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Influence of superplasticizers on the concrete mix properties

Влияние суперпластификаторов на свойства бетонной смеси

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Abstract. The most important technological properties of concrete mix are its workability, waterproof capacity, immutability of the properties and air-entrainment. The task of increasing the efficiency and quality of concrete and reinforced concrete is still very relevant and it cannot be successfully solved without the use of special chemical additives. The purpose of the research is to obtain workable concrete mix using special additives. The plasticizers based on polycarboxylate esters: Power Flow PF-2695, Power Flow PF-1130 and Power Flow PF-2237 have been determined as the most effective. It was found that some additives after the addition cause the creation of defects.

Аннотация. Наиболее важными технологическими свойствами бетонной смеси являются удобоукладываемость, водонепроницаемость, неизменность свойств во времени и воздухововлечение. Проблема повышения эффективности и качества бетона и железобетона остается актуальной, однако без использования химических добавок ее невозможно решить успешно. Данная работа нацелена на получение удобоукладываемой бетонной смеси путем применения специальных добавок. Пластификаторы на основе эфиров поликарбоксилатов такие, как Power Flow PF-2695, Power Flow PF-1130 и Power Flow PF-2237, по результатам работы были определены, как наиболее эффективные. Также было выявлено, что некоторые добавки способны вызвать появление дефектов.

Introduction

The most important technological properties of concrete mix are its workability, waterproof capacity, immutability of the properties and air-entrainment.

The possibility of obtaining self-compensating high workability concrete mix allows to lay it down in hard-to-get, densely reinforced, thin-shell concrete construction, which is especially important in the construction of unique buildings and structures, such as thermal and nuclear power structures [1-5]. Nowadays additives improving placeability of concrete are widely used. Depending on the effectiveness, they are called plasticizers and superplasticizers.

The use of these additives allows reducing material costs and avoiding complicated construction works in severe climate conditions.

The subject of this research is plasticizers – additives that increase plastic properties of the concrete mixture and cement spreadability at the same water-cement ratio. The use of plasticizers allows

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increasing the workability without any changes in strength of the resulting concrete and increasing adhesion to the reinforcement. Usually excess water is added to maintain plastic properties of the concrete mixture, which reduces the strength of the structure. Such situations can be avoided by using a plasticizer [6].

The most common plasticizers are polycarboxylates, lignosulphonates and naphthalenesulfonates [7].

Lignosulphonates are the product of sulfonation of natural polymer lignin, contained in the wood. Therefore, woodworks waste is a possible source for their production. However, non-treated lignosulphonate contains wood sugar, which slows down concrete setting, and promotes air entrainment. Last modified lignosulphonates have similar side effects in less degree, but have a restriction on dosage and relatively low efficiency. Lignosulphonate relates to strong plasticizers, increase workability of the concrete mixtures from P1 to P4, reduces water requirement up to 15 %.

Naphthalenesulfonate works well together with the lignosulphonate. It belongs to the superplasticizers, reduces water requirement up to 25% and it does not slow down the hydration process. In large doses, it slows the setting and does not work well in low cement consumption.

Currently most effective additives are plasticizers based on polycarboxylate esters. They do not prevent hydration, but you cannot use them at low cement consumption without stabilizer.

Polycarboxylates have a quite flexible chemical structure that allows to model molecules for accurate set properties [7, 8].

The same materials are used in the manufacture of self-compacting concrete mixture, but to obtain stable results tighter control and decrease in the values of limiting deviations are essential [9]. The basic requirements for self-compensating concrete are high plasticity and concrete disintegration minimizing. For this purpose superplasticizers based on polycarboxylates are used, and strict quality control is carried out at all stages – during the selection of materials, in the production process and the process of concrete casting.

The task of increasing the efficiency and quality of concrete and reinforced concrete is still very relevant and it cannot be successfully solved without the use of chemical additives [10-12]. Chemical additives are one of the simplest and accessible ways of improving the properties of concrete, which can significantly reduce the cost per unit of output. They allow to improve the quality and efficiency of a large range of reinforced concrete structures and to increase the working life of structures and buildings. Therefore, enormous attention is paid to the use of chemical additives in concrete technology all over the world. For example, by the end of 90ths the share of concrete additives for different purposes in Japan accounted for more than 80%, in the US, Germany, France and Italy - more than 70%. In Russia in the same period, the share of concrete with chemical additives was about 40%.

The problem of using additives for concrete modification is versatile [13, 14]. In global practice, there is currently no standard classification for additives for cement and concrete. Different countries have developed their own classification schemes. In view of the large differences of chemical additives depending on the material composition and the specific properties, the nature of their impact on the concrete mix and concrete may differ significantly, and sometimes even be selective [15].

In accordance with the classification of the additives introduced in [16], the term superplasticizer is applied to additives, which regulate the properties of concrete mixtures, and have gained the leading position in the group of water reducing admixtures due to extremely high effect of liquefaction of concrete mixture without reducing concrete strength in all terms of testing. Superplasticizers appeared in the early 70th because of research of Japanese and German scientists. The basic idea of such additives was to receive concrete mixtures that can be placed into shapes without applying mechanical action, or used them with respective sharp decrease in the level of intensity of mechanical action impacts [17, 18].

The purpose of the research is to obtain workable concrete mix using special additives.

The most advanced third generation water reducing admixtures, so called superplasticizers, which are oligomers based on polycarboxylate, are used in order to improve waterproof qualities of concrete. Polycarboxylates are sensitive to the properties of cement, so the choice of the most effective admixture was made with account of the chemical and mineralogical composition of the cement [19, 20].

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Research methods

Preliminary selection of the concrete compositions was performed to satisfy specified requirements for water resistance, strength, class of aggressiveness of environment [21]. In the appointment of concrete composition ingredients (cement [22], aggregates of different fractional composition [23], additives [24]) were selected in accordance with the European standards.

Comparing a number of cements was carried out five cements, which satisfy the requirements to the greatest extent were selected:

1. Portland cement with mineral additives CEM II/B-M(S-LL)-42.5 N, Finnsementi (Finland);
2. Sulfate-resisting portland cement CEM I 42.5 N-SR3, Finnsementi (Finland);
3. Sulfate-resisting portland cement CEM I 32.5 N SR-3, Mordovtsement (Russia);
4. Portland cement CEM I 42.5 N, Belarusian Cement Plant (Belarus);
5. Sulfate-resisting portland cement CEM I-42.5 N-SR3, Sukhoy Log (Russia) [25].

These cements were tested as part of the cement-water paste in accordance with European standards to determine their normal consistency.

The effectiveness of additives in relation to each of the cement determined by Suttard's viscometer. Paste quality was visually evaluated (the presence of water separation, air bubbles, spreading of cement-water paste).

The production of cement-water paste normal density was carried out according to EN 196-3 [26]. The density of the cement-water paste is determined using a Vicat apparatus and various accessories to it.

A comparative tests were carried out to select a new additive to assess the effectiveness of various modifiers with the use of Suttard's viscometer:

1. The glass with marked concentric circles and polished cylinder 100 mm height and 50 mm in diameter were moistened with water;
2. The cement-water paste was prepared in a spherical bowl. The desired dosage was measured in advance;
3. The resulting mixture had been stirring for 30 seconds, then it was left at rest for 1 minute;
4. The resulting substance was stirred using two quick circular motions and poured into the cylinder pressed to the glass in the center of the circles. The excess paste was cut with a knife and the paste was aligned with the surface of the cylinder;
5. The cylinder was raised in a strictly vertical direction, and the paste was poured in a cone-shaped pat;
6. The lower base cake reached a certain diameter, marked on the glass. That was the result of the first part of the experiment;
7. The same actions were carried out with a paste, but with a plasticizer in it;
8. The result of the experiment depended on the difference between the diameters of the base of the resulting pats.

Test results

The results of tests of additives with various cements are shown in Figures 1–5.

Our research was aimed to design workable concrete mix. To achieve the required results it is necessary to identify the plasticizers, which will be used to further concrete design and recommended for use in concrete mixture. As you can see from our study, plasticizing agents works very selectively with each kind of cement, which confirms the idea of the effect of the chemical and mineralogical composition of cement on water-reducing action of additives [11].

The results of the study also showed that superplasticizers based on polycarboxylate are more effective, which is expressed in comparatively low optimal doses and low sensitivity to the type and composition of cement [14].

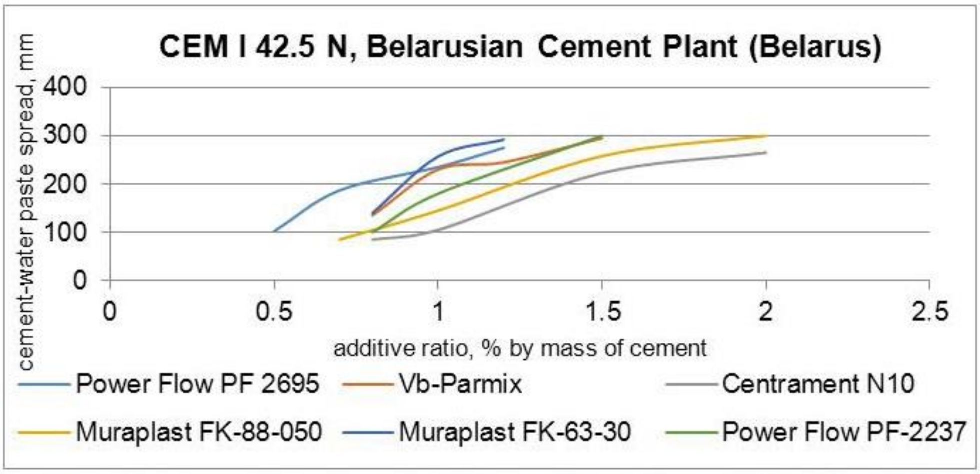

Figure 1. The results of tests of additives with CEM I 42.5 N, Belarusian Cement Plant

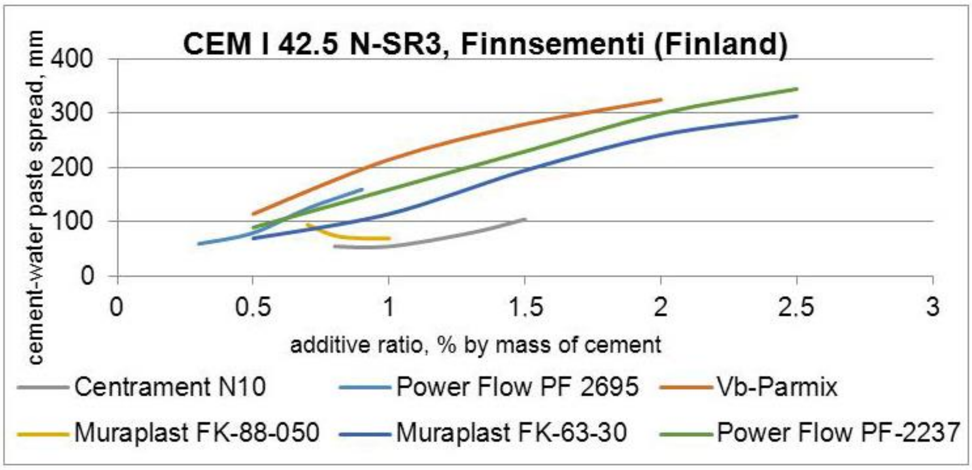

Figure 2. The results of tests of additives with CEM I 42.5 N-SR3, Finnsementi

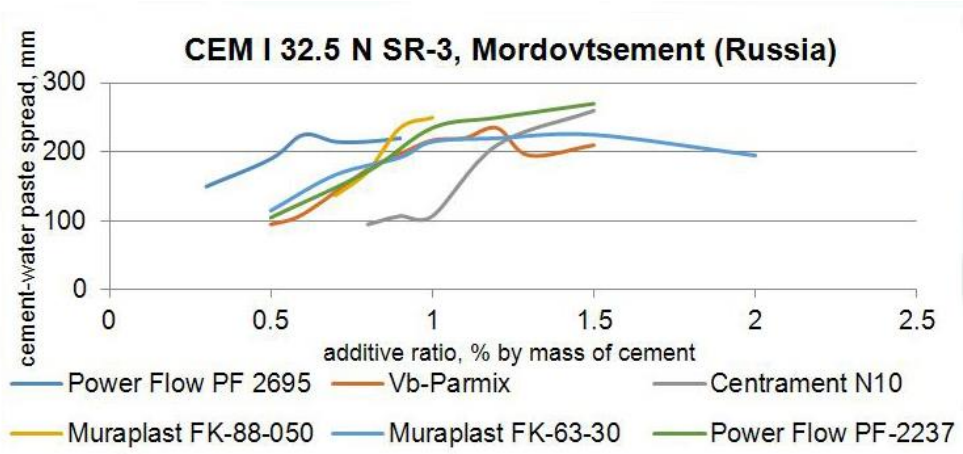

Figure 3. The results of tests of additives with CEM I 32.5 N SR-3, Mordovtsement

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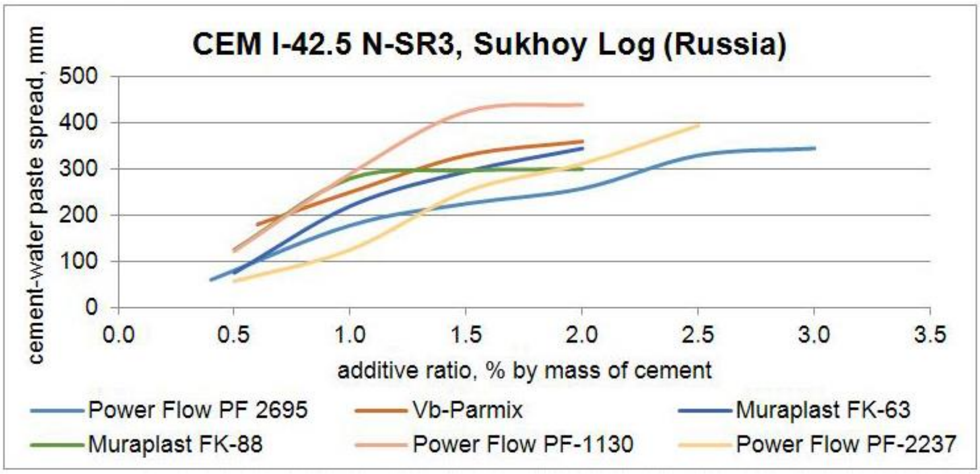

Figure 4. The results of tests of additives with CEM I-42.5 N-SR3, Sukhoy Log

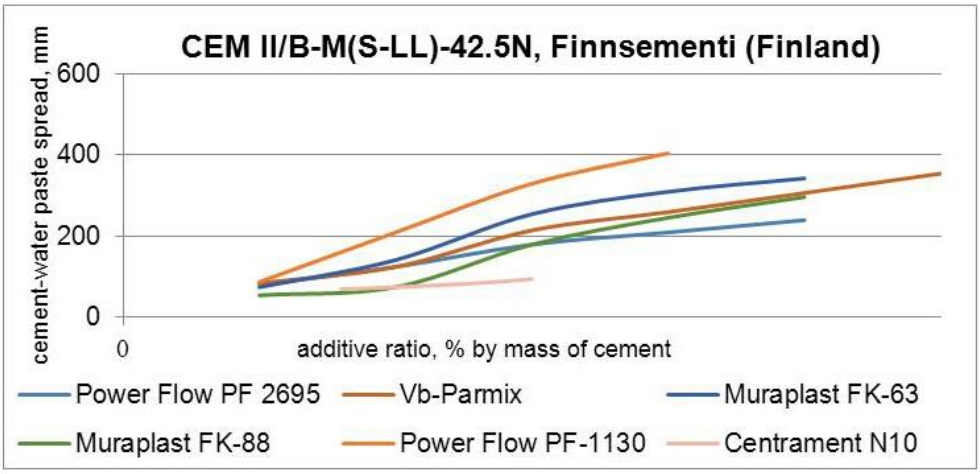

Figure 5. The results of tests of additives with CEM II/B-M(S-LL)-42.5N, Finnsementi

Conclusions

As a result of the experiment the following conclusions were made:

1. All tested additives showed the expected effect: an increase of cement-water paste spread after the addition of the plasticizer;
2. The same plasticizer showed different results with different cements;
3. A number of additives after the addition cause the creation of defects, such as oily stains, blistering, water gain;
4. One of the additives (TF 76) showed a negative effect when it was added at the same time with the silica fume – the concrete structure changed, gaining curdled consistency;
5. Some additives showed the desired effect when added up to 3% – cement-water paste spread achieved more than 30 cm with no defects.

According to test results, the following additives were selected as the most effective: PF 2695, PF 1130, and PF 2237.

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