Manufacturing Concrete Products

Demanding requirements – new challenges for mixing technology

New buyers have shown an unflagging appetite for concrete products over a period of decades now; many manufacturers have good capacity utilisation rates. The demands and expectations of private and municipal customers have grown increasingly. This article will show, using the example of facing concrete, what demands have been placed on zero slump concrete, what problems can occur related to its processing and how these can be solved.

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Concrete products – such as paving blocks, kerbstones, gutters, pavement flags, pipes, masonry blocks and roofing tiles – are manufactured from zero slump concrete. Production has been running at top speed in Germany for many years; information about quantities is available for 2010 and 2012 (Tab. 1).

In a dissertation published in 2005, concrete is described as follows: "Zero slump concrete is a technological hermaphrodite. In its fresh, young (green) state, it behaves primarily like a mixed-particle soil. Its great inner friction and cohesive composition enable it to be demoulded, transported and stored immediately after compaction without it disintegrating or being inadmissibly deformed. With ongoing hardening, it becomes a very strong concrete with good resistance, which, for example as a paving block, can withstand both heavy loading from traffic and harsh stress from frost and de-icing salt over decades and even permanently" [2].

Tab. 1: Overall market size for concrete products in road, landscaping and garden construction in Germany [1]

Products	Market size 2010	Market size 2010 2012
Paving blocks made from concrete incl. grass pavers and porous concrete blocks	15.1 million t. corresponds to approx. 88m m²	16.3 million t. corresponds to approx. 95m m²
Pavement flags and surfacing panels made from concrete	1.7 million t. corresponds to approx. 16 million m²	2.0 million t. corresponds to approx. 19 million m²
Kerbstones, gutters, edging blocks	3.3 million t. corresponds to approx. 58,000 km	3.6 million t. corresponds to approx. 63,300 km
Other concrete products for landscaping and garden design	2.0 million t	2.8 million t

For "normal" concretes, which are employed in in-situ concrete structures, structures made from precast as well as in precast elements for buildings and civil engineering projects, DIN EN 206, in conjunction with DIN 1045-2, specifies precise requirements such as: concrete constituents, properties of fresh and hardened concrete and their documentation, restrictions on concrete composition, etc. By way of contrast, there are no standard specifications related to producing zero slump concrete for concrete products.

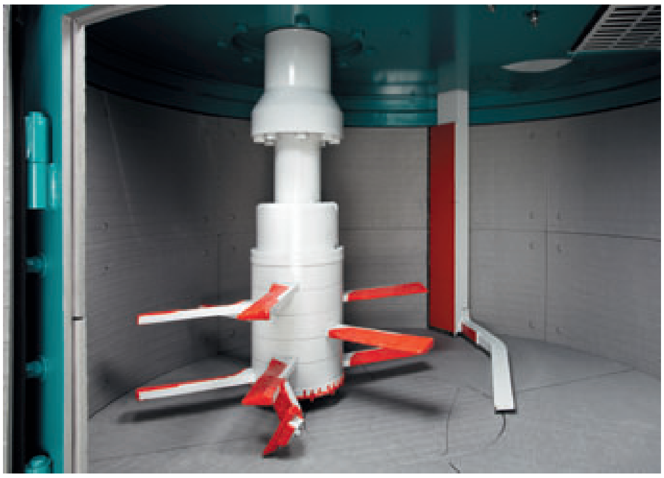

Fig. 1: Agitator with bottom scrapers; mixer without ceramic lining

Fig. 2: Ceramic lining in a ring trough mixer

Tab. 2: Mixing quality investigations for concretes with fines; determination of the coefficient of variation V

Mixing Time	20 s	40 s	40 s
V Ring trough mixer	40,5	11,7	16,2
V Eirich mixer	16,7	9,6	4,7

Fig. 3: Ceramic lining in a conical mixer

Manufacturers of concrete products work with recipes they themselves have created and which have proven to be sufficiently capable of living up to customer requirements as regards strength, bulk density, and resistance to abrasion and frost/de-icing salt under prevailing conditions. Good compactibility and high green strength are important in processing.

Requirements relative to facing concrete

Alongside aspects relating to concrete technology, other requirements need to be taken into account with facing concrete, such as its visual appearance with colour pigments or special granulations and the demand for flawless, closed surfaces. Through the addition of e.g. powdered rock, denser packing can be attained in the compaction process, which has a strength-enhancing effect. Besides the packing density of solids, the water/cement value is crucial for strength.

Special superplasticisers are also available nowadays for improving compactibility by decreasing the water content necessary for optimum compaction. The binding agent content can be reduced in combination with an optimisation of fine materials without the properties of strength and durability being altered [3].

It is now essential to gauge the water content in such a way that an optimum density of the concrete - the greatest packing density of the solids - can be attained when vibration energy is introduced. In this case, the operations are being carried out within a narrow range.
Besides superplasticisers, surfactants are also employed as admixtures. These generate air voids, which act like a lubricant in concrete and improve compactibility [3].

Fig. 4: RV12 (400 l) mixer, Denmark

Table 3: Investigations concerning mixing quality with facing concrete; determination of the coefficient of variation

	Planetary Mixer	Eirich Mixer
V Fresh concrete bulk density	0,46	0,19
V Water content	3,26	2,56
V Solids fraction 0.125 – 0.25	43,9	14,8
V Solids fraction 0 - 0.25	58,1	21,9
V Wear resistance	6,9	5,9
V Frost/de-icing salt resistance	6,2	4,7

Fig. 5: RV12 (400 l) and R24 (2,250 l) mixers, Germany

Processes in mixing

It is well-known that every mixing process is superseded by a segregation process. Seminal investigations were carried out on concretes at the University of Karlsruhe about the year 1980 [4,5,6]. Concrete must not be mixed too long because of the danger of segregation. Standards take this into account and specify that mixing be continued only until the mix appears homogeneous. If mixing is carried on longer than this, then mixing quality deteriorates. Any reason as to why concretes cannot be mixed "thoroughly" is not to be found in the standards [7].

Although there have been no investigations by experts for concretes with fines, reports from practice do exist. In 1982, a roofing tile manufacturer from the Netherlands carried out a comparative investigation between a ring trough mixer and an Eirich mixer from its 1960 model range [8]. To quote from the original report: "Mix homogeneity was determined by the distribution of water in a mix. In order to determine the amount of water, 10 samples each weighing 250 g were taken from each mix and dried to a constant weight. The samples were each removed after mixing times of 20, 40 and 60 seconds." The result is given in Tab. 2.

With the ring trough mixer, the coefficient of variation increases after 40 seconds; the mix becomes worse; the water distribution inhomogeneous.

What causes an irregular distribution of the water in concrete? The water/cement value is scattered locally; in some places it is higher, at others lower. When manufacturing concrete products, this is shown by an increasing number of rejects, e.g. through deformations and with a strong scattering of strengths on one production board.

One report derived from practical experience states that when the water/cement value is too great, it leads to material adhesion in the bevel and edge areas [9]. This has a very disadvantageous effect particularly on products with many edges, such as e.g. slatted floors for livestock. Another expert demonstrated that scattering as regards water content leads to varying compactibility and thus to a scattering in characteristic values. He recommends monitoring bulk density and diminishing deviations from standard in the production process [10] by this means. Other authors as well recommend managing production by logging bulk density [11]. Investigations have

Figs. 6-8: RV12 (400 l) mixers, in Germany...

... Norway ...

... and in the Netherlands

also been made into how changes in the water/cement value might have a quantitative impact on paving block characteristics – with water/cement values: 0.33 (too dry), 0.38 (optimum) and 0.43 (too wet) [12].

System-related concrete mixer properties

Single or twin shaft mixers (less frequently) are employed in processing facing concretes as well as ring trough, planetary and conical mixers. And Eirich mixers. The latter's' system requires fewer mixing tools close to the walls or bottom and is thus able to run with higher tool speeds without causing more abrasion and wear.
With "normal" mixers, the mixing tool assumes not only the task of mixing but also of transporting the mix materials. In the latest Eirich mixing system, its rotating pan takes over transporting the mix materials. In mixers from the R model series, invented in 1972, the mixing tool or agitator has practically speaking no contact with the bottom; two small scrapers maintain the bottom free from deposits (Fig. 1).
Since Eirich mixers exhibit very little wear on their walls and bottom, there is no need of a ceramic wear lining, as is often recommended with other mixers (Figs. 2 and 3).
The Eirich mixer with agitator, at that time built upright, was invented in 1960 and advertised as an "Intensive Mixer". In the meantime, "Eirich Mixer" has caught on as a name for the system.
What advantages does an Eirich mixer possess? Independent specialists formulated the matter in this way in 1989 [13]: "Intensive mixers were invented in order to better digest the cement paste. They not only mix the concrete constituents uniformly and thoroughly but also subject the same to an intensive rubbing and milling process. With intensive mixing, additional mixing organs, or agitators, are employed to perform a multiple of the mixing work which would otherwise occur with unaltered mixing times in normal processing. These agitators turn at great peripheral speed in the magnitude of 10 to 30 m/s (40 to 100 km/h) and cause the cement to be abraded and refined... The particle agglomerations formed especially when cement is stored over a longer period of time are dissolved; the otherwise flakily interconnected cement paste is pulverised and can thus cover a greater area of particles. Inner friction in fresh concrete is inhibited by a fine, but uniform sheathing of all particles and their processability is improved. Intensive mixing tends to have a similar effect on concrete strength as with utilising cement from a higher strength class." The authors are describing a 1960 model class Eirich mixer; the model class from the 1972 development stage of Eirich mixers adopted all these advantages.
One customer from Rosenheim, who changed over from a planetary mixer to a type R Eirich mixer, reported that his concrete needed 15% less water and that consequently he was able to reduce the cement quantity by 8% without any alteration in strength.
One special feature with Eirich mixers is that no segregation takes place during mixing. The stationary wall scraper ensures that 100% of the mixing materials are conducted to the agitator during one single mixing pan rotation, i.e. back-mixing does not occur continuously.

Neutral findings concerning mixing quality

In 2002, the IFF Weimar (today IAB Weimar) investigated mixing quality with facing concretes using a comparison of an Eirich mixer with a planetary mixer [14]. The Eirich mixer fared considerably better in all parameters investigated (Table 3).
Comparative investigations at the MFPA Leipzig show what improvements can be achieved for concrete product manufacturers with zero slump (or other) concretes in specific cases. Different

Fig. 9: RV12W (250 l) mixer for zero slump UHPC, Germany

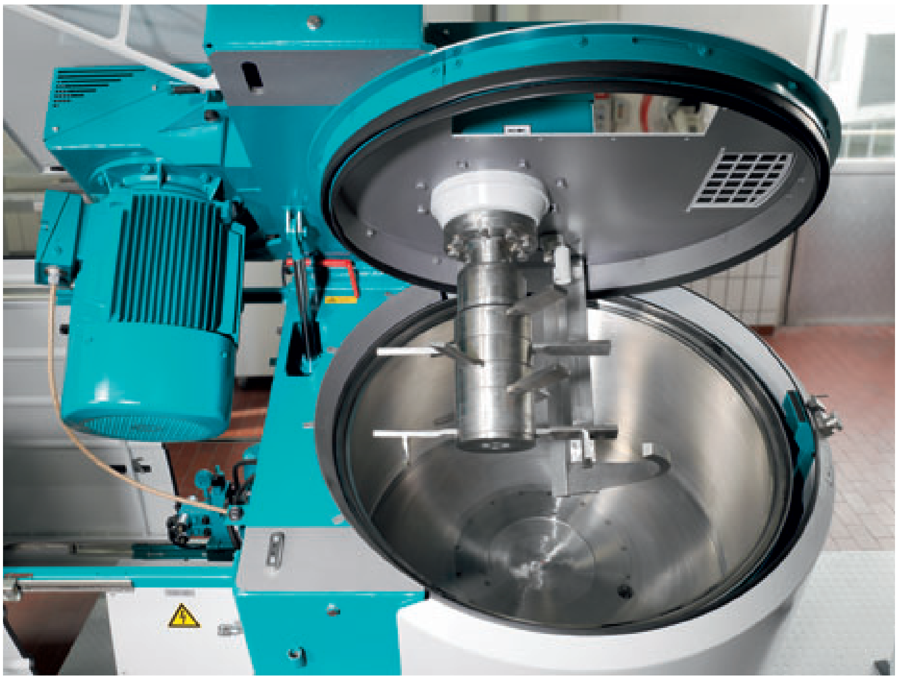

Fig. 10: RV12W mixer, head section open

types of mixer are available there for processing the raw materials supplied by customers. As a general rule, clear statements are issued on the same day as to whether and to what degree compactibility can be improved (e.g. by determining the Proctor density). Under the leadership of Prof Dr-Eng. Frank Dehn, MFPA Leipzig GmbH, institute for material research and testing for the construction industry Leipzig mbH, works with high practical relevance and possesses all essential facilities for testing fresh and hardened concrete according to current standards. This means that investigations can take place e.g. as to what extent savings on cement can be made through better processing. The head of the construction materials department, Dipl.-Eng. Marko Orgass, will be glad to supply further information, email: werkstoffe@mfpa-leipzig.de.

Examples of specific problems and their solution

In a CPI article, an explanation of the causes of surface flaws was given: "Irregular craters" and "pimples" on the block surface are caused by poor mixing sequences, the order and timing of the addition of individual components plus the duration of each partial mixing stage" [9]. It is obvious, then, that simple mixers demand that much attention be paid to all possible circumstances, if the aim is to achieve a somewhat uniform output.

In particular, lumps of clay in the sand, which some mixers cannot always digest due to their system, regularly generate rejects [15]. Even if this can just about be accepted with simple blocks, it means big money with high-value products.

A manufacturer of high-class concrete products from Denmark turned to Eirich because his planetary mixer generated a great quantity of rejects due to clay and cement lumps. Once an RV 12 (400 l) Eirich mixer had been installed, his problems were solved (Fig. 4). The customer wrote... we are very pleased with the new mixer. We do not have all the clay balls and only a few cement balls now".

Another producer of high-class concrete products in Hessen, Germany, had problems with rejects. Once his planetary mixer had been exchanged in this case for an RV12 (400 l) Eirich mixer, his problems disappeared. A larger type R24 (2,250 l) mixer was additionally ordered so as to be able to produce high-class masonry blocks without fear of lumps (fig. 5).

Still another manufacturer of high-class concrete products in North Rhine-Westphalia, Germany, had problems developing new products with his ring trough mixer. After its replacement by an RV12 (400 l) Eirich mixer, new product lines were initiated (Fig. 6).

A concrete goods manufacturer from Norway basically only produced rejects after changing over from small block formats to large slabs. The problems were eliminated when he exchanged his planetary mixer for an RV12 (400 l) Eirich mixer (Fig. 7).

Another producer from the Netherlands had problems with quality. Once his ring trough mixer was replaced by an RV12 (250 l) Eirich mixer, his problems were resolved (Fig. 8).

Many other examples could be named and displayed – almost always concerning problems with rejects caused by cement and clay lumps that had not been digested by previous mixer installations.

One current example needs to be mentioned at this point: the first zero slump ultra-high strength concrete (UHPC) mixer for manufacturing concrete products, a type RV12W (250 l), supplied to a manufacturer in North Rhine-Westphalia, Germany (Fig. 9).

A significant increase in the durability of concrete products can be expected with regard to the properties of UHPC – a practically non-porous, densely-structured material with great strength. This new substance's properties, from which e.g. special kerbstones can be manufactured, represent enormous progress in municipal road construction. Tremendous improvements in the area of resistance to frost/de-icing salt have been registered alongside great strength and appreciably enhanced direct and indirect tensile strength values.

UHPC contains high-performance superplasticisers, which often make the concrete sticky. In this case, a mixer can be supplied, whose head section with the mixing tool can be swivelled upwards for easier cleaning (Fig. 10).

Real-world recipes – mostly self-compacting – have been available for UHPC for a good ten years now. Reports have been published about its processing in a number of investigations at places of high-

Fig. 11: Paving blocks from a customer in France, 2002

er learning or research institutes. It has been shown that mixing times can be shortened by increasing the mixing speed [16]. Other authors have described how there is no linear correlation between a specified input and mixing effect with simple mixing systems, whereas an almost linear correlation exists with Eirich mixers [17].

Outlook

CPI publisher Gerhard Klöckner formulated the matter very appropriately in his editorial, "Concrete – the 3rd millennium construction material": "Anyone working with grandfather's pickaxe can only produce as much as grandfather – and only earns as much money as grandfather, too" [18].
It can now be understood why a customer in France replaced all his old mixing systems at all operational facilities with Eirich mixers in 2002 – and thanks to new and higher-quality products (Fig.11) was able to treble his turnover within six years at that time. The payback on investment can be easily calculated from the savings resulting from a reduction in rejects. Figures from a German manufacturer show that his ring trough mixer generated one to two rejects with high-class pavers per layer due to the mixer. In one day he had 50 m² of rejects; in 200 working days, it made 10,000 m² - corresponding to a loss in value in the region of € 100,000. Rejects decreased substantially after installing an Eirich mixer.

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