Equipment and measuring systems for testing the quality of concrete, mortar and additives

Dipl.-Ing. Markus Greim – Schleibinger Geräte, Buchbach, Germany – published in HORMIGON 09/2009

Introduction

The quality of cement-based building materials such as mortar and concrete can be divided into three fields: durability, dimensional stability and workability.
While the testing methods for testing the strength by compression testing machines has been standardized both nationally and all over the world for decades, tests and testing methods for the durability, dimensional stability and workability are not standardized at all, or the procedures differs from nation to nation. A lot of testing methods are very controversially discussed among experts and many arguments are influenced by an industrial, political and financial background. In this article testing equipment and methods are presented which are partially described in rules and standards. However, none of these testing methods has been established in a valid EN or ISO standard up to now.

Durability

The durability of a concrete construction is on the one hand influenced by the fair wear and tear, which is abrasion and alternating load. On the other hand, there are two further important damage factors, namely the damage due to frost attack and defrosting agents from outside, as well as the inner damage due to alkali-silica-reaction.

Freeze-Thaw resistance

There had been a draft standard prEN12390-9 [1] for the frost resistance test since 2002 which, however, was downgraded to a technical rule CEN/TS 12390-9 [2] with a validity of three years in 2005. Besides, each country has its own rules and standards. The national regulations are partly similar to European regulations (Austrian Önorm B3303 [3]) or do not comply with them at all (Italy UNI 7087:2002 [4]). But, also in the European CEN/TS three different testing methods are described, the least demanding Slab-test-procedure being the reference method.

The Slabtest

The slab test procedure which is also known as Boras procedure can be carried out in the Schleibinger Slabtester. Here the specimen, a concrete slab is completely covered with polystyrene foam, only the surface remains uncovered. On the surface a thin water layer is applied and on this surface the reference temperature is measured. In order to avoid evaporation of the water layer, the surface is covered with a plastic sheet with at least 15 mm distance. 58 freeze-thaw cycles are run, the reference temperature may deviate from the target temperature between ±3,5K when freezing and ±4K when thawing. One frost thaw cycle is run in 24 hours, so the test is run for 56 days (almost 2 months!).

The insulation of the cube shall guarantee a one-dimensional frost attack from the top surface. However, this does not work, as the air layer between the water surface and the sheet has a better insulation as the polystyrene foam on the back side. The water in the microporous totally freezes below -17°C, but the tolerance band allows temperatures of above and below this temperature. The result is, that - among other influences – the measured damage is widely scattered.

CDF/CIF Test

The CDF testing procedure which is carried out in the Schleibinger CDF Test Equipment works considerably faster and more selectively. The abreviation CDF is for **C**apillary suction of **D**e-icing solution and **F**reeze thaw test. At the CIF test also the inner damage is measured. CIF is the abbreviation for **C**apillary suction, **I**nner damage and **F**reeze thaw test This procedures comprises the specimen being placed upside down on spacers in a water bath which is

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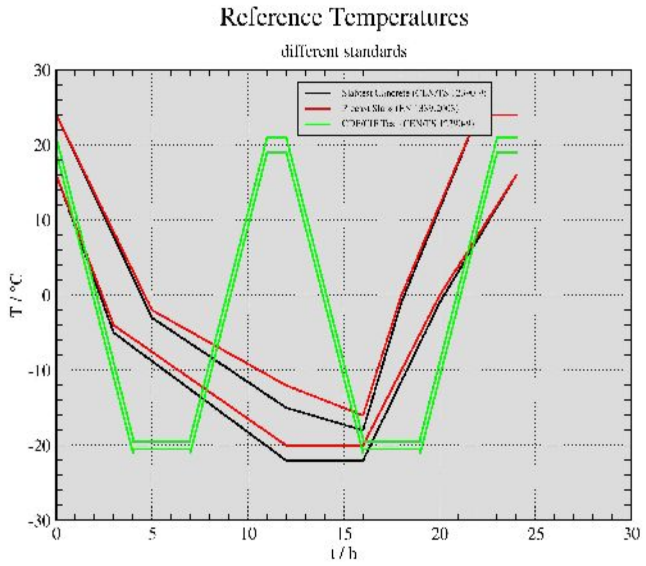

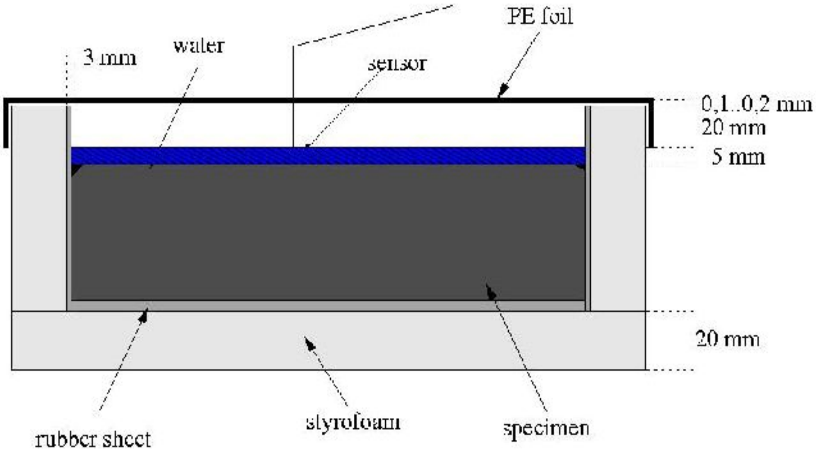

temperated from the bottom with a cooling liquid. The allowed deviation in temperature is very little (with ± 0,5K at minimal temperatures and ± 1,0K in the other temperatures) and heat transition and the direction of frost attack are well-defined. Two freeze-thaw cycles are carried out once a day, so that the test can already be terminated after 14 days. The damage is not measured by brushing scale material from the specimen like in the Slabtest – this test being very subjective depending on the brush used and the responsive person – but here the damage is measured by removing the scaled material from the specimen through an ultrasonic signal with defined power. Critics regard this CDF method as to strict, as even concretes which do not pass this test can be damage-free for years at the construction. However, it has the be countered, that this testing method does not create any wrong positive results, which means, that specimen passing this test do stand the construction by all means, though this is not the case vice versa.

Cube test

One more testing method from CEN/TS12390-9 is the cube test, which can also be carried out in the Schleibinger CDF test equipment. This method comprises two cubes being put in test container which is completely filled with water. Here, too, the tolerance band of the allowed temperatures is wide and the required cycle of 24 hours is very long. The cube test takes 56 days.

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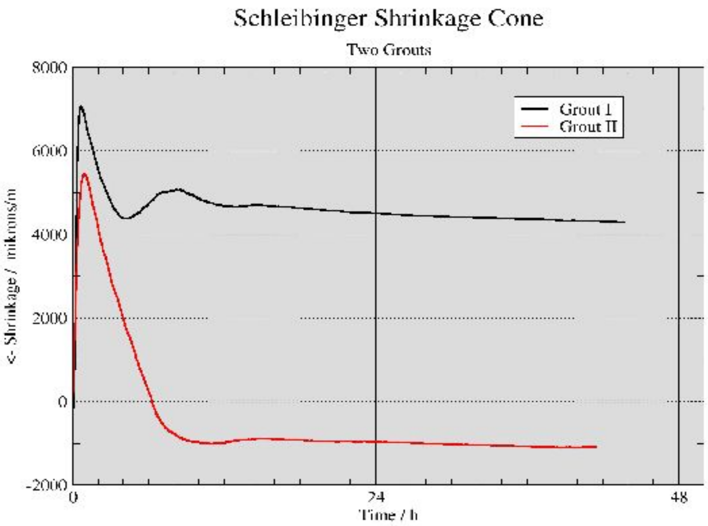
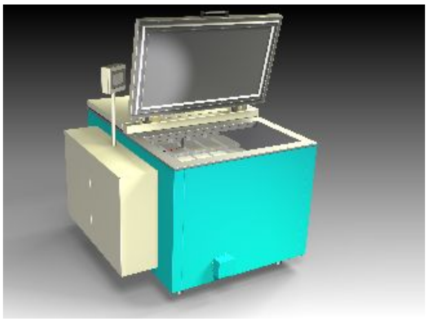
Alcali Silica Reaction



The alkali silica reaction comprises the forming of silica gel around the aggregate (particles) which bursts open the concrete from the inside out. This reaction is accelerated and induced by bases, high temperatures and high humidity. This damage is very dangerous, as it begins inside the concrete structure and normally leads to total breakdown of the construction. Great damage was caused during the last few years, after using new deicing agents at the airports, which on the one hand harmonized with the aluminium of the planes, but on the other hand induced and massively destroyed the runways. In the last years various testing methods have been developed in order to test the sensitivity of concrete to alkali silica reaction before starting construction. The RILEM comitee TC 191-ARP[8] keeps trying to suggest uniform tests. In France there is the standard NF P18-454 [7], which almost corresponds to the RILEM standard. This test can be carried out in the Alcali-Silica-Reactor. The concrete specimens being exposed to 60°C and almost 100 % humidity. In fixed intervals the change in length of the specimen is measured so that a beginning alkali silica reaction can be detected.



Dimensional stability

The volume of cement-based building materials changes during the setting procedure. The reasons therefore are among others, the gravity of fine particles, the loss of water due to dehydration, the forming and transformation of crystalls. As long as the material is still liquid, this effects are actually not dangerous. However, if a certain strength is reached, inner tensions are formed. When these tensions exceed the tensile strength of the material, cracks can be formed. In accordance with DIN 52450 [9] the shrinkage of mortar prisms is measured after 24 hours at the earliest. It is obvious, that the change in shape takes place already before this 24 hours to a great part. These measurements are carried out with Schleibinger's shrinkage cone [10], which measures the deformation by a laser when the material is still liquid without touching the surface. If, at the same time, when the material is still liquid, the early development of the E-modulus is measured with Schleibinger's ultrasonic test cell, it can be seen that tensions are formed in the material already in an early stage of setting.

Shrinkage of Thin Layers

In constructive engineering the drying-shrinkage does not play an important part, at least, if an adequate finishing treatment is given. Looking at wall or floor building materials such as plasters or self-levelling underlyments, the proportion of volume and surface is significantly disadvantageous. A little volume of material is in contrast with a very large surface. With Schleibinger's Thin-Layer-Shrinkage-System [11], this shrinkage can be detected in detail and from the beginning. Two small and lightweight reflectors are put on the thin layer, which separated by a sheet, being applied almost frictionless on a smooth underground. Two lasers being put on the right and the left hand side and measuring the distance to the reflectors. The sum of both measuring results designates the change in length of the test material. The whole test material is put on a electronical scale. The loss of mass due to evaporation is recorded at the same time as the change in length is. In case of thicker layers such as floor screed, different shrinkage of the surface and the underground of the material can be determined. The Schleibinger Bending drain [12] is able to measure the change in length and in addition to this, the bending of the sample. Furthermore, a floor heating can be simulated by the influence of temperature.

Workability

Contrary to durability and dimensional stability there are internationally approved test specifications for workability, such as the Slump-Test (EN 12350-2 [15] or ASTM C143 [15]) or the spread-table (EN 12350-5 [16]). However, these are purely heuristically testing methods, older than 80 years and accordingly imprecise. For the self-compacting concrete, where the workability is the most important aspect of concrete design, these testing methods were slightly modified (J-ring, flow time T70, [17]) without changing the essential part. Test result is only flow length in cm or flow rate in seconds. No flow curve is determined which would describe the flow limit (yield point) and viscosity of the test material. About 50 years ago, people begun to develop modern testing methods after having found out that rheometers as used in the fields of chemistry and food industry were not suitable for coarse dispersed system such as building materials. 1970 Tattersaal [18] developed a rheometer for fresh concrete in Norway, J. Teubert at the same time in Germany a rheometer for mortar. Both found out that during the measuring procedure the separation of the material into solid and liquid components had to be avoided, and thus not allowing the particles to sediment on the bottom of the test container due to gravitation. Instead of cylinders and plate-plate systems, commonly used in rheology, mixer formed measuring probes were invented which mixed through/up the test material during the test procedure.

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Rheometer for mortar

Based upon the tests and publications of J. Teubert, Schleibinger Geräte launched a rheometer for mortar in 1980, which was followed by a further development in the year 2000 based on the same measuring principle. The Viskomat NT enables a long term measuring procedure, without the test material shearing off at the measuring geometry and without sedimentation. Due to the test material volume of 360cm^3, a fast and easy to handle measurement procedure is possible. The particle size, however, is limited to a maximum of 2mm. However, if the test material contains enough mortar so that each particle is covered by a mortar film of a certain thickness (approx. 550l/m^3 concrete [20]), the flow properties of the fresh concrete are largely determined by the flow properties of the mortar, provided that the particle size of the aggregates is similar and the content of mortar is the same.

Rheometer for concrete

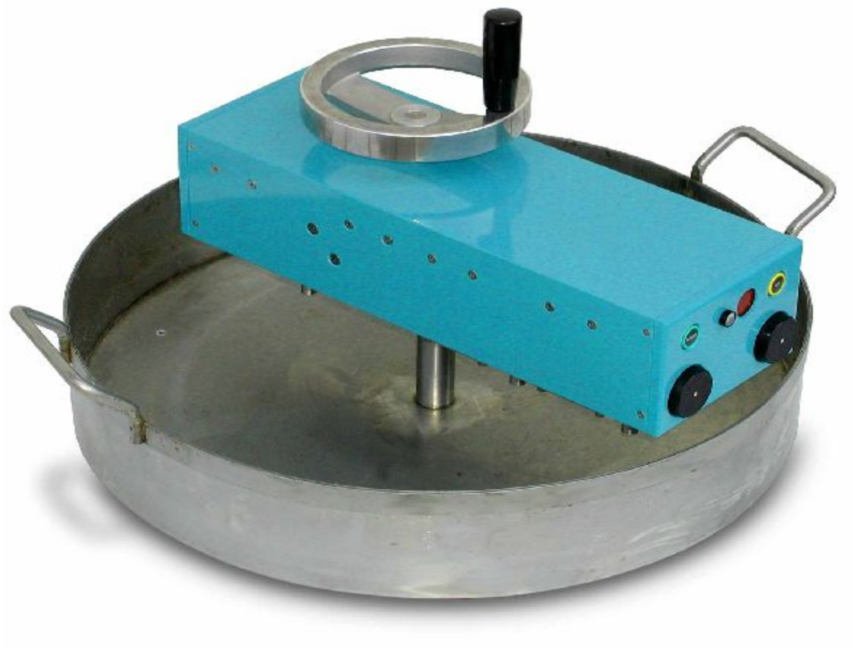
Although a rheometer for mortar is very helpful, this method is often enough not accepted, as tests are only carried out on a pre-product, namely mortar, and not on the final product, the fresh concrete. For particle sizes up to 8mm, the Viskomat XL can be used, which is a bigger version of the Viskomat NT. The principle of measurement corresponds to that of the rheometer for mortar. However, the sample volume has to be significantly increased, if the particle size is 16..32mm. Although the rheometer geometry could be made bigger, the result would be that the amount of equipment involved would only be increased disproportionately.

For example the help of two persons would be necessary for handling the sample.

The rheometer for fresh concrete BT2 [21] avoids this problem. It can easily be handled and transported by only one person. Two index arms rotate through the concrete. As the two index arms have different distances to the axis the rotate with different track speeds and so different forces act on the sensors. The index arms rotate only once through the specimen container. Thus, the test material is not decomposed/segregated and the measurement is effected fast and sedimentation is avoided.

Conclusion

In the fields of durability, dimensional stability and workability there are no binding standards or only minimum standards. By relying on these methods only, the building materials would only reach a minimum quality standard, too. Innovative product development, however, implies up-to-date measuring instruments. These are already on the market.



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Literature

1 Testing hardened concrete – Part 9: Freeze-thaw resistance – Scaling;German version CEN/TS 12390-9:2006

2 Prüfung von Festbeton Teil 9 Frost- und Frost-Tausalz-Widerstand, Abwitterung, Deutsche Fassung preEN12390-9:2002

3 Betonprüfung, ÖNORM B 3303:2002 09 01

4 UNI 7087:2002, 01/06/2002, Calcestruzzo - Determinazione della resistenza al degrado per cicli di gelo e disgelo

5 Stark, J.; Seyfarth, K.; Giebson, C.; Beurteilung der Alkali-Reaktivität von Gesteinskörnungen und AKR-Performance-Prüfung Beton; 16. International Baustofftagung ibausil; September 2006, Weimar, Germany, ISBN 3-00-018263-2

6 Deutscher Ausschuss für Stahlbeton, DAfSTb (Hrsg.): Vorbeugende Maßnamen gegen schädigende Alkalireaktionen im Beton: Alkali-Richtlinie, Anhang B, Teil3, Berlin: Beuth, 2007

7 Standard NF P18-454 (Décembre 2004) : Béton - Réactivité d'une formule de béton vis-à-vis de l'alcali-réaction - Essai de performance - Reactivity of concrete for alkali-silica Performance test

8 RILEM Test Method TC 191-ARP (Ed.): AAR-4.1: -Detection of Potential Alkali-Reactivity-60°C Accelerated method for testing aggregate combinations using concrete prisms - Bagneaux, 2006

9 DIN 52450 , Norm , 1985-08 Prüfung anorganischer nichtmetallischer Baustoffe; Bestimmung des Schwindens und Quellens an kleinen Probekörpern

10 Greim, M.; Teubert, O.; Patentanmeldung DE10046284A1, Vorrichtung zum Erfassen des frühen Dehn- und Schwindverhaltens von Baustoffen

11 Bühler, E. and Zurbriggen, R. (2004): Mechanisms of early shrinkage and expansion of fast setting flooringcompounds. Submitted to GDCh Baufachtagung, Erlangen, Germany

12 Gerstner, B; Haltenberger, H; Teubert, O.; Greim, M. Patentanmeldung DE000010123663A1; Vorrichtung zum Messen der Verformung an Mörteln, insbesondere Fliessestrichen, in zwei Richtungen unter verschiedenen Temperaturbedingungen [EN] Device for measuring deformation of mortar in two directions under different temperature conditions has sensors for simultaneous measurement of vertical and horizontal mortar movement

13 ASTM C 827 – 95a (Reapproved 1997): Standard Test Method for Change in Height at Early Ages of Cylindrical Specimens from Cementitious Mixtures

14 DIN EN 12350-2:2009-08 Prüfung von Frischbeton - Teil 2: Setzmaß; Deutsche Fassung EN 12350-2:2009, - Testing fresh concrete - Part 2: Slump-test; German version EN 12350-2:2009

15 ASTM C143 / C143M - 08 Standard Test Method for Slump of Hydraulic-Cement Concrete

16 DIN EN 12350-5 Norm , 2009-08, Prüfung von Frischbeton - Teil 5: Ausbreitmaß; Deutsche Fassung EN 12350-5:2009

17 DAfStb Selbstverdichtender Beton; SVB-Richtlinie:2003-11 Technische Regel, 2003-11 DAfStb-Richtlinie - Selbstverdichtender Beton (SVB-Richtlinie)

18 Tattersall G.H., Banfill P.F.G.: The rheology of Fresh Concrete. Pitman Books Limited, Boston 1983.

19 Teubert J.: Measuring the consistency of concrete mortar and its importance to the workability of fresh concrete. Betonwerk + Fertigeil Technik, Heft 4/81.

20 Gołaszewski J.: The influence of mortar volume in rheological properties, optimizing the properties of fresh high performance concretes, BFT Betonwerk + Fertigteil Technik, 10/2008

21 Greim, M; Teubert, O. ; Patent DE000019503028B4 Verfahren zum Messen des Fließverhaltens grobkörniger Stoffgemenge

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