# Study of Meta Kaolin Influence on Rheological Properties of Cement Mortars

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## ABSTRACT

Fast progress of present-day concrete practice brings development of new technologies applying new types of special concrete even in heavy conditions. Self-compacting concrete ranks among relatively new types of concrete. This concrete is characterized by very good physico-mechanical properties as well as high level of flowing property and long workability of fresh concrete. Cement matrix always contains certain amount of fine additions and, to reach desired rheological properties, it is modified by superplasticizers, mostly polycarboxylate based. To be safe in practical use, it is necessary to test rheological properties of modified cement matrix within the interval of at least 90 minutes in laboratory conditions.

The paper describes the research of different dosage of meta kaolin used as active addition and its influence on final rheological properties of fresh cement paste and resulting physico-mechanical properties of hardened cement stone.

Meta kaolin has become a popular partial replacement of cement in construction industry in the last few years. Meta kaolin has pozzolanic properties, which is the reason of its positive effect on final properties of concrete. Pozzolanic properties cause reaction of active components with calcium hydroxide and formation of binding phases of following types: C-S-H gel, $C_4AH_{13}$, $C_3AH_6$ and $C_2ASH_8$.

## INTRODUCTION

Use of Metakaolin in construction industry as partial replacement of cement started in the 1960's and the interest in this material has considerably increased in recent years. Metakaolin has pozzolanic properties bringing positive effects on resulting properties of concrete. Pozzolanic properties cause chemical reaction of active components with calcium hydroxide (portlandite), which is formed as a product of cement hydration. This reaction leads to formation of binding phases of following types: C-S-H gel, $C_4AH_{13}$, $C_3AH_6$, and $C_2ASH_8$.

The paper deals with the research of different dosage of metakaolin used as active additive and its influence on rheological properties of fresh cement paste and resulting physico-mechanical properties of hardened cement stone. Results of experiments with cement suspension imply similar behavior of input components in concrete.

## METAKAOLIN

Metakaolin is white, amorphous, highly reactive aluminiumsilicate pozzolan forming stabile hydrates after mixing with lime stone in water and providing mortar with hydraulic properties. Heating up of clay with kaolinite $Al_2O_3.2SiO_2.2H_2O$ as the basic mineral component to the temperature of 500 °C - 600 °C causes loss of structural water with the result of deformation of crystalline structure of kaolinite and formation of an unhydrated reactive form – so-called metakaolinite.

Action of metakaolin in concrete

Metakaolin is usually added to concrete in amount of 5 – 15% by weight of cement. Addition of metakaolin causes increase of mechanical strength, enhancement of long-term strengths, decrease of permeability, porosity, reduction of efflorescence, increase of resistance to soluble chemicals like sulphates, chlorides and acids.

Addition of metakaolin decreases workability of fresh concrete mix. This disadvantage can be reduced by superplasticizers. However, rheological properties of fresh concrete mix depend on the type of superplasticizer. Generally, polycarboxylate based superplasticizers have better influence on workability than poly naphthalene/melamine sulfonates. Worse workability of concrete mix caused by metakaolin can also be adjusted by addition of fly ash.

Content of metakaolin in concrete decreases permeability and rate of penetration of damaging ions because of refinement of structure of pores of cement stone. Higher dose of metakaolin in concrete increases the proportion of pores with diameter up to 0.02 μm. At the same time, the volume of capillary pores of the size 0.05 – 0.1 μm causing higher permeability, is lower.

Appropriate use of metakaolin can bring considerable increase of resulting strengths, in particular in the initial stages of hardening. Values of compressive strength of concrete with metakaolin after 28 days can be higher by 20%. Increase of resulting strengths is caused in particular by following aspects: immediate action of metakaolin as filler, speeding up of cement hydration during the first 24 hours and the above-mentioned pozzolanic reaction.

Addition of metakaolin as partial replacement of cement contributes to higher compactness of arrangement of concrete components, which increases flowability of mastic cement, enhances mechanical bond and improves adhesion between cement paste and aggregate.

## METHODS OF EXPERIMENTAL WORK

This paper deals with the research of influence of metakaolin on rheological properties of cement suspension. Knowledge found in experiments can be used for designing and production of concrete with special properties. Experiments tested influence of metakaolin on rheological behavior of cement pastes and resulting physico-mechanical properties. Rheological properties of cement paste were tested on the Rheotest apparatus. Physico-mechanical properties, in particular strengths after 48 hours and 28 days, were tested after hardening of modified mixes.

Physico-mechanical properties and chemical composition of metakaolin are stated in Tables 1 and 2.

Six mix-designs were designed and experimentally tested. Cement used was CEM I 42.5 R, constant proportion. Polycarboxylate based superplasticizer was used in amount of 1.2% a 1.8% by weight of cement. Amount of metakaolin was 5%, 10% and 15% by weight of cement. W/c ratio was constant for all mix-designs (0.395).

Table 1. Physico-mechanical properties of metakaolin.

| Properties | Value |
|---|---|
| Mean size of particle D50 (μm) | 3 - 5 |
| Maximal grain size (mm) | 1,0 |
| Specific activity 226Ra (Bq/kg) | 100 |

Table 2. Chemical composition of metakaolin.

| Chemical composition (%) | | | | | | | |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | MgO | $TiO_2$ | $K_2O + Na_2O$ | CaO | Loss by annealing |
| 51-53 | 40-42 | 1,2-1,4 | 0,30-0,45 | 0,80 | 1,35-1,45 | 0,25-0,30 | 3,5 |

Table 3. Average values of viscosity of cement paste with CEM I 42.5 R with addition of metakaolin and admixture.

| Additive | Dosage | Superplasticizer - 1,2% | | | | | Superplasticizer - 1,8% | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | viscosity (Pa.s) | | | | | viscosity (Pa.s) | | | | |
| | | 0 min | 30 min | 60 min | 90 min | 120 min | 0 min | 30 min | 60 min | 90 min | 120 min |
| Metakaolin | 5% | 804,9 | 157,8 | 134,1 | 126,2 | 102,6 | 489,2 | 189,4 | 134,1 | 110,5 | 86,8 |
| | 10% | 1041,5 | 292,0 | 244,6 | 228,8 | 228,8 | 962,7 | 268,3 | 205,2 | 173,6 | 149,9 |
| | 15% | 1468,0 | 552,4 | 315,6 | 465,6 | 599,7 | 946,9 | 449,8 | 355,1 | 323,5 | 347,2 |

Table 4. Compressive strength of cement paste – Cement CEM I 42.5 R, metakaolin, additive.

| Reference mix-design cement + water (w = 0,395) | | Additive | Dosage | Superplasticizer - 1,2% | | Superplasticizer - 1,8% | |
|---|---|---|---|---|---|---|---|
| Compressive strength $R_b$ [MPa] | | | | Compressive strength $R_b$ [MPa] | | Compressive strength $R_b$ [MPa] | |
| 48 hours | 28 days | | | 48 hours | 28 days | 48 hours | 28 days |
| 31,0 | 43,4 | Metakaolin | 5% | 29,9 | 38,9 | 30,2 | 43,1 |
| | | | 10% | 33,1 | 44,3 | 33,7 | 45,4 |
| | | | 15% | 34,2 | 49,3 | 35,1 | 50,0 |

## TEST RESULTS

Measured values of viscosity of tested mix-designs are stated in Table 3 and graphically represented in Fig. 1.

Fig. 1 shows decrease of viscosity in time. This phenomenon is apparent in particular for suspension with metakaolin in amount of 5% and 10%. Curves representing development of viscosity in time from 0 to 120 min were similarly decreasing for all mix-designs with addition of tested additive in amount of less then or equal to 10%. Curve of viscosity of cement suspension with metakaolin in amount of 15% showed increase at the end of tested period.

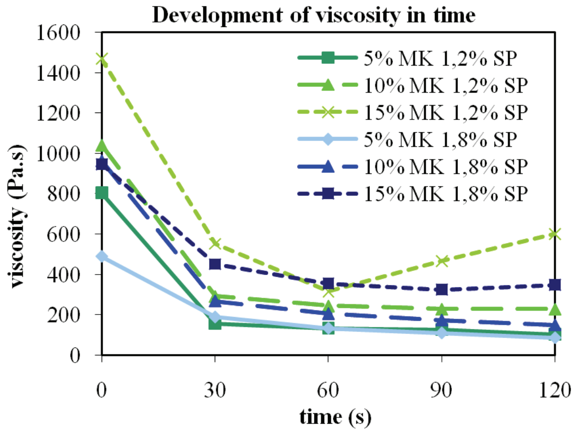


Figure 1. Development of viscosity in time.

Compressive strengths after 48 hours and 28 days of standardized maturing were determined for all tested mix-designs. Values of compressive strengths are stated in Table 4 and Fig. 2.

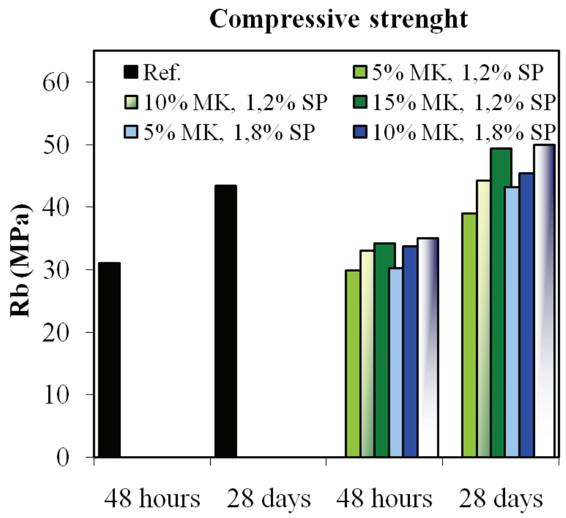


Figure 2. Development of compressive strength after 48 hours, 28 days.

Fig. 2 shows values of compressive strength of samples 48 hours and 28 days old. The results of measurement prove that compressive strength considerably increases even after 48 hours. The value of compressive strength grew proportionally to amount of metakaolin and superplasticizer.

Compressive strength of mix with metakaolin after 28 days was higher by 10% to 15% compared to reference samples.

## CONCLUSIONS

This paper describes influence of metakaolin used as partial replacement of cement on behavior of cement based suspense – rheological properties of fresh mix and strength characteristics of cement stone. Knowledge found by research of modified cement paste imply behavior of fresh and hardened concrete. On the basis of measurements it can be concluded that:

- Higher amount of superplasticizer increases workability of fresh mix. Higher addition of metakaolin also enhances workability. Dosage of 15% of metakaolin causes decrease of workability of suspension in time. Increasing amount of percentual proportion of metakaolin in concrete mix seems to require higher dosage of superplasticizer to ensure longer period of workability.

- Addition of metakaolin increases also final strength of cement stone. Compressive strength was growing with higher dosage of additive. Since the amount of 15% metakaolin results in loss of viscosity in time, it seems appropriate to use dosage of 10% by volume of cement.


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