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Clay-cement suspensions - rheological and functional properties

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Clay-cement suspensions - rheological and functional properties

L Wojcik, P Izak, J Mastalska-Poplawska, M Gajek

AGH University of Science and Technology, Faculty of Materials Science and Ceramics, Department of Ceramics and Refractories, Krakow, Poland

E-mail: lukasz.wojcik@agh.edu.pl

Abstract. The piping erosion in soil is highly unexpected in civil engineering. Elimination of such damages is difficult, expensive and time-consuming. One of the possibility is the grouting method. This method is still developed into direction of process automation as well as other useful properties of suspensions. Main way of modernization of the grouting method is connected it with rheology of injection and eventuality of fitting them to specific problems conditions. Very popular and useful became binders based on modified clays (clay-cement suspensions). Important principle of efficiency of the grouting method is using of time-dependent pseudothixotropic properties of the clay-cement suspensions. The pseudo-rheounstability aspect of the suspensions properties should be dedicated and fitted to dynamic changes of soil conditions destructions. Whole process of the modification of the suspension rheology is stimulated by the specific agents. This article contains a description of practical aspects of the rheological parameters managing of the clay-cement suspensions, dedicated to the building damages, hydrotechnic constructions etc.

Keywords: Pseudothixotropy, Clay-cement Suspension, Grouting, Piping Erosion

1. Introduction

Clay-cement suspensions are used in the construction and maintenance of hydrotechnic constructions such as embankments, dikes and dams, where the main factor in their suitability is high water tightness. This material, apart from the very good waterproofing properties, should be characterized by the low cost, simple fabrication and application [1-2].

During reparation of the embankments, using various drilling techniques (for example WIPS or DSM) enabling the creation of protective waterproofing barrier in the cross-section of the shaft or filling occurring cracks and voids (injection methods), binder is usually introduced as the suspension [3]. This operation aims to restore the integrity and liquidation of penetrations and waterways, whereby a major factor determining the suitability of the used material is its ability to retain water - determined by the filtration coefficient (k) [4].

Another very important factor determining suitability of the sealing material is its rheological properties. Modernization of levees, often located in inaccessible terrain, makes it necessary to transport the binder in considerable distances. The most widely used solution is to create a portable base, which is followed by the production of the binder in the form of suspension, and transport through pipelines to the place of performed work. Control and modification of the rheological properties at the place of the suspension preparation becomes one of the basic steps of determining their suitability in this type of work [5-7].

2. Materials and methods

The subject of the study were samples of the clay-cement binders prepared in laboratory using smectite-illite clay, CEM II / B-M 32.5 R cement produced by Lafarge and bonding inorganic modifier. The effect of changes in the share of individual components on the properties was investigated.

Studies have been conducted in two stages. In the first stage rheological properties of the freshly prepared suspensions were measured, whereas in the second stage mechanical strength and filtration coefficient of the binders after 90 days were checked. Studies of the hardened binders were performed by the use of Tiratest 300 apparatus and by the use of device measuring filtration coefficient by the flow pump method.

Rheological measurements were conducted by the use of two different rheometers, Brookfield R/S in the coaxial cylinders system and Anton Paar Physica MCR-301 in the parallel plates system. Flow curves, as well as G′ and G″ moduli as a function of the composition changes, were determined. The effect of changes in the cement quantities and clay substrate concentration on the rheological properties of hydrotechnic binders was identified.Two series of tests were made. In the first one, cement part at a constant concentration of the clay material was changed, whereas in the second series clay content was changed. All measurements were made on samples immediately after its preparation, at 20°C.

3. Results and discussion

3.1. Rheological measurements

Analysis of the obtained results have shown very characteristic course of the flow curves. All registered runs are accompanied by a sharp increase in the shear stress in the low shear rates until the characteristic peaks in the range of 5 to 10 s^{-1}. At higher shear rates, i.e.> 10 s^{-1} , stabilization of shear stress is obtained, what means shear thinning (pseudoplastic flow). Return flow curves corresponding to the decreasing shear rates are localized under curves recorded for increasing shear rates, indicating on thixotropic properties. In a series of samples with a variable cement content, shift of the maximum shear stress in the direction of lower shear rates with increasing cement content was registered (figure 1).

In a series with a variable clay content, shift of the shear stress maximum was not observed. But very rapid increase in the shear stress values was highlighted, especially with the participation of the two highest concentrations of clay, i.e. 29% and 32%. Registered maximum values were up to 7-fold higher than those recorded at lower concentrations (figure 2).

Oscillation tests were carried out at variable oscillation frequency, in the range of 0.05 to 500 Hz, for 120 minutes. In each case, slurry samples were examined immediately after its preparation. The measurements were performed at 20°C.

As in the case of the flow curves, tests were performed for two series - by changing respectively the content of cement and clay. Similar courses of changes in elastic modulus G' and viscous modulus G" were noticed.

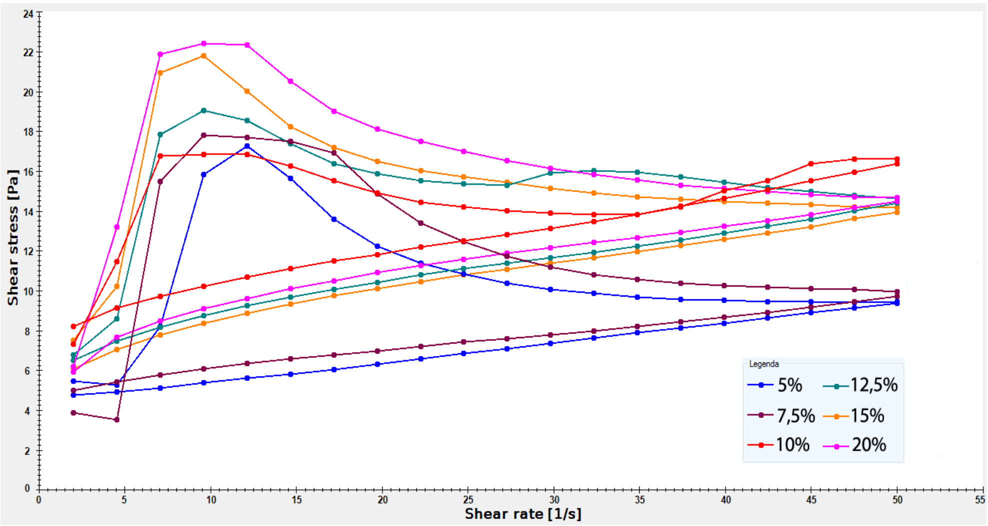

Figure 1. Influence of the cement content on clay-cement suspensions flow curves

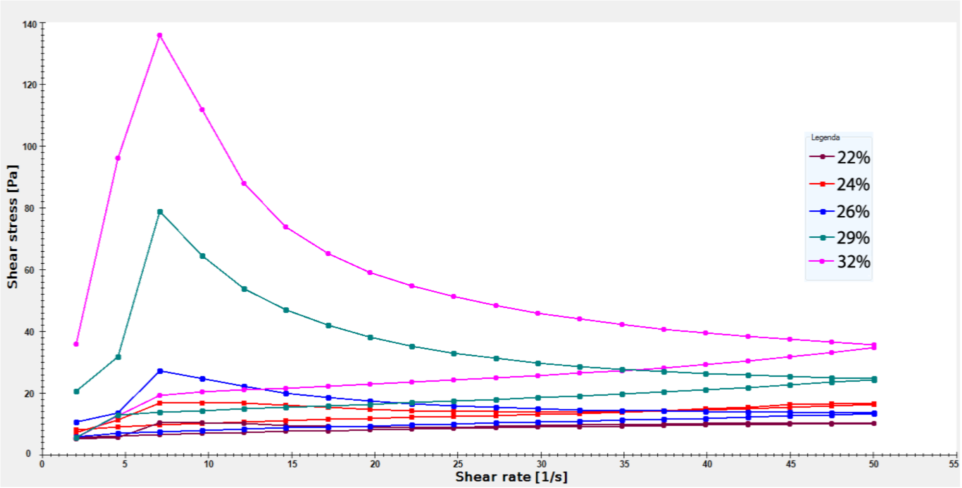

Figure 2. Influence of the clay content on clay-cement suspensions flow curves

With the passage of time and decrease of the oscillation frequency, an increase in the value of both moduli was recorded. At the beginning, values of the G" modulus were higher than the values of the G' modulus. As time passes, an increase in the value of the elasticity modulus G' was registered, and cross-over point as a function of the oscillation frequency occurred.

In a series of the samples with the increasing cement content describing phenomena also occurred (figure 3) but it is difficult to show any regularity associated with changes in the share of cement content (figure 4.).

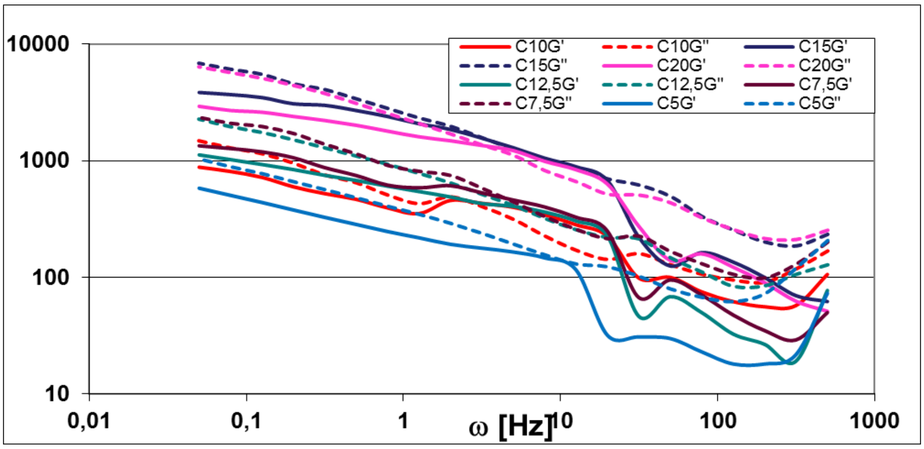

Figure 3. Influence of cement content on storage modulus G′ and loss modulus G″

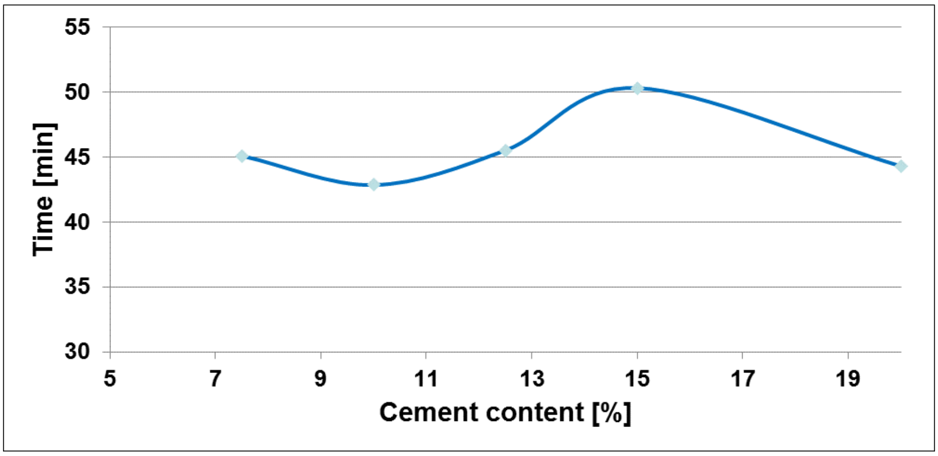

Figure 4. Influence of cement content on G′ and G″ cross-over points

In a series of samples with varying clay content (figure 5), said regularity is more visible. As for the previous series, an increase in G′ and G″ moduli values with increasing clay concentration was observed. However, the time after which "cross-over" phenomena occurs, is related to the change in composition of respondents suspensions. With the increase of the clay concentration, shortening of the cross-over occurrence follows. These values vary from 51 minutes for the lowest concentrations up to approximately 37 minutes for concentrations above 26% (figure 6). This means that the clay mineral accelerates the transition from liquid to solid state of the clay-cement suspension.

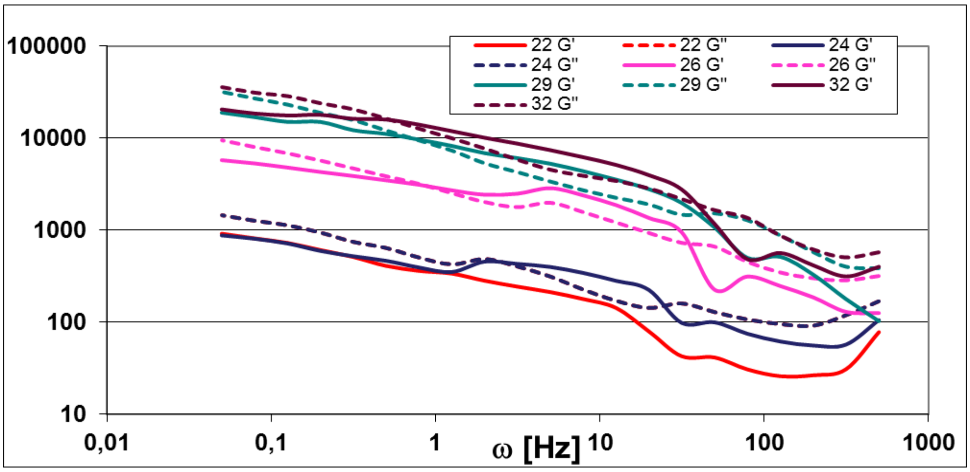

Figure 5. Influence of clay content on storage modulus G′ and loss modulus G″

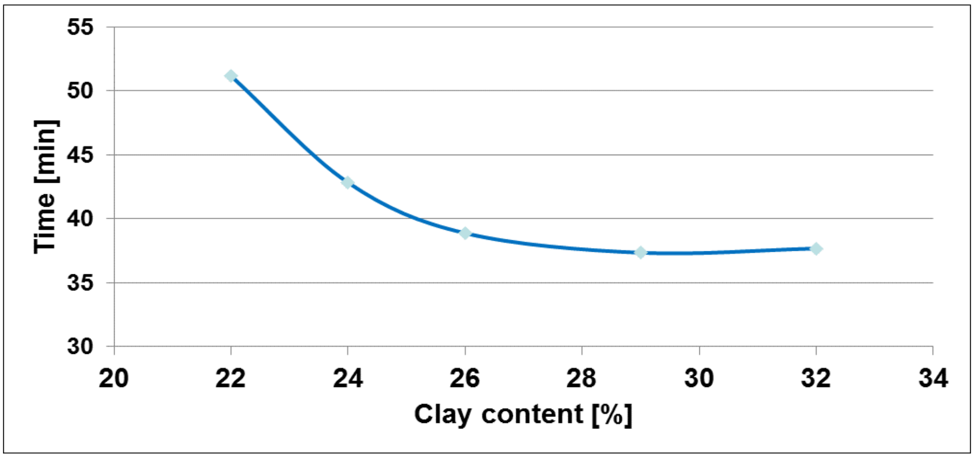

Figure 6. Influence of clay content on G′ and G″ cross-over points

3.2. Filtration coefficient and mechanical strength measurements

Filtration coefficient and mechanical strength measurements were performed on solidified binder samples after 90 days of puberty. Studies were carried out on cylindrical samples having a diameter of 35mm and 35mm height.

The results of the filtration coefficient measurements are shown in figures 7 and 8. Analyzing the obtained results, very strong relationship between the concentration of clay and the filtration coefficient of studied binders can be seen. With the increase of the clay component concentration the filtration coefficient rate decreases very rapidly. Particularly, decrease at lower concentrations of clay mineral can be seen, wherein the change in concentration of about 2% causes decrease of the coefficient rate of magnitude. For higher concentrations these drops are not so high, but trend persists. For the tested clay concentrations, values of the filtration coefficient are in the range from 10^{-8} to 10^{-11} m/s.

For a series of samples with varying cement concentrations decrease in the filtration coefficient rate with increasing concentration of cement was also observed, although these drops were not as high as in the case for a series with varying clay content. The total range of variation was approximately one order of magnitude, from 10^{-9} to 10^{-10} m/s.

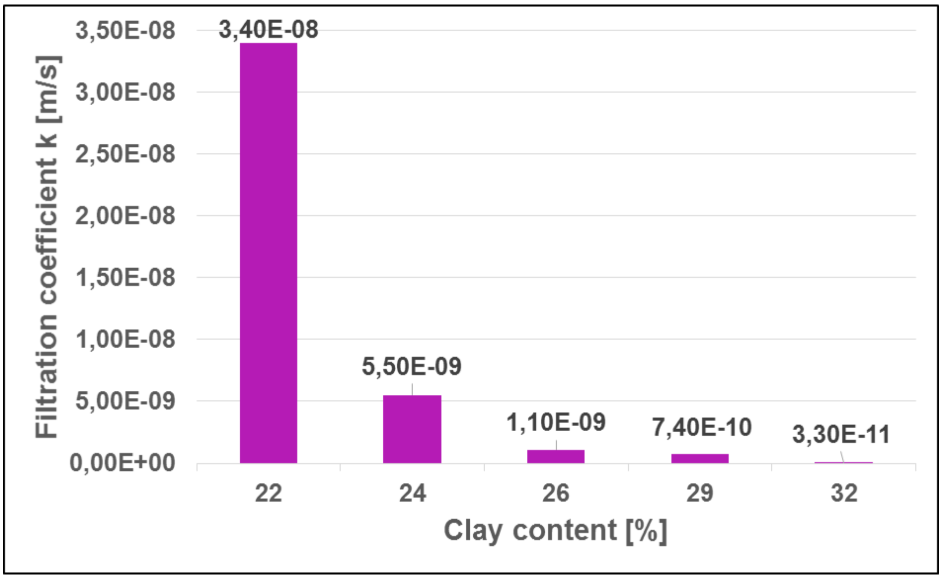

Figure 7. Influence of clay content on filtration coefficient

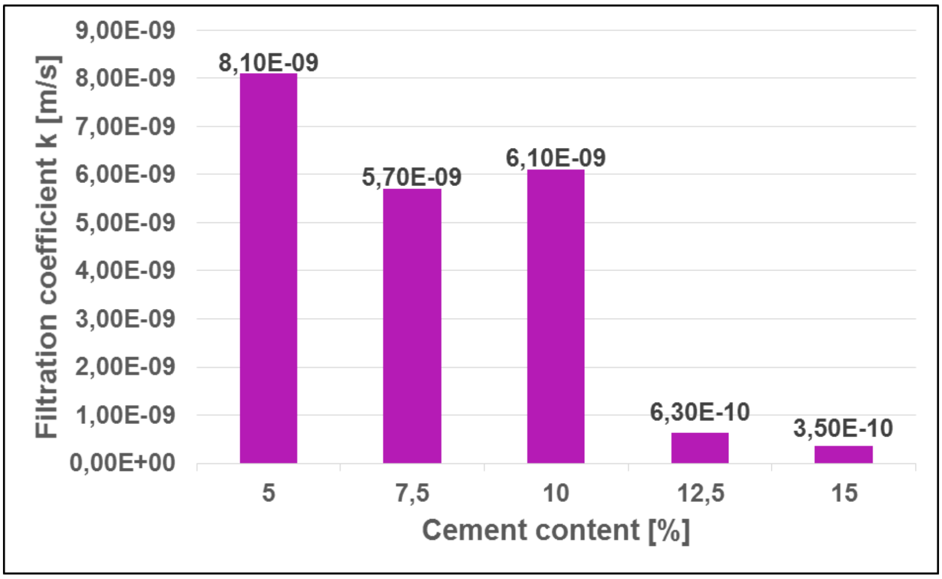

Figure 8. Influence of cement content on filtration coefficient

Mechanical strength measurements have shown that the crucial meaning has the cement content, where a steady increase in mechanical strength with an increase in the cement concentration was observed. The range of variation changed from 0.75 to 1.75 MPa. For a series with varying clay content, there were no significant influence of this parameter on the measured values. In the whole range of concentrations, values were more or less stable, approximately 1 MPa.

Results of the mechanical strength measurements are shown in figures 9 and 10.

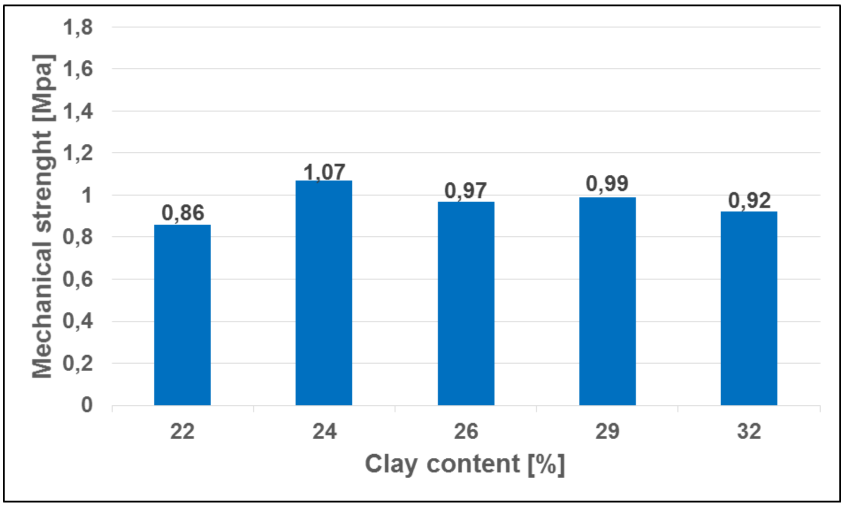

Figure 9. Influence of clay content on mechanical strength

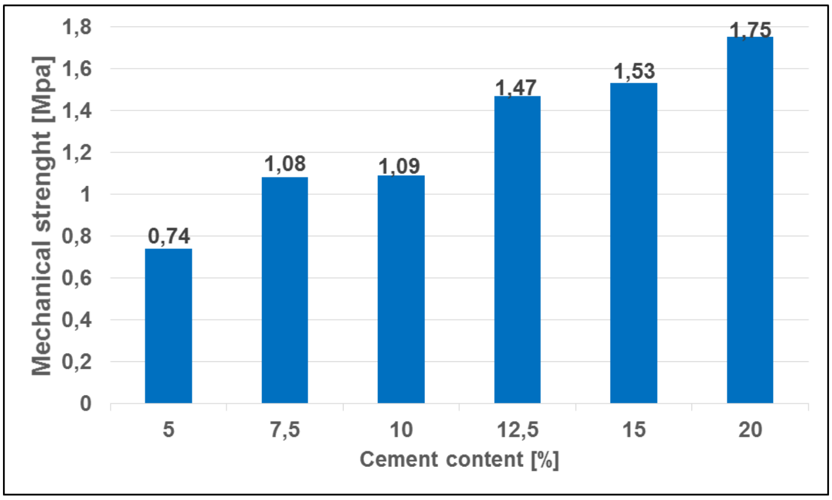

Figure 10. Influence of cement content on mechanical strength

4. Conclusions

Conducted tests showed that functional properties of clay-cement binders can be programmable in a wide range. Rheological behaviour is a result of the properties of clay materials and cement hydration products. Viscosity and shear stress could be changed in wide range by changing the composition. This enables the design of blends significantly different from each other with rheological properties, so that they can be used in different process conditions.

The oscillation moduli G′ and G″ shown that during the reaction viscoelastic properties of samples are changing. During the studies, the characteristic cross-over points, evidence of change in the properties of slurry from viscous to elastic, were observed. Time after which they appear is strongly dependent on the amount of raw mineral, i.e. illite-smectite clay. For the varying cement content there was no regularity in this case.

Mechanical strength and filtration coefficient can be modified by changing of clay or cement content. Mechanical strenght is related to cement content whereas the filtration coefficient strongly depends on the clay content.

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