# A clay additive for the enhancement of no-slump concrete properties

## Ein Tonzusatzstoff für die Verbesserung der Eigenschaften von erdfeuchtem Beton

*Krauss, Hans-Werner, Budelmann, Harald*


### Abstract

At the IBMB, TU Braunschweig a new method for inhancing no-slump concrete's properties has been developed. The use of a defined clay additive leads to distinctly improved rheological characteristics of the binder lime and consequently to better concrete performance, e.g. workability, green strength and packing density.


### 1. Introduction

The strength of no-slump concrete is mainly achieved by a high particle packing density due to intense compaction, which causes a strong interlocking of the coarse aggregates. Also fillers like fly ash are enhancing the strength by help of interlocking of microsized particles /1/. Another theory, wherein green strength is explained by capillary forces between micro-sized particles seems to fail /10/. The high green strength of no-slump concretes is realised by very low w/c-ratios. Accordingly there's often a lack of water for the cement hydration process, that is either retained by the filler or is replaced by high superplasticizer content. Anyway there is a discrepancy to be noted between high green strength (little water needed) and high compression strength of hardened concrete (more water needed). The stickiness of a filler-optimized mixture causes hindrances in manufacturing, yet another problem.

At the IBMB, TU Braunschweig a new approach for the enhancement of no-slump concrete has been developed /2/, /3/, /7/, /8/, which is based on improved rheological characteristics of the binder paste achieved by a new additive containing clay minerals. The resulting enhancement in workability and the cohesive forces cause higher compressive strengths in the green and hydrated state. It is known that raw clay materials normally reduce strength and durability of concrete /9/. Due to the adsorption of water at clay surfaces water it should not be taken into account for w/c ratio, which is usually not considered. The detrimental impact is also due to the low particle strength of clays. Nevertheless at the IBMB no-slump concrete mixtures were improved by addition of an additive containing clay minerals and quartz with defined composition. In order to model and systematically profit from the potentials of the additive, the understanding of interacting forces between particles in clay-cement-water systems is demanded.

### 2. Rheological behavior of clay cement suspensions

Rheological characteristics of clay-cement-water systems are determined by a variety of chemical, physical and electrochemical phenomena. The clay additive used contains kaolinite, illite and quartz. The specific surface area is 23 m²/g (BET) and the medium particle size $d_{50}$ =0,6 μm. Thus a great part of the additive is of colloidal size (d<0,1 μm). In an OPC pore solution (very high pH) we can assume permanently negative charged surfaces. The edge charges of kaolinite and can be positive with very high pH value. Solved in water several layers of polarized water molecules are adsorbed on clay surfaces. If available, counter-ions are adsorbed for the compensation of the negative layer charges. Therefore cations with high valence and such with low hydration energy (e.g. $Ca^{2+}$, $K^{+}$) are preferred /6/. The interactions of colloidal suspensions are explained by the DLVO theory. For more detailed information see e.g. /6/.

Due to the fact, that mixing and casting of no-slump concrete occurs within a few minutes, only the induction period of OPC must be considered here. This early period of OPC hydration is subdivided into three stages (<1 min, 1-15 min, 16-120 min), regarding the ion concentration development in pore solution /5/. The ion release process from cement phases stimulates the aggregation of particles and changes the rheological behaviour of clay water systems. Regarding the Schulze-Hardy law, OPC suspensions must always be in a flocculated or coagulated state, due to the high ion strength. The theory of colloid chemistry is applicable to dilute cement pastes in the early stage of hydration. The DLVO theory limited for suspensions with high particle concentrations, where other forces may dominate, e.g. ion-dipole forces. In addition capillarity, friction and gravity forces between micro-sized particles become important. Rheological studies at the IBMB with clay-cement and clay suspensions with opc pore solutions revealed a dependency between ionic strengths and the rheology /2/. Malonn

**Institut für Baustoffe, Massivbau und Brandschutz (iBMB) der Technischen Universität Braunschweig Materialprüfanstalt (MPA) für das Bauwesen**

Beethovenstraße 52
38106 Braunschweig
Tel.: +49 (0) 531 391 5400
Fax: +49 (0) 531 391 5900

E-Mail: info@ibmb.tu-bs.de
http://www.ibmb.tu-braunschweig.de
E-Mail: info@mpa.tu-bs.de
http://www.mpa.tu-bs.de

© 2008 Institut für Baustoffe, Massivbau und Brandschutz der TU Braunschweig – Materialprüfanstalt für das Bauwesen Braunschweig

derived an explanation model from comprehensive experimental data: colloidal clay particles are attracted and bonded by the bigger cement particles, as observed in microscope investigations. In this way the cement particles cohere and yield value is enhanced /2/, /3/.

## 3. Example of improvement of no-slump concrete

The benefit of the clay additive is shown for no-slump concrete pavement stones. For the reference concrete mixture C0 aggregates with a grading curve A8 were used. The C0 binder consisted of 280 kg/m² OPC and 83,5 kg/m³ fly ash. The modified concrete C1's binder consisted of 300 kg/m³ OPC and 14 kg/m³ clay additive. In fig. 1 some results for the green and the 24h compressive strength are presented. Despite a constant compaction energy, the maximum fresh concrete bulk density rose from 2,253 kg/dm³ (C0) to 2,337 kg/dm³ (+3,7%, C1), causing a raise of green strength (+127%), compressive strength after 24 hours (+146%) and after 28 days (+62%).

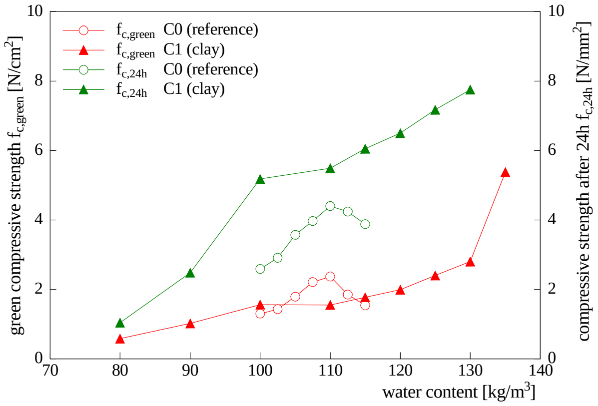


Fig. 1 *Concrete with fly ash C0 and with clay C1: green and 24h compressive strength /7/.*

The enhanced concrete characteristics mainly result from the improved rheological properties of the binder. Additional water, released from the clay-cement structures due to high compaction energy, leads to low viscosity and improved workability, bringing along a higher packing density and thus an interlocking of fine and coarse particles. Accordingly grain friction is enhanced and the C-S-H phases must bridge smaller distances and may grow tighter. The green strength rises significantly with high water contents, though the particle packing density then is constant. It is assumed that the cohesion between cement and clay particles causes the increase in green strength. The additional water causes also an increase of compressive strength after 24h, which is ascribed to the accelerated cement hydration. The medium pore size is reduced but no significant change of the freeze-thaw resistance can be observed /3/. This may be attributed to some weakening effects of the clay.

## 4. Summary

Despite the low strength of clay particles the compressive strength of concrete is enhanced. The increase in green strength can be explained by cohesive forces. The knowledge gained up to now should be used additionally for reducing the compaction energy and the sensitivity towards changing water contents and thus give rise to constant product qualities. Some more good results could be obtained in other tests, e.g. /3/. Further investigation is done at the time for modelling the modified microstructure of cement paste with clay, or very fine mineral fillers in general.

## 5. References


/1/ Bornemann R (2005) Untersuchungen zur Modellierung des Frisch- und Festbetonverhaltens erdfeuchter Betone. Ph. D. Thesis, Kassel

/2/ Budelmann H, Hariri K, Krauss HW, Malonn T (2007) Effects of a clay additive on the properties of no-slump concrete. ACM 2007:731 - 739

/3/ Budelmann H, Hariri K, Malonn T, Krauss HW (2006) Ton als Betonzusatzstoff – Produktqualität neu definiert. Proc. 50. Ulmer Betont.

/4/ Haque MN (1981) No-slump concrete with fine sand and clay. Cem Concr Res 11:531-539

/5/ Kelzenberg et Al (1998) Chemistry of the aqueous phase of Ordinary Cement Pastes at early reaction times. J Am Ceram Soc 81:2349-2359

/6/ Lagaly G, Schulz O, Zimehl R (1997) Dispersionen und Emulsionen. Steink., Darmstadt

/7/ Krauss HW (2005) Optimierung von Betonwaren mittels rheologischer Untersuchungen an Zusatzstoffen. Dipl. Th., Braunschweig

/8/ Malonn T, Hariri K, Budelmann H (2005) Optimierung der Eigenschaften von erdfeuchten Betonsteinerzeugnissen. BFT 71:20-26

/9/ Moukwa M et Al (1993) Effects of clays on fracture properties of cement-based materials. Cem Concr Res 23:711–723

/10/ Wierig HJ (1971) Zur Frage der Theorie und Technologie des grünen Betons. TU Hannover, Heft 19



**Institut für Baustoffe, Massivbau und Brandschutz (iBMB) der Technischen Universität Braunschweig**
**Materialprüfanstalt (MPA) für das Bauwesen**

Beethovenstraße 52
38106 Braunschweig
Tel.: +49 (0) 531 391 5400
Fax: +49 (0) 531 391 5900

E-Mail: info@ibmb.tu-bs.de
http://www.ibmb.tu-braunschweig.de
E-Mail: info@mpa.tu-bs.de
http://www.mpa.tu-bs.de


© 2008 Institut für Baustoffe, Massivbau und Brandschutz der TU Braunschweig – Materialprüfanstalt für das Bauwesen Braunschweig