Technical & Environmental benefits of using fine calcium carbonate fillers in concrete applications

Danish Concrete day – P. Gonnon, 23th Sept 2021

THINKING OF TOMORROW

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Agenda

1. What are fine ground calcium carbonate fillers (GCC)?
2. Environmental footprint contribution
3. How to use fine ground calcium carbonate fillers in different concrete?
4. Industrial applications

What are Fine Ground Calcium Carbonate fillers (GCC)?

- **Originates** from the exploitation of pure carbonate minerals – in Denmark mainly chalk or limestone
- **Fine particles :** D50% <5µm
- **Pure raw material** : $CaCO_3$ >95%
- **Filler aggregate** for concrete -> CE marking EN 12620
- **Specific national standard** assessment as limestone filler for concrete (FR, UK, NL, PT, DK)

In Denmark, fine GCC is approved according to DS/EN 206 DK NA:2020, Annex Q

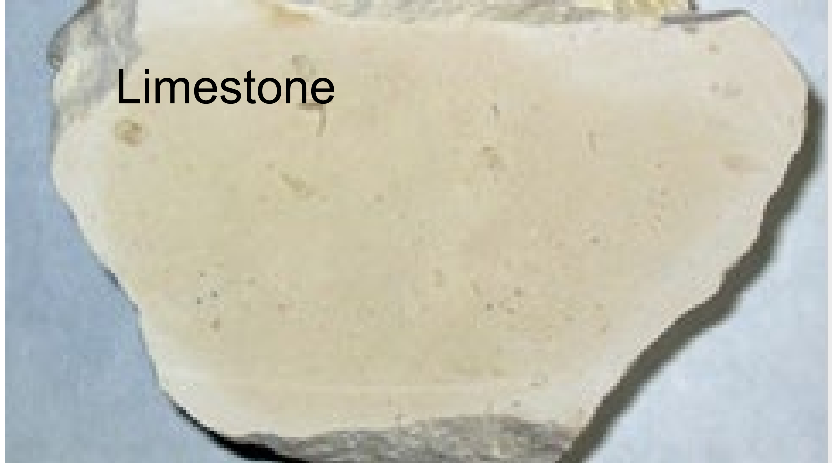
Raw material

Ground Calcium Carbonate originates from the exploitation of pure carbonate rock-forming minerals and falls into three structurally different groups:

- Limestone
- Chalk
- Marble

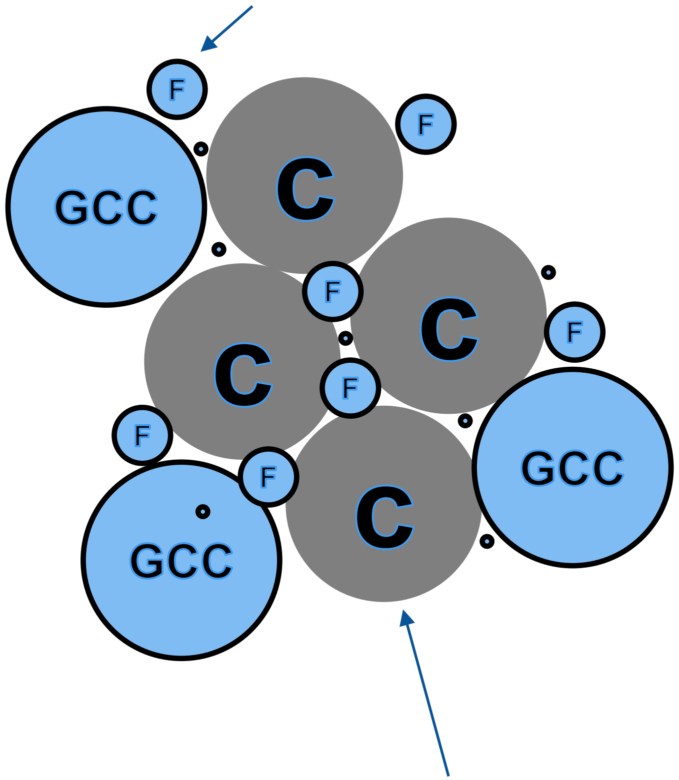
with different hardness and raw material density.

In Denmark, mainly chalk or limestone



Grading of fine GCC

Fine calcium carbonate filler



C = Cement or Mineral binder (OPC, CAC…)

REMINDER : DS/EN 206 DK - Annex Q

	Type A	Type B
%>1µm	8	1
%>10µm	90	52
%>40µm	98	82

REMINDER : DS/EN 12 620

	Filler
%>63µm	70
%>125µm	85

Pure raw material leads to high compatibility with admixtures

Fine GCC

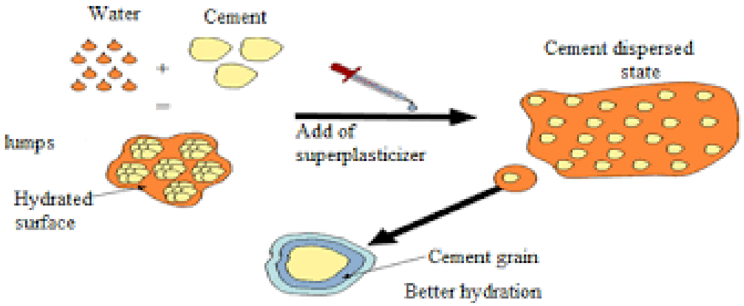
$CaCO_3$ >95%

+ Methylen Blue < 3g/kg

+ Blaine > 300 m^2/kg

= high purity

Fine GCC = No modification of the role of admixture due to low proportion of clay

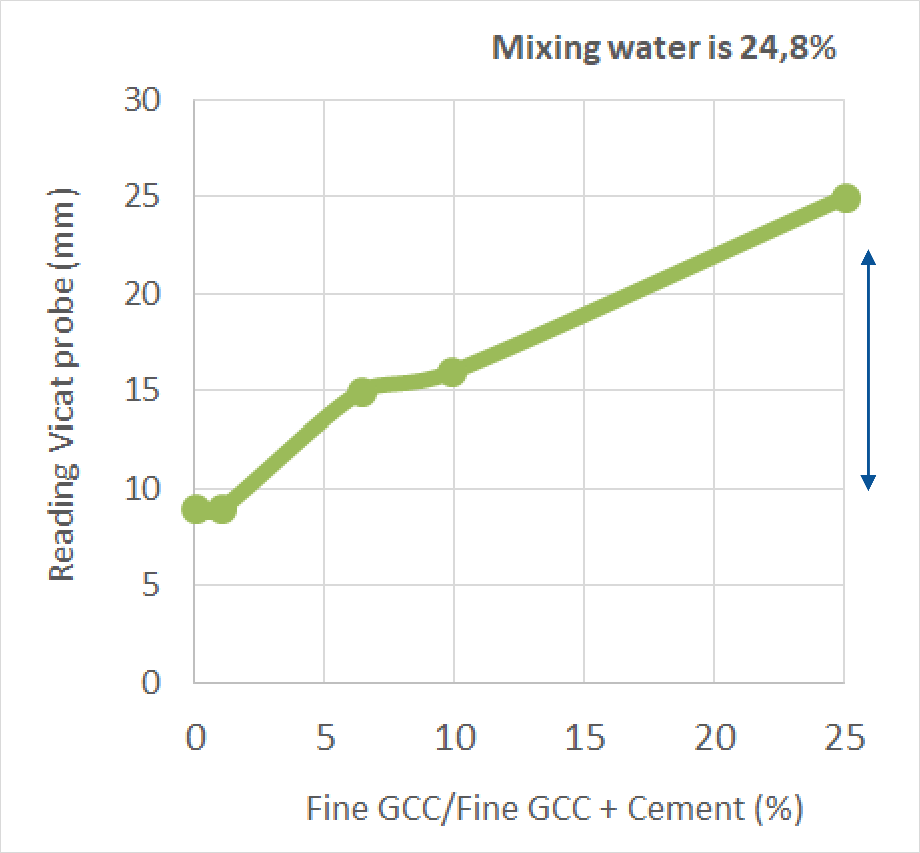


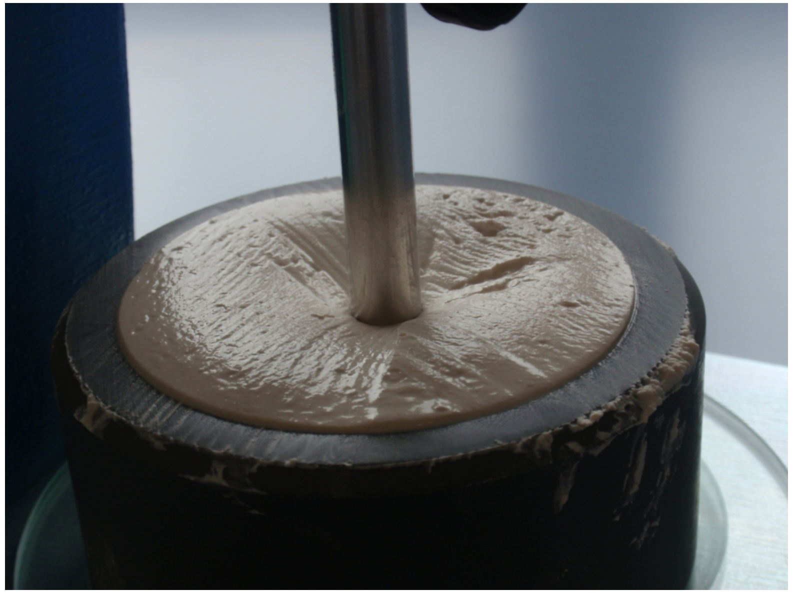
https://www.jmaterenvironsci.com/

Fine GCC =>

Search of the best quantity of paste (water + admixture + particle <125µm) to optimize the concrete stability and concrete surface.

Water demand of fine GCC

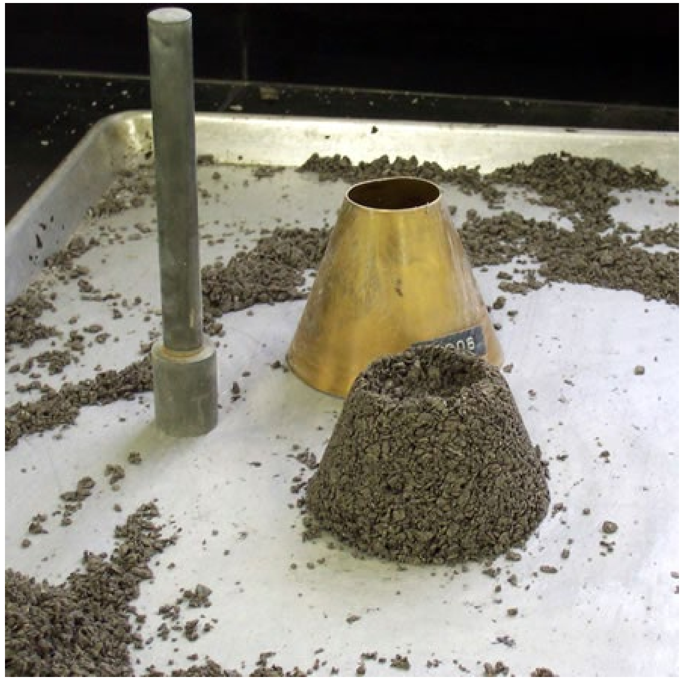


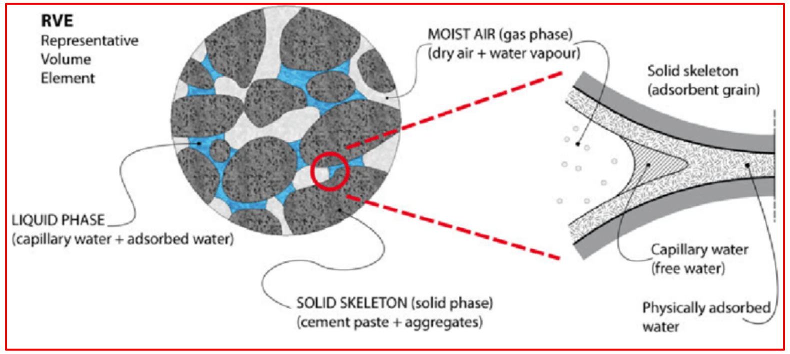


- ► Slight paste consistency modification (EN 196-3)
- ► Low need of admixture adjustment

TS CON – C&M laboratory – CEM I 42.5N and Betocarb F LG

Water absorption of fine <125µm





► not possible to use EN 1097-6 for fines <125µm (cement, fly ash, fine GCC …)

► water demand of fine GCC is evaluated with EN 196-3 method

TS CON – C&M laboratory – https://www.researchgate.net/figure/ EN 1097-6:2000

GCC - DS/EN 206 DK NA:2020 - Annex Q

DANSK STANDARD

Table A	Anneks Q DS/EN 206 DK NA:2020			
Title	Ground Calcium Carbonate			
Country	Denmark			
Application	Concrete			
	Norms	Type A - Limits	Type B - Limits	note
CaCO3 [%]	DS/EN 196-2	≥95	≥95	
Chlorides [%]	DS/EN 196-2	≤0,10	≤0,10	
Sulfate [%]	DS/EN 196-2	≤1	≤1	
Clay content [g/kg]	DS/EN 933-9	≤12	≤12	
Moisture content [%]	DS/EN 1097-5	to declare	to declare	
Organic mat. content [%]	DS/ EN 13639	≤0,5	≤0,5	
Total content alkalis [%]	DS/EN 196-2	≤0,25	≤0,25	
Passing 1µm [%]	Sedigraph	≥8	≥1	
Passing 2µm [%]	Sedigraph	≥40	≥13	
Passing 10µm [%]	Sedigraph	≥90	≥52	
Passing 20µm [%]	Sedigraph	≥96	≥65	
Passing 40µm [%]	Sedigraph	≥98	≥82	
Strength 7d [N/mm^2]	DS/EN 196-1	32	32	80% cement + 20% GCC
Strength 28d [N/mm^2]	DS/EN 196-1	≥42	≥42	80% cement + 20% GCC
Setting time	DS/ EN 196-3	90-150%	90-150%	80% cement + 20% GCC
Soundness [mm]	DS/ EN 196-3	≤10	≤10	80% cement + 20% GCC
Particle density [g/l]	DS/EN 1097-7	≥2,5	≥2,5	

GCC characteristic to be highlighted:

- High purity ($CaCO_3$ >95%)
- High fineness :
  - Type A : 98% ≤40µm
  - Type B : 82% ≤40µm

Information : specific national standard for GCC in Europe

These national standards allow the use of fine GCC in concrete with concepts defined by EN 206.

EN 206 concepts	Countries
K-value	FR (1995)
Equivalent Concrete Performance Concept (ECPC)	NL
Equivalent Performance of Combination Concept (EPCC)	UK (2001), PT, DK (2020)

REMINDER : GCC is not inert and has been used since years **to optimize the mineral binder proportioning** in given exposure classes and defined cement (i.e. CEM I).

Environmental benefits of using fine calcium carbonate fillers

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Sustainability is the key to future success on our journey of achieving our objectives

Environmental footprint contribution of fine GCC

Options	OPTION 1	OPTION 2
Definition	Use Fine GCC with EPCC concept when using CEM I 52.5N to : - Formulate greener mineral binder	Use Fine GCC in addition to all types of cement to: - Optimize the total Powder (1) content - Enhance the Segregation resistance (stability) of mortar & concrete -> Adjust the minimal cement content
Interest	Low	**High**
Exposure class	XO, XC1, XC2, XC3, XC4, XF1, XA1	**All**

(1) Powder = Material of particle size smaller than 0,125 mm (also include this size fraction of the sand)

Environmental footprint : OPTION 1

Fine GCC can be used with EPCC (Annex Q, DS/EN 206 DK NA:2020) to optimize the mineral binder carbon footprint for XO, XC1, XC2, XC3, XC4, XF1 and XA1 exposure classes :

Max CEM 52.5N substitution	Fine GCC	Recomposition	CO2 reduction (1)
			%
Up to 25%	Type A	CEM II/B-LL (2)	Up to 23
Up to 10%	Type B	CEM II/A –LL (2)	Up to 9

(1) Fine GCC is a natural and renewable material with a low carbon footprint (62 kg of CO_2 emitted per ton – source IMA). The calculation is based on CEM I 52.5 value (850kg of CO_2 per ton of cement produced).

(2) EN 197-1 – Part 1 : Composition, specifications and conformity criteria for common cements.

Environmental footprint : OPTION 2

Options	OPTION 2
Definition	Use Fine GCC in addition to all types of cement to: - Optimize the total Powder (1) content - Enhance the Segregation resistance (stability) of mortar & concrete -> Adjust the minimal cement content
Interest	**High**
Exposure class	**All**

Fine GCC can be used as an aggregate for concrete (EN 12620) to optimize the Total Powder Content.

- Compatible with all type of cement or mineral binder (cement + fly ash + slag …)

(1) Powder = Material of particle size smaller than 0,125 mm (also include this size fraction of the sand)

Environmental footprint contribution of fine GCC

SUMMARY

- Fine GCC is a natural and renewable material with a low carbon footprint (62 kg of CO_2 emitted per ton – source IMA).
- The use of EPCC can be used to define the "mineral binder" proportion (Anneks Q DS/EN 206 DK NA:2020).
- In a complementary work, Fine GCC (EN 12620) should be used to optimize the **Total Powder Content** to enhance the formula stability (SCC, SLS) and remain homogeneous in composition during transport and placing.

What is the optimal use and dosage of fine GCC in technical mortars and concrete ?

Case Study with Omya Betocarb® F

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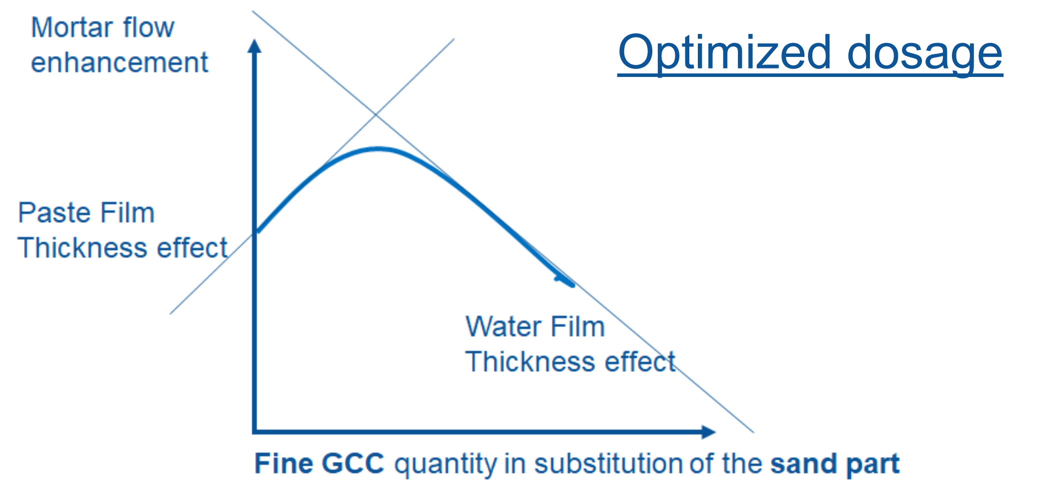
Enhance the flowability, viscosity and stability of technical mortars and concrete

What is the optimal use and dosage of fine GCC?

Opportunity : optimize the fine GCC proportion

Use of fine GCC initiated by
-> pumping/aesthetic need
-> EPCC
-> environmental objectives
-> fine optimization

Initial dosage of fine GCC
-> EPCC rule
-> by experience
-> mathematical model(1)



= derivative on the fine GCC dosage at the same W/C ratio and admixture dosage

(1) Betonlab (Ifsttar), Généralisation du modele CIPM, Denarié-Sofia-Gonnon (Rilem – 2020 Istanbul)

What is the optimal use and dosage of fine GCC?

Benefits

- Increase the mortar & concrete stability
- Remove the bleeding
- Improve the packing, segregation resistance
- Compatible with all type of cements
- Formulate concrete with low carbon footprint

REMINDER :

- Determine the GCC **point of saturation**
- EFNARC specification for SCC (2002)

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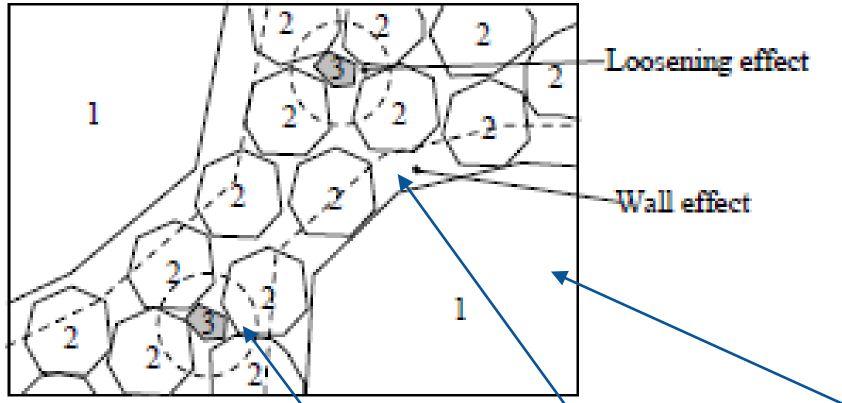
What is the optimal use and dosage of fine GCC?

Principe : optimize the formulation by adjusting the quantity of paste



De Larrard (1999)

Sand

Mineral binder (cement + fly ash or slag…)

Fine calcium carbonate filler (Fine GCC)

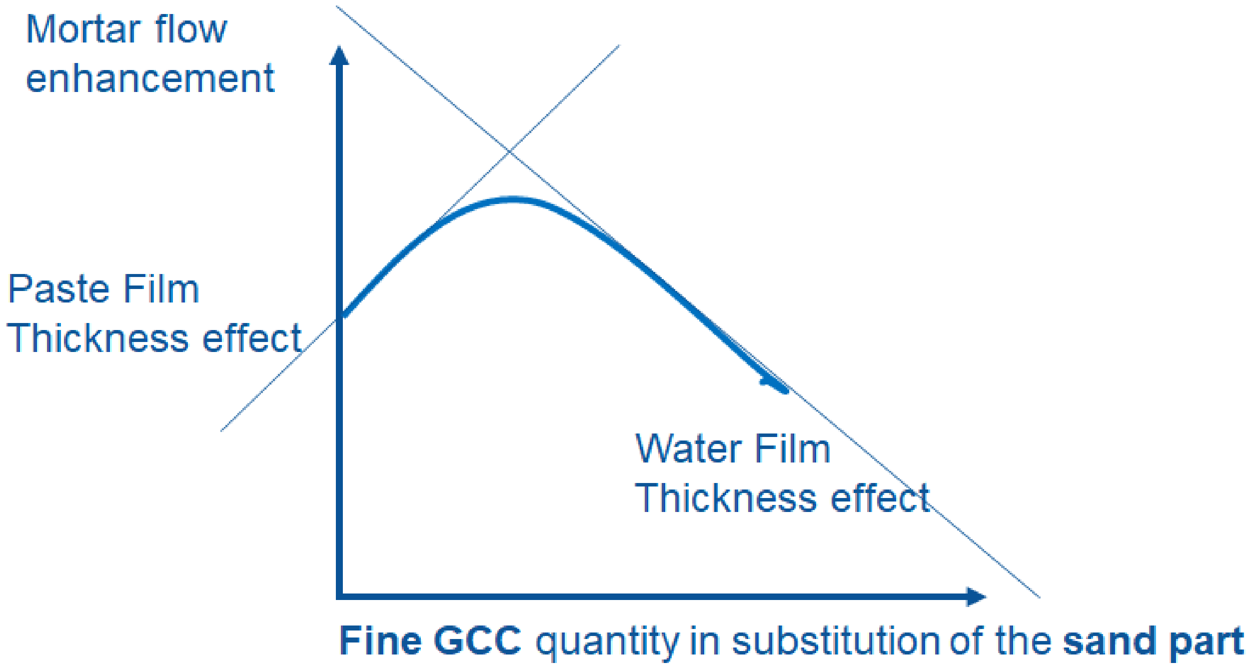
► Use of selected GCC (3) in substitution of the sand part (1).

► Keep the same w/c and additive content.

TS CON – C&M laboratory

What is the optimal use and dosage of fine GCC?

Principe : optimize the formulation by adjusting the quantity of paste



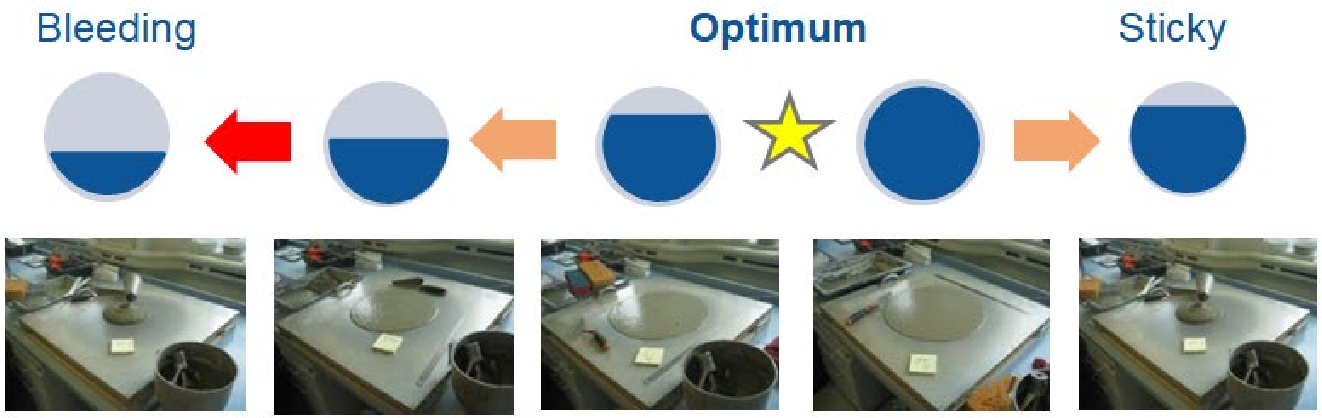
► High interest to establish the point of saturation

► The optimum dosage of Fine GCC is driven by the quantity of mineral binder, sand quality/quantity,water, admixture/cement performance

- TS CON – C&M laboratory - Towards tailored cement-based materials with ground calcium carbonates, Denarié, Lionel, Gonnon 2019

What is the optimal use and dosage of fine GCC?

Example : Self Leveling Screed (model formulation)



GCC (kg)	25	50	100	200	300
Sands (kg)	1425	1400	1350	1250	1150

Show the mechanism with : CEN sand, 380kg CEM I 42.5, w/c = 0.55, Superplasticizer 3 L.

What is the optimal use and dosage of fine GCC?

Conclusion

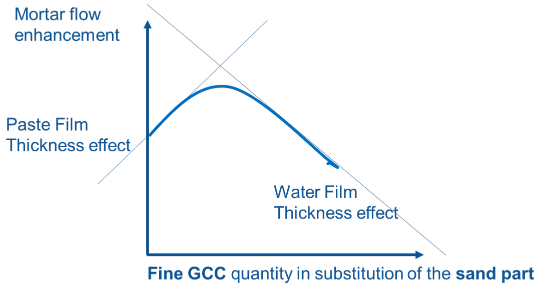
► **Initial dosage** of fine calcium carbonate can be done by using one concept defined by EN 206, experience or a mathematical model.

► **The best dosage** of GCC (DS/EN 12620) is defined with a constant mineral binder, water, coarse aggregate and admixture dosage.

► The best combination mineral binder/superplasticizer is a perquisite to define the optimal dosage of GCC.

DANSK STANDARD

Annex Q DS/EN 206 DK NA:2020



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Industrial applications

Case studies with Omya Betocarb® F

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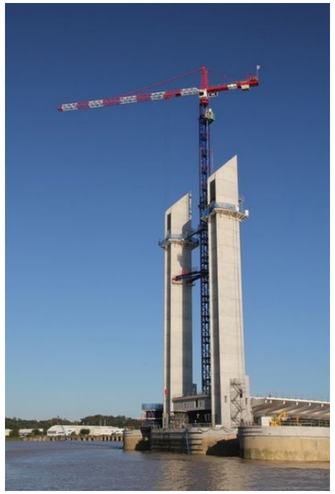
Enhance the flowability, viscosity and stability of technical mortars and concrete

Example with Betocarb® F






Omya International & Customer – Industrial trials

Example with Betocarb® F

S4, C20/25 – D16 mm, Low carbon footprint

Mineral binders (kg)	Ordinary Portland Cement, Fly ash	220
Betocarb® F (kg)	Fine GCC	94
Sand(s) (kg)		800
Aggregate 4/16 (kg)		950
Additives (kg)	Superplasticizer Air entrainer Hydrophobic agent	4

Performance

- Paste content optimization
- Resistance to segregation
- Partial Fly ash replacement
- Flow enhancement

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Example with Betocarb® F

Cementitious flooring formulation

Mineral binders (%)	Ordinary Portland Cement Calcium Aluminate Cement Gypsum	36
Organic binder (%)	Redispersible polymer powder	2
Betocarb® F (%)	Fine GCC	14
Sand(s) (%)		45
Additives (%)	Superplasticizer Defoamer Cellulose ether	3

Performance

- Paste content optimization
- Resistance to segregation
- Flow enhancement

Water

- 25% by weight of the recipe

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Example with Betocarb® F

SCC - C55/67 - D12 mm

Cem I 52.5R (%)	18.2
Betocarb F (%)	5.2
Fine aggregate 0/4 (%)	34.2
Coarse aggregate 4/12 (%)	35.2
Water (%)	6.9
Superplasticizer A (%)	0.16
Superplasticizer B (%)	0.12
Air modifier (%)	0.06

Performance

- Paste content optimization
- Resistance to segregation
- Color, flow and strength development

Flow diameter 700 mm, Compressive strength 7d : 60 MPa, 28d : 73 MPa, Workability time >45 min, Chlorides 31 kg/m^3, Air content 4%, W/C=0.38

Exposure class: XC0, XC3, XS1, XD1, XF4, XA1,
5.2% = 130kg/m^3, 0.16%= 3.7 ltrs/m^3

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Thank you for your attention

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