Warsaw University of Technology

Faculty of Civil Engineering

Department of Building Materials Engineering

BUILDING MATERIALS

LABORATORY TASK

Modification of concrete with mineral additives

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1. Aim of the task

Assessment of selected mineral material as potential additive to concrete on the basis of the activity coefficient.

2. Theoretical background

2.1. Definitions

- **Admixture** – a component added during the mixing process of a concrete mix in small amounts in relation to the weight of cement to modify the properties of the concrete mix or hardened concrete.
- **Additive** – a fine-grained component used for concrete to improve certain properties or obtain special properties; usually added in quantities above 5% of cement; the additive can significantly modify the properties of both concrete mix and hardened concrete.
- **Strength class of cement** – compressive strength class of cement

2.2. Theoretical background

Mineral additives are - in addition to admixtures - the most commonly used modifiers of concrete mix and hardened concrete. Siliceous fly ash is the most commonly used mineral additive for concrete in Poland; silica fume is less often used, while blast furnace slag is practically entirely consumed in Poland by cement producers, where it is the main component.

According to the standard PN-EN 206 the term "additive" means "a fine-grained inorganic component used for concrete to improve certain properties or obtain special properties". The definition of concrete admixtures according to standard PN-EN 934-2 indicates as a limit content of 5% cement mass, it is usually considered that the additive is a modifier added to the concrete mix in an amount exceeding 5% of the cement mass. Concrete additives, according to PN-EN 206, are divided into two basic groups:

- **Type I** - almost inert additives, which include pigments and mineral fillers, e.g. quartz flour, limestone powder and other stone powders.
- **Type II** - pozzolanic additives, e.g. silica fume, siliceous fly ash, metakaolinite, natural pozzolana or latent hydraulic properties, e.g. calcareous fly ash, blast furnace slag.

Pozzolanic properties are the ability to pozzolanic reaction, i.e. the reaction of amorphous silica and calcium hydroxide (a product of hydration of silicates) and water in which hydrated calcium silicates

are formed (C-S-H gel). Pozzolanic properties are characteristic of materials called Pozzolanas, which can be of natural or artificial origin.

Latent hydraulic properties are the ability (under certain conditions) and in the presence of an activator to bind in a manner analogous to Portland cement.

Coefficient k conception

In the standard PN-EN 206-1: 2003, in the context of type II mineral additives, the k factor has been introduced. Its value indirectly expresses the activity of a given additive in comparison with the activity of cement and allows to include such additives in the composition of concrete. This is done by replacing the **w/c (water/cement)** ratio with a ratio **w/(c + k·additive)**, yet the amount of binder (cement and additive multiplied by k) should not be less than the minimum amount of cement required by a given exposure class.

The values of the k coefficient recommended in the PN-EN 206 standard:

- fly ash: k = 0.4;
- silica fume (in exposure class XC or XF and w / c> 0.45): k = 1.0;
- silica fume (other exposure class): k = 2.0;
- ground granulated blast furnace slag: k = 0.6
  (note: the value regarding slag is disputed as inappropriate).

3. Practical tasks

3.1. Coefficient of activity of mineral additive

3.1.1. Materials and equipment

- reference cement (CEM I 42,5R),
- mineral additive (e.g. fly ash, silica fume, etc.)
- tap water,
- standard sand,
- anti-adhesion agent,
- automatic laboratory scale,
- 400 ml laboratory glass beaker,
- plastic bowl,
- automatic standard mixer,
- molds for set of 3 beams of dimensions 40 mm x 40 mm x 160 mm,
- laboratory vibrator,
- storage tub (air condition),
- storage tub (water condition).

3.1.2. Task completion

The test should be carried out on specimens of standard mortar and standard mortar in which 25% of the cement mass was replaced with a mineral additive. One need to prepare the amounts of individual components, i.e. cement or cement and the mineral additive being the subject of the test, tap water (meeting the requirements of PN-EN 1008) and prepare standard aggregate (standard sand meeting the requirements of the standard PN-EN 196-1), then place them in a standard mixer and follow the standard mortar sample preparation procedure:

- Weigh 450.0 g of cement specimen (or 337.5 g of cement and 112.5 g of mineral additive) in a plastic bowl.
- Measure 225 g of cold tap water in a 400 ml beaker.
- Check the tightness of the packaging, and then unseal the standard sand bag, place it in a special container in the automatic standard mixer.
- Unlock the standard mixer bowl and moisten its interior; moisten the mixer agitator.
- Place the water and then the cement (or cement and additive) in the standard mixer bowl and immediately start the mixer programmed for the standard mortar mixing procedure.
- The mixing procedure is as follows (see Fig. 1):

- 30 s of low speed mixing,
- 30 s of low speed mixing – during this time, standard sand is applied to the paste,
- 30 s of high speed mixing,
- 90 s break – during the first 15 s unlock the bowl and scrap the mortar from the walls and bottom to the center of the bowl,
- 60 s of high speed mixing.

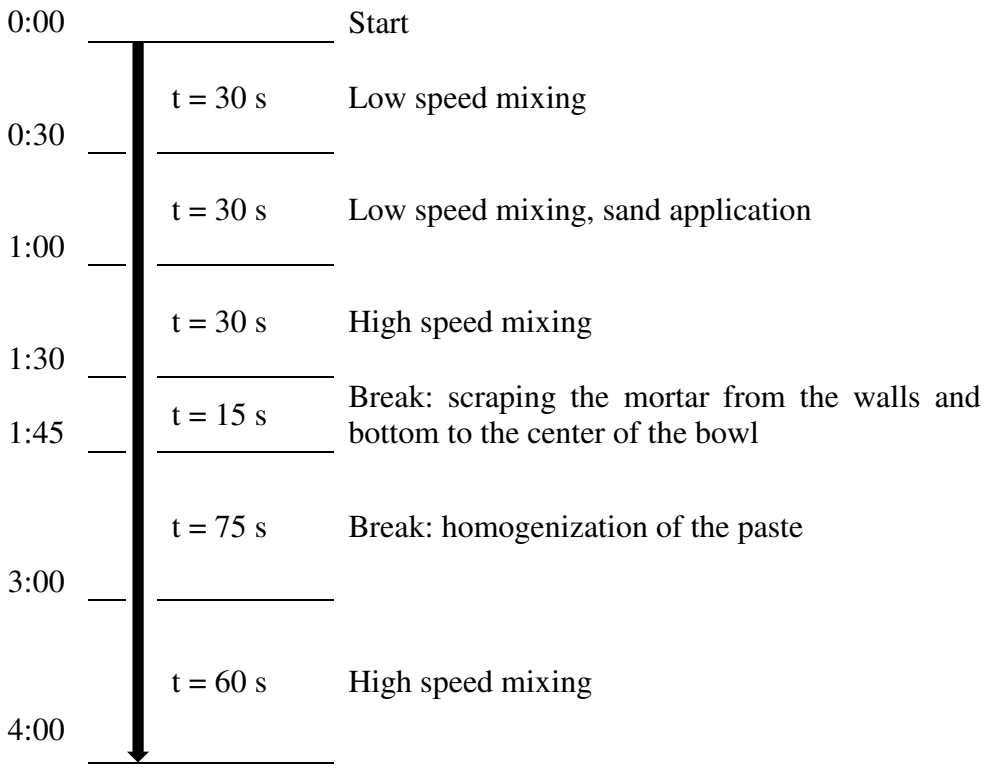

Fig.1. The standard mortar (or mortar modified with mineral additive) mixing procedure according to standard PN-EN 196-1

- Apply the mortar to the prepared (covered with anti-adhesion agent) mold placed on the vibrator stand - place the first of two layers of mortar in each mold compartment.
- Thicken the first layer of mortar with 60 shakes.
- Apply a second coat of mortar.
- Thicken the second layer with 60 shakes.
- Remove excess mortar with a knife.
- Place a smooth glass, metal or plastic plate on the mold.
- Place molds in an air-conditioned room.
- After 20 to 24 hours demold the specimens and place them on stainless steel grates in a container with water at temperature 18 ÷ 20°C in such a way that water has free access to all surfaces of the specimen.

- After 27 days (or 89 days), determine the flexural strength and compressive strength of the mortar, and evaluate the results in light of the standard requirements – the cement compressive strength class and the minimum od compressive strength in case of additive modified mortar.

Flexural strength of standard mortar is determined on three specimens. The specimen is placed in a testing machine on supports whose spacing is 100 mm, and then it is loaded with concentrated force in the middle of the span until destruction. The flexural strength of the mortar is calculated in MPa with an accuracy of 0.1 MPa according to the formula:

$$f_b = 2{,}34 \cdot P \tag{3.1}$$

where:
f_b – flexural strength, MPa,
P – bending force, kN.

The result is the arithmetic mean of three values of flexural strength, which was determined on a set of three specimens (beams).

Compressive strength of standard mortar is determined on six halves of specimens remining after the flexural strength test. The specimen is placed in a testing machine between two metal 40 x 40 mm (1600 mm^2) pads and then loaded until damaged. The device for determining the compressive strength should provide a load increase rate of 2400 ± 200 N/s. The compressive strength of the mortar is calculated in MPa with an accuracy of 0.1 MPa according to the formula:

$$f_c = P/A \tag{3.2}$$

where:
f_c – compressive strength, MPa,
A – compressed area (area of the metal pad), mm^2,
P – compressive force, N.

The result is the arithmetic average of six values of compressive strength, which was determined on halves of three specimens (beams). If one of the six strength values differs from the mean value by more than 10%, this value should be rejected and the average of the remaining five results recalculated. If one of the other five values differs from the new average by more than 10%, then the entire study should be rejected.

3.1.3. Results

Based on the average value of mortar compressive strength, the loss of mortar strength with mineral addition should be calculated relative to the strength of mortar without addition (standard mortar), and then the results should be evaluated in the light of standard requirements. According to the requirements of the PN-EN 450-1 standard, the mortar with the addition should achieve a minimum

75% strength of standard mortar after 28 days or a minimum 85% strength of standard mortar after 90 days.

3.1.4. Elaboration of results

An example of a table containing the results of the tests described above is Table 1 (set of results for one mortar). In order to make a better assessment of mortar homogeneity, in addition to the mean value, the standard deviation (SD) and coefficient of variance (CV) should also be calculated.

Moreover, the water/binder ratio of the modified mixture should be determined taking into account the k factor according to the formula in section 2.2.

Table 1. Test results for flexural strength and compressive strength of standard mortar or mortar with mineral additive

Flexural strength				Compressive strength					
No	P [kN]	f_b [MPa]	$f_{b,av}$ [MPa]	No	P [kN]	f_c [MPa]	$f_{c,av}$ [MPa]	SD [MPa]	CV [%]
1				1.1					
				1.2					
2				2.1					
				2.2					
3				3.1					
				3.2					

The compressive strength of the mortar with mineral addition determined after 28 days is ....% of the strength of standard mortar determined after 28 days..

4. Laboratory report

The laboratory report should include:

I. Subject, aim and scope of research (containing basic information about tested materials/products, test methods, requirements),
II. Tests results with proper units (results obtained in the laboratory prepared in the indicated manner, e.g. put in the proper tables),
III. Conclusions (bulleted statements formulated based on the results obtained),
IV. Bibliography (list of references to the literature or www used to prepare the report).