Smart dynamic construction

Friendlier self-compacting concrete

The use of Self-Compacting Concrete (SCC) in the precast industry has increased significantly from its introduction in the market, in the mid 1990s'. It is estimated that, in Europe, more than 50% of the concrete used for structural precast elements is SCC. However, the situation is quite different in the ready-mixed concrete industry where less than 1% of the concrete produced is SCC. The reasons of such scenario are mostly related to the higher cost of the material, which, very often, is supplied with excessive mechanical performance due to the higher cementiticious paste content necessary to achieve self-compactability requirements.

It has been demonstrated that the introduction of the Smart Dynamic Concrete (SDC) concept, associated to the production of SCC with low fine contents by making use of an innovative viscosity modifying admixture (VMA), can allow the ready-mix concrete industry to increase the energy efficiency, achieve a higher concrete durability and accomplish more rational and economical construction processes, reducing CO_2 emissions, and also increasing productivity.

This work presents and discusses the optimization of normal strength SCC mixes (25-35 MPa) with low content of fines through the application of the SDC concept, and corresponding field test results from experiences in different ready-mix and precast concrete plants. The analysis also includes the evaluation of the material robustness.

■ B. Barragan, BASF Construction Chemicals,
Admixture Systems Europe, Treviso, Italy
J. Roncero, BASF Construction Chemicals,
Admixture Systems Europe, Barcelona, Spain
R. Magarotto, S. Moro, R. Khurana,
BASF Construction Chemicals,
Admixture Systems Europe, Treviso, Italy ■

Self-consolidating concrete (SCC) is undoubtedly the major advance of concrete technology in the last two decades. Mainly due its flowability, SCC differs from conventional vibrated concrete essentially when in fresh state.

Guidelines and Standards

Currently, a number of guidelines are available for the proportioning, characterization, control and application of SCC [e.g. 1-7] which are accompanied by national standard test methods [e.g. 8-13] and, in some countries, like Spain, by code specifications [14].

The recommendations by the Japanese Society of Civil Engineers [1] define three types of SCCs according to the use of fines (type P), viscosity modifying agents (type V) or the combined used of both (type C). In type P, self-compactability is obtained by minimizing the ratio water/fines through the use of superplasticizers to provide appropriate resistance to segregation and bleeding. In the case of type V, the use of Viscosity Modifying Admixtures (VMA) provides enough stability to the concrete towards bleeding and segregation, since these admixtures fix the water providing the appropriate rheology to the cement paste. Type C consists of the combination of the other two types.

On the other hand, the European Guidelines [4] define different types of SCCs according to its fresh properties, regardless the composition of the concrete. Along these lines, there are three levels of self-compactability according to the value of slump flow:

SF1: from 550 to 650 mm (21,7 to 25,6 in.)
SF2: from 660 to 750 mm (26,0 to 29,5 in.)
SF3: from 760 to 850 mm (29,9 to 33,5 in.);
two levels of viscosity according to the value of T_{50} or the time to pass through the V-funnel, T_V:
VS1/VF1: $T_{50} \leq 2$ s or $Tv \leq 8$ s
VS2/VF2: $T_{50} > 2$ s or $9 \text{ s} \leq Tv \leq 25$ s
and two levels of passing ability according to the passing ratio in the L-box:
PA1: ≥ 0.80 with 2 bars
PA2: ≥ 0.80 with 3 bars.

In spite of the fact that these two guidelines [1, 4] involve the use of a wide range of SCC both considering its composition, as well as its fresh properties, the reality of the market indicates that SCC is mainly characterized by high content of fines, usually in the range from 450 to 600 kg/m^3 (28,1 to 37,5 lb/ft^3), along with a low volume of coarse aggregates. This high content of fines, which provides high volume of cementitious paste (i.e., within 35-40% by volume), is needed in order to provide flowability, passing-ability, and enough cohesion able to prevent bleeding and/or segregation.

SCC rheology

Though historically with only academic interest, rheological studies using concrete viscometers have become more important with the appearance of SCC, up to the point that the material itself can be defined and characterized in terms of its rheological parameters, such as the yield stress (T_0) and plastic viscosity (μ) [15]. The rheological studies have permitted a deeper comprehension of the material behavior, allowing in this way a more rational mixture proportioning. SCC is characterized by having very low yield stress (T_0) and enough plastic viscosity (μ), which redounds in the material flowability, passingability, and segregation resistance during transport, casting and hardening; the engineering properties of the material. In this manner, SCC requires an adequate combination of T_0 and μ to allow for mobility without segregation. Generally, very viscous mixes require a T_0 value close to zero, while a higher value of such parameter can be convenient in the case of low viscosity mixes. A combination of extremely low T_0 and μ could imply risks of segregation [15].

The composition of SCCs varies significantly from one country to another. According to [16], the content of fines in Sweden and The Netherlands is usually higher than 550 kg/m^3 (34,3 lb/ft^3) with yield values and plastic viscosity values ranging from 0 to 30 Pa and from 50 and 120 Pa·s, respectively. These ranges agree with those shown in a recent study by [16]. In Denmark, Norway and Iceland, the content of fines is usually lower than 450 kg/m^3 (28,1 lb/ft^3) with yield values and plastic viscosity ranging from 10 to 60 Pa and from 20 to 45 Pa·s, respectively. Along these lines, the concrete with higher content of fines is characterized by a higher plastic viscosity and is suitable for heavily reinforced structures, whereas the concrete with lower content of fines show higher yield values being more suitable for lightly reinforced structures.

Even when the use of rheometers or viscometers leads to a better characterization of conventional concrete and SCC [17], their use is usually more expensive and difficult in field applications. Progress is being

Bryan E. Barragan holds a Doctoral Degree in Civil Engineering from the Universitat Politecnica de Catalunya (Barcelona, 2003). Since 2008 he has been a concrete technology research specialist of the Technology and Development team of BASF Construction Chemicals- BU Admixture Systems Europe, Treviso, Italy. Has co-authored more than 100 technical publications in different fields of concrete technology, largely on fiber-reinforced concretes and self-compacting concretes.

bryan.barragan@basf.com

Joana Roncero graduated in Chemistry in 1994 at the University of Barcelona and received a Ph.D degree in 2000 at the Civil Engineering School of the Technical University of Catalunya in Spain. She has been working in concrete technology since 1995. Since 2004 she has been head of the Technology and Development Center in Spain of the European Business Unit Admixture Systems of BASF Construction Chemicals. Her research interests include admixture development and utilization, concrete technology, self-compacting concrete and high performance concretes.

Roberta Magarotto graduated in Industrial Chemistry at Venice University (Italy). Since 1993, she has been working in the field of concrete admixtures focusing in the development of new polymeric superplasticizers and the study of cement-admixtures interaction. From 2002 to 2007 she had been head of the Admixture Department of R&D at BASF Construction Chemicals Italy. Since 2008, she has been head of the Technology and Development of the European Business Unit Admixture Systems of BASF Construction Chemicals (E-EBA/D)

Sandro Moro graduated in Sciences and Technology of Materials at Venice University (Italy). Since 2001 he has been Head of the Technological Laboratory at BASF Construction Chemicals Italia Spa, where he has been working in the fields of concrete admixtures development and concrete technology development.

Rabinder S. Khurana obtained his Post-graducted Diploma in Reinforced Concrete Structures from Milan Polytechnic Italy. He has more than 30 years of experience in concrete technology and admixtures application worldwide.

made to address this issue and some portable equipment has been recently developed [18,19]. In this way, the relationships between rheological parameters and results from engineering type tests turn to be of great practical importance. In this regard, it is shown in [20] that SCC prepared with similar types of component materials show direct relationships between the slump flow diameter and the yield stress and also between the plastic viscosity and the flow times (T_{50} or T_V), even when the concrete temperature, the mixing energy, the environmental conditions or the time after mixing was varied (Fig. 1)

The actual situation

The use of SCC in the precast industry has increased significantly from its introduction in the market, in the mid 1990s'. It is estimated that, in Europe, more than 50% of the concrete used for structural precast elements is SCC. However, the situation is quite different in the ready-mixed concrete industry where less than 1% of the concrete produced is SCC. The reasons of such scenario are mostly related to the higher cost of the material, which, very often, is supplied with excessive mechanical performance due to the higher cementiticious paste content necessary to achieve self-compactability requirements.

On the other hand, the use of additional fines (fillers) can also imply new silos and more quality control testing that, along with the elevated cement content, and the higher sensitiveness of SCC to variations of the mix proportions, can consequently lead to an increase in production costs.

QUADRA

MANUFACTURER FOR THE CONCRETE INDUSTRY

QUADRA solutions are reference in terms of innovation, flexibility and productivity. Quadra is represented worldwide to serve the concrete industry.

CUSTOMISED EQUIPMENT

- Production units with vibrating presses
- Transfer and handling systems
- Wet cast production lines
- Robotic applications
- High precision concrete block milling machine
- Batching and mixing plant

MACHINE TO PRODUCE

- Pavers, blocks, slabs, kerbs, landscape products, ...

Robotic application

High precision concrete block milling machine

Wet cast production

Contact our sales / distribution service at +33 (0)4 50 03 92 21
www.quadra-concrete.com

Location : 40 route de Findrol - 74130 Contamine-sur-Arve - France
Tel. : +33 (0)4 50 03 92 21 - Fax : +33 (0)4 50 03 69 97 - info@quadra-concrete.com

Evidently, it is technically difficult to prepare SCC with low content of fines (cement + filler), even using currently available VMAs. On the other hand, the characteristics of locally-available materials (i.e., cement, aggregates and filler) for SCC production are not always the most appropriate, and consequently, a lot of laboratory work is needed in order to adjust the mixture proportions with the aim of obtaining stable concrete. Also, variations in the moisture content of the aggregates, especially of the sand, can significantly influence the stability of the SCC, implying continuous adjustments in the mixture proportions.

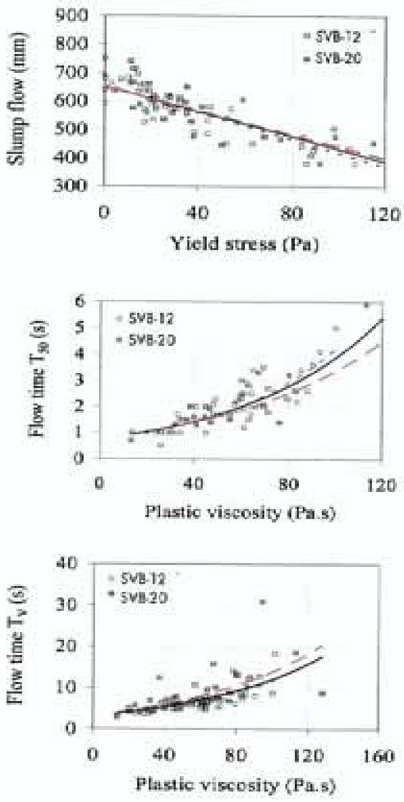


Fig. 1: Relationship between engineering measurements and rheological parameters

Consequently, the use of SCC as a common every-day concrete is nowadays difficult, especially in the case of the ready-mixed concrete industry. Note that, the required mechanical performance in most of the applications is significantly lower than that provided by standard SCC (i.e., with high amount of fines) and, therefore, SCC is supplied, very often, with suboptimal performance.

An innovative alternative

The above reality justifies the development of an innovative VMA, which is allowing the design of SCC with the required stability (bleeding and segregation resistance) but without incorporating extra fines and, consequently, having a total content of fines (cement + filler) of about 380 kg/m³. The use of this new family of VMAs, along with superplasticizers especially designed for SCC, leads to the development of smart dynamic concrete [21 - 23], in other words, to an improvement in the cost-effectiveness of SCC that can contribute expanding its use in the ready-mixed concrete industry, as well as consolidate its use in the precast concrete industry.

This study presents the results of industrial-scale testing in different European countries, aimed at achieving the following objectives: proportioning SCC with normal cement contents for everyday concrete, study the possible upgrade of conventional concretes of high workability into concretes with self-compacting characteristics, and the possibilities of replacing/reducing the filler content of reference SCC maintaining the compressive strength and its evolution.

Results demonstrate the usefulness of the new VMA to overcome the common drawbacks of current type of admixtures, and its capacity to increase the mix robustness and decrease the necessity of filler materials, if desirable. Such powerful capacities could certainly help self-compacting concrete increase its market share in the ready-mix sector and further consolidate its use in precast applications, leading to more productive, environmentally friendly, optimized and smart construction processes.

Mechanism of action

The preparation of SCC with low fines content requires the optimum control of the rheological parameters providing the appropriate balance between the high fluidity needed and the stability required (bleeding and segregation). In this respect, a VMA able of assuring enough plastic viscosity without sacrificing the slump flow of the concrete, that is, without modifying significantly the yield value, is essential.

Some state of the art VMAs belonging to different chemical families (natural gums, starches and synthetic polymers) modify the rheology of concrete mainly by increasing the yield value without providing significant improvement of the plastic viscosity as can be seen in Fig. 2. Note that these tests were done in mortars from concretes that were sieved at 2 mm and tested with a Viskomat NT rheometer from Schleibinger Geräte. Note, also, that the dosage of each VMA was adjusted in order to obtain a slump flow of about 65 cm in each concrete. Moreover, in other cases, the VMA does not affect the yield value but provides a slight increase in the plastic viscosity. Note, additionally, that in other cases (see Natural Gum A and B), both the yield value and the plastic viscosity are not affected when compared to the reference mortar. Nevertheless, as can be seen in the figure, the new and innovative VMA is able to increase significantly the plastic viscosity of the mortar without influencing the yield value and, consequently is able to provide stable concrete without affecting significantly

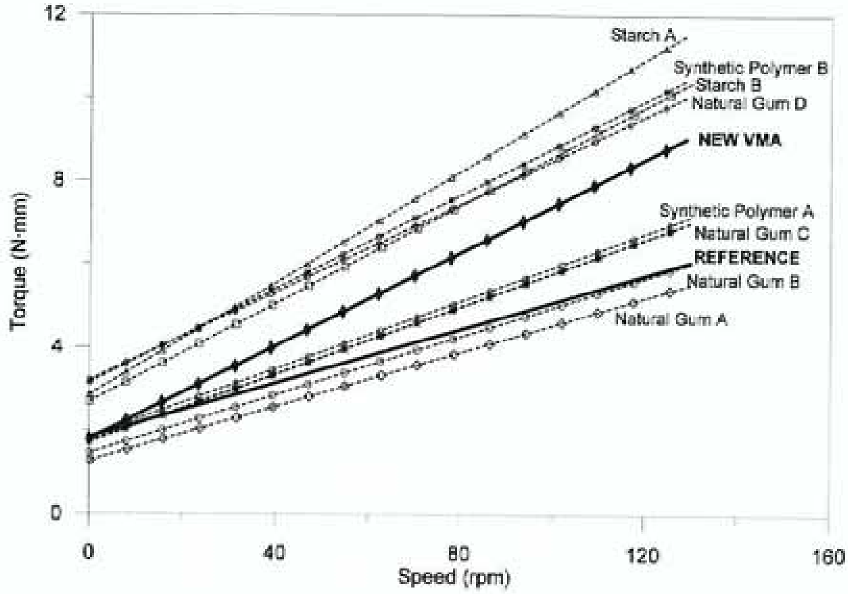


Fig. 2: Influence of several commercial VMAs on the rheology of mortar compared to a reference mortar without VMA and to the new VMA. Note that the mortars tested in the rheometer were obtained by sieving the concretes

its slump-flow. This innovative chemical admixture consists in a new ionic polymer of high molecular weight whose molecules interact between them apart from interacting with the water molecules. This leads to a tridimensional structure that embraces both water molecules and fine solid particles (cement and the fines belonging to the sand). This tridimensional network made up, not only by VMA-water interactions, but also by VMA-VMA and VMA-solid particles interactions as shown in Fig. 3, leads to a strong interconnected molecular network able to provide, at the macroscopical level, enough stability in the concrete.

The use of this innovative VMA provides the appropriate stability in the concrete towards segregation and/or bleeding in concretes with paste volume significantly lower than those used usual for SCC. Along these lines, the rheological behavior of this type of concretes depends on the optimized mixture proportions of the concrete, as well as the use of chemical admixtures of last generation. Accordingly, high-performance polycarboxylate-based superplasticizers are needed to modify and control the yield value (T_0) of the concrete, whereas, the plastic viscosity (μ) is optimized through the use of the new VMA.

Mixture proportioning

The most important characteristic of smart dynamic concrete lies in its composition. In this way, the amount of cement and water will be fixed by the mechanical and durability requirements, since its composition is quite similar to that of conventional vibrated concrete of similar strength class. The self-compacting ability is obtained by means of using the latest generation superplasticizers with high-water reducing ability, the new and innovative VMA, as well as the optimization of the amount and quality of the mortar. Therefore, in comparison to conventional vibrated concrete, SCC with low fines content has higher proportion of sand (Ø < 4 mm, 0.16 in.). This is needed in order to ensure the appropriate transport of the coarser aggregates during placing and decreasing their risk of segregation.

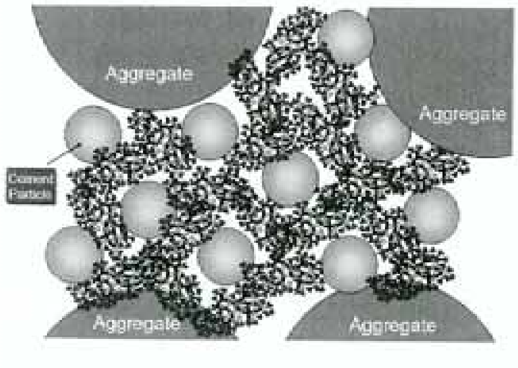


Fig. 3: Mechanism of action of the innovative VMA called RheoMATRIX that provides a tridimensional network made up by admixture-admixture, admixture-water, and admixture-solid particles interactions

Experimental program

The experimental program involves a wide industrial-scale test program aimed to study the possibilities of the new VMA to provide sufficient stability yet not compromising the flowability, while keeping the fine contents at a minimum. These industrial tests were carried out in several European countries (Germany, Italy, Spain and Turkey) focusing on obtaining concrete with self-compacting properties but with reduced fines content in comparison to standard SCC.

The material characterization in the fresh state included the slump-flow test, and in some cases the determination of the unitary weight. In more qualitative terms, the general material appearance, the stability after the slump-flow test (bleeding or paste halo), and stickiness, was evaluated.

Decrease cement content

The main objective of these industrial tests consists in minimizing the cement content of a reference SCC with the objective of obtaining compressive strengths in the range of 25-35 MPa (3600-5000 psi). Industrial tests in two different Spanish plants were performed (plant A and B). In plant A, the reference SCC has a composition based on 412 kg/m³ (25.7 lb/ft³) of cement without filler, and crushed limestone aggregates, as can be seen in Table 1 (Reference-A). As described, the objective of the tests consists in obtaining a cost-efficient mixture with self-compacting properties and low-medium compressive strengths.

In these experiences, the use of the innovative VMA has permitted decreasing the cement content to 310 kg/m³ (19.4 lb/ft³), still maintaining the stability of the concrete towards bleeding and segregation. The composition and properties of this concrete (SDC-A) is also shown in Table 1. Note, also, that some fly ash belonging to the cement appears in the surface of the reference concrete. However, the presence of fly ash in the surface of the concrete was avoided in the concrete with the new VMA, denoting high stability. It is important also to highlight the appearance of the concrete with lower fines content (SDC-A), which is less sticky and easy to handle than the reference SCC with higher fines content. The appearance of the concretes described in Table 1 is shown in Fig. 4.

A similar experience was done in plant B where, as in the previous case, the cement content was decreased in comparison to a reference SCC with the aim of obtaining SCC with compressive strength in the range of 25-30 MPa (3600-4350 psi). The dosage of the reference concrete, with 400 kg/m³ (25.0 lb/ft³) of cement, is shown in Table 2.

In this case, the cement content was decreased by 50 kg/m³ (3.1 lb/ft³) through the incorporation of the new VMA, maintaining

Table 1: Composition and properties of reference SCC and smart dynamic concrete with lower fines content in plant A

Composition in kg/m³	Reference-A	SDC-A
0-2 mm sand	330 (20.6)	350 (21.8)
0-4 mm sand	760 (47.4)	840 (52.4)
4-12 mm gravel	700 (43.7)	700 (43.7)
CEM II/B-M 42.5R*	412 (25.7)	310 (19.4)
Water	175 (10.9)	190 (11.9)
Superplasticizer (Glenium type)	7.6 (0.5)	5.5 (0.34)
New VMA	–	0.5 (0.03)
Properties		
Slump flow	63 cm (24.8 in.)	57 cm (22.4 in.)
Appearance	Slight bleeding. Presence of fly ash in the surface of the concrete	Good, without bleeding or segregation
Compressive strength, 7 days	39.9 MPa (5790 psi)	25.6 MPa (3710 psi)

* *Composition of Portland cement CEM II/B-M according to European Standard EN-197: 65-79% of clinker + 21-35% of blends of slag, silica fume, natural pozzolan, fly ash or limestone + 0-5% minority components*

Fig. 4: Appearance of (a) reference concrete and (b) smart dynamic concrete in plant A

the stability of the concrete as shown in Table 2 (SDC-B). The appearance of both concretes is shown in Fig. 5. As in the previous case of plant A, this concrete has a less sticky appearance in comparison to the reference SCC (Reference-B).

Upgrading of conventionally vibrated concretes

The objective of these field tests consist in obtaining concretes with self-compacting properties but with the same ease of production and robustness as conventional vibrated concrete, at minimum extra cost. The results of tests performed in three different ready-mixed concrete plants (C, D and E) are presented.

In plant C from Italy, the reference concrete has a consistency class S4 and exposure class XC2 (characteristic compressive strength of 30 MPa or 4350 psi) according to EN 206-1. The durability class fixes the amount of cement and the water/cement needed. The mixture proportions of the reference concrete are shown in Table 3 (Reference-C). Accordingly, 800 m³ (1046 yd³) of concrete with the composition shown in

Table 2. Composition and properties of reference SCC and smart dynamic concrete with lower fines content in plant B

Composition in kg/m³	Reference-B	SDC-B
0-2 mm sand	558 (34.8)	558 (34.8)
0-4 mm sand	596 (37.2)	646 (40.3)
4-10 mm gravel	604 (37.7)	604 (37.7)
CEM II/B-M (V-S-LL)*	400 (25.0)	350 (21.8)
Water	260 (16.2)	255 (15.9)
Superplasticizer (Glenium type)	7.0 (0.44)	7.0 (0.44)
New VMA	—	1.0 (0.06)
Properties		
Slump flow	77 cm (30.3 in.)	73 cm (28.7 in.)
Appearance	Good, without bleeding or segregation	Good, without bleeding or segregation
Compressive strength,		
7 days	38,0 MPa (5510 psi)	22,0 MPa (3190 psi)
28 days	47,1 MPa (6830 psi)	33,2 MPa (4820 psi)

* *European Standard EN-197: 65-79% of clinker + 21-35% of blends of fly ash, slag and limestone + 0-5% minority components*

INTERNATIONAL LTD

For Low Transport & Installation Costs Choo a Mobile Batch Plant fr Rapid International...

RUNNING COSTS FR AS LITTLE AS 39p/m

- 120m³ Max Output Including Twin Shaft Mixer
- Includes Aggregate Bin Unit
- Control Cabin and Cement Si
- Easy On-Site Set Up
- Full Mobility from Job to Job
- No Foundations Required
- Short Mixing Times

www.rapidinternational.

Rapid International Ltd
96 Mullavilly Road - Craigavon
Co. Armagh - N. Ireland- BT62 2LX

Tel: +44 (0) 28 38840 671
Email: info@rapidinternational.com
Web: www.rapidinternational.com

Fig. 5: Appearance of (a) reference concrete and (b) smart dynamic concrete in plant B

Table 3 (SDC-C) were prepared in series of 10 m³ (13 yd³). The mixing was done directly in the truck since no mixer was available in the plant. The chemical admixtures (superplasticizer and the new VMA) were incorporated along with the mixing water. The concrete was transported one hour before placing (Fig. 6), and the temperature at the job site was of 30°C (86°F).

In plant D from Turkey, the reference concrete was a conventional concrete with characteristic compressive strength of 25 MPa (3600 psi) and S3 consistency that had to be vibrated. The superplasticizer used was naphthalene-based. The composition of this reference concrete, as well as the composition of the concrete with the new VMA, is shown in Table 4.

In this case, 8 m³ (10 yd³) of concrete SDC-D with self-compacting characteristics were prepared in batches of 2 m³ (2.6 yd³) that were pre-mixed before discharging in the truck. The concrete, which shows a slump flow of 71 cm (27.9 in.), was transported throughout 90 minutes at 38°C (100°F). After this period, the slump flow was measured again and was of 60 cm (23.6 in.). Finally, in plant E from Germany, the corresponding reference mixture proportioning was optimized and upgraded to self-compacting concrete. The reference concrete at this plant had a consistency of type F5 according to DIN 18218 with a composition shown in Table 5, and need vibration. In this case, 24 m³ of concrete SDC-E, as described in Table 5, was prepared. The concrete was transported for 30 minutes before being placed (Fig. 7).

In these cases, the use of the new VMA allowed transforming conventional vibrated concretes of S3, S4, and F5 classes into truck-mixed medium-range self-compacting concretes, capable of maintaining its self-compactability during realistic periods of time, even at elevated temperatures. The robust SCCs achieved also maintained the reference compressive strength.

Replacement of the filler

The objective of this test program was to completely eliminate the filler used in the mixture proportioning of a reference SCC and to propose an alternative composition able to provide similar strength development at plant F, in Spain. This would permit to free a silo that is currently used to store filler and, consequently, to improve the logistics at the plant. The sand available was natural siliceous sand with about 1% of fine content (Ø < 0.125 mm or 0.005 in.). The composition of the reference SCC is shown in Table 6. The cement and filler content were of 330 and 170 kg/m³ (20.6 and 10.6 lb/ft³), respectively.

Table 3. Composition and properties of reference vibrated concrete and smart dynamic concrete with lower fines content in plant C

Composition in kg/m³	Reference-C	SDC-C
0-4 mm natural siliceous sand	992 (61.9)	1090 (68.0)
8-16 mm gravel	396 (24.7)	820 (51.2)
16-25 mm gravel	596 (37.2)	–
Fly ash	30 (1.9)	30 (1.9)
CEM II/A-LL 32.5R*	280 (17.5)	300 (18.7)
Water	165 (10.3)	180 (11.2)
Superplasticizer (Glenium type)	2.6 (0.16)	3.2 (0.20)
New VMA	–	0.4 (0.02)
Properties		
Slump Flow	S4 - 20 cm (7.9 in.) slump	68 cm (26.7 in.)
T_{50}	–	> 2 s
Compressive strength, 1 day	NA	10.5 MPa (1520 psi)
7 days	NA	26.4 MPa (3830 psi)
28 days	NA	34.1 MPa (4950 psi)

* *Composition of Portland cement CEM II/A-LL according to European Standard EN-197: 80-94% of clinker + 6-20% of limestone + 0-5% minority components*

Fig. 6: Placing of smart dynamic concrete prepared in plant C (SDC-C)

The use of the innovative VMA permitted to prepare a new mixture proportioning (SDC-F) with similar strength development using 400 kg/m³ (24.9 lb/ft³) of cement. The fines content (cement + filler) was reduced in 100 kg/m³ (6.2 lb/ft³) compared to the reference SCC (Reference-F). Both concretes had similar appearance (Fig. 8).

Conclusions

From the range of materials and conditions studied, the following conclusions can be drawn from the results obtained:

The new and innovative viscosity modifying admixture tested in this study permits obtaining concretes with self-compacting properties but with fines content (cement + filler) lower than 380 kg/m³. This can contribute to extend the use of SCC in the ready-mixed concrete industry as an 'everyday' concrete and to extend its use in the precast concrete sector.

Such VMA provides enough cohesion and stability in the concretes by increasing its plastic viscosity without modifying significantly the yield value.

The concretes incorporating the new viscosity modifying admixture show appropriate robustness toward changes in the composition, especially water content, as well as variations in the characteristics of the mate-

Fig. 7: Placing of smart dynamic concrete prepared in plant E (SDC-E)

rials. This allows a) proportioning SCCs with normal cement contents for everyday concrete, b) upgrading conventional concretes into robust concretes with self-compacting characteristics, and c) replacing/ reducing the filler content of SCC maintaining the compressive strength and its evolution.

The achieved smart dynamic concretes with medium-range self-compactability can be truck-mixed and are capable of maintaining self-compacting characteristics during realistic periods of time, even at elevated temperatures.

Table 4. Composition and properties of Reference vibrated concrete and smart dynamic concrete with lower fines content in plant D

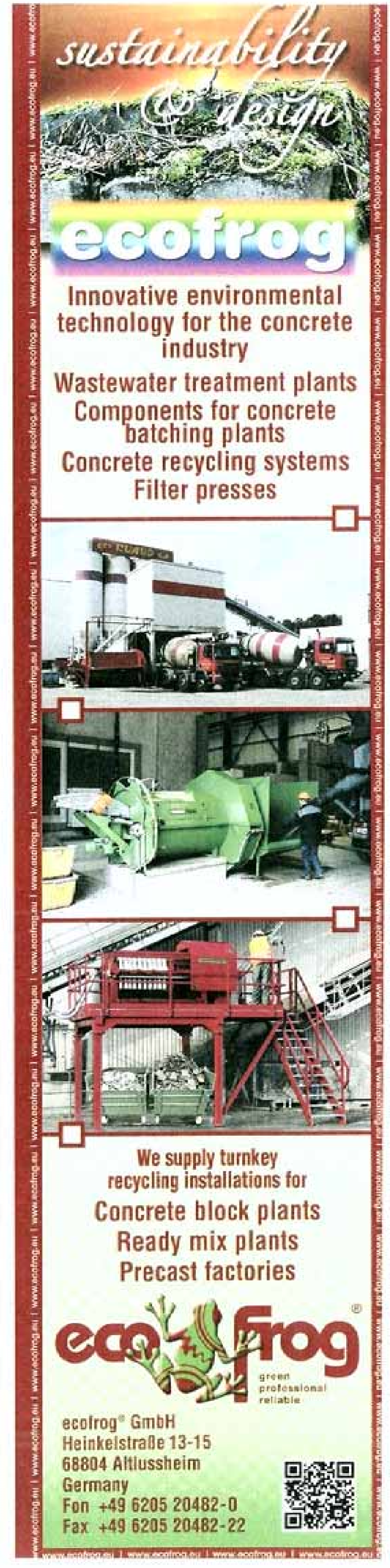
Composition in kg/m³	Reference-D	SDC-D
0-2 mm natural siliceous sand	266 (16.6)	371 (23.2)
0-5 mm crushed limestone sand	578 (36.1)	658 (41.1)
5-12 mm gravel	497 (31.0)	371 (23.2)
12-22 mm gravel	478 (29.8)	430 (26.8)
CEM II/B-S 42.5 *	330 (20.6)	330 (20.6)
Water	185 (11.5)	185 (11.5)
Naphthalene based superplasticizer	4.3 (0.27)	–
Superplasticizer (Glenium type)	–	4.0 (0.25)
New VMA	–	0.7 (0.04)
Properties		
Slump Flow	53 (not determined)	71 cm (28.0 in.)
Compressive strength, 7 days	19.9 MPa (2890 psi)	20.5 MPa (2970 psi)
28 days	28.9 MPa (4190 psi)	29.7 MPa (4310 psi)

* Composition of Portland cement CEM II/B-S according to European Standard EN-197: 65-79% of clinker + 21-35% of slag + 0-5% minority components

Table 5. Composition and properties of Reference vibrated concrete and smart dynamic concrete with lower fines content in plant E

Composition in kg/m³	Reference-E	SDC-E
0-2 mm crushed limestone sand	753 (47.0)	774 (48.3)
-12 mm gravel	368 (23.0)	172 (10.7)
-16 mm gravel	630 (39.3)	774 (48.31)
Fly ash	120 (7.5)	80 (5.0)
CEM III/A 42.5 N *	280 (17.5)	300 (18.7)
Water	175 (10.9)	185 (11.5)
Superplasticizer (Glenium type)	3.5 (0.22)	4.5 (0.28)
New VMA	–	0.6 (0.04)
Properties		
Slump flow	–	69 cm
50	–	2 s
Compressive strength, 7 days	27.5 MPa (4000 psi)	29.2 MPa (4230 psi)
28 days	34.8 MPa (5050 psi)	35.9 MPa (5210 psi)

* Composition of Portland cement CEM III/A according to European Standard EN-197: 35-64% of clinker + 36-65% of slag + 0-5% minority components



Innovative environmental technology for the concrete industry

Wastewater treatment plants
Components for concrete batching plants
Concrete recycling systems
Filter presses

We supply turnkey recycling installations for
Concrete block plants
Ready mix plants
Precast factories

ecofrog® green professional reliable

ecofrog® GmbH
Heinkelstraße 13-15
68804 Altlussheim
Germany
Fon +49 6205 20482-0
Fax +49 6205 20482-22

Fig. 8: Appearance of (a) reference concrete and (b) smart dynamic concrete in plant F

Table 6. Composition and properties of Reference SCC and smart dynamic concrete with lower fines content in plant F

Composition in kg/m³	Reference-F	SDC-F
0-6 mm natural siliceous sand	1015 (63.4)	1150 (71.8)
6-12 mm crushed limestone gravel	680 (42.4)	620 (38.7)
Limestone filler	170 (10.6)	–
CEM II/A-V 42.5R *	330 (20.6)	400 (25.0)
Water	196 (12.2)	225 (14.0)
Superplasticizer (Glenium type)	7 (0.44)	8.5 (0.53)
New VMA	–	0.40 (0.02)
Properties		
Slump flow	63 cm (24.8 in.)	62 cm (24.4 in.)
Fresh density	2322 kg/m³ (145 lb/ft³)	2244 kg/m³ (140 lb/ft³)
Compressive strength, 1 day	15.5 MPa (2250 psi)	13.6 MPa (1970 psi)
7 days	29.0 MPa (4210 psi)	29.2 MPa (4230 psi)
28 days	33.8 MPa (4900 psi)	33.2 MPa (4820 psi)

* *Composition of Portland cement CEM II/A-V according to European Standard EN-197: 80-94% of clinker + 6-20% of fly ash + 0-5% minority components*

Literature

[1] Japan Society of Civil Engineers (JSCE), 'Recommendation for Self-Compacting Concrete', Tokyo, Japan, August 1999.

[2] Swedish Concrete Association, Report No. 10 (E) 'Self-Compacting Concrete- Recommendations for Use', Stockholm, Schweden, August 2002.

[3] Precast/Prestressed Concrete Institute (PCI), 'Interim Guidelines for the Use of Self-Consolidating Concrete in Precast/Prestressed Concrete Institute Member Plants', Chicago, USA, April 2003.

[4] European Project Group, 'The European Guidelines for Self-Compacting Concrete. Specification, Production and Use', (joint work by EFNARC, BIBM, CEMBUREAU, EFCA, ERMCO), May 2005.

[5] The Concrete Society, Technical Report No. 62 'Self-Compacting Concrete- a Review', Surrey, UK, 2005.

[6] American Concrete Institute (ACI), 237R-07 'Self-Consolidating Concrete', Farmington Hills, USA, April 2007.

[7] Spanish Scientific-Technical Association for Structural Concrete (ACHE), 'Self-Compacting Concrete- Design and Application', Spain, September 2008. (in Spanisch)

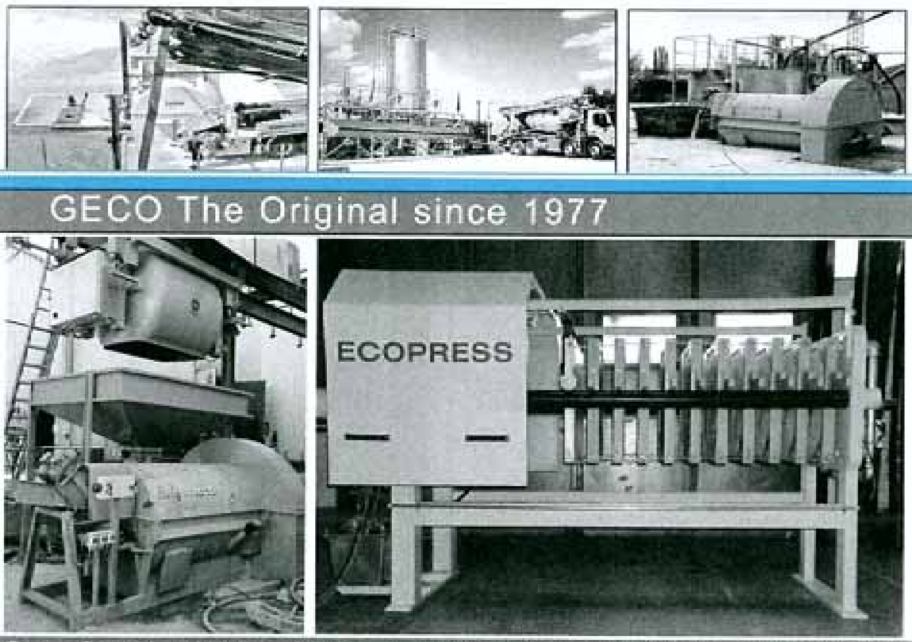
[8] ASTM C 1611/ C 1611M- Test Method for Slump Flow of Self-Consolidating Concrete. USA 2005.

[9] ASTM C 1621/ C 1621M- Test Method for Passing Ability of Self-Consolidating Concrete by J-Ring. USA 2006.

[10] ASTM C 1610/C 1610M- Test Method for Static Segregation of Self-Consolidating Concrete Using Column Technique. USA 2006.

[11] UNE 83363. Self-Compacting Concrete. Characterization of flowability by the L-box method, Spain 2007. (in Spanisch)

[12] UNE 83364. Self-Compacting Concrete. Determination of flow time by the V-funnel test, Spain 2007. (in Spanisch)



GECO
Conditioning Technology
Recycling Plants

GECO The Original since 1977
- www.geco.biz -

- Residual concrete recyling
- Filter presses
- Water conditioning
- CO₂ neutralization

Geco GmbH • Walldorfer Str. 1 • 68775 Ketsch • Germany • Tel.: +49-6202-6996-0 • Fax: +49-6202-699

IT IS RED, GIVES DURABLE PROTECTION AND IS EASY TO CLEAN.

KOBAFLEX POLYURETHANE COATING

Prevents damage to hoppers, troughs and buckets from impact blows.
Shorter cleaning times.
Minimum wear.

KOBATO
PERFECT IN ABRASION-PROOF POLYURETHANE

DE MORS 118
7631 AK OOTMARSUM - NL
T +31 (0)541 - 291 651
F +31 (0)541 - 293 247
E INFO@KOBATO.NL
WWW.KOBATO.NL

[13] UNI 11044- Test for fresh Self-Compacting Concrete. Determination of confined flow by the U-box test, Italy 2003. (in Italienisch)

[14] Spanish Structural Concrete Code (EHE). Ministry of Public Works, Madrid, 1999. (in Spanisch)

[15] Wallevik, O.H., 'Rheology - A Scientific Approach to Develop Self-Compacting Concrete', Proceedings of the 3rd International RILEM Symposium on Self-Compacting Concrete, RILEM PRO33 Reykjavik, Island, 2003, pp. 23–31.

[16] Wallevik, O.H., 'Why is Self-Compacting Concrete Different from Country to Country', Plenary Session 2nd North Am Conf. on the Design and Use of Self-Consolidating Concrete (SCC) and Fourth Int RILEM Symp on Self-Compacting Concrete, Chicago, USA, 2005

[17] Ferraris C., de Larrard F., Martys N. 'Fresh Concrete Rheology: Recent Developments', in Skalny J, Mindess S (eds) Materials Science of Concrete V, American Ceramic Society, USA, p 215-241, 1998

[18] Koehler E.P., Fowler D.W. 'A portable rheometer for Self-Consolidating Concrete', in Shah SP (ed), 2nd North Am Conf. on the Design and Use of Self-Consolidating Concrete (SCC) and Fourth Int RILEM Symp on Self-Compacting Concrete, Hanley Wood Pub, Addison, IL, USA, p 693-699, 2005

[19] Koehler E.P., Fowler D.W., Ferraris C.F., Amziane S. 'A New, Portable Rheometer for Fresh Self-Consolidating Concrete', in Shi C, Khayat KH (eds) ACI SP-233-7, p 97-115, 2006

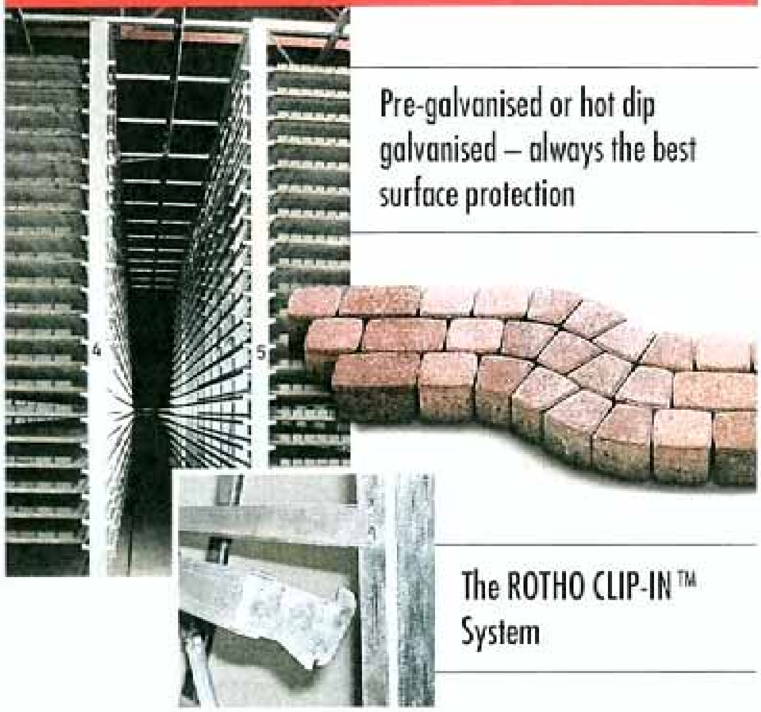
[20] Zerbino, R., Agulló, L., Barragan, B., Garcia, T. and Gettu, R. 'Workability tests and rheological parameters in self-compacting concrete', Materials and Structures, V.42, I.7, pp. 947-960, 2009

[21] Roncero, J., Corradi, M. and Khurana, R.S, 'New admixture-system for low-fines self-compacting concrete'. Proc. 5th Intnl. RILEM Symp. on Self-Compacting Concrete - SCC2007, Ghent, Belgien, Vol. 2, pp. 875-880, 2007.

[22] Khurana, R.S., Magarotto, R., Moro, S. and Roncero, J. 'Smart Dynamic Concrete: an innovative approach for the construction industry', Role for Concrete in Global Development (Proc. of 7th International Congress 'Concrete: Construction's Sustainable Option', July 2008), Ed. R. K. Dhir, P.C. Hewlett, L. Csetenyi, M. D. Newlands, IHS, bepress, pp. 725-734, 2008

[23] Roncero, J., Corradi, M., Khurana, R.S., Magarotto, R. and Moro, S. 'Smart Dynamic Concrete: New approach for the Ready-Mixed Industry', SCC 2008: Challenges and Barriers to Application, 3rd North-American Conf. On the Design and Use of Self-Consolidating Concrete, Chicago, USA, 2008

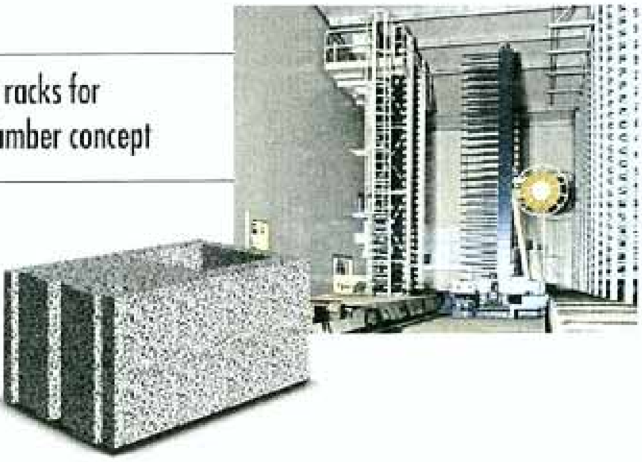
ROTHO CURING FACILITIES:
THE RIGHT SOLUTION FOR EVERY SYSTEM



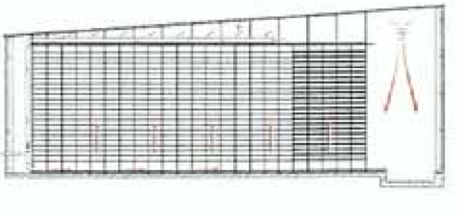
Pre-galvanised or hot dip galvanised – always the best surface protection

The ROTHO CLIP-IN™ System

Curing racks for big chamber concept



Air circulation system with moisture control



ROTHO Robert Thomas Metall- und Elektrowerke GmbH & Co. KG
Emilienstraße 13 · 57290 Neunkirchen/Germany
Tel.: +49(0)2735/788-543 · Fax +49(0)2735/788-559
Internet: www.rotho.de · e-mail: info@rotho.de

ROTHO