New type of multifunctional silicate composite

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Abstract. There are introduced basic information about the composition and the properties of
the precast cement-based mixture in the paper. Studied multi-functional composite was
developed for the easy and rapid reconstruction of the concrete structures. This composite
exhibited rapid evolution of utility properties and volume stability during the process of
hardening.

1. Introduction
Currently is known prefabricated mixtures for preparation concrete used in the field of civil
engineering and building structures. Concrete can be transported already done - ready for use or can be
prepared directly on the site by adding the mixing water to the prefabricated mixture, optionally by
addition of other substances.

Figure 1. Production of dry prefabricated mixture.

The basic components of dry prefabricated mixtures (figure 1) are binder matrix ensuring the
cohesion of the setting concrete, aggregates and regulation systems ensuring setting and hardening
concrete.

Current approach to composite materials is using different sources of aggregates. Those can be
granular or fibrous character with different origin - natural or industrial. Binder matrix is based on the
most commonly used silicate cement. This silicate base cement can be pure Portland cement, or
blended cements containing, for technical, economic or environmental reasons, different admixtures.
Used admixtures can be latently hydraulically active or inert, but it must be preferably such
granulometry, which complements the granulometry of used binder, to obtain a continuous granulometry of the entire system of solid components in the final preparation of the freshly prepared mixture with water.

The use of commercially available silicate cements, declared as pure Portland cements, blended cements and standardized cements e.g. in accordance with CSN EN 197-1 or other normative regulations, brings to the formulation of special cement composites a number of problems arising from basic standard requirements for physicochemical parameters of commonly produced cement binders. This is primarily about the reliable control of hydration and setting mechanisms of used type of silicate cement, referred to as time development of the so-called setting and hardening processes, the achievement of acceptable workability of the freshly mixed mixture, simple processing and storage, bulk stability of the curing composite, achievement of predicted parameters and long-term stability under various conditions of use.

The available literature describes a number of possibilities for controlling the properties for various types of silicate binders, to modify or supplement them to produce a low or high-value cementitious composite. There are various options for modification so-called ratios of setting and hardening process with a variety of retarding or accelerating additives, the use of plasticizers or superplasticizers and stabilizers of various compositions, the mixing method for the necessary homogenization of the fresh mixture with the required amount of mixing water, or with other requirements for achieving the declared parameters such as the time consuming to preparation of composite, storage and compaction of freshly prepared composite with mixed water.

Mineral and pozzolanic components from natural or artificial sources such as micronized limestone, micro-silica, ground blast-furnace slag, fly ash, various aluminosilicates and others are used as super-fine admixtures. Their basic physicochemical parameters must be respected in order to avoid undesired effects on the control of setting and hardening processes and also to maintain a sufficient time for workability by the used flowability additives and to achieve the volume stability of solid structure of the composite.

Other fine aggregates above 0.1 mm are mainly sand fractions of different purity (high content of pure SiO₂), but can be also another dense or porous minerals (corundum, carborundum, fireclay, basalt, etc.). The use requires respecting their physical properties (absorption, etc.), which leads to the need for careful formulation of considered composite.

This paper presents the results of some preferred variants of a dry prefabricated multifunctional composite, which were mixed on slow-speed mixers with different mixing vessel volumes.

2. Experimental program

The individual components of multifunctional mixture are usually available at commercial distributor. The binder components are products of Czech cement companies from Čížkovice, Lochkov, Prachovice, Mokrá and Hranice. The additives in the powdered form, which are needed for this composite, are available on the domestic market by SIKA, BASF, STACHEMA, CHRYSO, RADKA and others [9].

The prefabricated mixture was mixed for 1.5 minutes. Mixing water was only 0,1 weight of all dry components.

| Designation of mixture | 1 | 2 | 3 |
|------------------------|---|---|---|
| Flow consistency without tapping [cm] | 28 | 28 | 28 |
| Start of setting [min.] | 20 | 130 | 330 |

The setting ratios were tested by cementation methodology, placeability by the flow methodology according to mortar standards without the use of tapping. Further were tested also flexural and compressive strength (see table 2) and volume changes (see figure 4).
After summarizing the results of the extensive experimental program are there presented the values of three selected mixtures with different processing times ranging from a few tens of minutes to several hours see table 2. More over mixture 2 was made with different fiber content and for each of them fracture energy was tested (see table 3).

**Table 2.** Mechanical properties of study mixtures.

| Designation of mixture | 1 hr. | 2 hr. | 5 hr. | 10 hr. | 15 hr. | 1 day | 7 day | 28 day |
|------------------------|-------|-------|-------|--------|--------|-------|-------|--------|
|                        |       | flexural [MPa] | compressive [MPa] |       | flexural [MPa] | compressive [MPa] |       | flexural [MPa] | compressive [MPa] |
| 1 hr.                  | 0,9   | 5,8   | -     | -      | -      | -     | -     | -      | -      |
| 2 hr.                  | 1,4   | 8,0   | -     | -      | -      | -     | -     | -      | -      |
| 5 hr.                  | 3,7   | 22,1  | 0,3   | 1,6    | -      | -     | -     | -      | -      |
| 10 hr.                 | -     | -     | 4,5   | 26,1   | 0,1    | 0,8   | -     | -      | -      |
| 15 hr.                 | -     | -     | -     | 1,6    | -      | -     | -     | -      | -      |
| 1 day                  | 8,1   | 47,4  | 8,7   | 50,2   | 7,6    | 45,5  | -     | -      | -      |
| 7 day                  | 13,2  | 79,4  | 13,1  | 78,3   | 11,2   | 65,3  | -     | -      | -      |
| 28 day                 | 19,7  | 106,1 | 16,2  | 95,6   | 19,2   | 95,5  | -     | -      | -      |

**Figure 2.** Development of flexural strength.
**Figure 3.** Development of compressive strength.

**Figure 4.** Volume changes vs. time of curing.
Table 3. Effective fracture energy values for mixture 2.

| Fiber content % vol. | Effective fracture energy J/m² |
|----------------------|-------------------------------|
| 0                    | 80                            |
| 0,5                  | 3 000                         |
| 1                    | 11 000                        |
| 2                    | 17 000                        |
| 3                    | 22 000                        |

After 168 hours (7 days) of curing in water basin were samples subjected to freeze/thaw cycling and residual properties were studied. The course of flexural strength and compressive strength declare no damage during the testing. Moreover, gradual increase of studied properties was observed, what was probably caused by the gradual hydration. Destructive testing does not correspond with non-destructive methodology very well. Used pulse method is actually sensitive on the moisture content, which could noticeably misrepresent the results, that is why it is used only as an indicative procedure [5-6, 8].

Table 4. Index of frost resistance after 100 freeze/thaw cycles for mixture 2 [-].

| Compressive strength | Flexural strength | Modulus of elasticity |
|----------------------|-------------------|-----------------------|
| 1.23                 | 1.63              | 1.00                  |

Figure 5. Evolution of dynamic modulus of elasticity during freeze/thaw cycling.

Frost resistance is usually expressed by the index of frost resistance calculated as a ratio of final and initial value of the observed property [4, 7]. Reached values of index of frost resistance for compressive strength, flexural strength and modulus of elasticity are shown in table 4 and figure 5. Obtained values well declare high resistance to action of frost of developed composite and its ability to hardening in such severe condition. Because binder system hydration was not demonstrably interrupted due to freeze/thaw cycling.
3. Conclusion

Dry mixture is made up of a new and very advantageous combination of commonly available ingredients. When combining their sometimes contradictory parameters, lead to a beneficial effect. The mixture is easily elaborate and needs a low dose of mixing water. Multifunctional composite prepared from dry prefabricate mixture is easily usable in practice with the wide range of applications, with a controlled hydration process and simply preparation technology. The composite has a sufficient workability time, a rapid increase in initial mechanical properties and reaches reliable stability after final hardening. Durability testing was presented through the freeze/thaw cycling what means one of the crucial parameter of the restoration of concrete structures. High performance concrete mixtures often exhibited low frost resistance due to extreme high density which does not allow transfer of the creating ice, since they have very low water adsorption.

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