Evaluating shotcrete accelerator efficiency

Instruments to which this note applies: I-Cal 4000, I-Cal 8000, I-Cal 2000 HPC, I-Cal 4000 HPC, I-Cal 8000 HPC

Target use: Mix Design development and Quality Control at the concrete producer or contractor level.

Introduction

Shotcrete accelerators are added to wet concrete mixes immediately before shotcrete application for the purpose of accelerating set and early strength development, as well as to reduce the so called re-bound. A reduced re-bound essentially means that the amount of material lost from the freshly placed shotcrete is reduced. Modern alkali and chloride free shotcrete accelerators are designed to instantaneously accelerate the formation of cementitious hydrates in the mix, a process which is well suited for evaluation by isothermal calorimetry. The performance of any given shotcrete accelerator typically depends not only on the accelerator formulation, but also the reactivity of the cementitious binder used in the shotcrete mix. Since most shotcrete accelerators work through accelerated formation of calcium aluminate sulfate hydrates, the reactivity of the aluminate and sulfate phases present in the cementitious binder used in the shotcrete mix is of particular importance. Unfortunately it is difficult and in many cases not possible to infer from standard cement chemistry analysis if and how well a given cementitious binder will perform when used with a shotcrete accelerator. Isothermal calorimetry has proven to be an excellent tool for optimizing admixtures for shotcrete as well as for the selection of binders for shotcrete. This application note outlines a simple test procedure that can be used either for selecting binders for a given admixture package, or to optimize the admixture package for a given cement.

Figure 1 shows the typical hydration performance of a cementitious binder in presence of a dispersant and a retarder mixed in a cement paste. These admixtures, which are independent from the shotcrete accelerator, are used to ensure that the concrete remains fluid during transportation from the concrete mixing station to the shotcrete site, which often involves several hours of transportation. While for normal concrete it is not recommended to test for the effect of dispersants and retarders in cement paste, this is normally not an issue for shotcrete, provided that the shotcrete accelerator is strong enough to instantly terminate any retarding effects through massive nucleation of hydration products. This in turn implies the use of a large dose of accelerator relative to the dose of retarder and dispersant.

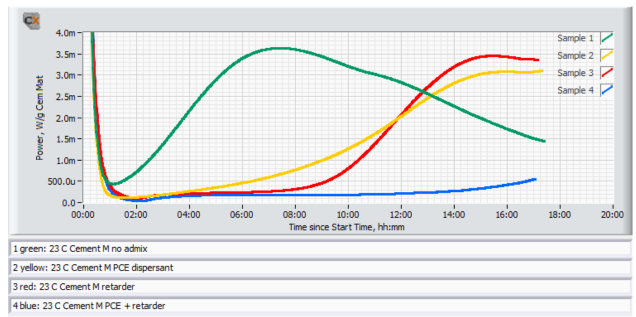

Figure 1. Hydration performance of a cementitious binder "A" in presence of a dispersant and a retarder tested as cement paste at 23 °C without shotcrete accelerator.

Figure 2 shows the hydration performance of the same cementitious binder as in Figure 1, i.e. in presence of a dispersant, a retarder and four different dosages of accelerator.

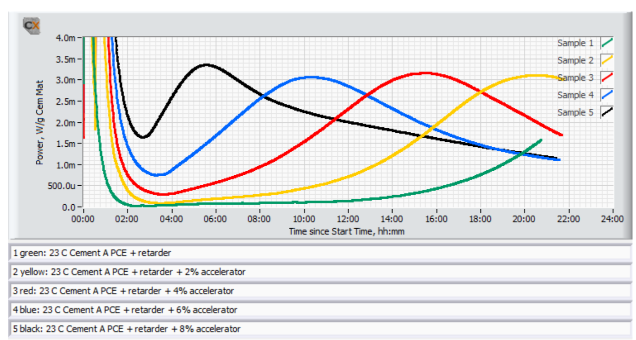

Figure 2. Effect of shotcrete accelerator dose on the hydration performance of a cementitious binder "A" in presence of a dispersant and a retarder tested as cement paste at 23 °C.

Figure 3 shows a zoom-in with more details on the hydration pattern during the first 4 hours after initial mixing, with the accelerator added 30 minutes after initial mixing.

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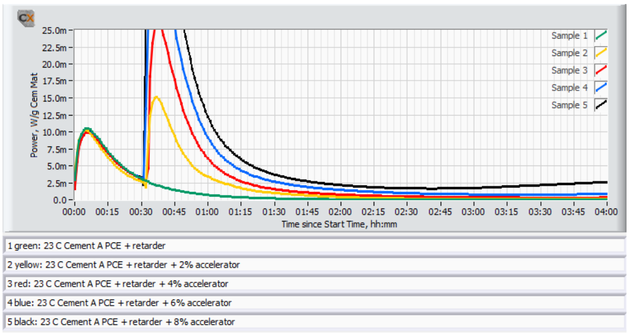

Figure 3. Effect of shotcrete accelerator dose on the early hydration performance of a cementitious binder "A" in presence of a dispersant and a retarder tested as cement paste at 23 °C.

Figure 4 shows the integrated power – Heat of hydration – for the four mixes with accelerator compared to the mix without admixture.

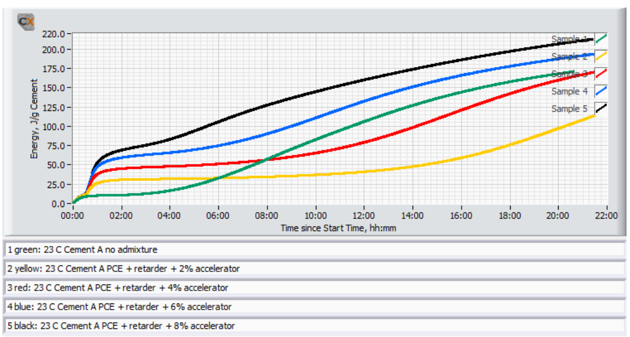

Figure 4. Effect of shotcrete accelerator dose on the Heat of Hydration of a cementitious binder "A" in presence of a dispersant and a retarder tested as cement paste at 23 °C.

A few comments about mixing

Retarders and most dispersing admixtures are known to affect the hydration performance differently in cement paste compared to concrete. Typically these admixtures retard much more in cement paste than in concrete, due to the higher mixing energy introduced in concrete and even mortar compared to cement paste.

However, testing the efficiency of a shotcrete accelerator in concrete or mortar is impractical, since the mix stiffens up within seconds after mixing. Therefore, the most practical method is to prepare a cement paste with all admixtures dosed upfront with the mix water, except for the accelerator. We recommend following the procedure for Heat of Hydration (see Calmetrix Video Tutorial 1). At the desired accelerator addition time, quickly remove the paste sample from the calorimeter and inject the target dose of accelerator, followed immediately by a few seconds mixing using a disposable spatula left in the sample vial, then close the sample lid and re-insert the paste sample into the calorimeter.

Note that provided that the accelerator is fairly efficient, the large dose of accelerator is more than enough to offset any extended retardation caused by the retarding or dispersing admixture in the paste.

Figures 5 to 8 show the corresponding results for a cementitious binder with a not-so-good response to the accelerator. Note how the binder without accelerator performs similar or even better than in the previous example, while the mixes with accelerator do not reach the same level of acceleration as in the previous example. While the accelerator for both binders (binder "A" and binder "I") is able to generate a similar and strong exotherm that likely translates to rapid setting, there is a large difference in the overall size of the main hydration peak (compare Figures 2 and 6). The effect becomes even more apparent when plotting the integrated power – Heat of hydration and comparing it to the binder without admixture (compare Figures 4 and 8).

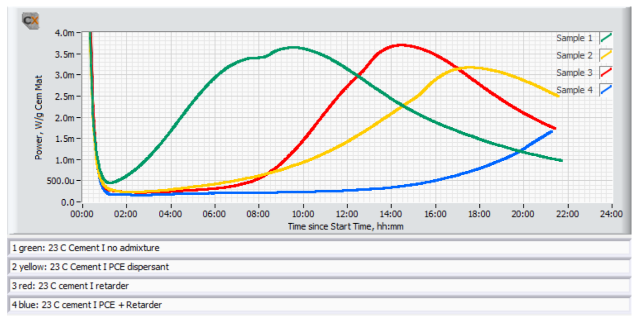

Figure 5. Hydration performance of a different cementitious binder "I" in presence of the same dose of dispersant and retarder as in Figure 1, tested as cement paste at 23 °C without shotcrete accelerator.

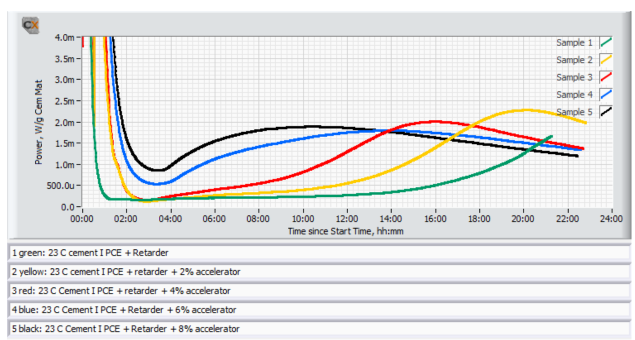

Figure 6. Effect of the same shotcrete accelerator doses as in Figure 2 on the hydration performance of cementitious binder "I" in presence of the same dose of dispersant and retarder as in Figure 2, tested as cement paste at 23 °C.

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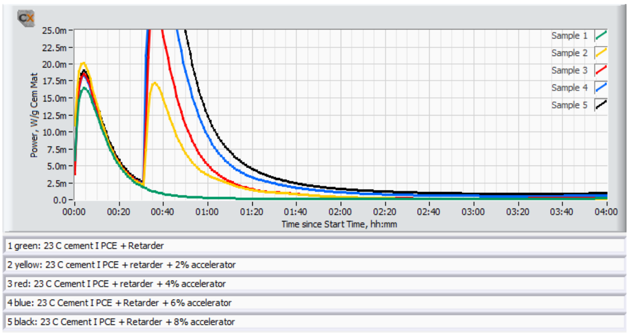

Figure 7. Effect of shotcrete accelerator dose on the early hydration performance of a cementitious binder "I" in presence of the same dose of dispersant and retarder as in Figure 2, tested as cement paste at 23 °C.

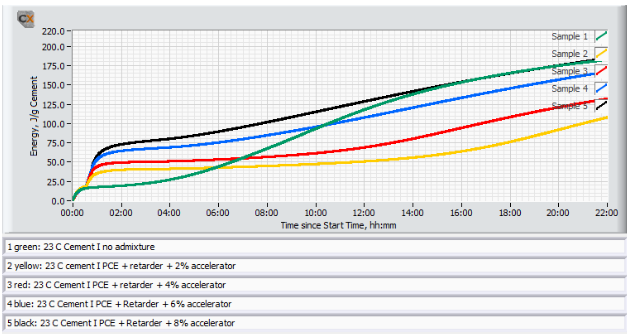

Figure 8. Effect of shotcrete accelerator dose on the Heat of Hydration of a cementitious binder "I" in presence of a dispersant and a retarder tested as cement paste at 23 °C.

Discussion

The performance of most shotcrete accelerators is highly specific to the binder used as shown in this example. The initial exotherm measured immediately after dosing of the accelerator correlates primarily to set (more heat equals more hydrates and therefore faster set), while the main cement hydration peak occurring after the accelerator exotherm correlates to strength development. For a given binder, the relative impact of the accelerator on strength development is most easily visualized by plotting the integrated power – Heat of hydration.

Test Protocol – shotcrete accelerator efficiency in paste

1. Set the calorimeter at the desired test temperature and wait for at least 16 hours for the calorimeter to stabilize.
2. Select an industrial or laboratory cementitious binder sample
3. Weigh 50.0 g cementitious binder in each sample vial
4. Weigh 25 g of mix water in separate sample vials and include any dispersing and/or retarding admixtures to be used in actual shotcrete. Insert the vials with water/admixtures into the calorimeter and start logging. Then wait for the heat flow to stabilize at or very close to zero, at which point the mix water with admixture has reached the desired pre-conditioned temperature. This stabilization normally takes no more than 2 hours provided that the calorimeter has been stabilized as in step #1.
5. Stop logging data, configure each cell for testing.
6. For each cell remove the water from the calorimeter and immediately add the water with admixture to the corresponding cement sample and mix for 30 s, then place the cement paste sample in the calorimeter and start logging. Continue to log data for the desired test duration.
7. At the time of accelerator dosage, for each cell remove the paste sample vial from the calorimeter and immediately add the accelerator to the corresponding paste sample and mix for 10 s using a vortex mixer or a disposable spatula (leave the spatula in the vial after mixing), then return the paste sample vial to the same calorimeter cell and continue logging.

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Calmetrix Product Overview

calmetrix

Calmetrix offers several products for a wide range of applications and adapted to every budget. To choose the calorimeter that is best suited for your needs, we recommend that you first decide between isothermal and a semi-adiabatic, then by number of sample channels, and then by type of testing and applications. You can use the table below, product specifications and the information contained in our website at www.calmetrix.com. And of course, feel free to contact us at sales@calmetrix.com with any questions.

	I-Cal 2000 HPC	I-Cal 4000 HPC	I-Cal 8000 HPC	I-Cal 4000	I-Cal 8000	P-Cal 1000	F-Cal 4000	F-Cal 8000
								
Type of calorimeter	Isothermal	Isothermal	Isothermal	Isothermal	Isothermal	Semi-adiabatic	Semi-adiabatic	Semi-adiabatic
Number of test channels	2	4	8	4	8	1	4	8
Sample type (C=cement, M= mortar, CT=concrete)	C, M, CT	C, M, CT	C, M, CT	C, M, CT	C, M, CT	C, M, CT	C, M, CT	C, M, CT
Sample size for mortar or concrete	up to ~320 g	up to ~320 g	up to ~320 g	up to ~320 g	up to ~320 g	up to ~4.5 kg	up to ~4.5 kg	up to ~1.9 kg
Test duration	0 - 28 days	0 - 7 days	0 - 7 days	0 - 72 hours	0 - 72 hours	0 - 28 days	0 - 48 hours	0 - 48 hours
Standards								
ASTM C1679 (Isothermal Calorimetry)	✔	✔	✔	✔	✔			
ASTM C1702 (Heat of hydration testing)	✔	✔	✔					
Examples of Applications (partial list)								
Mix Design Optimization	✔	✔	✔	✔	✔	✔	✔	✔
Detect Cement - admixture interaction	✔	✔	✔	✔	✔	✔	✔	✔
Characterization of fly ash, slag, etc.	✔	✔	✔	✔	✔	✔	✔	✔
Optimal admixture dosage and addition time	✔	✔	✔	✔	✔	✔	✔	✔
Compare different sources of materails (QC)	✔	✔	✔	✔	✔	✔	✔	✔
Sulfate optimization	✔	✔	✔	✔	✔			
High temperature studies (> 50 °C)	✔	✔	✔					
Compressive strength estimation	up to 28 days	up to 28 days	up to 28 days	up to 48 h	up to 48 h	up to 28 days		
Setting Time estimation	✔	✔	✔	✔	✔	✔	✔	✔
High Volume Fly ash mix testing	✔	✔	✔	✔	✔	✔	✔	✔
Shotcrete testing	✔	✔	✔	✔	✔		✔	✔
Field testing (portable equipment)						✔	✔	✔
Determination of activation energy	✔	✔	✔	✔	✔			
Admixture formulation	✔	✔	✔	✔	✔			
Sensitivity tests on temperature variations	✔	✔	✔	✔	✔			

Ihr Ansprechpartner in der DACH-Region:

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