A Chinese success story

While the use of chemical additives is well established in the cement industry, customised additives can have the edge over off-the-shelf solutions. One Chinese cement plant called in GCP Applied Technologies to develop an additive to improve its PO 42.5 cement.

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Cement plants have used chemical additives for more than 80 years. From grinding aids to quality improvers, cement additives are now well known and widely used in the industry.

The need for customisation

But not all cement additives are the same, and GCP Applied Technologies believes its customised solutions are able to provide greater customer value.

The customisation of grinding additives enables cement producers to supply a product in line with its customer needs and as such is part of the drive for continuous improvement of the cement quality, its production cost and the cement company's competitiveness in the market.

GCP Applied Technologies (formerly WR Grace) has recently invested in a brand-new research laboratory in Beijing, which includes the skills of a talented team and the use of state-of-the-art equipment and processes for the development of customised cement additives.

However, to provide the optimally-customised product, GCP works closely with its customers. Objectives and constraints of the additive are defined and the best solution is identified that meets all performance requirements at minimum cost. The following case study highlights the benefits of using an advanced and customised GCP product for one of the largest cement plants in western China.

Objectives

The cement plant produces several million tonnes of a PO 42.5 cement per year. No additive had been used prior to this study.

From about 2013 a rapid increase in market competition was seen all over China, mainly as a consequence of overcapacity. In response, cement plants started to look at ways to improve their competitiveness, including the use of quality improvers.

The performance of the cement in its final application in concrete (as opposite to that as measured by mortar or paste standards) was identified as crucial to success in the specific example being studied.

XiTao Deng, Riccardo Stoppa and Kieren Qiu at the grand opening ceremony of the GCP Beijing laboratory and office facilities in March 2016

After a preliminary screening of different chemical suppliers, GCP Applied Technologies (at the time known as WR Grace) was chosen as the preferred partner to help with the project, of which the target was not only complex and ambitious but also kept evolving over time.

GCP assigned a dedicated team to the project, including a sales engineer, a formulator and a concrete expert to work with the staff at the cement plant. Following a visit to the plant and numerous ready-mix producers, the objectives of the project were identified as follows:

1. strength enhancement at all ages to allow a clinker replacement of up to five per cent
2. improved particle size distribution (for the same purpose as under 1.)
3. retardation of setting time of 30min
4. constant water demand in paste (normal consistency)
5. improved slump retention up to 120min (as measured in a standard concrete mix design).

The customisation study also involved testing up to four supplementary cementitious materials (SCMs), all available at the customer site, and the effect of the SCMs and cement additives on the following cement characteristics:

- compressive strengths (mortar and concrete)
- particle size distribution (cement powder)
- initial and final setting time (mortar)
- normal consistency (paste)
- calorimetry and sulphate balance optimisation (paste)
- rheology (mortar flowability and concrete slump/slump retention/slump flow).

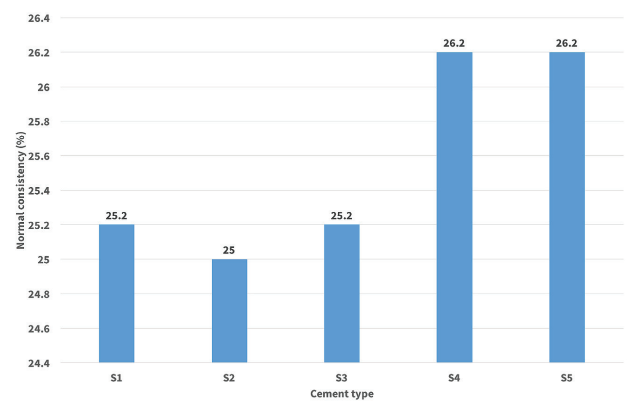
SCM optimisation

The cost and availability of the SCMs, as well as their effect on cement strength, were directly assessed at the plant.

Their effect on normal consistency and mortar flowability is shown in Figures 1 and 2.

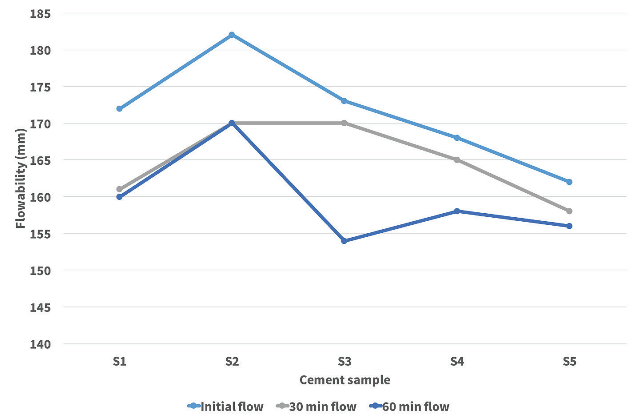
After evaluating the cost, availability and performance characteristics of all four SCMs (slag, basalt, low siliceous sandstone, high siliceous sandstone), ground granulated blastfurnace slag (GGBS) was finally selected as the primary means for clinker replacement.

Figure 1: the effect of different SCMs on normal consistency



S1 = blank cement – S2 = 10% slag addition – S3 = 10% basalt addition – S4 = 10% low siliceous sandstone addition – S5 = 10% high siliceous sandstone addition

Figure 2: the effect of different SCMs on mortar flowability



S1 = blank cement – S2 = 10% slag addition – S3 = 10% basalt addition – S4 = 10% low siliceous sandstone addition – S5 = 10% high siliceous sandstone addition

Table 1: effect of sulphate addition on mortar flowability

Cement	Initial flow (mm)	1h flow (mm)	2h flow (mm)
Blank	231 ±2	209 ±2	162 ±2
Blank + 0.3% SO_3	236 ±2	218 ±2	172 ±2

Table 2: results of the first field trial with GCP 215 additive

Sample	Additive	Dosage (%)	SO_3 (%)	Clinker (%)	Lime-stone (%)	Slag (%)	Basalt (%)	Gyp-sum (%)
1	Blank		2.9	79.0	8	3.5	3.5	6.0
2	GCP 215	0.10	2.9	74.0	8	**6.0**	**6.0**	6.0

Table 3: results of the first field trial with GCP 215 additive

Sample	45µm (%)	Blaine (m²/kg)	NC (%)	IST (min)	FST (min)	3d CS (MPa)	28d CS (MPa)	Flow spread (mm)	Flow spread in 1h (mm)	Flow spread in 2h (mm)
1	10.4	371	24.5	160	205	29.8	50.2	585	625	630
2	**8.5**	371	25.0	158	211	29.5	49.9	**620**	595	535

Sulphate optimisation

To verify the SO_3 optimum, 0.3 per cent of SO_3 was added in the form of calcium sulphate hemihydrate to the blank cement, and the retention of mortar flowability was measured, as shown in Table 1.

An improvement over the entire 120min of analysis was observed, suggesting the need for a slightly higher "gypsum" addition during cement manufacturing. Following plant verification, the additional SO_3 level was implemented in cement formulation.

First field trial

A first field trial was run with the GCP 215 quality improver, as identified by preliminary GCP laboratory tests. Due to slag availability issues, the field trial was run by replacing clinker with both slag and basalt. The results of the field trial are shown in Table 2 and Table 3.

The field trial results with the GCP 215 additive were partially positive, ie targets were met for:

- strength enhancement at all ages (same strengths at 3 and 28 days while decreasing clinker from 79 to 74 per cent)
- mortar flowability (flow increased from 585 to 620mm at time 0)
- improved particle size distribution (Alpine residue at 45µm decreased from 10.4 to 8.5 per cent at constant Blaine specific surface area).

Insufficient results were achieved for setting time (no retardation) and flow retention for 120mins.

Advanced customisation

Several new chemicals and their combinations were screened in GCP's Beijing laboratories to find a new formulation able to provide the same strength enhancement and grinding aid

Table 4: mortar screening of selected customised additives (only showing retardation of IST and flow)

Additive	Retardation of IST (min)	Initial flow (mm)	1h flow (mm)	2h flow (mm)
Blank	-	231	209	161
EXP 04	61	235	233	206
EXP 08	73	237	228	204
EXP 12	**85**	**234**	**225**	**210**

Table 5: concrete rheology with and without best customised additive (same w:c ratio)

Additive	Initial slump (mm)	Slump at 1h (mm)	Slump at 2h (mm)
Blank	231	209	161
EXP 12	230	**225**	**202**

Table 6: results of the second field trial with GCP 31 additive (paste/mortar)

Cement sample	Clinker (%)	Limestone (%)	Slag (%)	Gypsum (%)	Normal consistency (%)	IST (min)	FST (min)	3d CS (MPa)	28d CS (MPa)
Blank	78.5	8.0	7.5	6.0	26.4	198	257	28.3	56.0
GCP 31	75.5	8.0	**10.5**	6.0	26.6	**221**	**288**	28.9	56.5

Table 7: results of the second field trial with GCP 31 additive (concrete)

Cement sample	Water (wt %)	Cement (wt %)	Fly ash (wt %)	Sand 1 (wt %)	Sand 2 (wt %)	Total aggregates (wt %)	Plasticiser (wt %)	Slump (mm)	Flow spread (mm)	Slump in 2h (mm)	Flow spread in 2h (mm)
Blank	7.6	10.4	4.1	14.6	21.9	41.3	0.11	235	535	220	450
GCP 31	7.6	10.4	4.1	14.6	21.9	41.3	0.11	235	**570**	220	**555**

GCP's mortar laboratory in Beijing, China

GCP's grinding room in Beijing, China

contribution of the GCP 215 additive, and delay the setting time and improve concrete rheology up to two hours. Selected results with new experimental additives are reported in Table 4.

The best candidate formulations were tested in concrete, with a standard mix design and reference materials as defined by the plant. Results with the best solution ("EXP 12") are reported in Table 5, showing a good improvement of slump retention over the target period of two hours (at same initial slump and w:c ratio).

Second field trial

The results with the EXP 12 additive were considered satisfactory, and a second field trial was eventually run with a modified version of the EXP 12, ie the "GCP 31" additive, as shown in Table 6 (mortar tests) and Table 7 (concrete tests).

Field trial results confirmed the expectations (most notably, higher share of slag at same early strengths, longer setting times, improved concrete rheology) and the GCP 31 additive has been in use at the plant ever since.

Summary

A tailor-made additive was designed and put in place in one of the biggest cement plants in the world, located in western China. The use of the additive allowed the cement plant to deliver a better and more competitive PO 42.5 cement to the market, most notably having a higher SCM content and improved concrete rheology.

The case study is a good example of what an advanced and customised additive is able to provide versus off-the-shelf standard additives, a result achieved by the combined expertise of cement producers and GCP Applied Technologies. ■