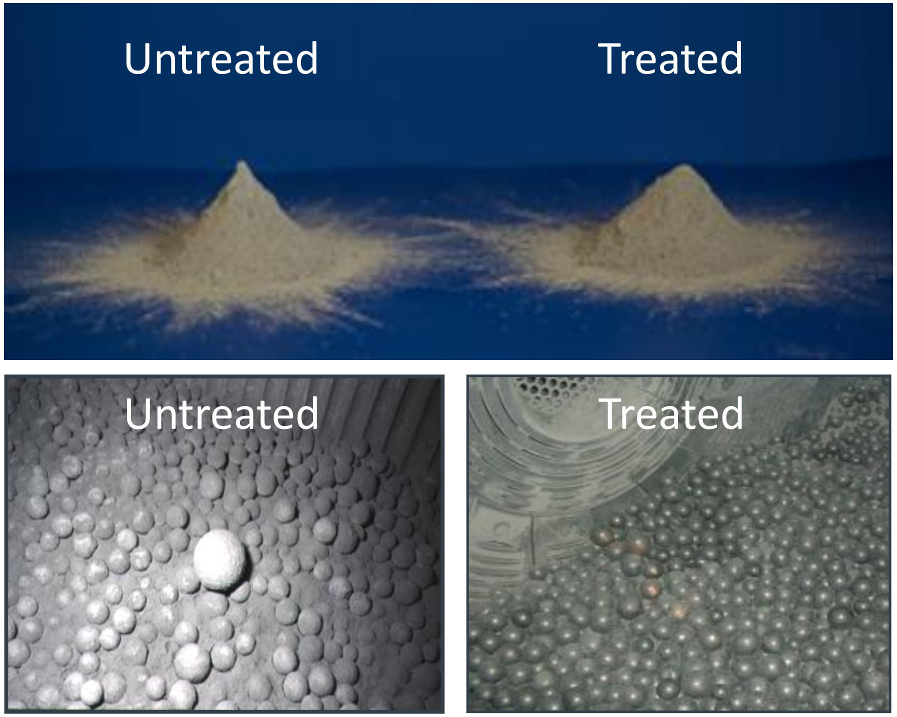
			Benefits	Value
Quality Improvers	Grinding Aids	Process	Reduce coating	Improve grinding efficiency (kWh/tonne), ➢ Reduce cement grinding costs
			Reduce Pack-set	Shorten loading/unloading operations ➢ Reduce distribution costs
			Increase mill output	Increase production capacity ➢ Reduce cost and meet sales volume
			Narrower cement PSD	Improve cement performance ➢ Improve market position

Quality	Increase early strength	5-15%; 2-12 MPa	Lower clinker factor Use of alternative fuel Lower cost or higher grade
	Increase late strength	10-30%; 2-8 MPa	
	Reduce initial set	15-45 minutes	Meet customer needs in temperature changes
	Extend set time	15-90 minutes	
	Reduce water demand	2-6% in concrete	Improve market position

- **Reduce environmental impact**
- **Meet customer needs, satisfy Standards, meet/exceed competition**
- **Improve market position**

Ariane Marto, GCP

Benefits of Grinding Aids



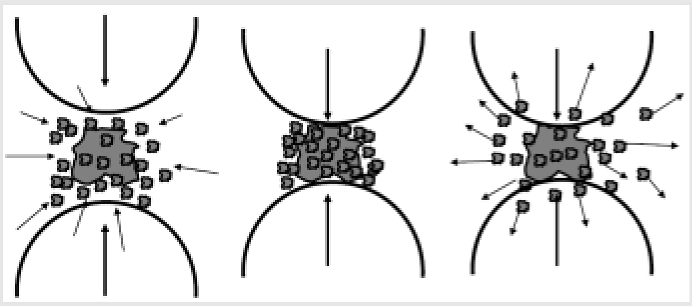
Cement can be treated to increase flowability giving a smaller angle of repose, resulting in less cement sticking on balls and mill

- Improve particle size distribution for strength & water demand
- Increase cement flowability to reducing pack-set during transportation

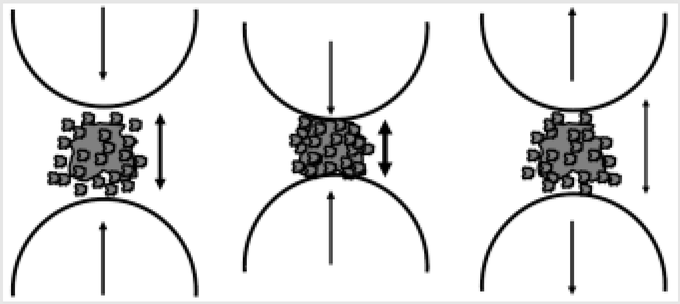
Ariane Marto, GCP

Mechanisms of Grinding Aids
- Causes of Agglomeration and Coating

- Agglomeration



- Compressibility



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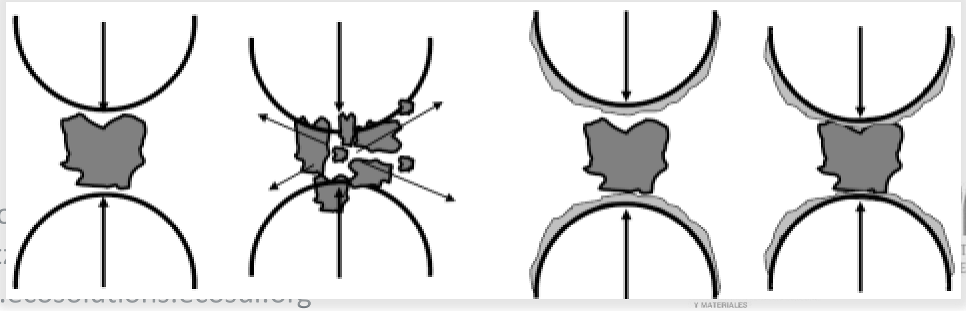
- “Coating”



Agglomeration and Coating
- Causes of Lower Grinding Efficiency

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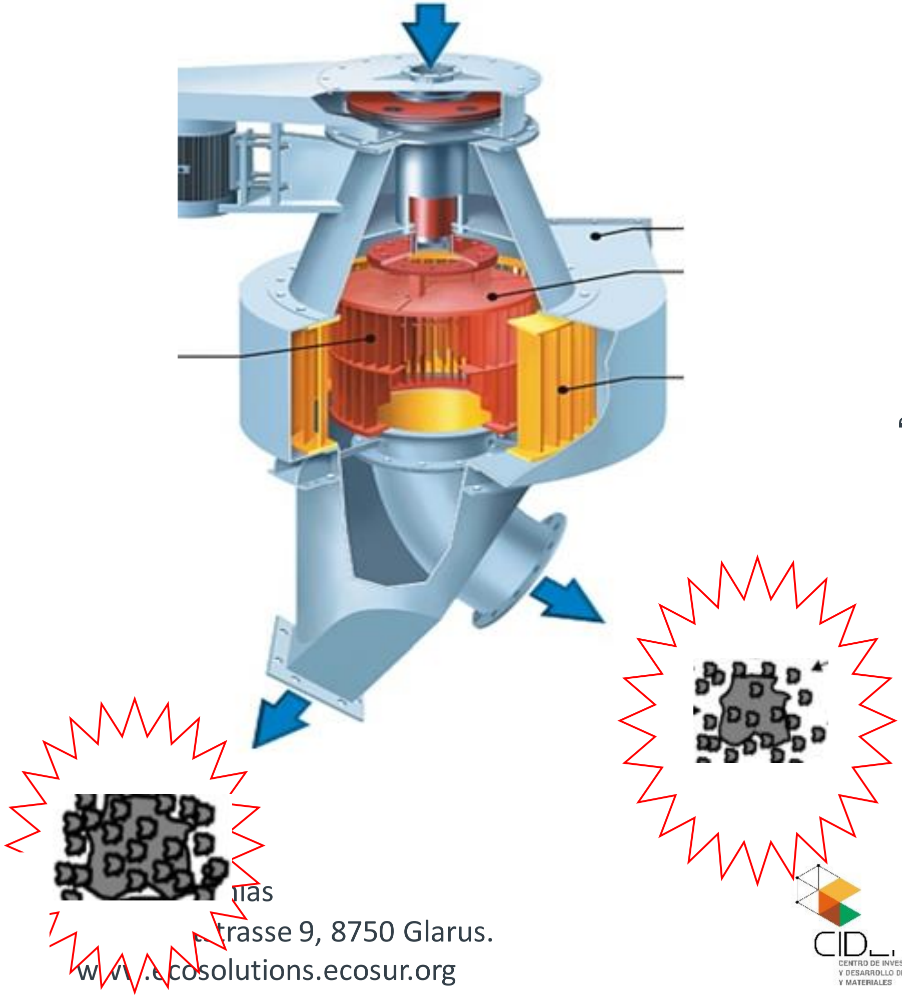
Effect of the force of attraction between particles:



Higher rolling load.

Drag from fine particles to return.

“PSD” of the cement less efficient.

Drag from coarse particles to final product.

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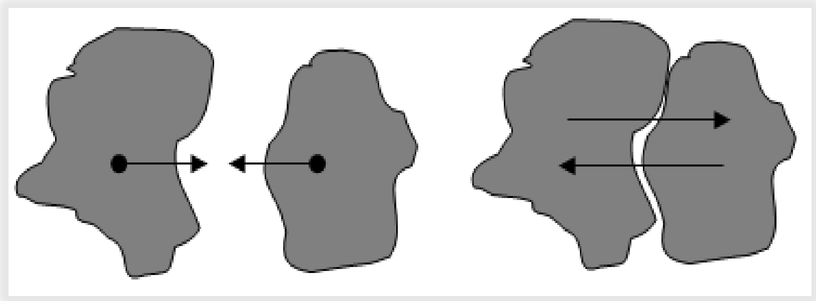
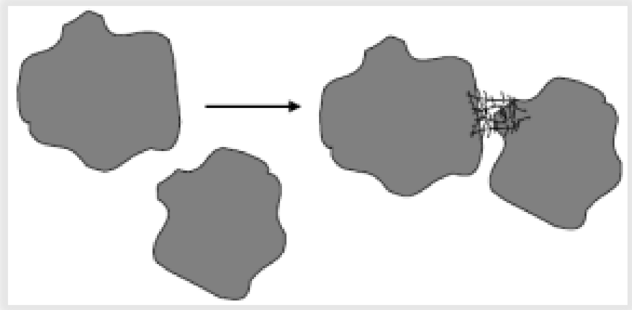
Mechanisms of Grinding Aids
- Causes of Agglomeration and Coating

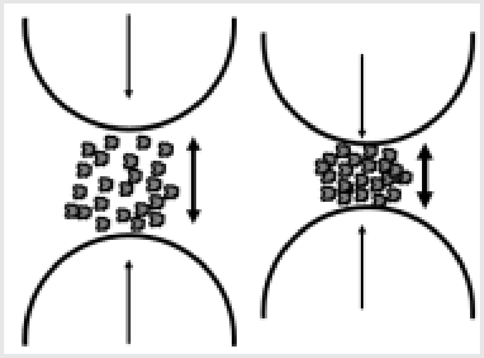
Physical - Surface Charges



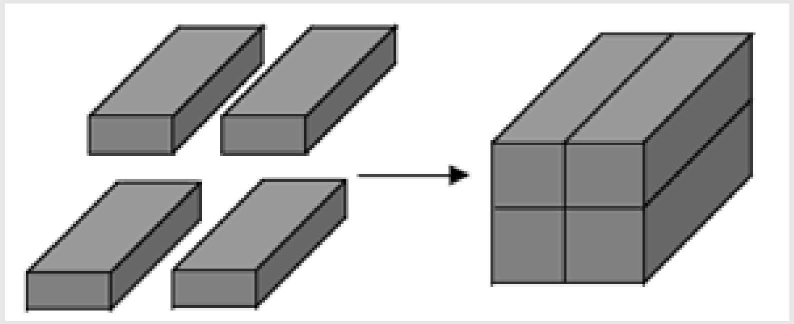
Chemical - e.g. Hydration Bridges



Mechanical - Particle Packing



Thermodynamic - Surface Energy



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Mechanisms of Grinding Aids

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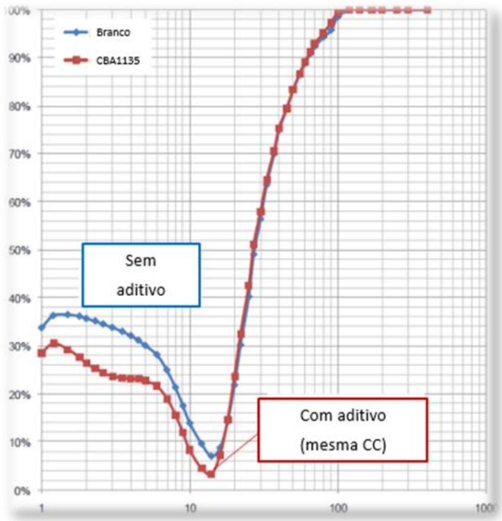
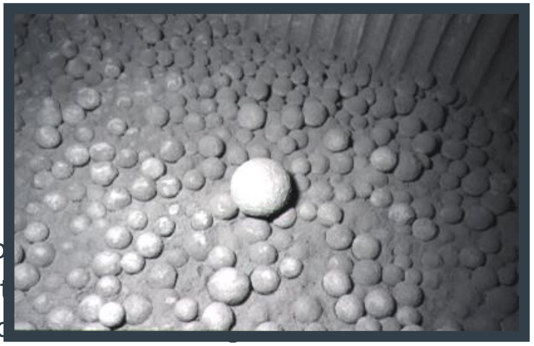
Main influence: reduce the effects of the forces of attraction between particles.

- **All systems:**
  - Improves dispersion and fluidity of the material.
  - Increase the separator bypass.
  - Closer PSD curve (positive on resistors).
- **Ball mill:**
  - Reduction of agglomeration and coating.
  - Reduction of residence time.
  - Filling level reduction.





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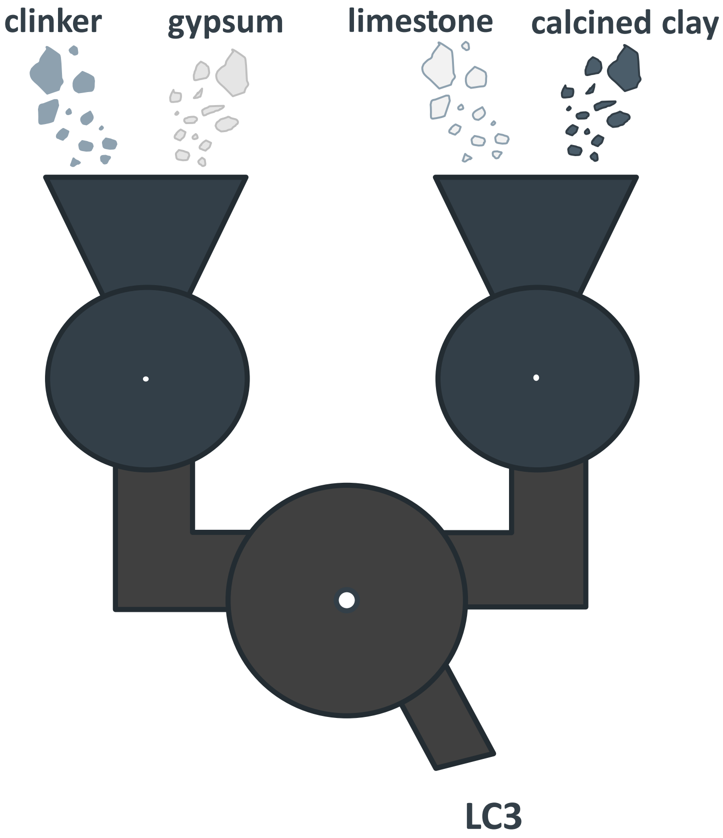
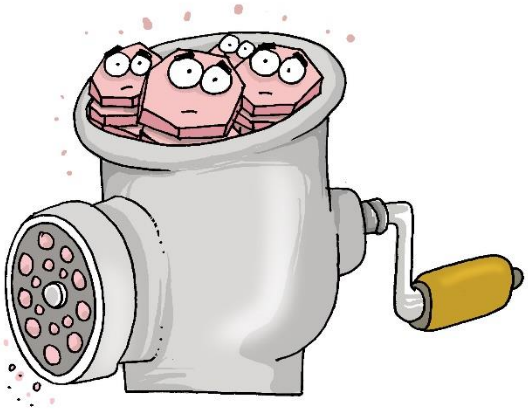
An alternative: separate grinding

- Clinker and gypsum are ground together
- Calcined clay and limestone are ground together
- Both materials are mixed together and homogenized

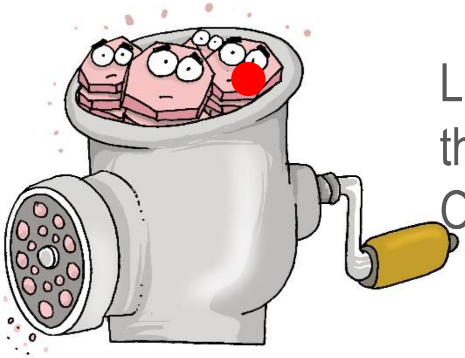




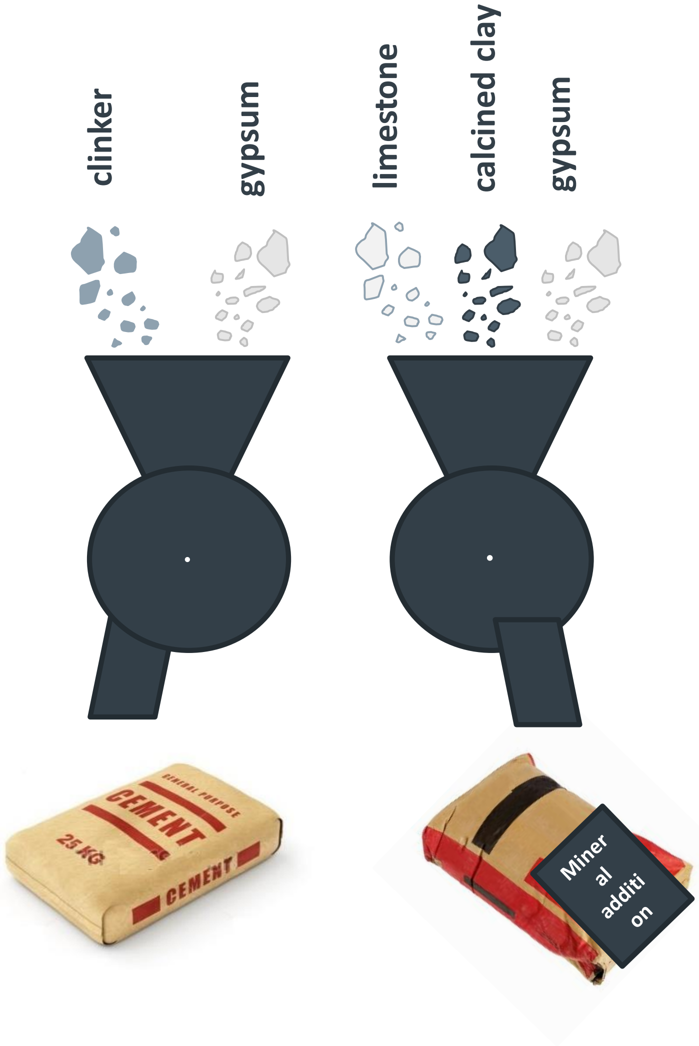
LC^3, by addition to concrete

- LC^3 can also be produced at the concrete stage by incorporating a **mineral addition** of calcined clay and limestone as an independent product

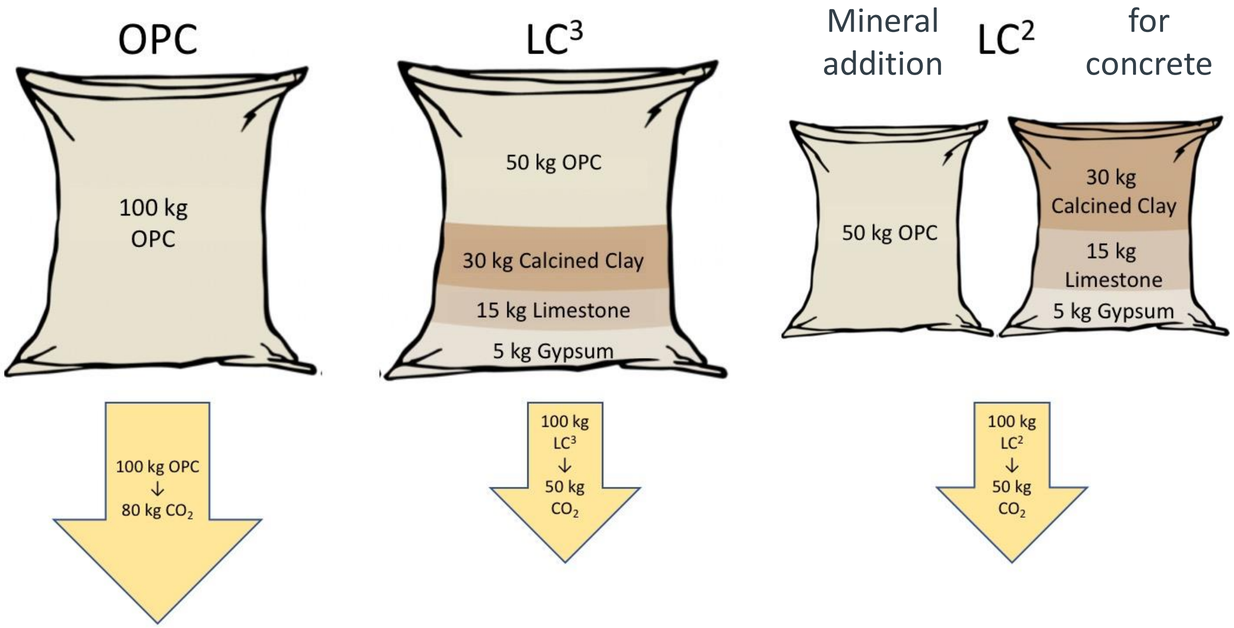
- It can be used in combination with OPC for masonry applications or as addition to high strength concrete



- Level of addition depends on the application and the purity of OPC used

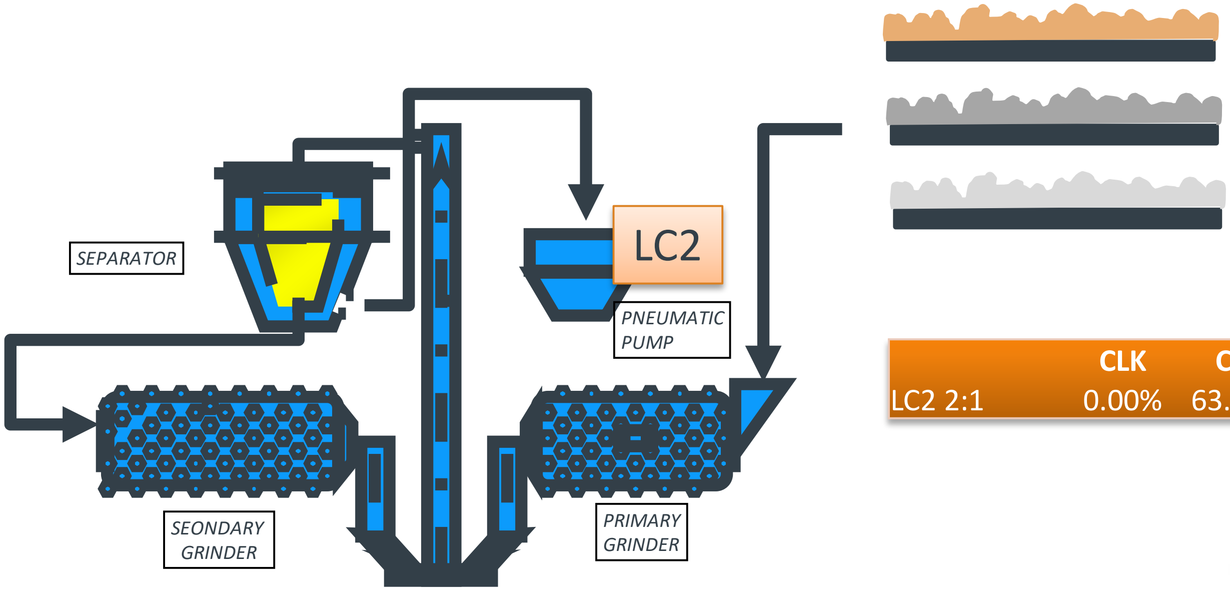


La adición mineral puzolánica “LC2”



	CLK	CCL	LS	GYP	Total	Na equiv	SO3	Al2O3
LC2 2:1	0%	63%	30%	7%	100%	0.43	3.16%	17.46
patron P35	94%			6%	100%	0.77	2.71%	3.69
LC3-50 2:1 (mezcla separada)	**47%**	**32%**	**15%**	**7%**	**100%**	**0.60**	**2.93%**	**10.57**

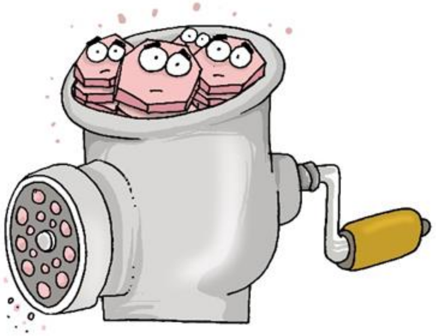
Estrategia de molienda del LC2



BELT 1: calcined clay
BELT 2: gypsum
BELT 3: limestone

	CLK	CCL	LS	GYP	Total	SO3
LC2 2:1	0.00%	63.00%	30.00%	7.00%	100.00%	2.80%

Cost	P-35	PP-25	LC3	LC2
USD	111.70	84.89	77.15	42.83



Ventajas de la estrategia LC2

- Most cement plants have 3 feeders for the grinding system, so calcined clay and limestone should be mixed before being fed to the hopper
- Better PSD during grinding. No overgrinding takes place
- LC2 has a much longer shelf life
- More flexible LC3 formulation, including sulphation

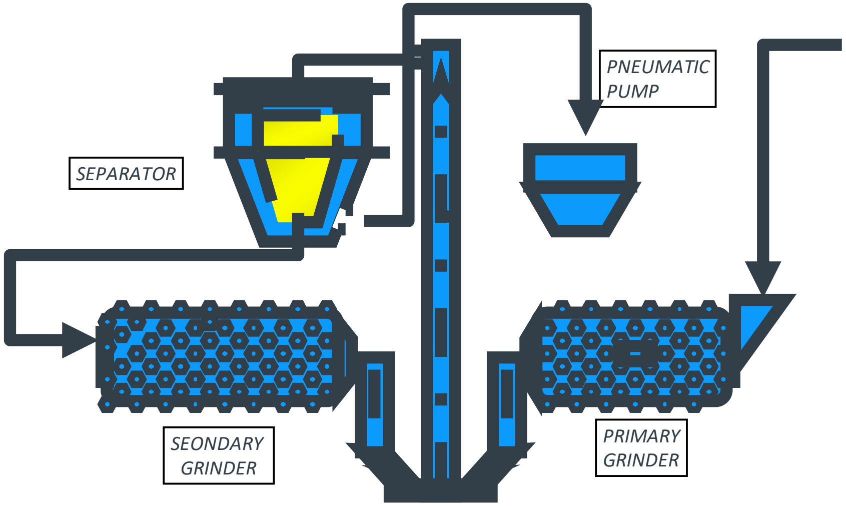
Future work

- Use of grinding aids

Separate grinding vs. Intergrinding

Separate grinding	Intergrinding
Little probability of excess grinding	Harder materials overgrind softer ones
Enables strict control of particle size distribution (PSD)	Control of PSD is not possible, only the maximum size allowed.
Better energy efficiency during grinding (shorter grinding time)	Poor energy efficiency during grinding (prolonged grinding times)
Proper technology needed for blending and homogenization	The intimate mixing guarantees a complete blend and the result is a highly homogeneous material

Industrial grinders: ball mills

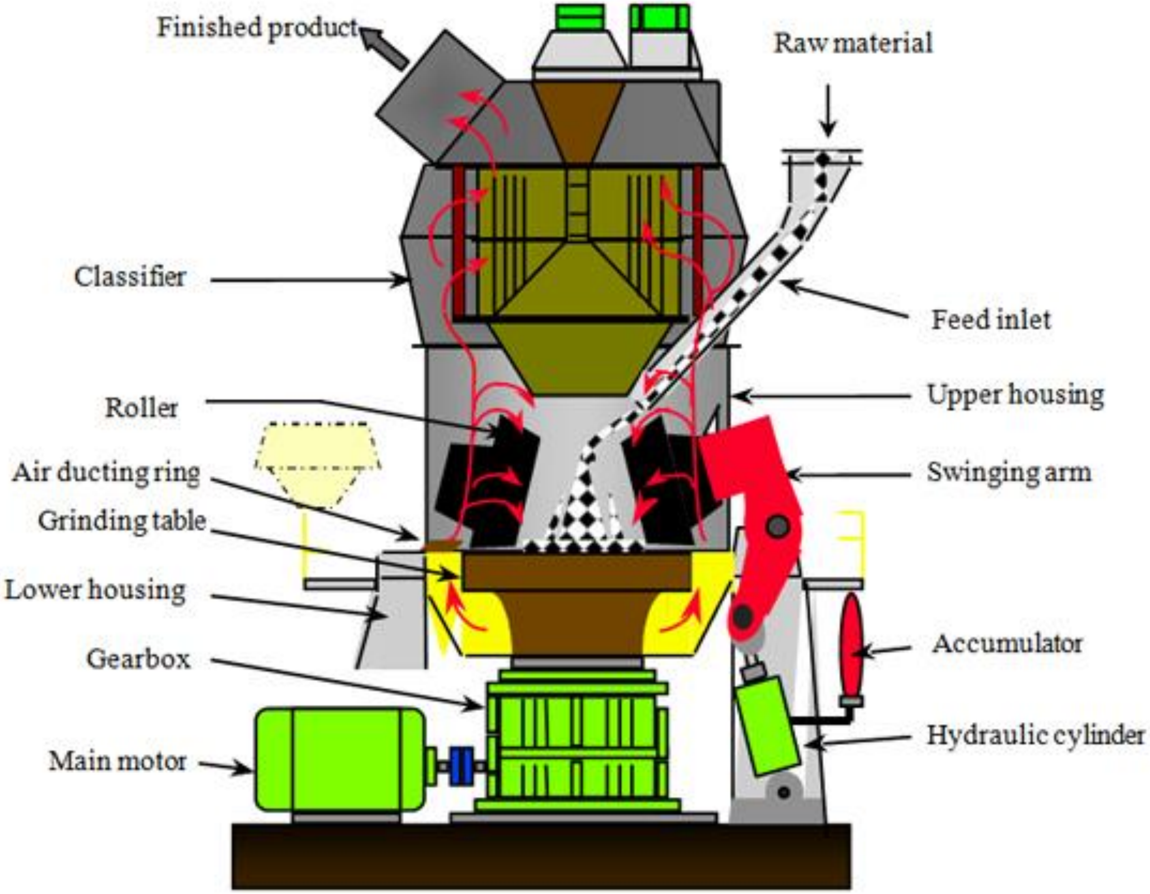


- Industrial grinders are way more efficient than lab grinders.
- Particle size distribution is controlled by an air separator

Industrial grinders: Vertical roller mil, VRM

The VRM guarantees a better and more efficient grinding

Target PSD possible



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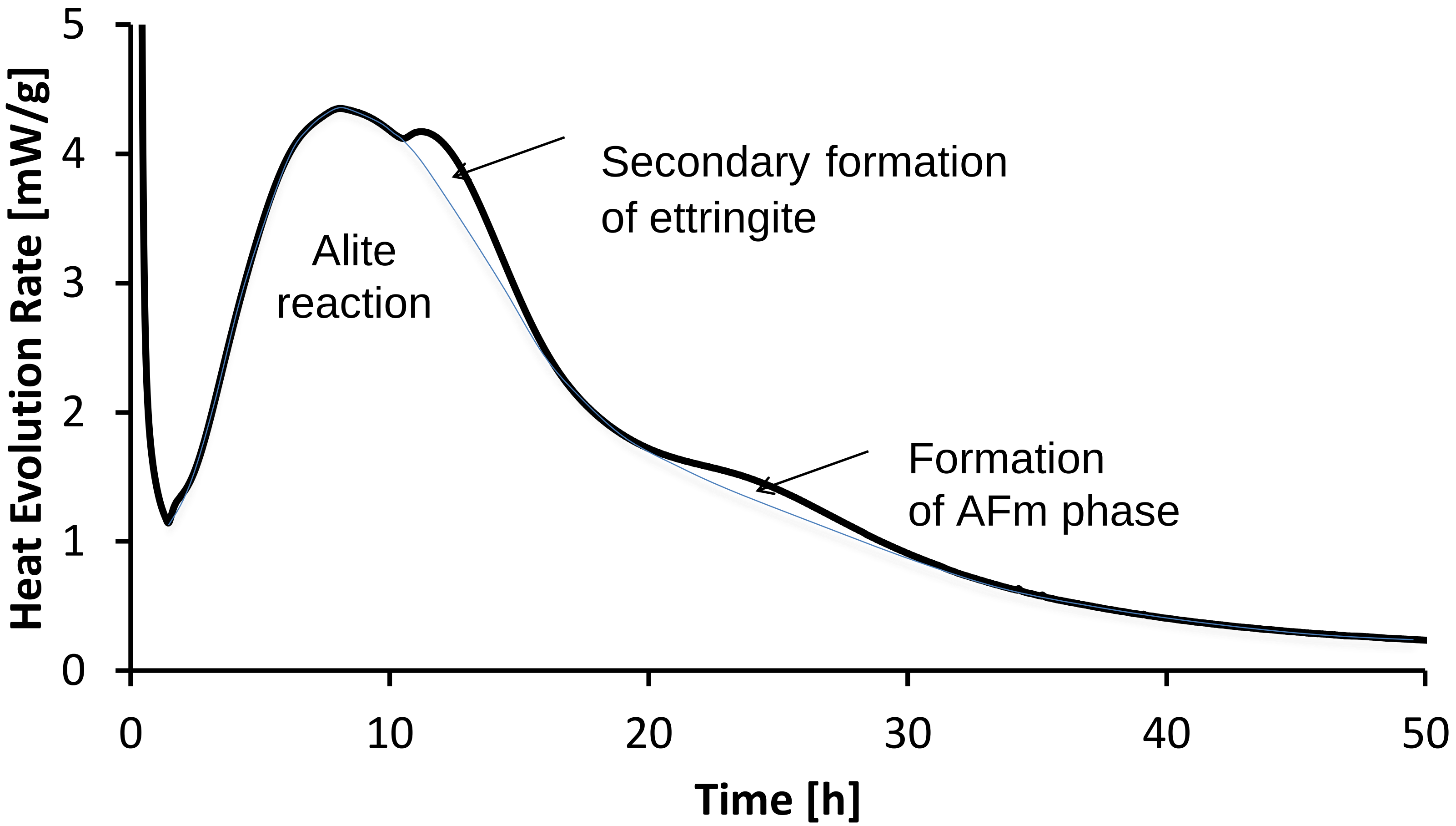
- » Consideraciones sobre normas

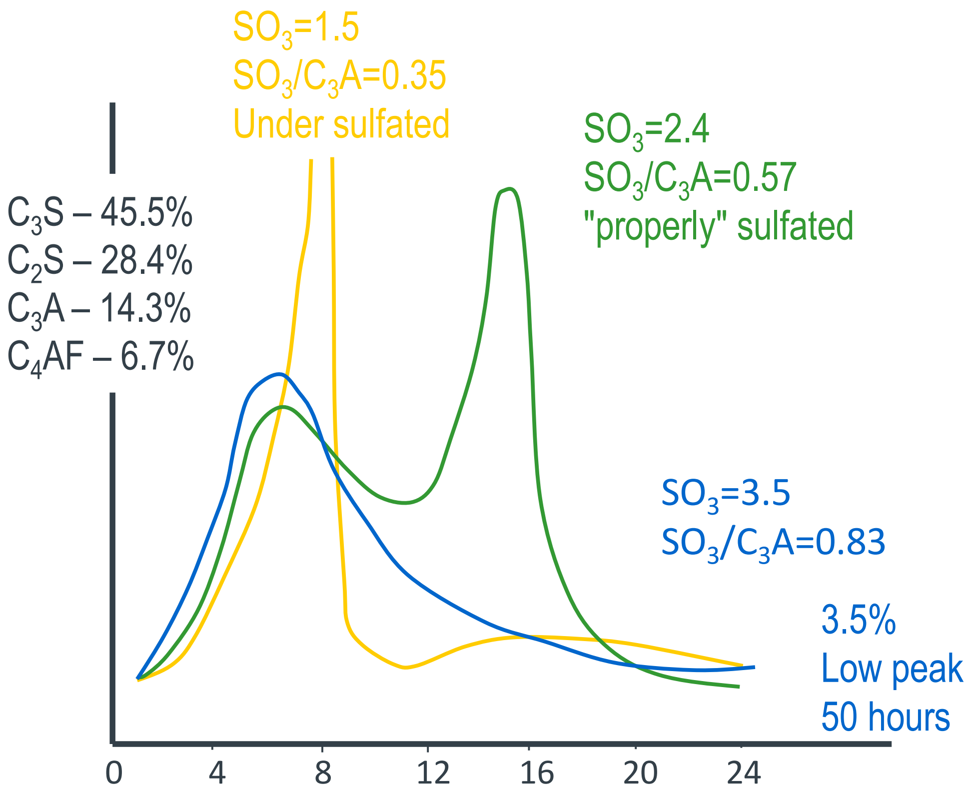
The aluminate reaction in Portland cement



Role of sulphates in Portland cement

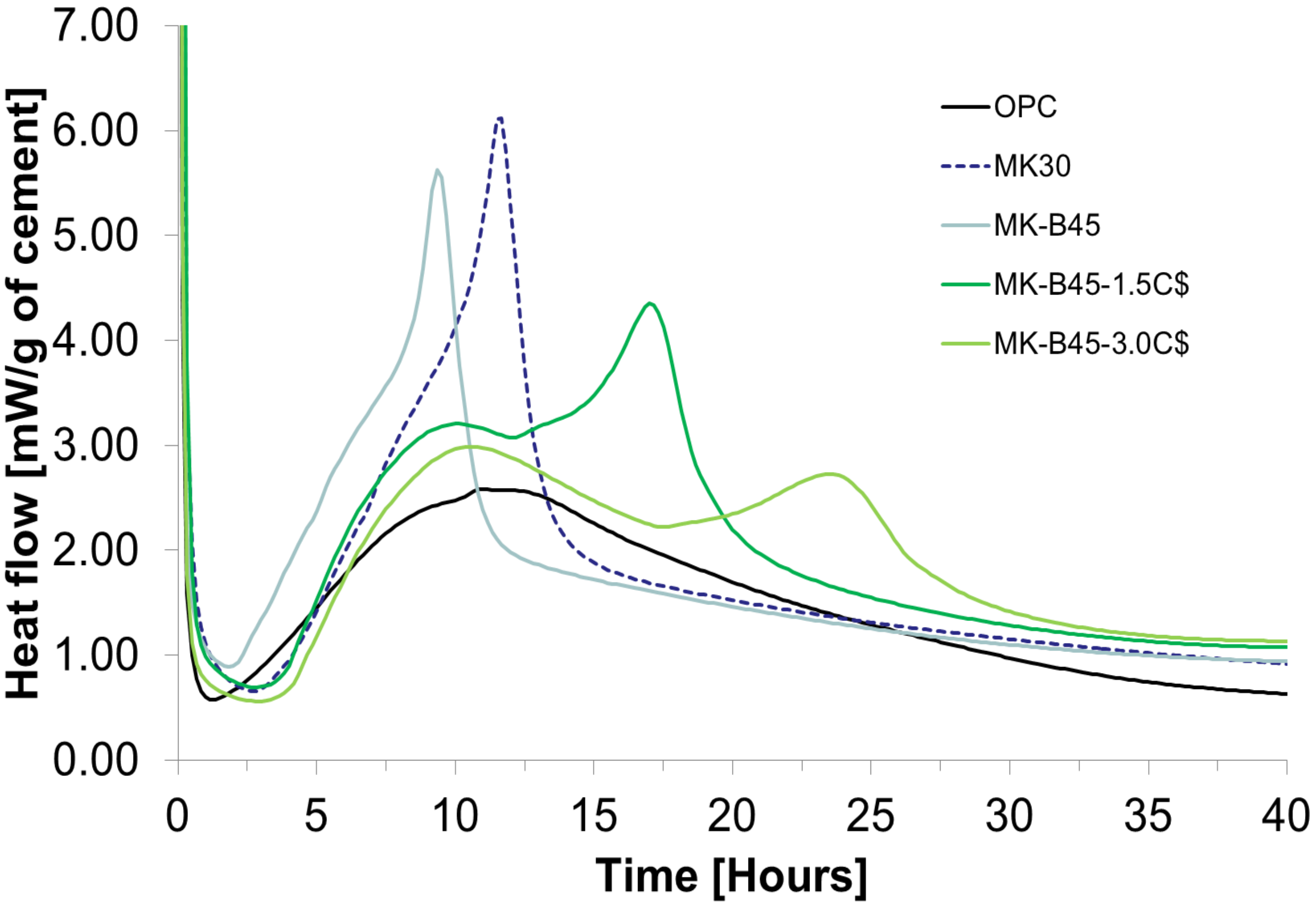
Sulphates adsorb on the surface of unhydrated alumina and prevents it from reacting. This allows the silicates to react well.

If undersulphated the aluminate reaction “overwhelms” the silicates reaction

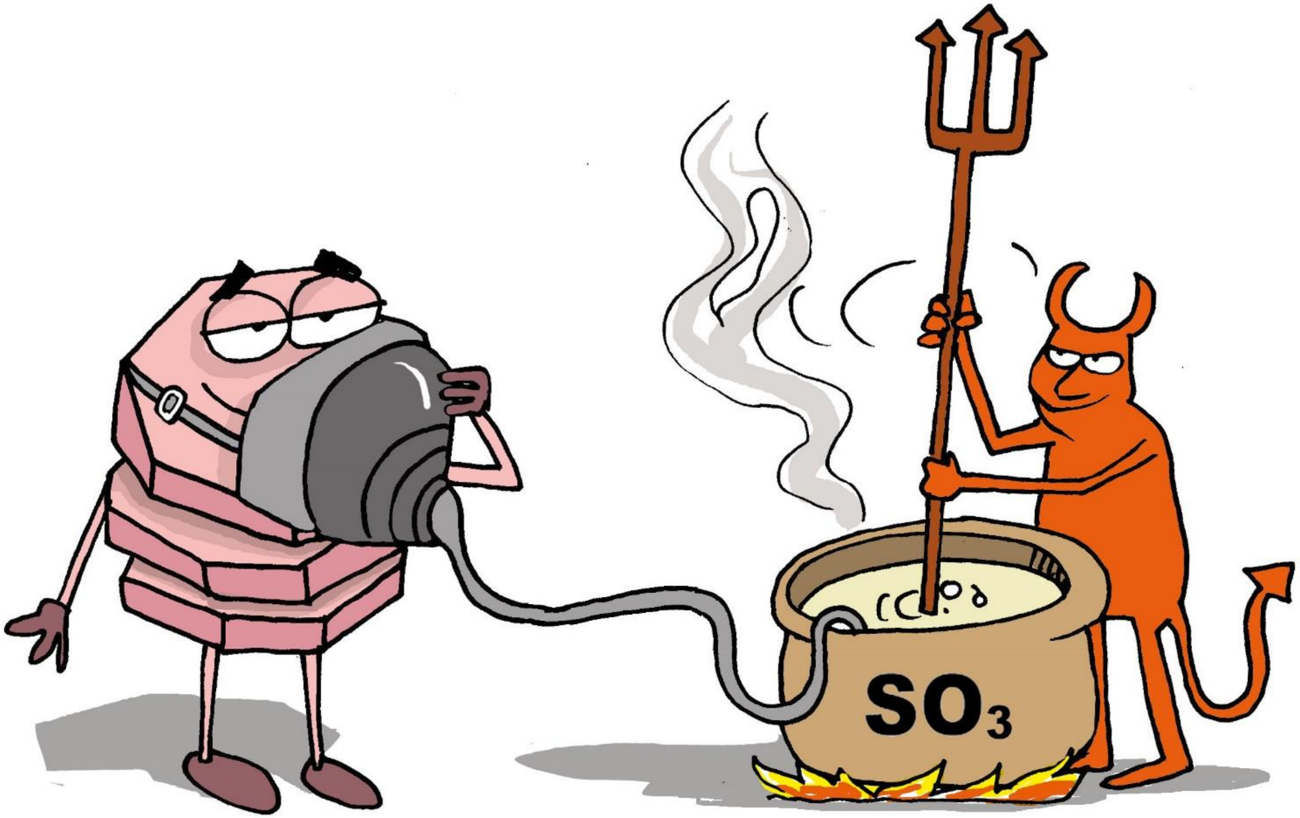


According to Lerch 1945

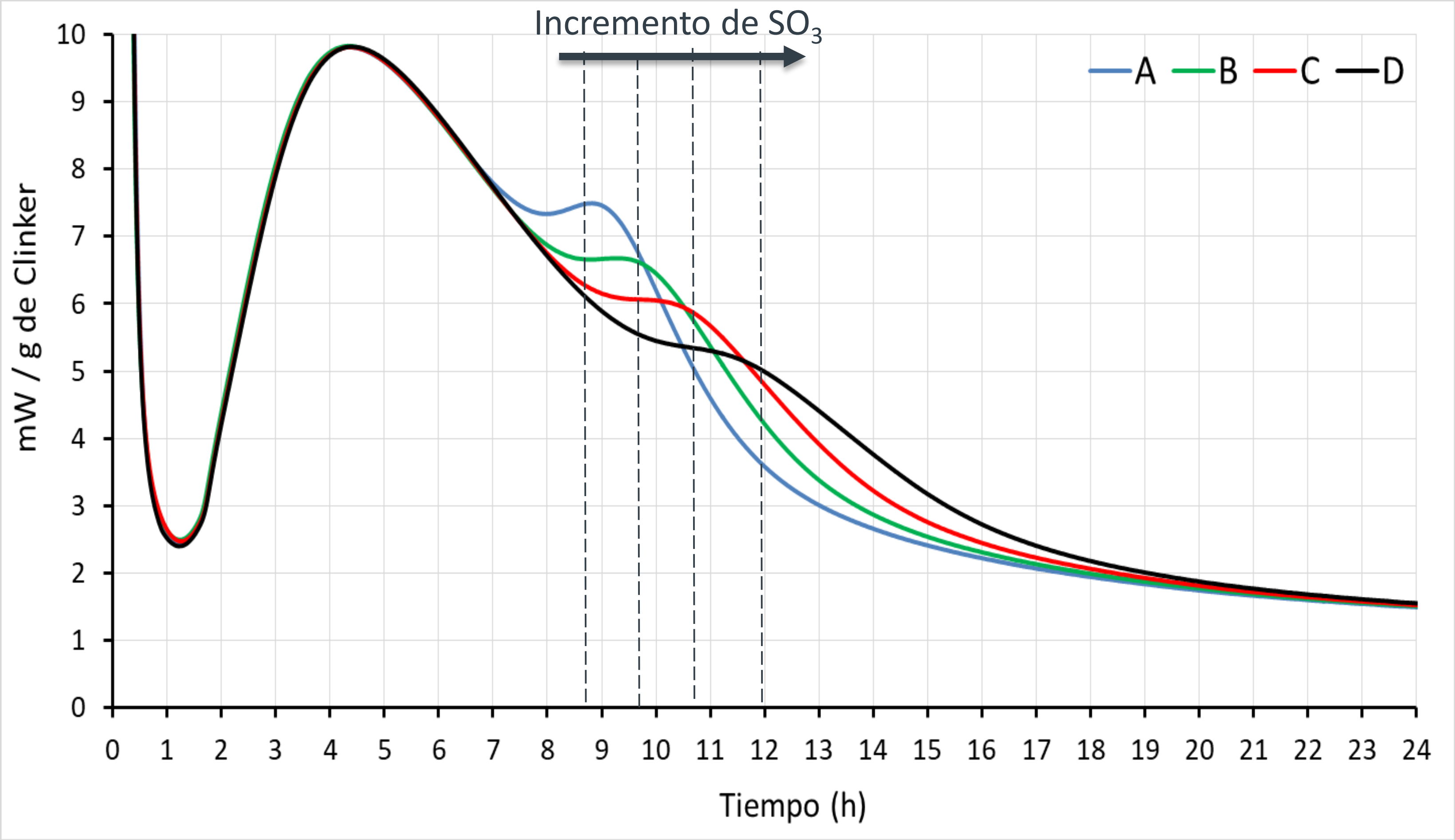
What happens if the alumina content is increased?



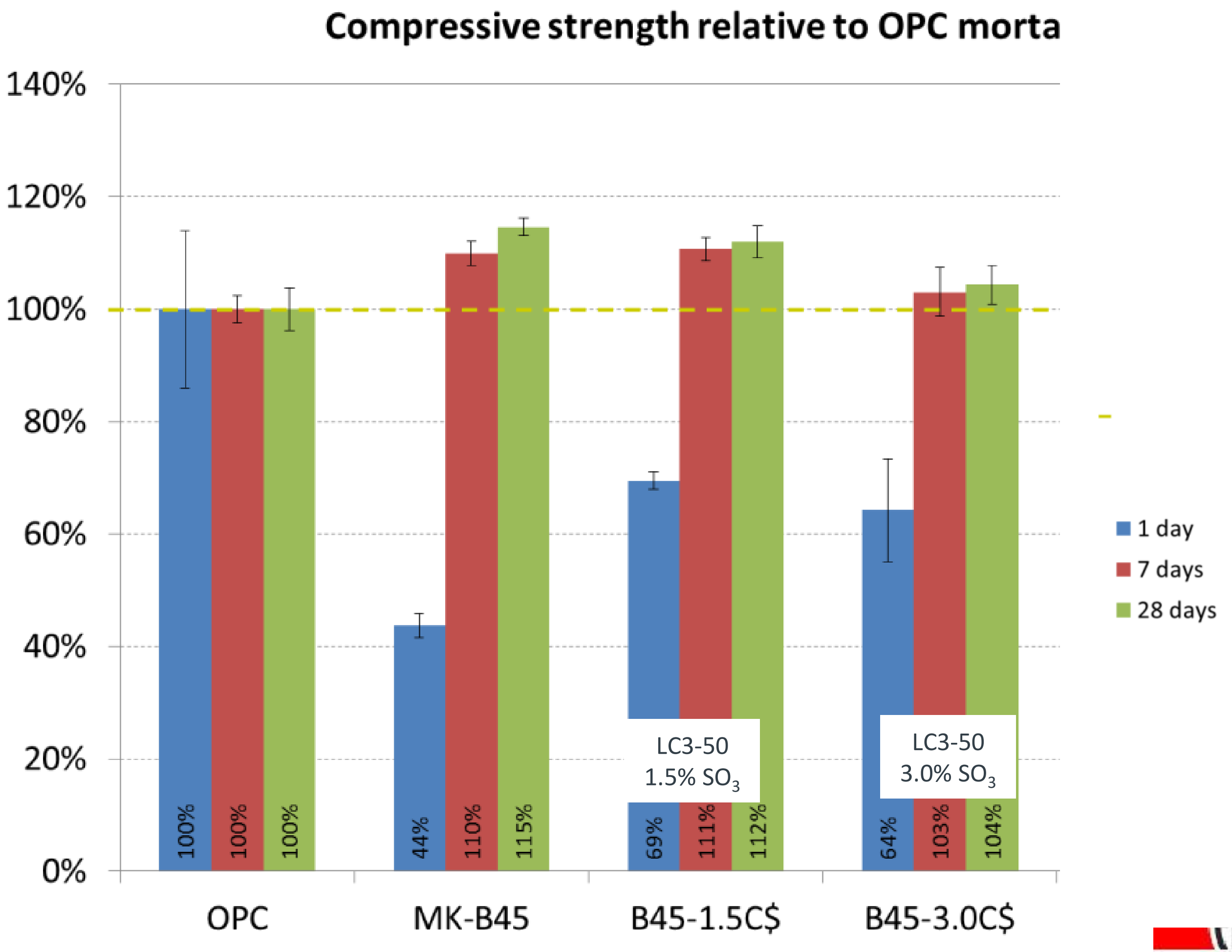
Cements having calcined clays need sulphation!!



Ejemplo de sulfatación



Impact of sulphation on early strength



Guion de la presentación

- » Introducción general al proceso productivo
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- » La sulfatación de sistemas cementicios con arcillas calcinadas
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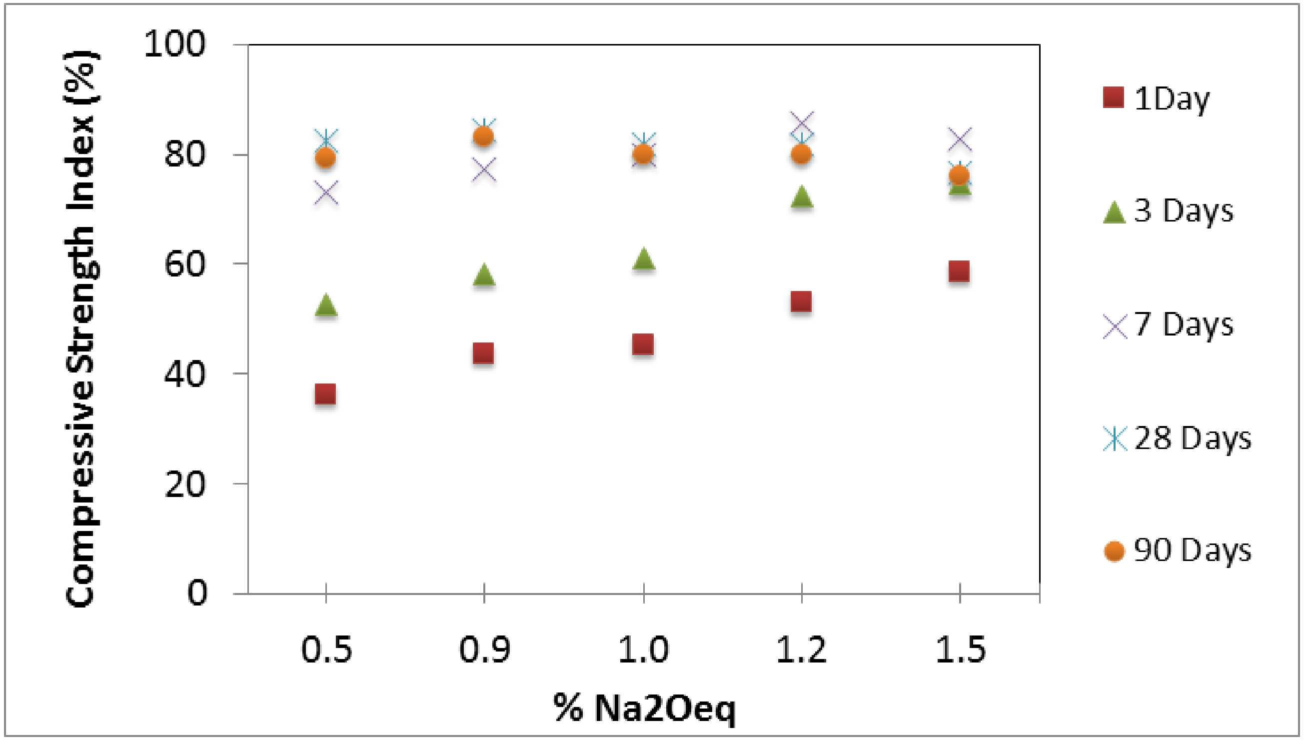
Impact of alkalis

- As with all pozzolans,
  a certain level of alkalinity is needed for calcined clay to react.

- The early strength of an LC^3 blend may be low if the alkali content of the clinker is very low.

Impact of alkalis in the system

- Direct increase in compressive strength with increase of alkalis
- The effect is reversed for very high alkalis concentration



Alkali Silica Reaction

- There is a concern that increasing alkalis in the cement could lead to alkali silica reaction.

- BUT alumina silicate SCMs (fly ash, slag AND calcined clay) are the best method to avoid ASR

Equivalent Na

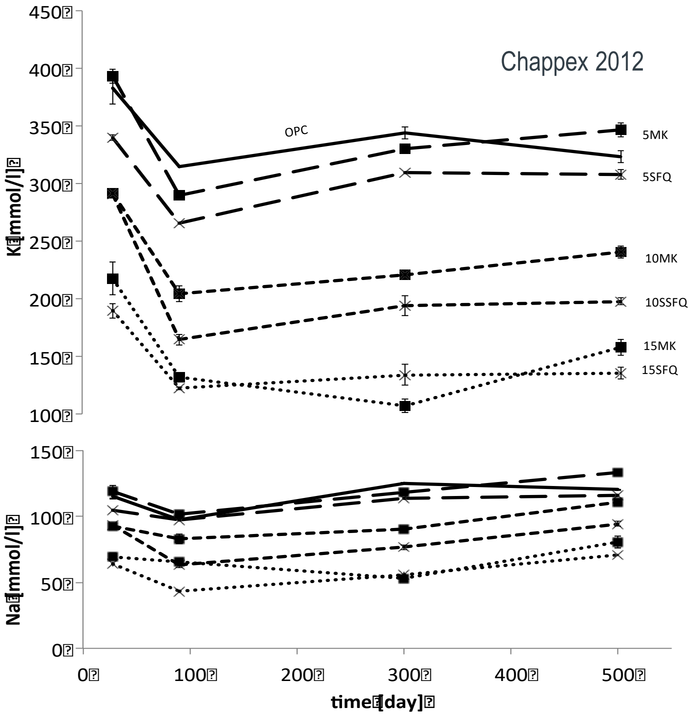
- $Na_{equiv} = Na_2O + 0.58*K_2O$
- Low alkali cements have $Na_{equiv} < 0.6\%$ claimed to prevent ASR
- However field testing and experience with large structures such as dams shows that this does not work ***in the long term***

Impact of alumina silicate SCMs

- SCMs containing silica and alumina are very effective to prevent ASR
- Silica lowers the Ca/Si ratio of the C-S-H by the pozzolanic reaction
- This in turn lowers the pH of the system:

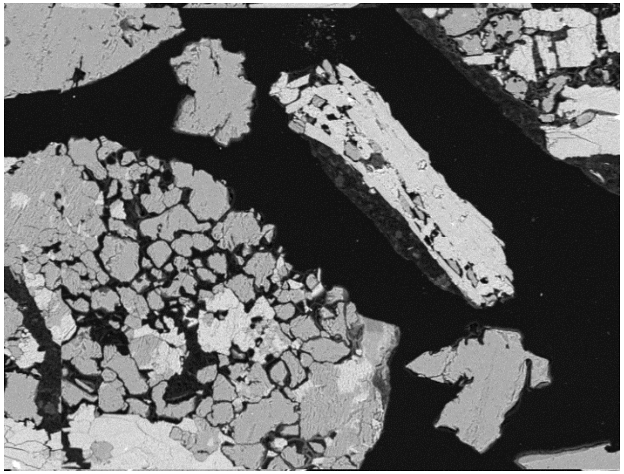
Here we can see that just 15% of metakaolin or silica fume reduces the concentration of alkalis by a factor of 3

But as for low alkali cements this lowering of the pH seems only to delay rather than prevent ASR

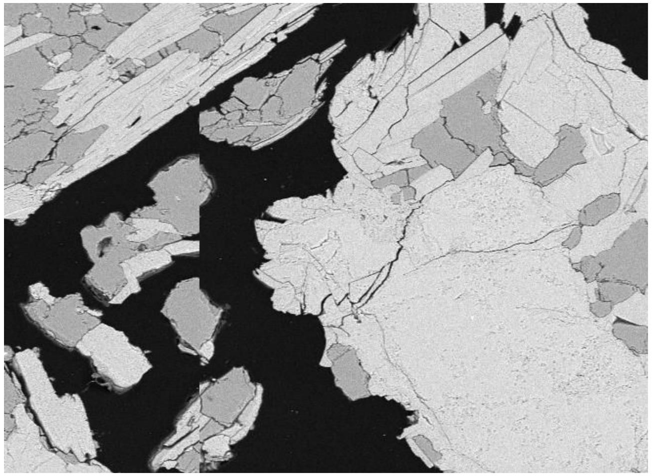


Impact of alumina silicate SCMs

- It have been realised for some time that SCMs containing alumina are more effective
- The work of Chappex at EPFL showed this was because alumina absorbs on reactive sites of reactive silica and inhibits the dissolution:



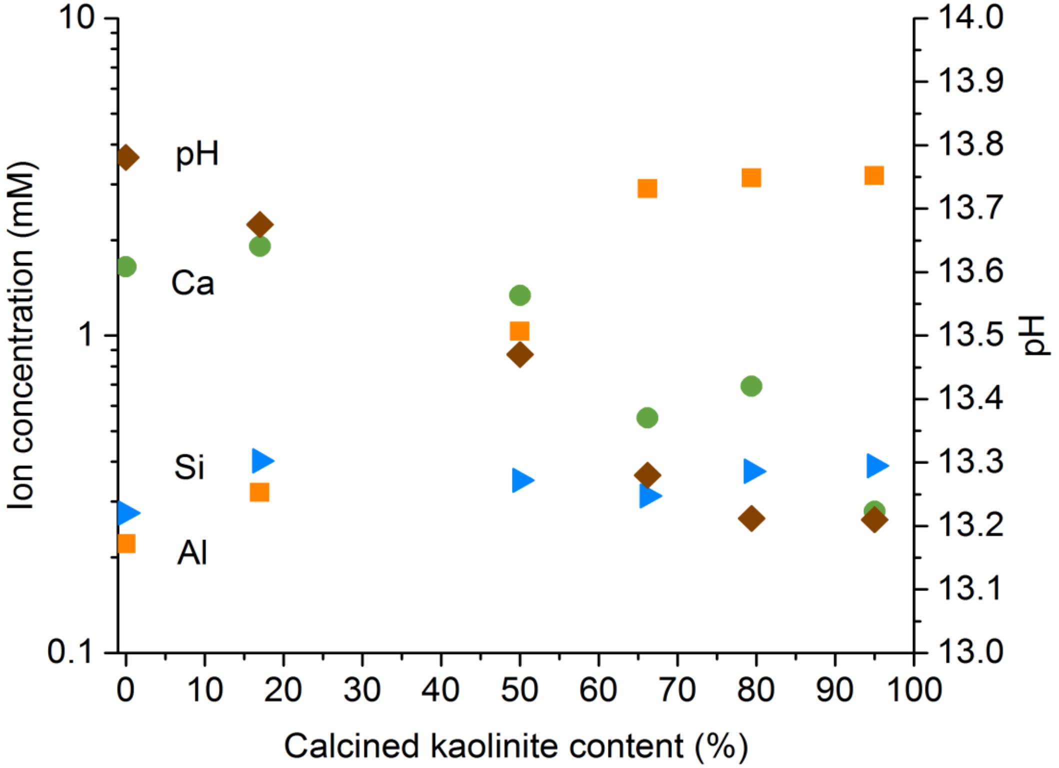
Dissolution of aggregates after 1 year in alkaline solution, no alumina



Chappex 2012

Dissolution of aggregates after 1 year in alkaline solution, with alumina

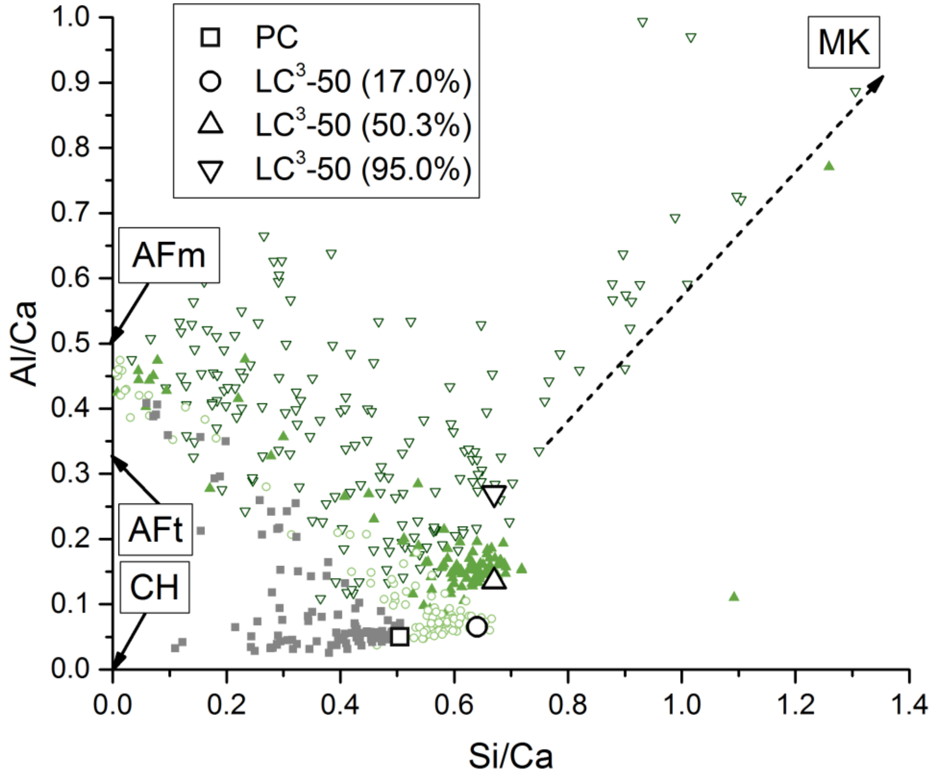
Alumina in solution increases with kaolinite content



Pore solution compositions from LC^3systems

Avet 2017

Reserve of alumina in C-S-H



Excess alumina goes into solid solution in the C-S-H, this (and unreacted metakaolin) provide a reserve to protect against ASR

Test in simulated pore solution

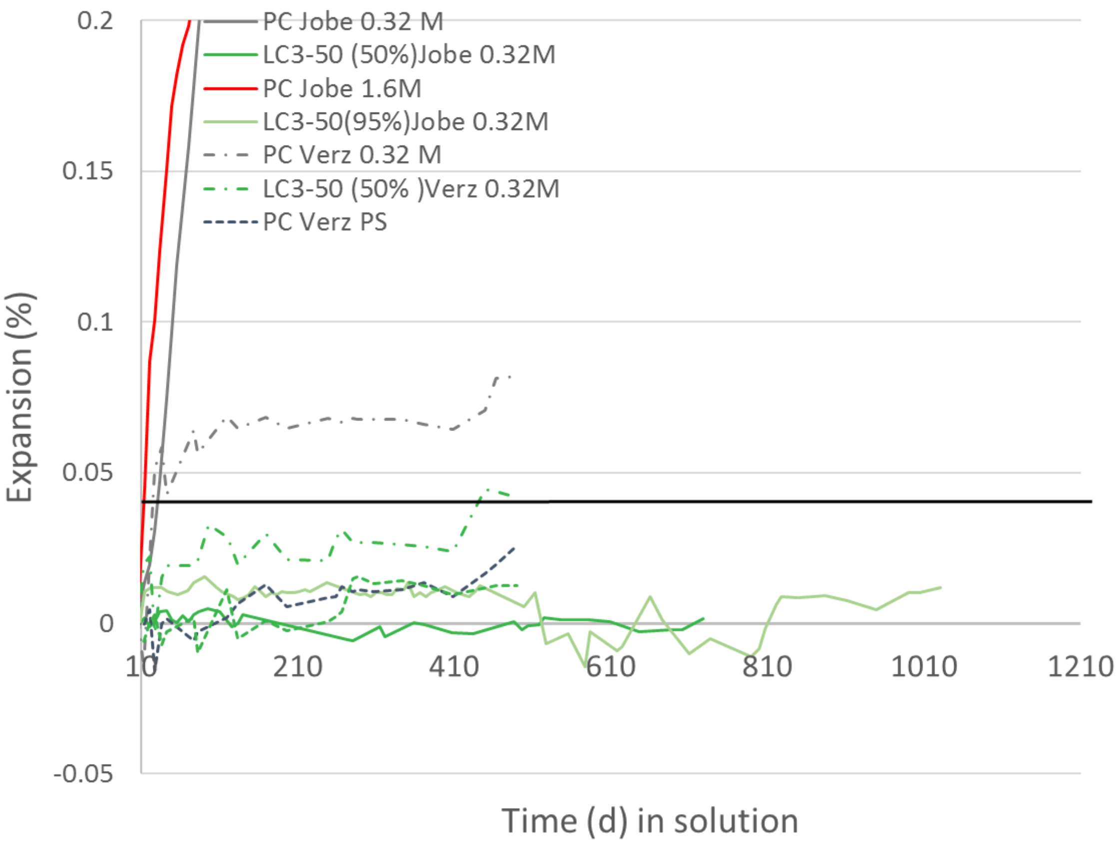
No expansion after 3 years

In accelerated conditions

Jobe (high reactive)		Verzasca (low reactive)	
PC	LC3-50	PC	LC3-50
0.32M	0.32M	0.32M	0.32M
1.6 M		Pore Solution	PS
		1.6M	

-Immersed in solution after 28days curing

-Stored at 38°C



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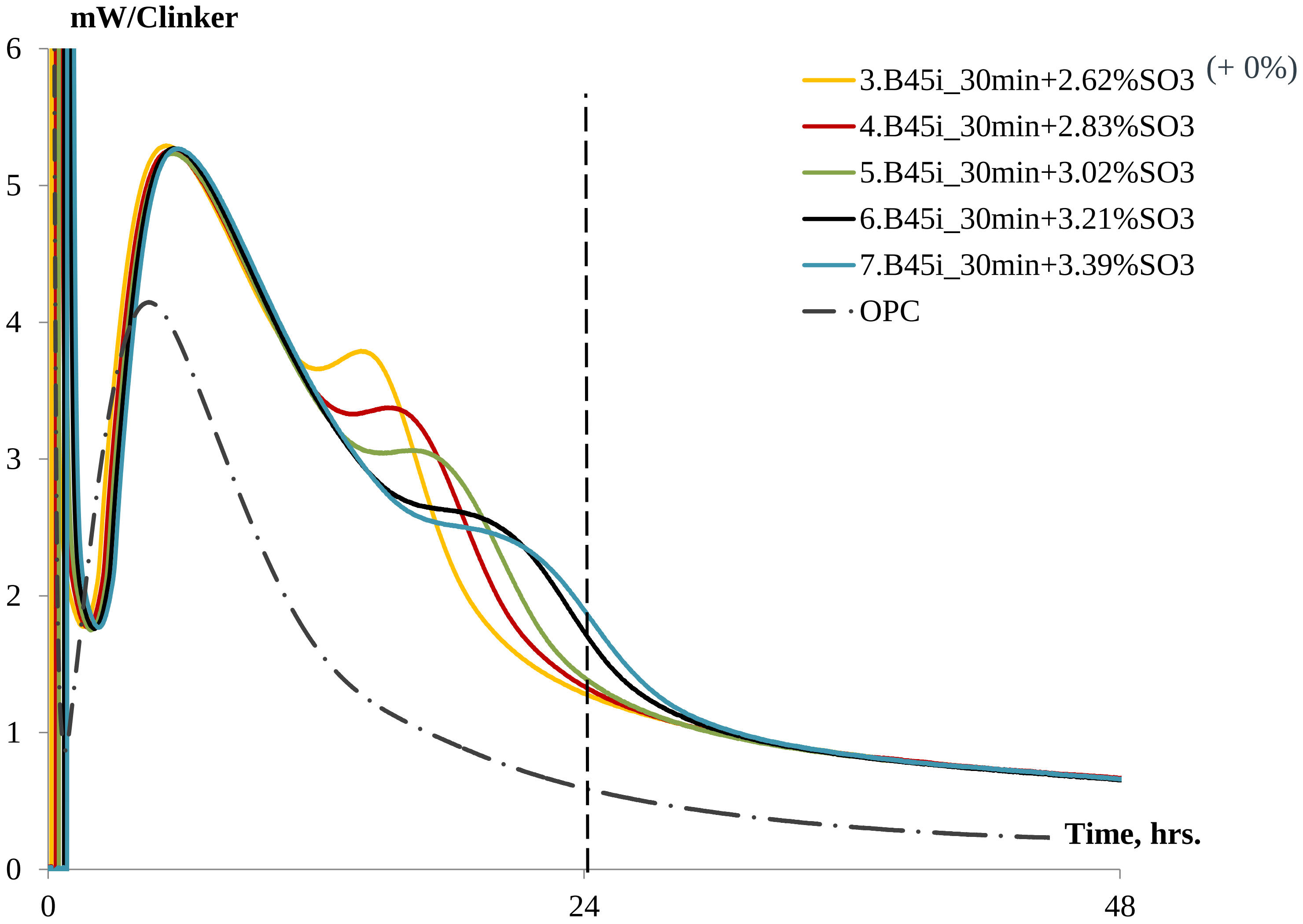
Interground material

Intergrinding of the raw materials

Time (min)	20	30
Blaine (cm2/g)	5529	6858
% Passed 90µm	90.6	94
Consistency (%)	31.50	30.50
Initial setting time (min)	120	110
Final setting time (hrs.)	3,75	3,33
Bulk density (g/cm3)	2.88	2.91

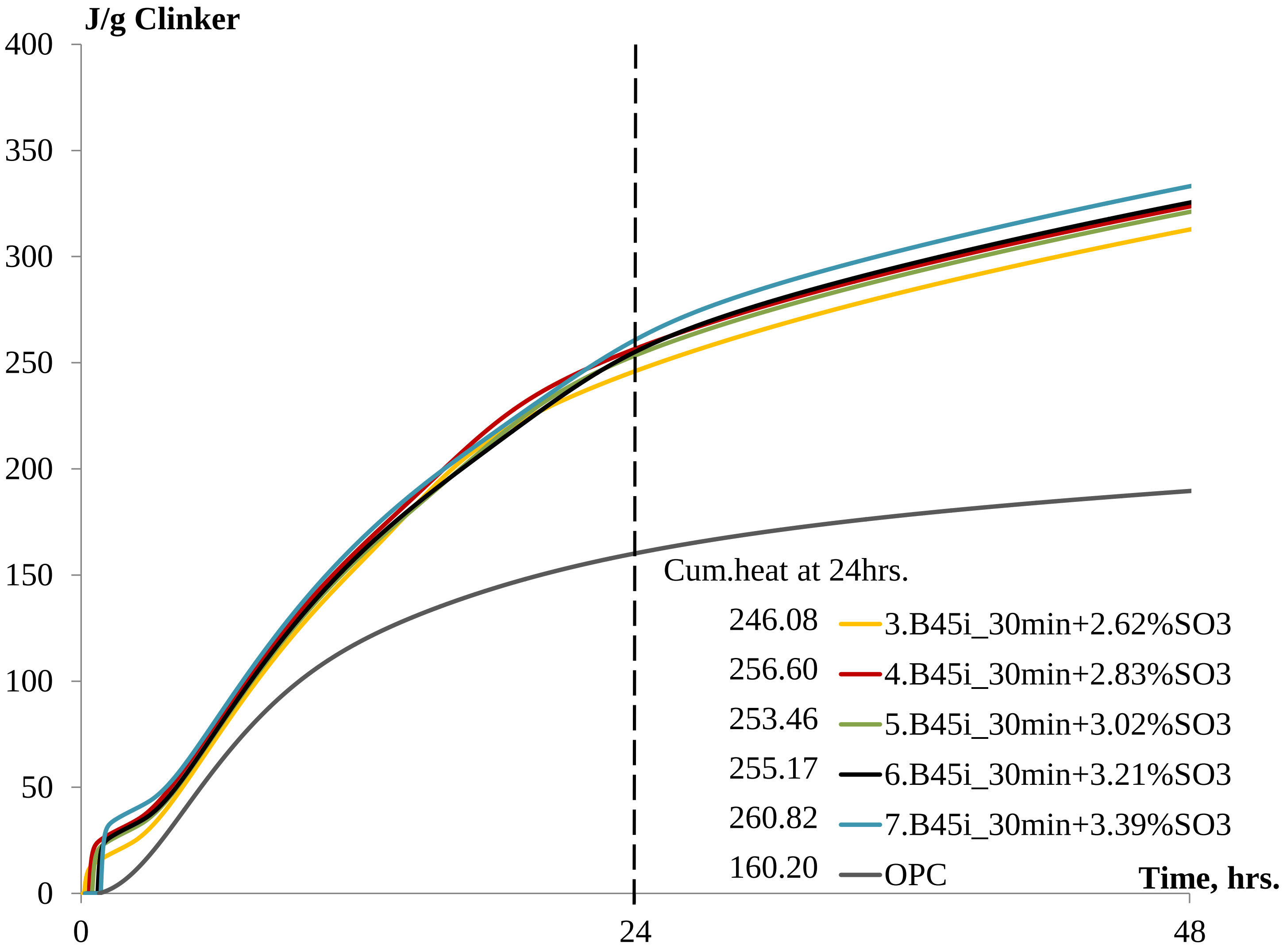
Gypsum Adjustment

Temperature in the calorimeter: 30ºC

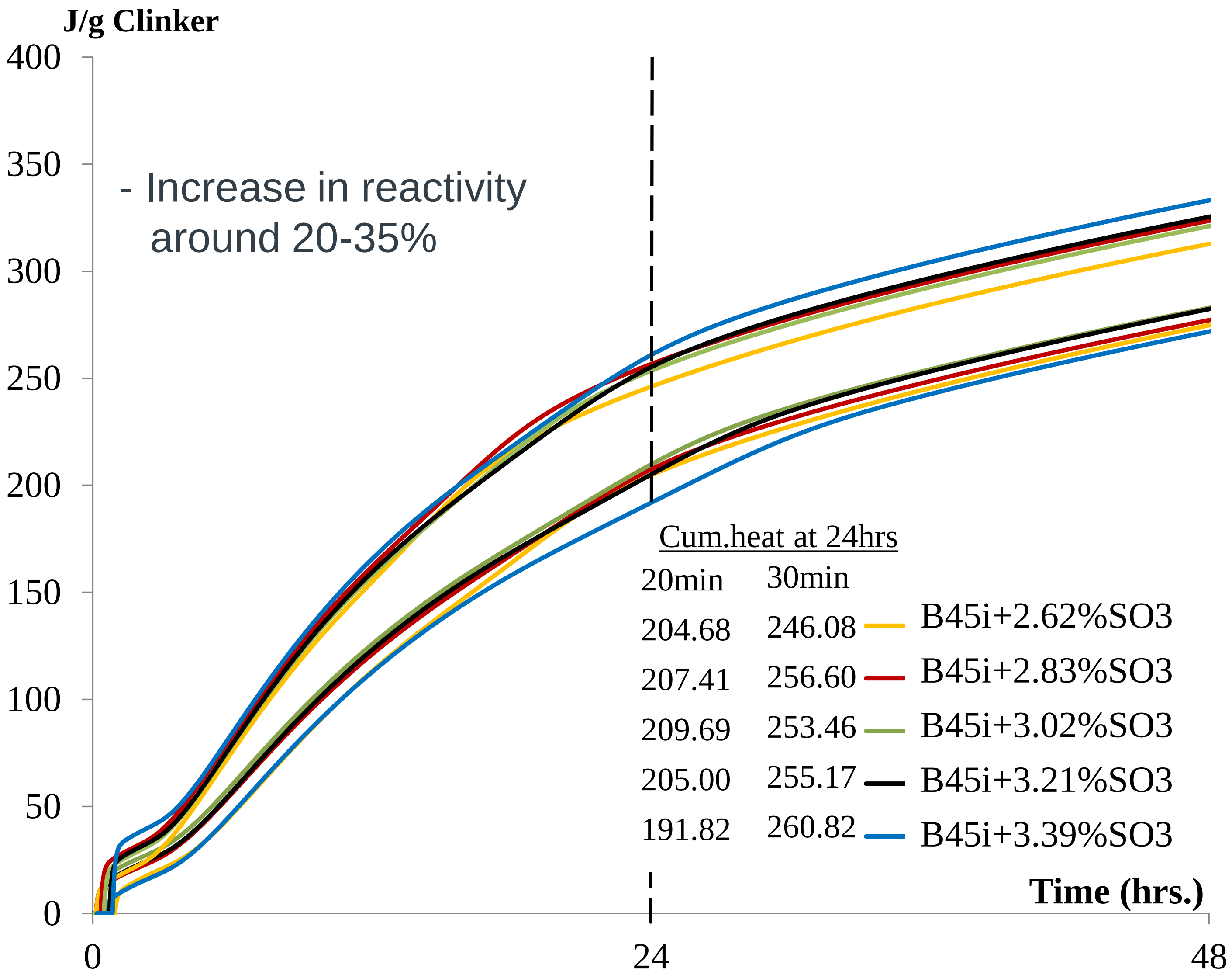


EcoS

Gypsum Adjustment



Influence of Fineness

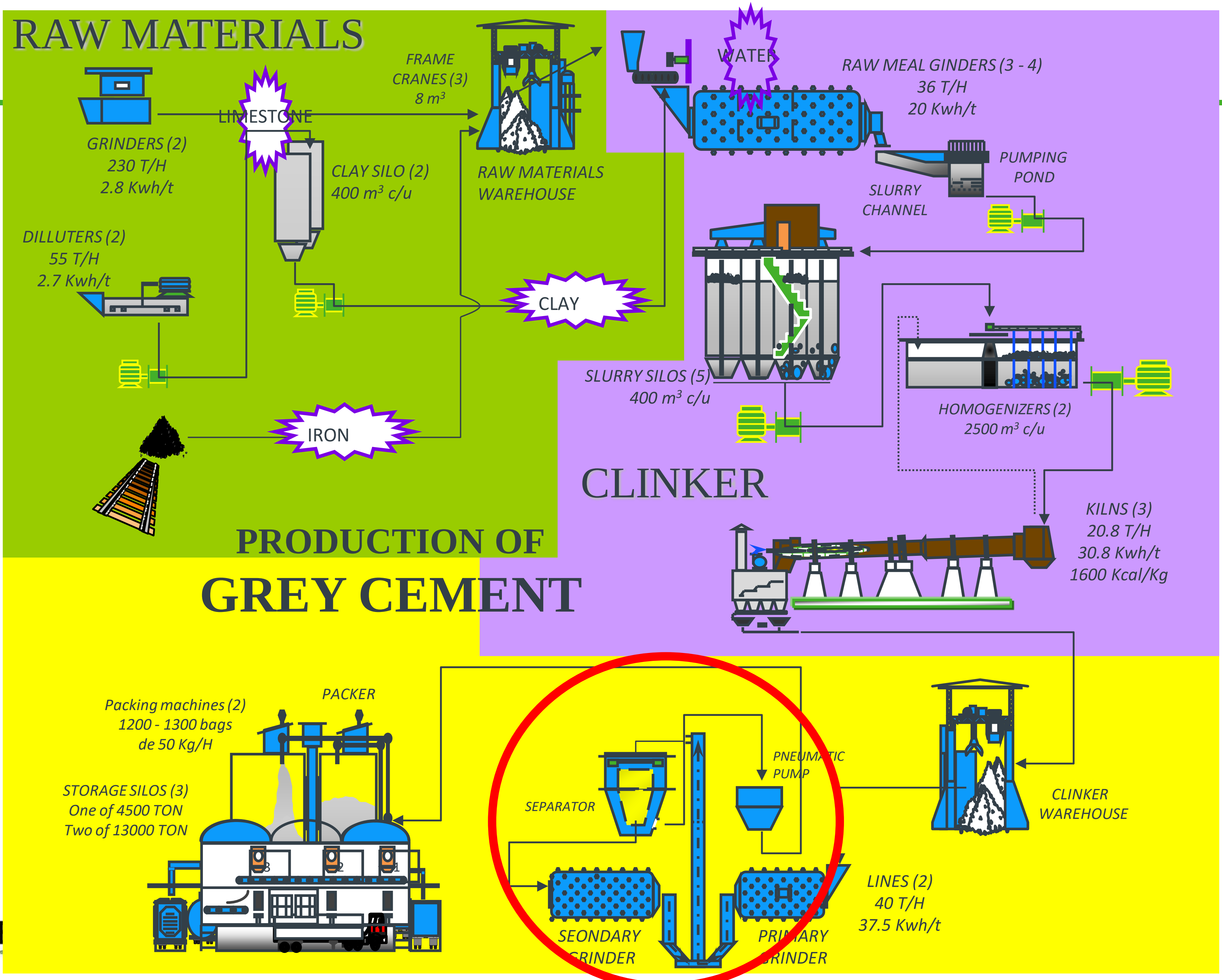


- Increase in reactivity around 20-35%

Cum.heat at 24hrs

20min	30min	
204.68	246.08	🟨 B45i+2.62%SO3
207.41	256.60	🟥 B45i+2.83%SO3
209.69	253.46	🟩 B45i+3.02%SO3
205.00	255.17	⬛ B45i+3.21%SO3
191.82	260.82	🟦 B45i+3.39%SO3

PRODUCTION OF GREY CEMENT



Sistema de molienda de circuito cerrado

Prueba industrial Cuba: molienda

10 In bags

120 t in silo

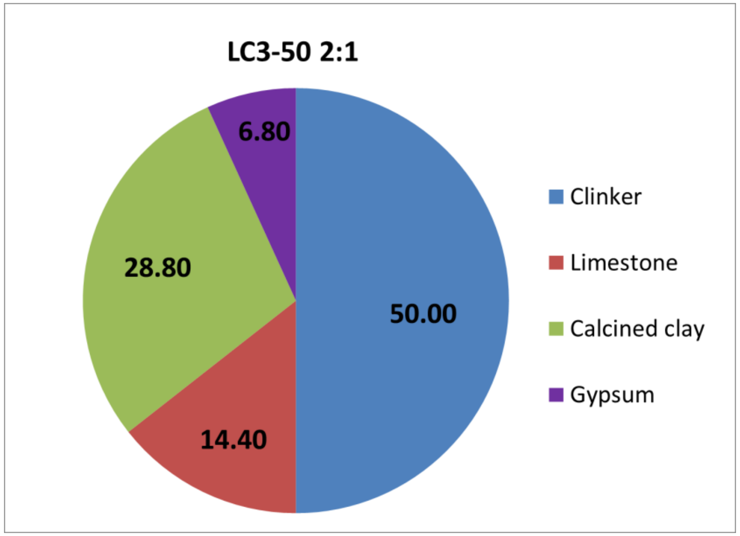
Results standardized mortars

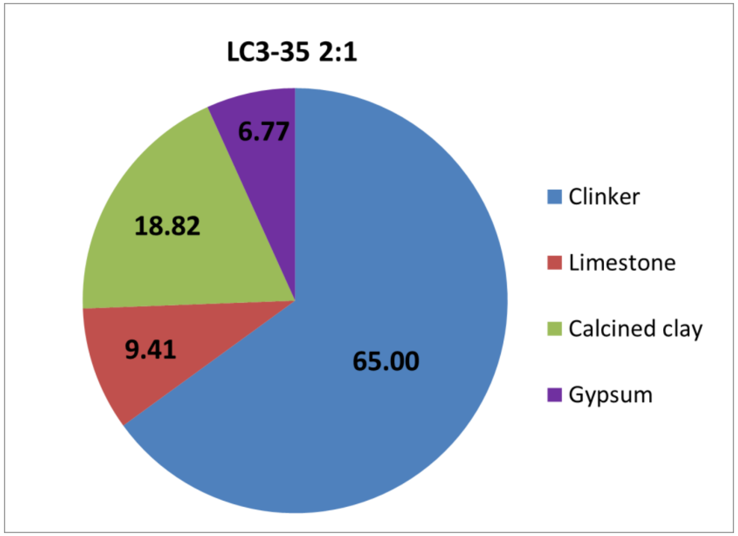
				Setting time		Comp. Strength, MPa		
Institution	**Retain. Sieve 4900 (%)**	**Blaine (cm2/g)**	**consist. (%)**	**initial (min)**	**Final (hrs.)**	**3d**	**7d**	**28d**
SIG B45 Ind. Trial (Lab #1)	12.0	3528	25.0	135	2.9	11.0	17.5	30.3

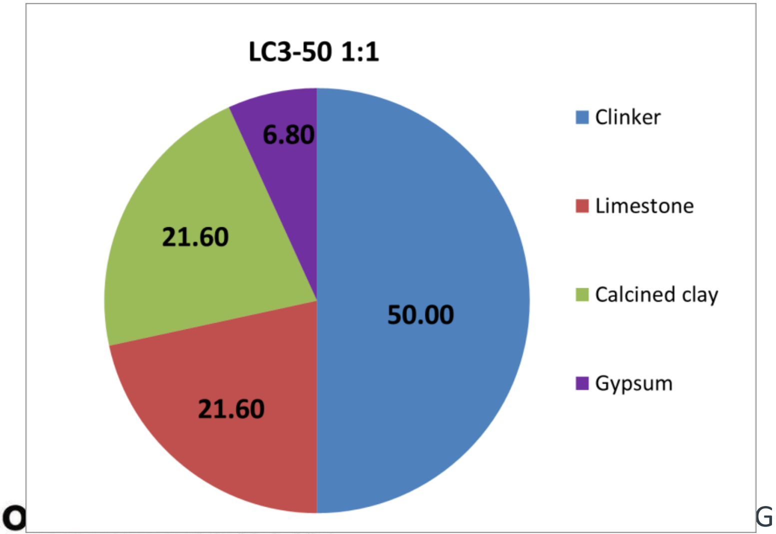
OPC P35 standard	6.5	>2800	25-35	>45	<12h	17	25	35
PP-25 standard	10	4000	25-35	>45	<12h	-	17	25

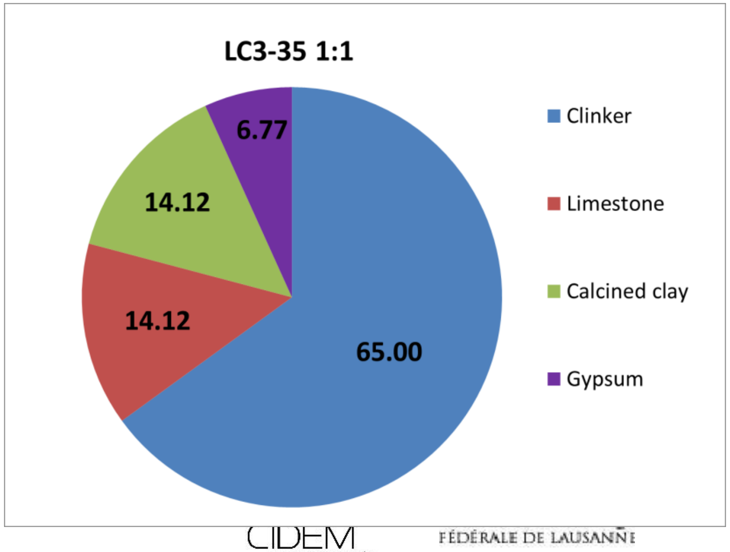
Influence of fineness!!

Cements produced during the 2nd industrial trial


LC3-50 2:1


LC3-35 2:1

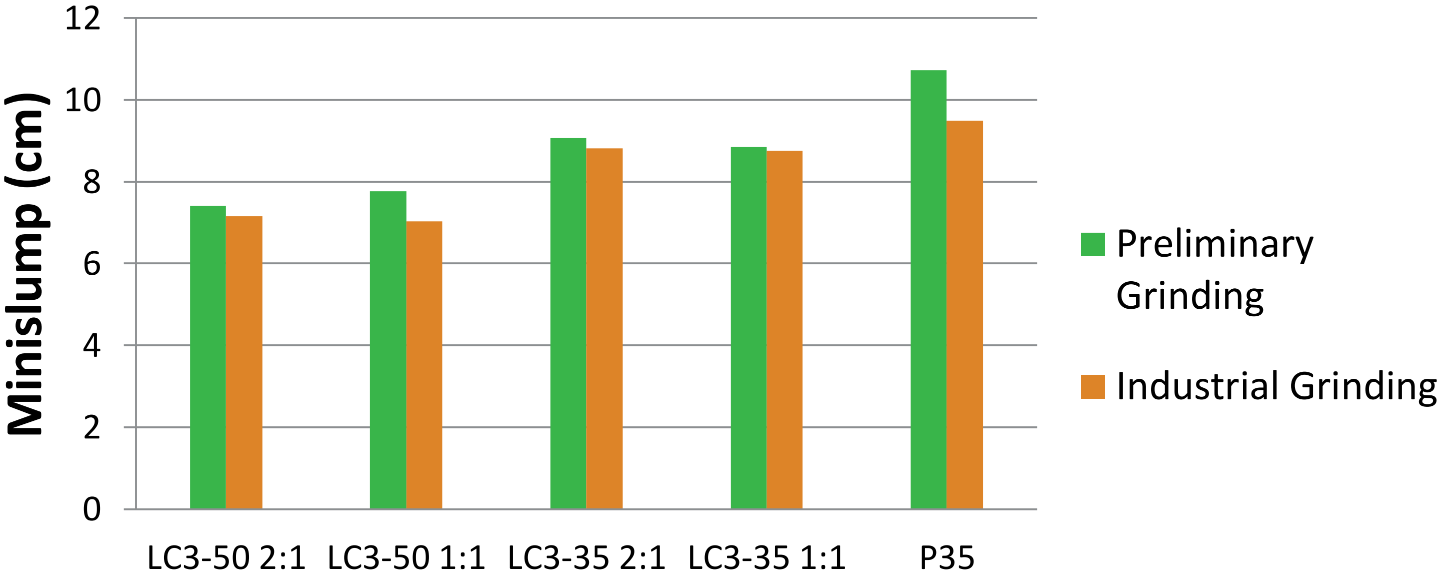

LC3-50 1:1


LC3-35 1:1

Industrial trial, CIDC, 03-2015

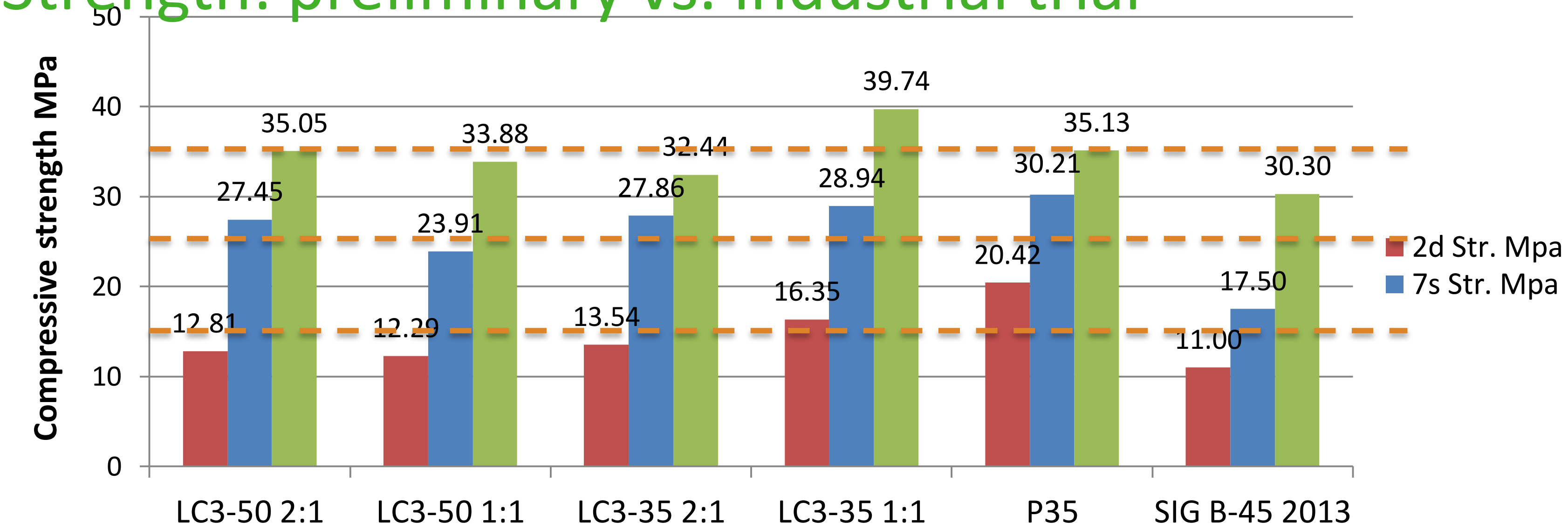
2.5 t in bags

Rheology: preliminary vs. industrial grinding

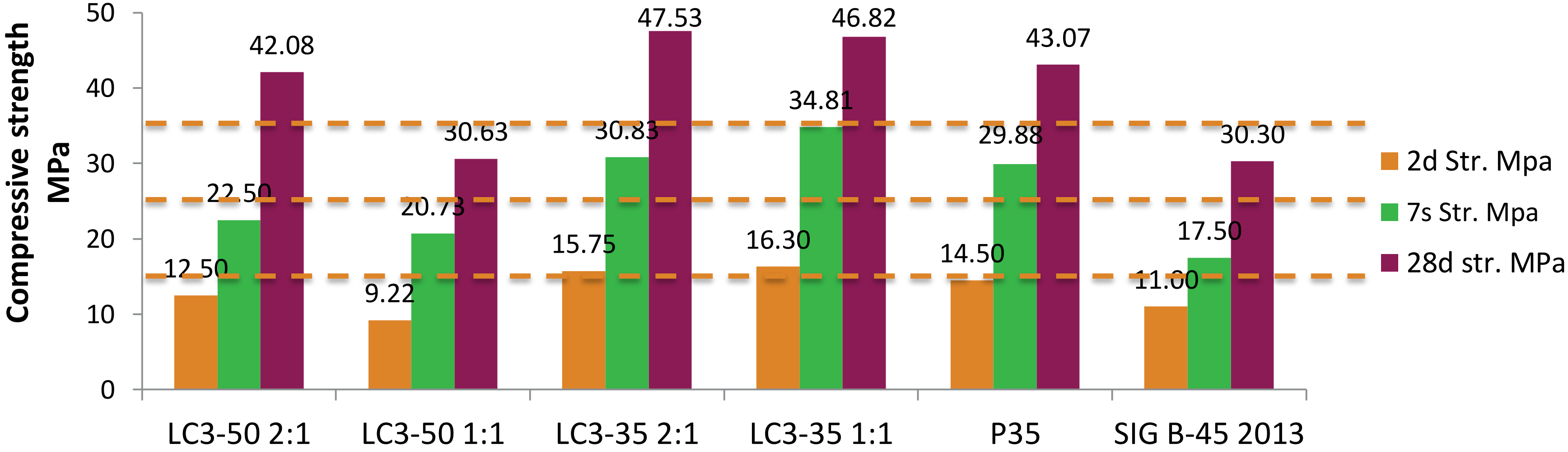


Series		Blaine		Passing 90 µm	
		Prelim.	Indust.	Prelim.	Indust.
P	P-35	3571.28	3852.16	98.00	96
2	LC3-50 2:1	8348.91	8267.52	94.50	95
6	LC3-50 1:1	6749.25	7118.61	97.50	96
8	LC3-35 2:1	4772.41	4416.23	94.50	95
11	LC3-35 1:1	4768.9	4925.64	94.60	96

Strength: preliminary vs. industrial trial



Preliminary grinding trials



Industrial trial

Propiedades de los cementos producidos (2013/2015)

				Setting time		Comp. Strength, MPa		
Institution	**Retain. Sieve 4900 (%)**	**Blaine (cm2/g)**	**consist. (%)**	**initial (min)**	**Final (hrs.)**	**3d**	**7d**	**28d**
SIG B45 Ind. 2013	12.0	3528	25.0	135	2.9	11.0	17.5	30.3
LC3-50 (2:1) 2015	5.0	8267	-	-	-	12.50	22.50	42.08
LC3-50 (1:1) 2015	4.0	7118	-	-	-	9.22	20.73	30.63
LC3-65 (2:1) 2015	5.0	4416	-	-	-	15.75	30.83	47.53
LC3-65 (1:1) 2015	4.0	4925	-	-	-	16.30	34.81	46.82

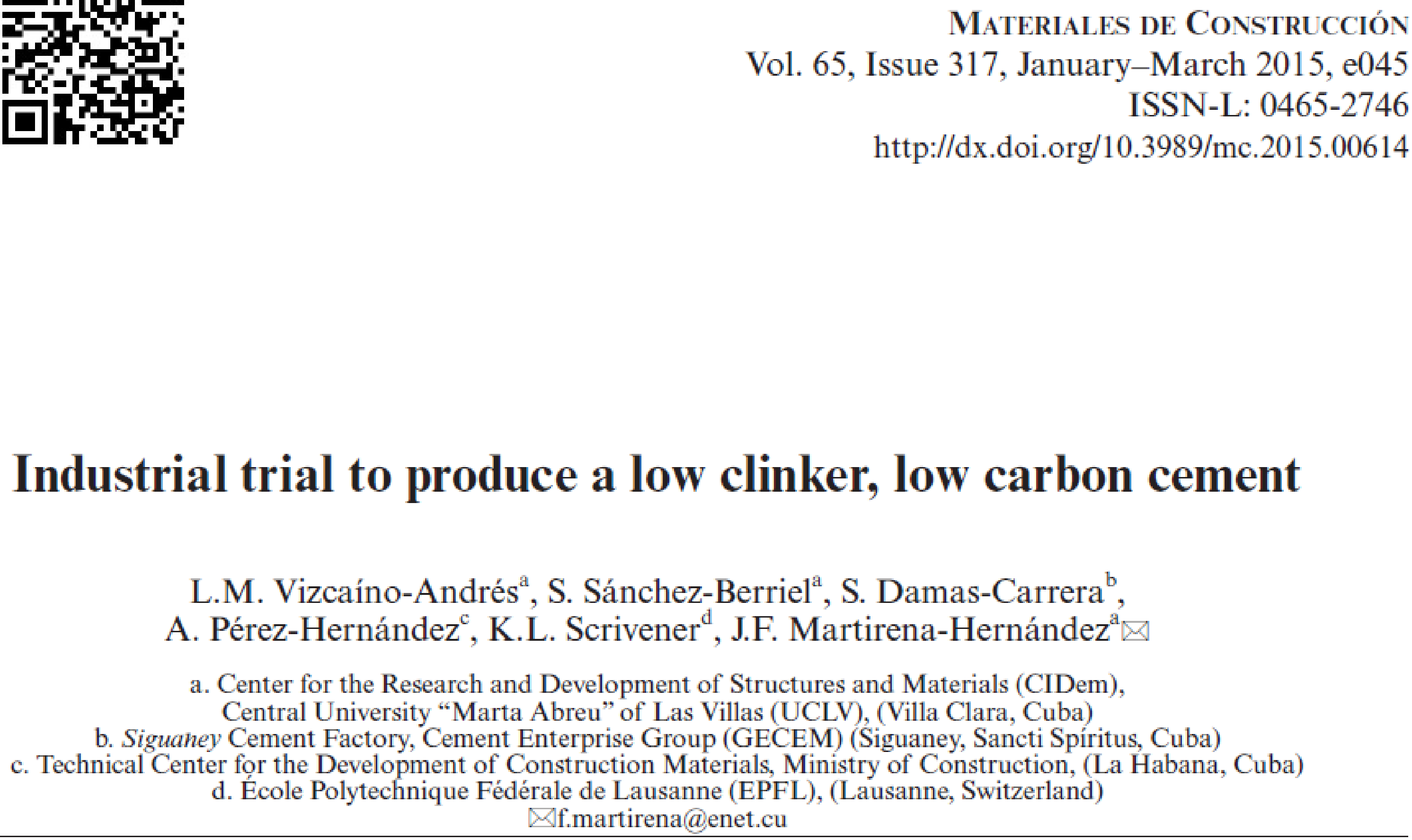
Resumen de las pruebas industriales

» La intermolienda a escala industrial brinda parámetros físicos aceptables, incluido el Blaine (Blaine≈5000 cm^2/g) y se cumplen los requisites de reologia y resistencia.

» La aglomeración del material previo a la calcinación produce un efecto sobre la demanda posterior de agua (no estudiado al detalle)

» Incrementos de Resistencia a retenido 95% en el tamiz de 90 µm producen significativas mejoras de Resistencia sin afectar reología.

Mas información



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Industrial trial to produce a low clinker, low carbon cement

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Guion de la presentación

- Introducción general al proceso productivo
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Relevant requirements in standards

Standard	**European Union** **EN 197-1**	**France** **AFNOR P18C 513**	**India** **IS 1344**	**United States** **ASTM C618**	**Brazil** **NBR 12653**
Strength requirement	32.5 min. at 28d + 16MPa at 7d or 10MPa at 2d	90% at 28d	80% at 28d	Min of 13, 20 and 25 MPa at 3, 7 and 28d	8, 15, 25 MPa at 3, 7 and 28d
Substitution level	35% max	15%	-	40% calc. clay 15% limestone 45% of cement	14% calc. clays 10% limestone 76% cement
Chemical requirements	$SiO_2 \geq 25.0\%$	$SiO_2 + Al_2O_3 \geq 90\%$	$\Sigma(SiO_2 + Al_2O_3 + Fe_2O_3) \geq 70\%$ $SiO_2 \geq 40\%$	$\Sigma(SiO_2 + Al_2O_3 + Fe_2O_3) \geq 70\%$ Limestone ≥ 70% calcite	$\Sigma(SiO_2 + Al_2O_3 + Fe_2O_3) \geq 70\%$
Reactivity test	Based on Frattini test for CEM IV	Modified Chapelle test ≥ 700 mg of CH / g of MK	Lime reactivity test ≥ 3 MPa (curing 50°C 8d)	-	Lime reactivity test ≥ 6 MPa (curing 55°C 6d)
Drying shrinkage	-	-	0.15% max	0.03% of difference with PC	0.05% of difference with PC
Loss of ignition	-	4% max	10% max	10% max	10% max

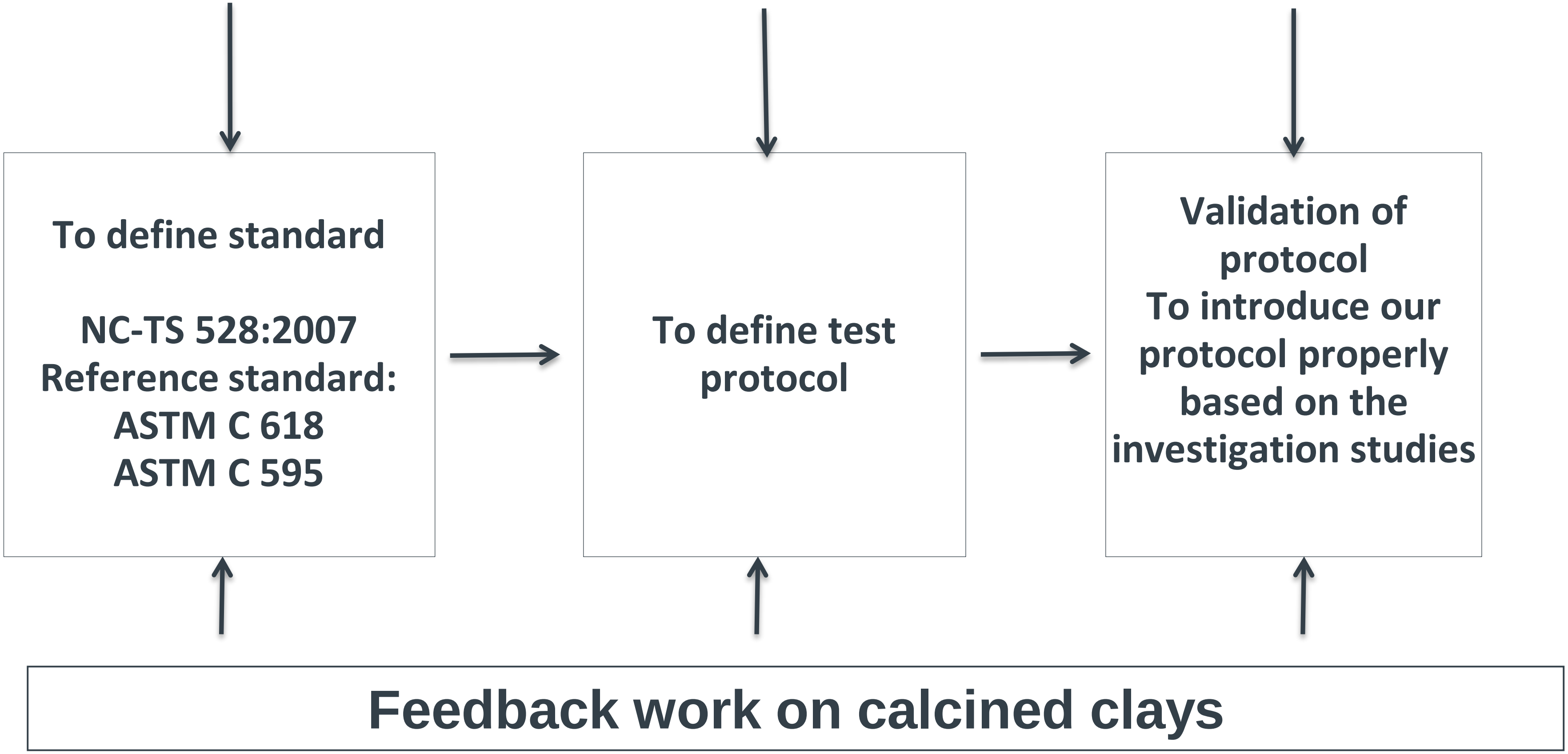
Brazilian standard

- NBR 12653: “Pozzolanic materials – Requirements”
- “Class N”: natural and artificial (calcined) pozzolans
- Requirements for chemical composition:
  - $\Sigma(SiO_2 + Al_2O_3 + Fe_2O_3) \geq 70\%$
  - LOI ≤ 10%
  - Moisture content ≤ 3.0%
- Water demand: 115% max
- Strength requirements: “Strength Activity Index” of 75% at 28 days
- Lime reactivity test: strength ≥ 6 MPa at 7 days
- Drying shrinkage at 28d: 0.05% max. of difference between blend and PC

Cuban standard

- NC-TS 528:2007: “Hydraulic cement – Pozzolan – Standard Specification”
- “Class N”: natural and artificial (calcined) pozzolans
- Requirements for chemical composition:
  - $\Sigma(SiO_2 + Al_2O_3 + Fe_2O_3) \geq 70\%$
  - $SO_3 \leq 4.0\%$
  - Alcali Na_2O Eq.:≤ 1.5%
  - LOI ≤ 10%
  - Moisture content ≤ 3.0%
- Water demand: 115% max
- Strength requirements: “Strength Activity Index” of 75% at 28 days

Analysis and modification of Cuban standard: Evaluation of CCL as pozzolan



To define standard

NC-TS 528:2007
Reference standard:
ASTM C 618
ASTM C 595

To define test protocol

Validation of protocol
To introduce our protocol properly based on the investigation studies

Feedback work on calcined clays

Utilization of calcined clay as supplementary cementicious materials.

NC 528:2013 Hydraulic Cement — Pozzolan — Standard Specification

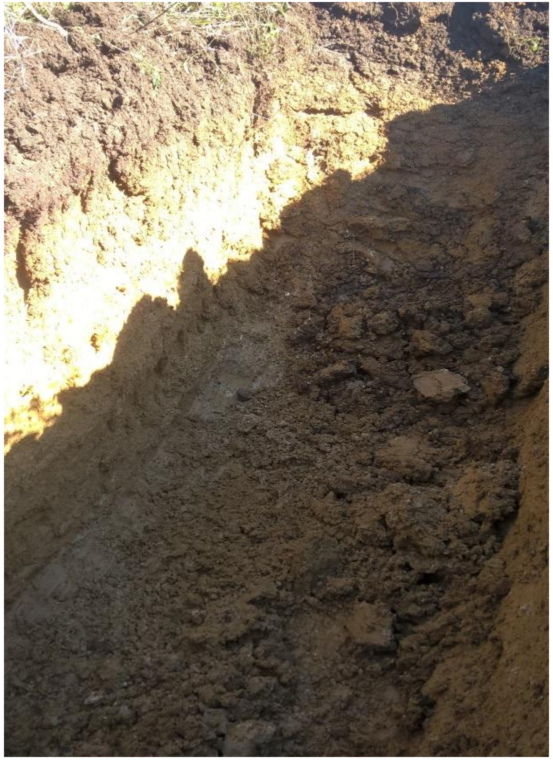
Pozzolan Classification

4.1 Class N – Natural Pozzolans calcined and not calcined meeting the applicable requirements for this class, such as some diatomea lands, opaline shale, tobas, volcanic ashes or pumitics, and other materials that require calcination to obtain favourable properties as the clays and pizarras.

Table 1 — Chemical requirements	**Addition mineral class**		
	N	**F**	**C**
(S_iO_2) + (Al_2O_3)+ (Fe_2O_3), % minimun	70,0	70,0	50,0
(SO_3), % maximun	4,0	5,0	5,0
Humidity content, % maximun	3,0	3,0	3,0
Loss on ignition, max, %	10,0[a]	6,0[b]	6,0

Table 2 — Physical requirements	**Addition mineral class**		
	N	**F**	**C**
Fineness: Quantity retained with humid sieving on the sieve 45 µm (No. 325), max. % [a]	34	34	34
Resistance Activity Rate: [b] With Portland cement, 28 days min. % of control mortar	75 [c]	75 [c]	75 [c]
Water requirement, max. % of control	115	105	105
Uniformity requirements Density and fineness of individual samplings will not fluctuate from the established average for the 10 previous tests or for all the previous tests if the number is less than 10,			
Density, máximum fluctuation of the average %	5	5	5
Retained in % over 45 µm (No. 325), max. fluctuation, average points percentage	5	5	5

Proposal for Standardization of Technical Committee No 22 (cement and lime)



1.1 Sampling of the raw materials

- Instructions Guideline of the Geological Research Activity

1.2 Chemical Composition Determination

- NC 505:2007, NC 507:2007
- NC 44-16:1970, NC 44-18-5:1984. NR-MG-5-04

Chemical composition requirements for the clays utilized as source of pozzolans

1.3 Determination of OH- Groups content associated to the clays minerals

CaO (% maximum)	5.00 %
MgO (% maximum)	2.00 %
SO_3 (% maximum)	0.50 %
Al_2O_3 (% minimum)	16.00 %

1.4 Determination of the clays minerals content

$$\% H2O = \frac{100 * ((P0 - PF) - 0.79 * (\%CaO))}{PS}$$

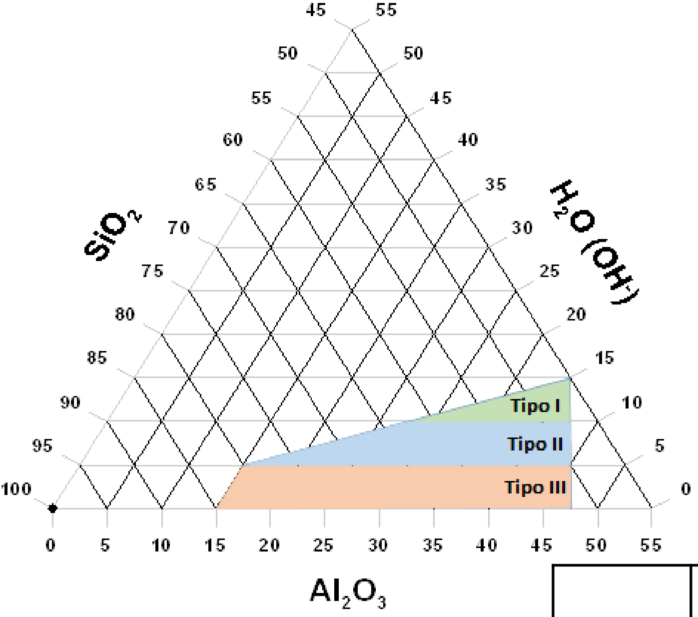
Where,

P0: Initial weight

PF: Final weight

PS: Dry weight

$$\% Ceq = \frac{100 * (\%H2O)}{13.95}$$



Determination of the clay potencial as a source of pozzolans

The clay potencials improve with the increase of the ratio Al_2O_3 /SiO_2 and the content of OH- Groups in the structure (% H_2O (OH-))

Classification of clays as per their potencials

	General Characteristics	Potencial Reactivity of calcination products	Recommended Calcination Temperatures (ºC)
Type I	Caolinitical clays are predominant, with content of caolinite over the 50%	High – Very High	750 - 850
Type II	Caolinitical clays are predominant, with content of caolinite equivalent, similar or over the 40 % Other moderate clay materials content can be found	Moderate - High	750 - 850
Type III	Clay minerals 2:1 are predominant. Low Caolinite content can be found.	Low - Moderate	800 - 950
Type IV	Similar to Types II, but with calcite content up to a 10%.	Low – Moderate - High	700 - 800

Note: Clays corresponding to Types I, II and IV are recommended for the use of raw materials for the obtention of pozzolanic materials.

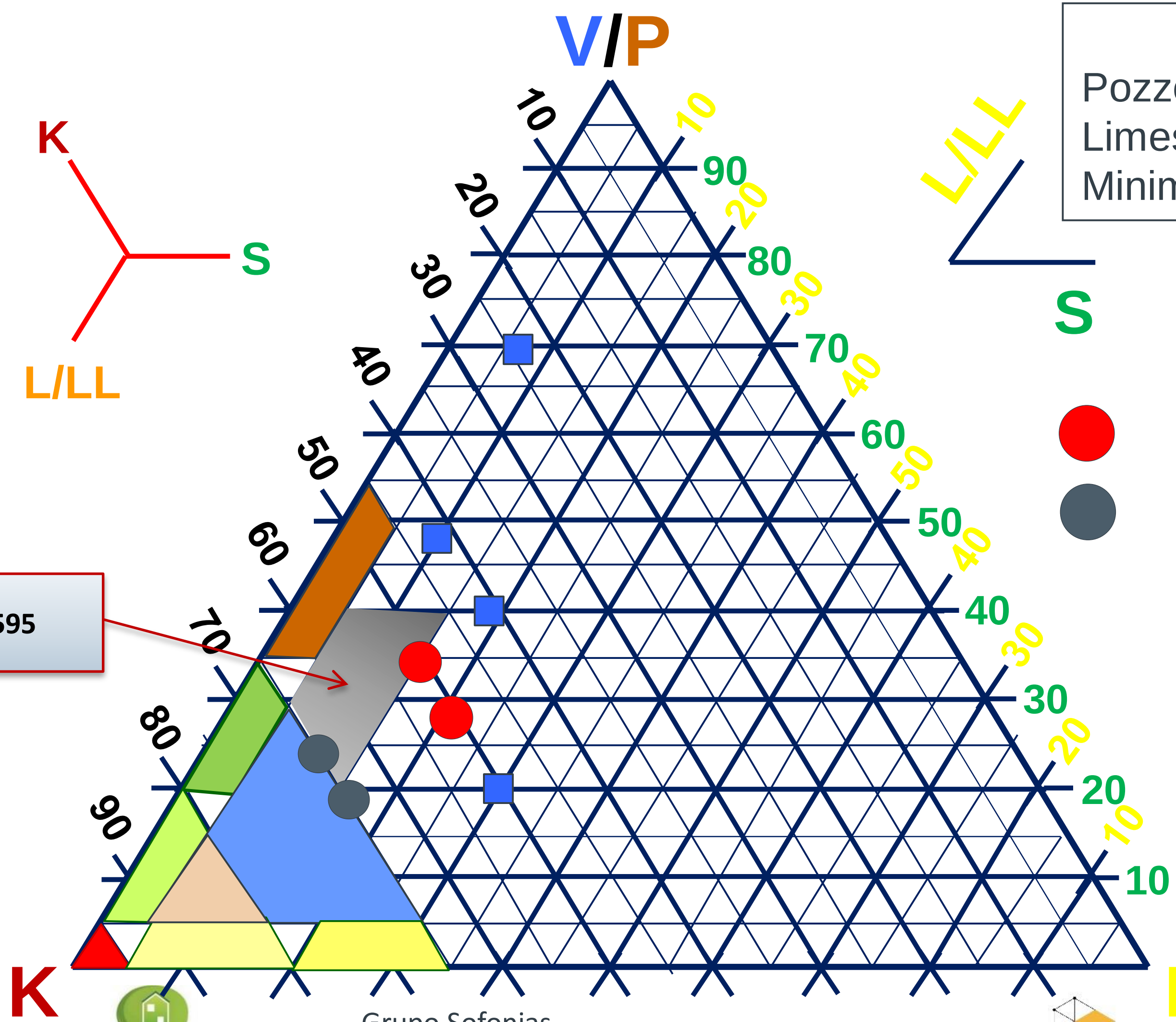
PART II

EVALUATION METHODS OF THE POZZOLANIC ACTIVITY FOR CALCINED CLAYS

2.1 Determination of pozzolanic reactivity by means mecanic strength tests in standardize mortar

2.2 Determination of pozzolanic reactivity by means paste test

Camino hacia normas que cubran el LC3



ASTM C595
Pozzolan content: ≤ 40%
Limestone content: ≤ 15%
Minimum clinker content: 45%

ASTM C595

● **LC3 50% clinquer**

● **LC3 65% clinquer**

M. Schnaider 7th International VDZ Congress 2013

(**) tests carried out by Lafarge (France)

Production and implementation of LC3 in Cuba

Development of a new standard about the specifications of ternary cements in Cuba

References: North American Standard ASTM C595/595M-14
Cuban Standard NC 96:2011, and others

» Four groups of ternary cements:

Two different pozzolans + Portland cement or Portland cement clinker

Slag and a pozzolan + Portland cement or Portland cement clinker

A pozzolan and a limestone + Portland cement or Portland cement clinker

A slag and a limestone + Portland cement or Portland cement clinker

Proposal for Cuban Standard

NORMA CUBANA

NC
XX: 2016

TÍTULO: CEMENTO TERNARIO — ESPECIFICACIONES

Ternary blended cement — Specifications

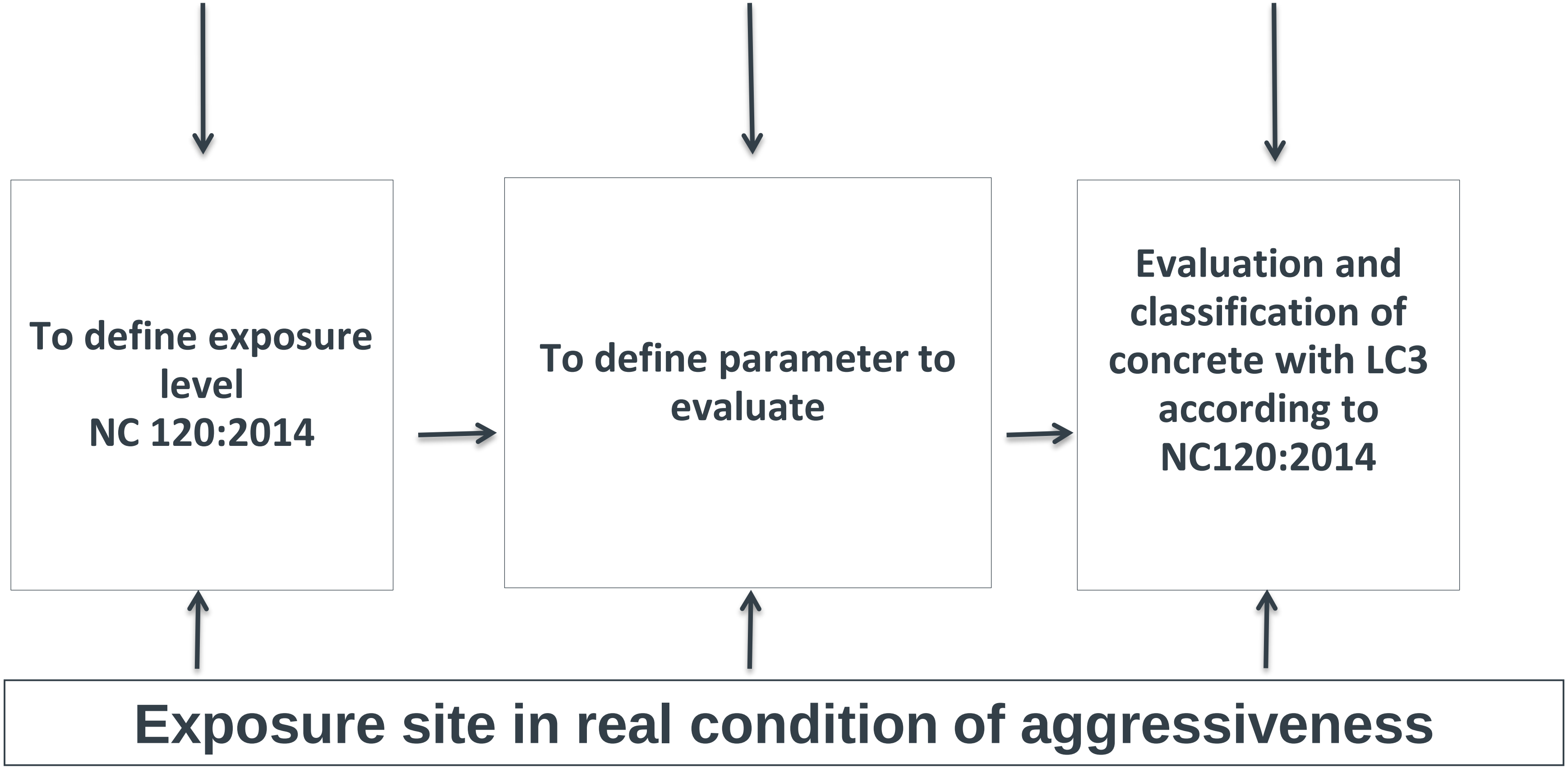
ICS:

1. Edición xxxxx 2016
REPRODUCCIÓN PROHIBIDA

Oficina Nacional de Normalización (NC) Calle E No. 261 El Vedado, La Habana. Cuba.
Teléfono: 830-0835 Fax: (537) 836-8048; Correo electrónico: nc@ncnorma.cu; Sitio Web: www.nc.cubaindustria.cu

Cuban National Bureau of Standards

Validation of ternary cement for the production of concrete according to the Cuban Standard NC120:2014



To define exposure level
NC 120:2014

To define parameter to evaluate

Evaluation and classification of concrete with LC3 according to NC120:2014

Exposure site in real condition of aggressiveness

- Validation in real building
- Corrosion preliminary studies
- Estimation of service useful life

Cuban National Bureau of Standards

NC 120: 2014

Hydraulic concrete - Specifications

Durability by concrete performance

LEVELS OF AGGRESSIVENESS

VERY HIGH	HIGH	MEDIUM	LOW
Tide < 500 m coast High CL content	Submerged 500 m < coast < 3 Km Underground	3 Km < coast < 20 Km Underground Indoor – high humidity RH > 65%	Distance coast > 20 Km Underground dry Indoors RH ≤ 65%

Sitios de exposición (NC 120:2014)

Sitio 1 ***(menos de 500 m de la costa)***: Punta Matamoros en Cayo Santa María

Sitio 2 ***(entre 500m y 3 km de la costa)***: Sede Universitaria Cayo Santa María

Sitio 3 ***(entre 3 y 20 km de la costa)***: Sala de carbonatación, CIDC, Habana

Sitio 4 ***(más de 20 km de la costa)***: CIDEM, Universidad Central

Conclusiones

- Los sistemas cementicios con arcillas calcinadas demandan consideraciones especiales en la molienda
- Igualmente hay que sulfatar el sistema debido al incremento de aluminio
- Una corrección de álcalis podría ayudar a obtener más alta resistencia temprana
- Las pruebas industriales demuestran que es factible producir un cemento similar al tradicional con tecnología existente.

Muchas gracias!

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