Dow Construction Chemicals

TECHLINE 10

WALOCEL™ Methyl Cellulose for cement render: robust performance in a range of cement qualities

Abstract

Mortar producers wishing to use blended cements in order to help reduce the carbon footprint of their materials need to know how additives such as cellulose ethers interact with such products and what impact they might have on the final, desired product qualities. This paper analyses the correlation between different cement qualities and their behaviours and assess the performance of WALOCEL™ MKW Methyl Cellulose from Dow Construction Chemicals when used with such materials.

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Introduction

According to the CSI Report 2012, current cement manufacture results in approximately 5 % of global carbon dioxide (CO_2) emissions, which in turn have a role to play in terms of global warming. By the end of 2012, cement consumption was 5 % higher compared to 2011. The International Project Review forecasts that global demand for cement will continue to rise by around 4.4 % annually over the next 4 years.

As cement plays a vital role in construction, and is the main ingredient in all mortar formulations it is obviously of critical and global importance to producers of mortar-based construction materials: trends and developments that affect the quality of cement, product availability and pricing are relevant to them too.

A range of different cements are available in today's market, some of which claim to offer a reduced carbon footprint. Unfortunately, there is not yet a high demand for such products due to a reputation that they could negatively influence the final performance of mortars in some cases, and in others that they could require a complete reformulation of mortar materials, which would result in additional effort and cost.

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In an effort to help clarify the situation and support mortar producers in their materials specification, technicians from Dow Construction Chemicals have analysed the correlation between a range of cement materials manufactured with fly ash or slag i.e. those which release less CO_2 during manufacture, as well as some of the most important characteristics producers require from cement products.

In addition, technicians also evaluated how WALOCEL™ MKW Cellulose Ether from Dow Construction Chemicals would interact with such types of cement, and the impact this would have on the desired mortar performance.

The results show that WALOCEL™ MKW Methyl Cellulose helps mortar manufacturers to achieve a consistent quality of performance features in formulations even when using different quality cements.

Supporting carbon footprint reduction

With the before mentioned growth forecast, the pressure to find solutions to help control emissions and support the goals that have been set and agreed by governments – such as the Kyoto protocol – increases. Industry must play its part.

CO_2 is emitted as a by-product of the chemical conversion process used in the production of cement clinker. In addition to this, the production of clinker is the most energy intensive step in the manufacture of cement.

One way to reduce the carbon footprint of cement production is through the use of so-called blended cements. In such cements, a portion of the clinker is replaced with industrial by-products such as coal fly ash (a residue from burning coal in power stations), blast furnace slag (a residue from iron production) or other pozzolanic materials. These materials are then blended with ground clinker, meaning that less clinker needs to be produced.

However, such blended cements have different properties than pure Portland cement. For example, setting can take longer.

European standard EN 197-1 establishes the range of different cement qualities and their compositions. Twenty seven different cement qualities are classified under the standard, and these are divided into five groups. The groups range from pure Portland cement (known as CEM I) to composite cements (known as CEM V) (see table 1).

In current mortar formulations Portland cement (CEM I) is a standard component. Portland lime-stone cement (CEM II /A-L) is also used frequently. However, both of these materials have a negative impact on the industry's CO_2 balance sheet.

			Composition (parts by weight in %) [1]										
			Major components										Minor components
						Pozzolanes		Fly ashes					
			Portland cement clinker	Slag	Silica dust	Natural	Artificial	High silica	High lime	Burnt shale	Limestone		
Main cement type	Designation	Cement type	K	S	D [2]	P	Q	V	W	T	L [4]	LL [5]	
CEM I	Portland cement	CEM I	95 – 100	–	–	–	–	–	–	–	–	–	0 – 5
CEM II	Portland slag cement	CEM II/A-S	80 – 94	6 – 20	–	–	–	–	–	–	–	–	0 – 5
		CEM II/B-S	65 – 79	21 – 35	–	–	–	–	–	–	–	–	0 – 5
	Portland silica dust cement	CEM II/A-D	90 – 94	–	6 – 10	–	–	–	–	–	–	–	0 – 5
	Portland pozzolan cement	CEM II/A-P	80 – 94	–	–	6 – 20	–	–	–	–	–	–	0 – 5
		CEM II/B-P	65 – 79	–	–	21 – 35	–	–	–	–	–	–	0 – 5
		CEM II/A-Q	80 – 94	–	–	–	6 – 20	–	–	–	–	–	0 – 5
		CEM II/B-Q	65 – 79	–	–	–	21 – 35	–	–	–	–	–	0 – 5
	Portland fly ash cement	CEM II/A-V	80 – 94	–	–	–	–	6 – 20	–	–	–	–	0 – 5
		CEM II/B-V	65 – 79	–	–	–	–	21 – 35	–	–	–	–	0 – 5
		CEM II/A-W	80 – 94	–	–	–	–	–	6 – 20	–	–	–	0 – 5
		CEM II/B-W	65 – 79	–	–	–	–	–	21 – 35	–	–	–	0 – 5
	Portland shale cement	CEM II/A-T	80 – 94	–	–	–	–	–	–	6 – 20	–	–	0 – 5
		CEM II/B-T	65 – 79	–	–	–	–	–	–	21 – 35	–	–	0 – 5
	Portland limestone cement	CEM II/A-L	80 – 94	–	–	–	–	–	–	–	6 – 20	–	0 – 5
		CEM II/B-L	65 – 79	–	–	–	–	–	–	–	21 – 35	–	0 – 5
		CEM II/A-LL	80 – 94	–	–	–	–	–	–	–	–	6 – 20	0 – 5
		CEM II/B-LL	65 – 79	–	–	–	–	–	–	–	–	21 – 35	0 – 5
	Portland composite cement [3]	CEM II/A-M	80 – 94	6 – 20									0 – 5
		CEM II/B-M	65 – 79	21 – 35									0 – 5
CEM III	Blast furnace cement	CEM III/A	35 – 64	36 – 65	–	–	–	–	–	–	–	–	0 – 5
		CEM III/B	20 – 34	66 – 80	–	–	–	–	–	–	–	–	0 – 5
		CEM III/C	5 – 19	81 – 95	–	–	–	–	–	–	–	–	0 – 5
CEM IV	Pozzolan cement [3]	CEM IV/A	65 – 89	–	11 – 35					–	–	–	0 – 5
		CEM IV/B	45 – 64	–	36 – 55					–	–	–	0 – 5
CEM V	Composite cement [3]	CEM V/A	40 – 64	18 – 30	–	18 – 30			–	–	–	–	0 – 5
		CEM V/B	20 – 39	31 – 50	–	31 – 50			–	–	–	–	0 – 5

1) The numbers in the table refer to the total major and minor components.
2) The silica dust content is limited to 10 %.
3) In the Portland composite cements CEM II/A-M and CEM II/B-M, the pozzolan cements CEM IV/A and CEM IV/B and the composite cements CEM V/A and CEM V/B, the major component type must be specified by the cement designation.
4) Total organic carbon (TOC) must not exceed 0,2 % by weight.
5) Total organic carbon (TOC) must not exceed 0,5 % by weight.

Table 1: Types of cement and their composition according to EN 197-1

Issues with blended cements

So if there are benefits to be gained from using blended cements in terms of carbon footprint reduction, why are they not used more frequently in mortar formulations?

There is currently a commonly held belief amongst many mortar producers – as well as some experience – that using cements with a high content of blast furnace slag, fly ash or any pozzolanic components will result in inferior results against a number of critical performance properties of the final mortar product.

These include:

- slower cement hydration leading to a delay in early strength development
- unwanted post hardening (controlled and specially designed strength development is particularly important for mortars applied in very thin layers, such as basecoat mortars or light-weight mortars used for the protection of heat insulating brick masonry)
- higher temperature sensitivity (particularly at low temperatures), narrowing the application window
- insufficient fresh mortar adhesion to substrates
- inferior workability (due to lower sag resistance and shear stability, for example)

Laboratory evaluation of pure CEM I compared with blended cements using fly ash and slag

In order to more fully understand the impact of using different types of fly ashes as well as a variety of slag materials in blended cements, Dow Construction Chemicals carried out a number of laboratory tests.

The data confirms the impact on performance as predicted and/or experienced by mortar producers in terms of setting behaviour and cement hydration, and therefore strength development and workability.

The cement composition used for the laboratory evaluation shown in table 2 was based on a 30% fly ash content, equalling the composition of a CEM II B-V material. The results for an equal water-to-solid ratio show significant variances in water demand as well as slump, indicating that a re-formulation might be necessary in order to avoid a negative impact on workability. Results also show that using a CEM II B-V material setting would be delayed and cement hydration retarded.

In addition, the early strength development and compressive strength measured after 28 days was shown to be lower compared with CEM I quality cement materials – another impact on properties predicted by many mortar producers.

The fly ash tests were made according to DIN EN 450 wherein the activity index, the ratio between compressive strength of OPC CEM I and the composite cement after 7d/28 d storage, is a main parameter.

The tests with different types of slag were done in accordance with EN 196-1 which defines the methods for testing cements – specifically the determination of strength as outlined in part 1. This standard is referred to in DIN EN 15167, Ground granulated blast furnace slag for use in concrete, mortar and grout, part 2, Conformity evaluation.

As required by the norm, the compositions that were evaluated contained 50% slag and a water-to-solid ratio at 0.5. The results of the tests performed by Dow Construction Chemicals are summarized in table 3.

Differences in water demand were also significant, particularly for slag type Merrit 5000. Based on an equal water-to-solid ratio, differences in slump indicated that the formulation would probably need to be adapted in order to maintain workability levels.

In terms of the impact on setting it can be stated once again that cement hydration was retarded, particularly with slag types Enningerloh S 09 and Merrit 5000.

All slag-containing cements fulfilled requirements according to DIN EN 15167 in respect to the activity index after seven and 28 days. In fact, those containing Ennigerloh or Merrit 5000 even showed a higher activity index for the 28 days measurements than CEM I quality cements.

	1 OPC CEM 42,5R Ennigereloh	6 FA Sament H4	7 FA Bergkament A	8 FA KW Gerstein-werk K	Dim
CEM I 42,5R HeidelbergCement	450	315	315	315	g
Slag					g
Fly ash		135	135	135	g
Norm sand EN 196-1	1350	1350	1350	1350	g
w/s	0,50	0,50	0,50	0,50	
Slump CE 63.3	177	182	149	166	mm
Setting Start	125	167	156	157	min
Finish	183	258	219	275	min
Time frame	58	91	63	118	min
Activity index after 7 days					
Flexural strength	6,9	5,8	5,6	5,5	N/mm²
Compressive strength	41,4	32,1	31,5	29,3	N/mm²
Activity index	100,0	77,5	76,0	70,8	N/mm²
Activity index after 28 days	Desired value: Fly ash > 75 %				
Flexural strength	7,6	7,3	7,2	7,4	N/mm²
Compressive strength	47,7	41,4	39,1	42,1	N/mm²
Activity index	100,0	86,7	82,0	88,3	N/mm²

Table 2: Laboratory evaluation *) cement with fly ash

	1 OPC CEM 42,5R Ennigereloh	2 Slag Enningerloh S09	3 Slag Merrit 5000	5 Slag Karcimsa, Türkei	Dim
CEM I 42,5R HeidelbergCement	450	225	225	225	g
Slag		225	225	225	g
Fly ash					g
Norm sand EN 196-1	1350	1350	1350	1350	g
w/s	0,50	0,50	0,50	0,5	
Slump CE 63.3	177	183	194	176	mm
Setting Start	125	151	177	138	min
Finish	183	234	292	227	min
Time frame	58	83	115	89	min
Activity index after 7 days	Desired value: Slag: > 45 %				
Flexural strength	6,9	5,8	6,1	5,3	N/mm²
Compressive strength	41,4	32,6	31,0	25,1	N/mm²
Activity index	100,0	78,7	74,8	60,6	N/mm²
Activity index after 28 days	Desired value: Slag: > 70 %				
Flexural strength	7,6	8,9	8,8	7,2	N/mm²
Compressive strength	47,7	51,4	51,8	38,2	N/mm²
Activity index	100,0	107,8	108,5	80,1	N/mm²

Table 3: Laboratory evaluation *) cement with slag

*) Laboratory evaluation performed by Dow Construction Chemicals, 2012

Spray trial comparison with WALOCEL™ MKW Methyl Cellulose based cement render

In order to identify the impact of cellulose ether in terms of stabilizing formulations using varying cement qualities, spray trials were undertaken and feedback collected on all the performance features critical to any cement render.

The formulated material for all benchmark tests contained:

a) 12 % CEM I 42,5 (either Portland slag cement CEM II/B-S or Portland fly ash cement CEM II/B-V)
b) 88 % quartz sand base material for render application (steady particle size distribution, 0 – 1.25 mm)
c) 0.09 % methyl cellulose

The benchmark was pure CEM I 42,5. The standard value was set at 100, meaning a value higher than 100 indicates 'better than standard' and a value below 100 indicates 'inferior to standard'.

A PFT G4 spray plaster machine (which is standard for machine application) was used to apply the materials during the test series, using a 12.5 m length of hose with 25 mm diameter (which is standard on construction sites). A 12 mm thickness of cement render was applied. Consistency was defined at a water demand level of 380 respectively 400 l.

First series tests: WALOCEL™ MKW 20000 PP 20 Methyl Cellulose

The first series of spray trials was done with mortars containing WALOCEL MKW 20000 PP 20 Methyl Cellulose. The results show a very homogenous picture for both cement types, whether formulated with slag or fly ash (see table 4 and 6).

Formulations containing WALOCEL MKW 20000 PP 20 Cellulose Ether show very good results for all critical properties during the application of render, demonstrating excellent shear stability even after strong shearing, with various types of fly ashes. The materials also demonstrate sufficient mortar freshness allowing for good reworking after 30 minutes.

Second series tests: alternative cellulose ether grade

A second series of tests with an alternative cellulose ether grade typically used in cement renders resulted in mortars with relatively robust application features but at a lower performance level: less shear stability, more stickiness to the tool and insufficient performance during the reworking application step (the so-called peeling effect).

Formulations containing competitor grades showed significantly different behaviour compared with those based on WALOCEL MKW Methyl Cellulose, particularly in relation to the critical shear stability.

Feature	Pure CEM I 42,5 WALOCEL™ MKW 20000 PP 20	65 % CEM I 42,5 35 % HS Enningerloh S09 WALOCEL MKW 20000 PP 20	65 % CEM I 42,5 35 % HS Merrit 5000 WALOCEL MKW 20000 PP 20	65 % CEM I 42,5 35 % HS Karcimsa WALOCEL MKW 20000 PP 20
Splattering, wetting	100, good flow	100	100, good flow	100
Tack/standing strength	100	100	100	100
Ease of application	100	105	100	105
Shear stability	100, also after strong shearing	100, also after strong shearing	100, also after strong shearing	100, also after strong shearing
Stickiness to tool	100, little	105	100, little	105
Quality of surface	100, O.k.	100, O.k.	100, O.k.	100, O.k.
Freshness/reworking	100	105, fresh	100	105, fresh
Water demand (gauge)	380 L/hr	380 L/hr	380 L/hr	380 L/hr
Slump (consistency)	200 mm	197 mm	195 mm	185 mm

Table 4: Spray trials *) – impact of slag cement on critical properties (formulation contains WALOCEL MKW 20000 PP 20 Methyl Cellulose)

100 = standard
< 100 = superior
> 100 = inferior

*) Spray trials performed by Dow Construction Chemicals, 2012

Feature	Pure CEM I 42,5 Well-established competitor grade	65 % CEM I 42,5 35 % HS Enningerloh S09 Well-established competitor grade	65 % CEM I 42,5 35 % HS Merrit 5000 Well-established competitor grade	65 % CEM I 42,5 35 % HS Karcimsa Well-established competitor grade
Splattering, wetting	95	100	100	100
Tack/standing strength	100	100	100	100
Ease of application	100	100 – 95	100	100
Shear stability	90 – 95	90 – 95	100, also after strong shearing	90 – 95
Stickiness to tool	105	90	100	100
Quality of surface	100	100	100, O.k.	100
Freshness/reworking	95, little peeling effect	90 – 95, peeling effect	105	90 – 95
Water demand (gauge)	380 L/hr	380 L/hr	380 L/hr	380 L/hr
Slump (consistency)	189 mm	191 mm	187 mm	182 mm

Table 5: Spray trials *) – impact of slag cement on critical properties (formulation contains well-introduced cellulose ether typically used in cement render application)

Feature	Pure CEM I 42,5 WALOCEL™ MKW 20000 PP 20	65 % CEM I 42,5 35 % FA Sament H4 WALOCEL MKW 20000 PP 20	65 % CEM I 42,5 35 % FA Berkament A WALOCEL MKW 20000 PP 20	65 % CEM I 42,5 35 % FA KW Gersteinwerk K WALOCEL MKW 20000 PP 20
Splattering, wetting	100	100, good flow	110, very good flow	95, slight spattering
Tack/standing strength	100	105	105	100
Ease of application	100	105, smooth running	100, good flow	100
Shear stability	100, also after strong shearing	100	100, also after strong shearing	100
Stickiness to tool	100, little	105	95	100, little
Quality of surface	100, O.k.	100	100, O.k.	100, O.k.
Freshness/reworking	100	95, slight peeling effect	95, slight peeling effect	90, peeling effect
Water demand (gauge)	380 L/hr	400 L/hr	400 L/hr	400 L/hr
Slump (consistency)	188 mm	193 mm	193 mm	201 mm

Table 6: Spray trials *) – impact of fly ash cement on critical properties (formulation contains WALOCEL MKW 20000 PP 20 Cellulose Ether)

Feature	Pure CEM I 42,5 Well-established competitor grade	65 % CEM I 42,5 35 % FA Sament H4 Well-established competitor grade	65 % CEM I 42,5 35 % FA Berkament A Well-established competitor grade	65 % CEM I 42,5 35 % FA KW Gersteinwerk K Well-established competitor grade
Splattering, wetting	100	105, very good flow	105	100
Tack/standing strength	100	100	100	100
Ease of application	95 – 90, tight	100 – 95	100 – 95	95 – 90, tight
Shear stability	100	100, also after strong shearing	100	100
Stickiness to tool	100	100	90, stump	95, stump
Quality of surface	95	100	100	100
Freshness/reworking	90 – 95, peeling effect	95, slight peeling effect	90 – 95 peeling effect	85, strong peeling effect
Water demand (gauge)	390 L/hr	400 L/hr	400 L/hr	400 L/hr
Slump (consistency)	176 mm	186 mm	184 mm	179 mm

Table 7: Spray trials *) – impact of fly ash cement on critical properties (formulation contains well-introduced cellulose ether typically used in cement render application)

*) Spray trials performed by Dow Construction Chemicals, 2012

Conclusion

WALOCEL™ Methyl Cellulose offers mortar producers high formulation robustness and consistent performance in formulations using a range of cement qualities.

Test results show that using WALOCEL MKW 20000 PP 20 Methyl Cellulose enabled a consistent product performance in render formulations based on Portland cement (CEM I), Portland slag cement (CEM II/B-S (21–35 % slag)) and Portland fly ash cement (CEM II/B-V (21–35 % fly ash)).

When used in combination with all three cement qualities, WALOCEL Cellulose Ether impart a particularly high level of performance with regard to shear stability, stickiness to tools and smooth-running workability, balancing out the variances in raw materials.

This will be welcome news to mortar producers looking to reduce the carbon footprint of their products without needing to compromise on performance.

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