Conference Report I

Rheological Measurement of Building Materials

March 10 - 11, 2004
Regensburg, Germany

M. Greim, opening the conference.

The 13th "Rheology of Building Materials" Workshop has been held at the University of Applied Science Regensburg (Prof. Kusterle), mid of March 2004. The series of meetings started 1991 with as few as 20 national participants, and has grown to an international conference with roughly 100 participants from the European research community as well as the application engineers from the construction materials and building industries.

Beneath the strength and durability the workability is an important property of mineral-based materials like concrete, mortar, and plaster. These features are still often estimated heuristically using spread tables, slump cones etc. In recent years the development of new additives like stabilizer and superplastizisers lead to new construction materials such as self leveling screed and self compacting concrete. Those materials are of interest for at least two reasons. They need no kind of vibration at the building site, thus avoid noise, and safe a lot of manpower. They further achieve new kinds of freedom in the architectural design. On the other hand these new materials require a design concerning their rheological properties not only in a heuristic way, but with scientifically founded methods of rheometry, including rheological modeling.

Prof. Kusterle and S. Uebachs dicuss with the participants.

This tendency and related developments are represented through the topics of the presented papers 2004 in Regensburg. They can coarsely be divided in three groups: General lessons regarding the rheology of building materials, the effects of additives and admixtures, and the self compacting concrete (SCC). Building materials like cement paste, mortar, or a lime putty are unfortunately not just 'simple' non-Newtonian fluids, but also time-dependent and affected by deformation history. A. Eberhard, from the Finger-Institute, University Weimar/Germany, presented in his paper the influence of the hydration of C3A, the several sulfate forms and the kiln-fines to the stiffening of Portland cement. Parallel to the characterization of the hydration process with several methods like microscopy (ESEM-FEG), DSC, X-ray analysis, the stiffening of the cement paste was tested in a rheometer with a constant shear rate. It can be shown that there is a strong correspondence between the hydration and shear resistance measured by the rheometer. After the first phase of initial reactions the stiffening can be divided in two other phases. First during the hydration of aluminate the water needed for the hydration is no longer available for the flow process. Therefore all effects pushing the aluminate-reaction like more fines or more calcium-sulfate will cause stiffening. Later there is stiffening due to structural changes. If there is less sulfate there are growing, beneath ettringite, monosulfoaluminate (Afm) phases which are supporting the agglomeration of the cement paste. If there is too much sulfate beneath ettringite gypsum is growing also causing a stiffening of the cement paste. In the conclusion it was shown that the rheological properties of the cement paste can be optimized by the fines as well as by a reducing of the aluminate-hydration by sulfate-optimized cement.

Mrs. Vavorva from the Department of chemical technology of monument conservation, ITC Praha/Czech Republic, did present her research on the rheological properties of lime putty. Calcium oxide CaO, also called quick lime, is slacked with water to calcium hydroxide $Ca(OH)_2$. After this process there is a curing period necessary from three weeks up to several years. This curing may be accelerated by a mechanical activation. It can be shown that the

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freshly prepared lime putty has a viscosity two levels below the matured lime putty. A mechanical activation of fresh lime putty by mixing it 15 minutes rises the viscosity nearly to the same level than the matured one. Also inorganic salts have an influence on the viscosity of the lime putty, but not so strong than the mixing effects. So controlling the rheological parameters prior to application can avoid using inadequate materials on historical buildings and monuments.

E. Schneider, SAFA, Baden-Baden/Germany, demonstrated a concept for a concrete design process based on the rheological properties of cement-paste and mortar to predict the workability (spread table value) of fresh concrete. These developments are based on the work of J. Teubert [1] in 1981. First a cement paste with, a fix water-cement ratio a no segregation effects is designed, which is as fluid as possible. If necessary additives like fly ash or plasticizers are used to get an optimal paste. In the next step the mortar is filled with the fine aggregates up to two millimeters. The consistence of this mortar is determined by a mortar rheometer. With the equation of Teubert one can now calculate the spread table value at a fix amount of mortar per cubicmeter fresh concrete, or one can determine the volume of mortar you need to get a certain spread table value. Schneider validates this equation, with some modification for modern superplasticizer. Also the influence of other admixtures can be integrated in this design concept. Dr. J. Golaszewski, University Gliwice, Poland shows the influence of air entraining agents on the rheological properties of superplasticized mortars. Air bubbles in the concrete are important for the durability of concrete against a frost thaw attack. From the rheological point of view air-entraining agents (AE) lowers the viscosity as well as the yield stress of a mortar. Superplasticizers (SP) generally lower the plastic viscosity. In detail this trends depends on the (chemical) compatibility of the used cement, SP and the AE. It is known that reducing the amount of water in the mortar rises the viscosity and the yield stress of the mortar. This effect, working in the opposite to the AEs may be used to compensate the rheological effects of the AEs. Dr. O. Wallevik, IBRI, Reykjavik/Island presented a rheological study on interaction between different types of cements and dispersing admixtures.

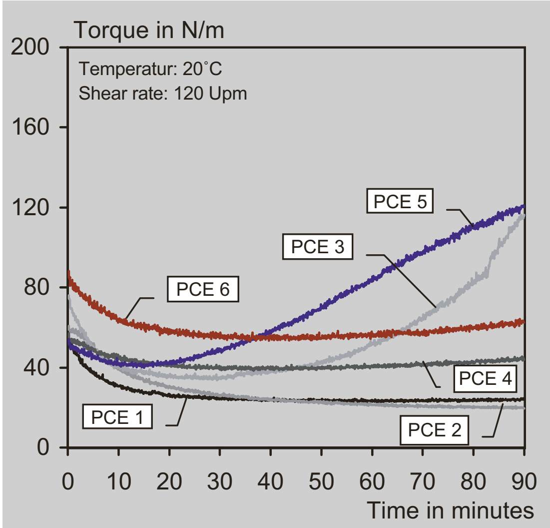

Figure 1: Shear values at constant shear rate. One cement, several SPs

The second part of the colloquium was concerned with self-compacting concrete (SCC). S. Uebachs, University, Aachen/Germany, discussed the influence of several SPs varying the temperature in the rheological behavior of superplasticized mortars. Figure 1 shows the differences between several SPs using the same cement. The shear value at constant shear rate for several SPs and the same cement. It was also pointed out that mortars used for SCC are more according to the Bulkley-Herschel than to the Bingham-model. H. Eckhardt, Readymix Institut, Ratingen, Germany, shows in his lesson ''rheometry and praxis'' the application of rheological methods for the design and quality testing during a big building project for (BMW, Leipzig/Germany) for more than 4000m^3 of SCC. Also in this study the influence of the temperature in the power of modern SPs was shown. The workability of standard concretes it mostly influenced by the yield stress whereas the plastic viscosity is quite low. In the opposite the workability of SCC is mostly influenced by the viscosity.

S. Kordts, VDZ Düsseldorf/Germany, presented a simple piece of test equipment, the so-called ''flow cone''. It was developed in order to simplify the amount of testing when SCC is delivered as ready-mixed concrete. That is suitable for site conditions, with which the two decisive test slump flow and V-funnel flow time for describing the required fresh concrete properties of an SCC can be determined reliably in a single test. The flow cone is a normal commercial slump cone mounted on an appropriate supporting stand and closed off at the bottom by a slide. A flow nozzle with an outlet diameter of 63.5 mm exhibiting the same slope of the slump cone was attached to the underside of the support. After the SCC was poured into the flow cone and the slide was removed the time was measured the SCC needed to flow out of the flow cone. With the SCC investigated here the same flow times

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Testing several mortars at the laboratory workshop (right)

were measured as those obtained using the V-funnel with low-viscosity and higher-viscosity SCC, respectively. The slump flow measured at the same time was not affected by the tapered shape when compared with the conventional slump cone test. The flow cone therefore represents an alternative way of determining the viscosity of SCC that can be used particularly advantageously for acceptance testing on site.

M. Greim, Schleibinger Geräte, Buchbach/Germany, answered some frequently asked questions, regarding the rheometry of building materials. It was shown that measuring a Bingham fluid like mortar at low shear rates with a standard geometry like cylinder-cylinder will not shear the material completely. In the gap between sheared and non-sheared material the fluid phase will be separated from the coarse. This effect, often called wall slip, is independent from the roughness of the cylinder-material. At higher shear rates the complete material is sheared, but centripetal forces will cause segregation. Gravity will cause also sedimentation. These effects can be avoided by mixing the mortar and removing the mortar by a scraper from the specimen container during the measurement. A so designed measuring-mixer like the Viskomat NT has no well defined geometry. A calibration can be done for Newton fluids. Unfortunately for mortar this is quite useless because most mortars are non-Newton fluids.

Preparing the specimen (above).

Testing concrete during the laboratory workshop (below).

After the colloquium on March 10th, discussions continued during the evening in a typical restaurant located at the historical city of Regensburg. On March 11th at a laboratory workshop some basic principles of rheology of building materials were demonstrated in a quite practical way. Tests with a mortar (rheometer Viskomat NT), and furthermore with a concrete based on this mortar (rheometer BT2) showed the participants how to transfer results between the laboratory to the building site. The next Regensburg colloquium and workshop will take place mid of March 2005 at the FH Regensburg.

[1] Teubert, J.: Die Messung der Konsistenz von Betonmörtel und ihre Bedeutung für die Verarbeitungseigenschaften des Frischbetons, BETONWERK+FERTIGTEIL-TECHNIK, 4 (1981) 217-222.

Most of the papers are completely presented at http://www.schleibinger.com/k2004/regen04US.html

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