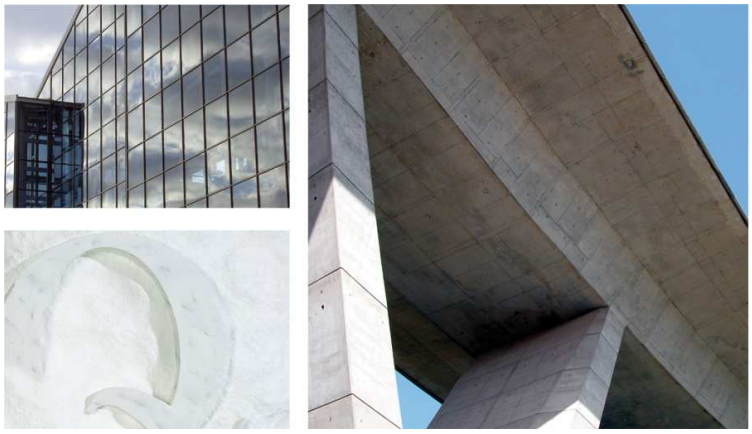
TECHNICAL BULLETIN

ATS GIA - Construction



Betoflow®

Ultrafine calcium Carbonate for concretes

Version 5 – May 2011

Omya International AG
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INTRODUCTION

Betoflow® is originated from the exploitation of pure carbonate rock-forming minerals (limestone, chalk, marble and travertine). From the mineralogical point of view, calcium carbonate falls into three structurally different groups: the calcite group, the aragonite group, and the vaterite group. The production process maintains the ultrafine carbonate very close to its original state, ending up in a finely ground product. The production of ultrafine calcium carbonate starts with its extraction and the processing includes grinding, size classification of particles and sometimes washing, sorting of undesirable by-minerals (clays, micas, dolomite, quartz) and drying.

DESCRIPTION

Betoflow® is an ultrafine divided and dried calcium carbonate. It is the smallest constituent of the concrete recipe, designed ultrafine as silica fumes or metakaolin. Associated with gravel, sand, cement and additions (Betocarb®, fly ash, blast furnace slag, siliceous filler), it is part of the granulometric base of cement or anhydrate based mortars and concretes.

Betoflow® D is a regular white ultrafine calcium carbonate (d_{50}<5µm) that significantly optimises the packing, flowability and mechanical performance of high performance concrete. Its special features are a grain size and surface quality that uses little water and increases the yield of the high-range water-reducing superplasticizer.

Betoflow® belongs to the European aggregate standard EN 12620 and has depending on the countries Level 2+ or 4 CE marking.

MAIN CHARACTERISTICS

Natural product

- $CaCO_3$+$MgCO_3$ > 90 %

Grading

- Passing 63 µm > 100 %
- D_{50} < 5µm

High cleanliness

- Methylene blue value < 3 g/kg for fluid and Self Compacting Concrete (SCC)

Low silica content and no risk of alkali-reaction

- SiO_2 < 4%

Fineness similar or higher than the cement product

- BET surface > 2 m^2/g

Adapted for a storage in a silo as the cement

- Moisture < 1 %
- Bulk density < 1 t/m^3

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In the local place of use i.e. in France and UK, a national standard defines additional requirements to use Betoflow® with a k-value concept. This could be possible today in all European countries, when Betoflow® refers to a European Technical Approval conforming to CUAP 03.01/41. Betoflow® overcomes the K-value concept as the main property concerns high fineness, improvement of workability and water/cement ratio reduction.

Standards	EN 12620	BS 7979:2001	NF P 18-508			CUAP 03.01/41
Country	Europe	UK	France			Europe
			B	A		
CaCO3 [%]		≥ 75	> 65	> 95		≥ 95
MgCO3+CaCO3 [%]			> 90	> 95		≥ 95
Chlorides [%]		≤ 0,1	≤ 0,1	≤ 0,1	≤ 0,1	≤ 0,1
Total sulfur [%]		≤ 1	≤ 0,4	≤ 0,4	≤ 0,4	≤ 0,4
Clay content [g/kg]	< 12	≤ 12	< 10	< 3	< 3	≤ 10
Additives [%]		≤ 1	< 1	< 1	< 1	
Moisture [%]		≤ 0,5	≤ 1	≤ 1	≤ 1	≤ 1
Organic mat. content [%]		≤ 0,5	≤ 0,2	≤ 0,2	≤ 0,2	≤ 0,5
Sulfate [%]			≤ 0,15	≤ 0,15	≤ 0,15	≤ 0,20
Activity index 28d			> 0,71	> 0,71	> 0,71	≥ 0,71
Total content alkalis [%]						≤ 1
SiO2 [%]			< 4	< 4	< 4	< 4
Blaine surface [m^2/kg]			> 220	> 300	> 300	≥ 280
Passing 45µ [%]		≥ 90				
Passing 63µ [%]	> 70		> 70	> 70	> 70	≥ 70
Passing 125µ [%]	> 85		> 85	> 85	> 85	≥ 85
Passing 2 mm [%]	100		100	100	100	100
Strength 7d [N/mm^2] (1)		≥ 16				
Strength 28d [N/mm^2] (1)		≥ 32.5 and ≤ 52.5				
Setting time [mn] (1)		> 75				≤ 120 (4)
Soundness [mm] (1)		≤ 10				≤ 10 (5)
Carbonatation						pass/fail
Freeze thaw resistance						pass/fail
Suitability K value						0,25
A/A+C [%]		≤ 20 (1)	≤ 25			≤ 25 (6)
Cement		CEM I ≥ 42,5 (2)	CEM I ≥ 42,5			CEM I > 42,5
Minimum Cement		C+A	C+K.A (3)			C+K.A (3)

Table 1: Standards in the local place of use

Betoflow® is a type I addition with catalytic binding properties for production of concrete, including in particular cast in situ and prefabricated structural concrete conforming to European standard EN 206-1 and all the European standards and Eurocodes related to concrete applications.

Betoflow® may also be used in mortars and grouts.

EXPECTED BENEFITS

Whatever the type of cement used, that is to say with or without a k-value concept, when Betoflow® is formulated as an ultrafine to optimize the particle size distribution and water/cement (w/c) of the recipe, the expected benefits are:

- Improvement of flowability and early-age strength
- Robustness development for fluid and SCC
- Lowers efflorescence
- Smoother surface
- Improves performance of admixture and pigments
- Contribution to lower CO_2 emissions

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GRANULOMETRIC CORRECTION

Betoflow® D is a very pure, ultrafine powdered limestone, specifically adapted for cement matrices.
Its grains are 10 times smaller than those of fines (cement and additions such as Betocarb®), which allows it to intercalate evenly between larger grains, physically take the place of mixing water and thus optimizing granular stacking.

Passing (%)	Betoflow® D	CEM I 42.5R
355	100	100
250	100	100
192	100	100
128	100	100
96	100	99
80	100	98
63	100	95
48	100	89
32	100	76
20	97	59
16	94	47
12	87	35
10	82	30
8	74	21
6	64	17
4	48	11
2	26	6
1	11	4

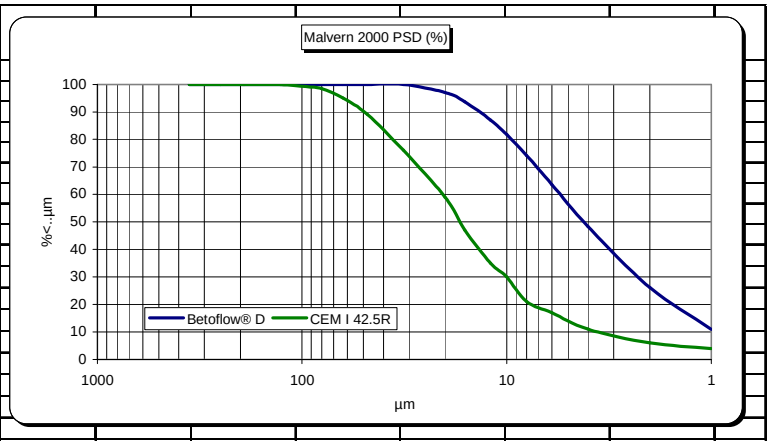

Table 2: Granular size distribution

	Unit	d_{50}	Ultrafine	CaC03 filler or addition	Omya products
Blaine surface	m^2/kg	> 5 µm		X	Betocarb®
BET surface	m^2/g	< 5 µm	X		Betoflow® D

Table 3: Calcium carbonate classification with d_{50}

This means that whatever the cement content and w/c ratio, the volume of fines (Cement + Blast Furnace Slag, Fly ash or Betocarb®) can easily be adjusted, the density of formulations optimized and regularity improved. Betoflow® D dosage is accordingly from 5 to 20% of the cement or fines weight.

In the past few years, in High Performance Concrete or Ultra High Performance Concrete (UHPC), tests have shown that Portland cement may not be replaced by just a single component particularly when early strengths are required. For Eco-concrete (Table 4), an intelligent combination of several components with different particle size distributions and hardening characteristics appeared to be a promising approach. Sometimes this is also done with simultaneous use of CEM I and CEM III with Betoflow® D (table 5).

	CEM I 52.5N	GGBS	Fly ash	Betoflow® D	D max	w/c	Rc 2d	Rc 28d	Slump class
Unit	kg	kg	kg	kg	mm		MPa	MPa	
E1	150	150	0	30	14	1,17	4	45	S2
E2	138	0	38	70	14	1,24	5	23	S3

Table 4: Eco-concrete with Betoflow® D

- w/c: water/cement ratio.
- Rc2 and Rc28: compressive strengths at 2 and 28 days.
- GGBS: blast furnace slag.

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	Unit	Data		Unit	Data
CEM I 52.5N	kg	600	**Compressive strength 24h**	MPa	56
CEM III/A 42.5N	kg	300	**Compressive strength 28d**	MPa	112
Betoflow® D	kg	120	**Exposure classe**		XF3
D max	mm	4	**Flow classe**		F6
w/c		0,24			

Table 5: UHPC with Betoflow® D and blended cements

The production of high performance concrete (HPC) structures has always been based on regionally available materials. For example, today, CEM II/A and CEM III/A blast-furnace cements are used as standard cements in some regions for producing ready-mixed concrete for civil engineering and building construction purposes.

Mixes are optimized on the basis of the usual reference concretes. A particular challenge is the identification of a suitable superplasticizer (E1, E2 or E3) to achieve the best w/c ratio and ensure concrete flowability within the required period without any loss of the specified early strength (table 6).

	CEM I 52.5N	Betocarb®	Betoflow® D	w/c	Superplasticizer	Slump class	Rc 16h
Unit	kg	kg	kg		l		MPa
E1	410	60	40	0,44	2,1	S5	10,9
E2	410	60	40	0,44	4,9	S5	7,4
E3	410	60	40	0,44	3,6	S5	<1

Table 6: Concrete workability and early age strength

CONSISTENCY

The water/powder ratio required for making the grout, mortar or concrete workable can be reduced considerably by optimizing the particle size distribution using superplasticizers. So, the effect of superplasticizer influences not only the flowability but also the viscosity of the concrete.

	CEM I 52.5N	Betocarb®	Betoflow® D	w/c	Super-plasticizer	Funnel time	Slump class	Rc 16h
Unit	kg	kg	kg		l	s		MPa
E1	420	130	0	0,47	4,0	26	F6	30
E2	420	130	0	0,47	4,2	29	F6	37
E3	420	130	0	0,47	6,9	7	F6	38
E3	420	70	50	0,47	6,9	7	F6	41
E3	420	70	50	0,44	7,0	11	F6	49

Table 7: Superplasticizer influence on concrete viscosity

The results (Table 7) show that superplasticizer (E1, E2 or E3) for technical concrete must, in each specific case, be carefully chosen and adjusted to the type of cement and additional com-

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ponents such as ultrafines. Betoflow® D increases the effectiveness of the high-range water reducing superplasticizer admixture and makes it possible to reduce w/c and increase early age strength.

Main mechanism:

A B C

Coarse cement particles (see A) are filled with ultrafine particles (see C). Betocarb® particules complete cement particles (see B). The water reduction property of Betoflow® D will reduce space between coarse particles from cement and addition (see B) and improve consistency. So, the high steric effect of superplasticizer is a critical issue to perform w/c and plastic viscosity of the technical concrete (Table 7).

Specific test OmyaLG_16 developed by Omya International (Table 8) helps to compare ultrafine contribution on mortars or concrete flowability (Table 9) and particularly Betoflow D® performance at the early age. As a reference, T0 is a self levelling mortar and diameter is measured.

	CEM I 52.5N	Betocarb® HP	Ultrafine	Sand 0/2	w/c	Super-plasticizer	% Ultrafine
Unit	kg	kg	kg	kg		l	%
E1.1	415	260	0	1350	0,55	2,5	0
E1.2	415	260	41	1309	0,55	2,5	10
E1.3	415	260	82	1268	0,55	2,5	20

Table 8: OmyaLG_16 plan test

% Ultrafine	Flowability	Limestone	Chalk	Marble	Silica fume	Kaolin calcinated	Betoflow® D	
		3	3	3	4	10	4	d_{50} (µm)
0	mm	410	410	410	410	410	410	
10	mm	410	410	405	170	200	440	
20	mm	390	325	360	0	50	470	

Table 9: OmyaLG_16 results with different ultrafine

It appears clearly that Betoflow D improves flowability of the technical mortar. In comparison with others ultrafines, w/c ratio can be reduced and robustness enhanced. This is particularly true when the superplasticizer used has a low steric effect.

State of the art indicates that UHPC materials have a very high content of Portland cement and a very dense structure without capillary pores resulting from a dense packing fine particles (cement and ultrafine), but also from a high content of micro-steel fibers and a very low w/c ratio of around 22%. Considerable amount of superplaticizer (Table 10) are needed to modify the flowability of this material according to the process and final product requirements.

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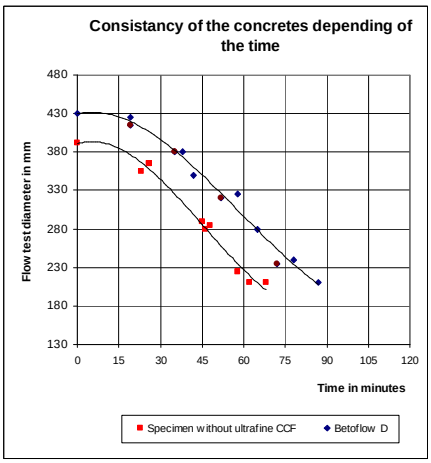
	CEM I 52.5N	Ultrafine	w/c	Steel fibers	Super-plasticizer
Unit	kg	kg		kg	l
E1	930	230	0,23	180	13
E2	780	240	0,20	145	31
E3	740	280	0,24	90	18
E4	800	125	0,27	160	45

Table 10: Amount of superplasticizer in BUHP (with or without thermal treatment)



Open time or evolution of the workability of the recipe will be greatly influenced by quality of the surfaces of the fines and ultrafines.

With Betoflow® D, open time will be improved (table 11).

In comparison with other ultrafines, the water migration to the Betoflow® D particle surface is reduced and workability improved. The mineral steric effect plays a major role.

Table 11: OmyaLG_16 – open time with Betoflow® D

MECHANICAL STRENGTH PROPERTIES

This property concerns particularly two main applications:

- The early age for architectonic and/or structural concretes C25/30 to C50/60 for external component exposed i.e. to frost at moderate water saturation levels without deicing agent.
- The early age for High Performance Concrete (>C50/60) or Ultra High Performance Concrete (UHPC) is an innovative construction material that possesses about five times the compressive strength (>100 MPa) of normal concrete (25 MPa). In smaller optimized cross-sections, the compressive, flexural tensile and shear stress is increased.

Betoflow® D is used to enhance mechanical strength properties of concretes after the two following steps and verifications:

- Firstly, the use of superplasticizers makes it possible to reduce w/c to a level that was previously not possible (saturation point).
- Secondly, the choice of rapid setting cement (R index in EN 197-1) contributes to a significant shortening of the required hardening period. Compatibility between superplasticizer and cement is verified and funnel time or viscosity of the concrete is low.

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This development is aimed at reducing the period between pouring and the onset of hardening even with heat treatment cost optimization. So, the mechanical strength property of Betoflow® D does not concern pozzolanic activity but both a physical effect known as heterogeneous nucleation and a water-reduction. As a result, compared to other ultrafines such as Silica fumes or Metakaolin, Betoflow® D increases concrete strength at the early age (Table 12).

	CEM I 52.5N	Betocarb® HP	Ultrafine	Sand 0/2	w/c	Super-plasticizer	Rc 16h	Flowability
Unit	kg	kg	kg	kg		l	MPa	mm
Silica Fume	415	260	41	1309	0,61	2,5	23	385
Calcite d_{50}=3µm	415	260	41	1309	0,55	2,5	27	410
Betoflow® D	415	260	41	1309	0,53	2,5	31	395

Table 12: OmyaLG_16 – iso-workability and additive content – w/c and Rc16h evolution

A particular challenge concerns the mixing time to optimize particle size distribution, cement hydration and robustness of the recipes. Many studies have shown that dry mixing period and addition of superplasticizer in two steps and not previously weighted with water can increase flowability (Table 13). As an example:

- Dry mixing time: 2 to 3 min
- Water and half part of additive: 2 to 8 min
- Half part of additive: 2 to 10 min

	CEM I 52.5N	Betoflow® D	Super-plasticizer	Other admixture	w/c	Funnel time
Unit	kg	kg	%	%		s
E1 test 1	930	105	1,0	1,8	0,23	>240
E1 test 2	930	105	1,5	2,5	0,23	>120
E1 test 3	930	105	1,2	3,5	0,23	40
E1 test 4	930	105	1,0	3,0	0,23	47

Table 13: Mixing time and workability

The Feret equation (1) helps to understand strength evolution when Betoflow® D is used to enhance superplasticizer performance and reduce the w/c ratio (table 14).

(1) $Rc = Fcd \; 0{,}5 \; [C/W - 0{,}5]$

- Rc = compressive strength (MPa)
- Fcd = day compressive strength of the cement according to EN 196-1
- C = cement weight (kg/m^3)
- W = water content (kg/m^3)

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	Unit	E1	E2	E3	E4	E5
CEM I 52.5N	kg	350	400	500	600	800
Betoflow® D	kg	50	50	100	100	150
water	l	160	160	160	160	160
w/c		0,46	0,40	0,32	0,27	0,20
Rc 1d	MPa	26	31	40	50	69
Rc 28d	MPa	53	63	82	102	141

Table 14: Compressive strength estimation at 1 and 28 days with CEM I 52,5.

It is important to note that strength evolution also depends on the quality of the cement used (C_3A, C_4AF, fineness) and superplasticizer compatibility (Table 6).

CEM method – Calcium Carbonate Fine is used as a mineral additive

The aim is to design a concrete equivalent mortar (CEM) deduced from the concrete composition in order to reduce the amount of concrete batches and prepare industrial test. Used since 15 years, this scientific approach used all over the world by the main laboratories, allows anticipating the main effects of the following parameter:

- Addition of Betocarb®
- Ultrafine of Betoflow® D
- Admixture (s)
- Sand (s)

After monitoring fluidity versus time relationship, early strengths and density, compatibility of the main constituents is verified. CEM tests highlight the correlations between the admixture effectiveness, w/c, fine content and flowability.

	Unit	E1	E2	E3	E4	E5	E6	E7
Sand (s)	kg	1350	1330	1309	1309	1268	1309	1309
Cement	kg	415	415	415	415	415	415	415
Betocarb®	kg	260	260	260	260	260	260	260
Silica fume	kg	0	20	41	0	0	0	0
Dolomite d_{50}=3µm	kg	0	0	0	41	82	0	0
Betoflow® D	kg	0	0	0	0	0	41	41
Water	l	230	230	230	230	230	230	215
Superplasticizer	l	2,5	2,5	2,5	2,5	2,5	2,5	2,5
Flowability	mm	420	310	220	410	230	460	410
w/c		0,55	0,55	0,55	0,55	0,55	0,55	0,52
Visual aspect		High flowability	viscosity grow up	loss of workability	soft, easy to handle	loss of workability	reduce w/c	reduce w/c

Table 15: CEM tests – compatibilities

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E1


E3


E4


E7

CEM tests allow us to demonstrate main properties and functionality of our products Betocarb® and Betoflow® D.

WHITENESS

Betoflow® D is particularly white and can therefore be added to white cement.

The whiteness of Betoflow® D is defined by the L value, the luminance. In the colorimetric L a*b* model (also know as CIELab) a colour is indicated by three values:

- L, the luminance, expressed as a percentage (0 for black to 100 for white)
- “a” and “b” two ranges of colour respectively going from green to red and from blue to yellow with values from -120 to +120.

The OmyaLG_007 test was developed by Omya International, to verify and promote Betoflow® D for fluid or self-compacting concrete (SCC) without risk of discoloration with grey or white cements. This quality is very interesting for white or pigmented concrete to enhance regularity of the final products.

APPLICATIONS

Plastic and plasticized concrete

Plastic concrete such as pits, gutters, beams, building and road concretes are used to manufacture concrete elements that are removed from the moulds after several hours. Time is needed with or without thermal treatment to remove the products without damages. Vibration helps to cast concrete properly and to optimize its quality.

Fluid and technical concretes concrete

Concretes called technical concretes are characterized by a significant volume of fines (Cement + Betocarb®). Fluid concrete is used to cast horizontal or vertical products. Flowability improves productivity and aesthetics. Their usage and the mechanical strength requirement is often high. Also, high homogeneity of facings is desired. It is therefore necessary to control the viscosity, water/cement ratio and additive/cement ratio. The quality and consistency of Beto-

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flow® allows the granulometric correction of the mixtures to be optimised. Performance is significantly improved with Betoflow®.




Use of Betoflow® D	Dry concrete	Plasticized and admixtured concrete	Fluid and self compacting
Grain size corrector	X	X	XXX
Whiteness	XX	XXX	XXX
k-value	X	X	X

Table 16: Uses of Betoflow® D

Key: X possible, XX common, XXX recommended

LGmixture

Use of Betocarb® and Betoflow® products depending on type and concrete workability

Concrete strength family		kg/m³ = total content of fines (Cement+Betocarb®)				+ Betoflow® D
28d strength >100 Mpa	Very high performance concrete 700					
28d strength >50 Mpa	High performance concrete 400					
28d strength >25 Mpa	Usual strengths for building 280					
	Concrete workability	Dry (S1)	Plastic	Very Plastic	Fluid	Self compacting (S5)
	Keys	Choice of the constituants and fines volume			**Fines quantity and viscosity management**	
Betocarb® - OmyaLG_001 evaluation (1)		● , ●●		●●● , ●●●●		
(1) marks the suitability for a given Betocarb® grade: ● = low and ●●●● = best						