REFERENCES

1. Бернштейн, С.А. Основы расчета статически неопределимых систем / С.А. Берштейн. – М. : Стройиздат, 1936. – 223 с.
2. Рабинович, И.М. Курс строительной механики. Ч. 2. Статически неопределимые системы / И.М. Рабинович. – М. : Стройиздат, 1954. – 543 с.
3. Киселев, В.А. Строительная механика / В.А. Киселев. – М. : Стройиздат, 1986. – 520 с.

UDC 691.33:659.475.4

THE COMPOSITE BINDER FOR SELF-COMPACTING CONCRETE

NATALLIA SHPILEUSKAYA, VOLGA LAZARENKA
Polotsk State University, Belarus

Application of self-compacting concrete (SCC) is one of the prior directions in *modern construction. Despite the reduction of energy consumption in the production of reinforced concrete structures, high physical and mechanical properties, the SCC is more expensive material compared to conventional vibration compaction concrete. One of the solutions of this problem is the use of secondary products industry as raw material components of the SCC. The effect of water treatment of sludge of thermal Electrical Station on the kinetics of a set of strength of the cement stone, together with the introduction of its hyperplasticizer was studied. The possibility of using water treatment of sludge as dispersed filler was shown, the optimum filler content and hyperplasticizer was defined.*

The use of self-compacting concrete (SCC) in modern construction is one of the most significant achievements of construction technology in recent years. Self-compacting concrete is a concrete, whose properties are determined by vibration-free sealing of concrete, able to spread, completely fill the cavity of the formwork and compacted under its own weight [1].

Depending on the method of providing resistance to delamination and water separation there are two basic types of self-compacting concrete: fine divided type; stabilizing type.

In the first type of self-compacting concrete mixtures high extendable grains coarse and fine aggregate is achieved by introduction in composition of concrete thin concrete inert or active filler, comparable on dispersion with a binder.

Chemical analysis of the majority of fillers allows to conclude that the basic compound included in them composition are calcium carbonate CaCO3 and magnesium carbonate basic 3MgCO□MgOH□2H2O.

Many researchers established that carbonate-containing additives are not inert fillers, and can have a significant influence on the processes of formation of structure of cement stone, performing not only the function of thickeners and activating the binder hydration process, and contributing to an increase in the degree of crystallinity formed hydrate [2, 3, 4, 5, 6].

Analysis of the results of numerous studies on the use of cement compositions containing SCC fine carbonate fillers shows:

– there are different points of view on efficiency, optimal dispersive capacity and aggregate consumption, in each case these indicators are determined experimentally;

– the most commonly used fillers are metakaolin and silica fume, they are expensive mineral additions, which leads to increased cost of SCC in comparison with a similar concrete type;

Accordingly, many researchers give the priority to active carbonate containing fillers, manufactured by using local raw materials or secondary products of various industries.

By considering a group of technologeneous products of similar composition in Belarus it was revealed that the greatest interest represent a sludge chemical water treatment (SCHWT) thermal power plants, stored in large quantities in the tailings pond or industrial landfills. The problem of sludge disposal in Belarus is not completely solved [7].

Application of SCHWT as a part of self-compacting concrete allows to utilize waste and thereby improve the ecological situation in the republic.

In the number of papers the results of research related to the use water treatment sludge of thermal Electrical Station are shown.

Vishniakova J.V. determined that in the cement matrix filled with sludge water treatment of thermal Electrical Station internal defects are localized – microcracks, and their number and size decrease, stress concentrations are reduced [8].

In studies [9] it is shown that the use of waste water treatment with a moisture content of 40% leads to retardation of setting of the cement for 4 hours, and to decrease of strength of cement stone by 25%.

The optimal dosage of the dried and ground slag in the amount of 2.5-7.5% was established when co-administered with it polycarboxylate plasticizer in a dosage of 0.6%, wherein the strength of the cement stone is increased by 12% on the 7th day of hardening.

In studies [10] the effective use of water treatment sludge in an amount not exceeding 7.5% was detected, jointly with 15% of microsilica as a filler sand SCC.

Chypshev V.B. [11] proposed the use of sludge waste of thermal Electrical Station without further processing from 2.5 to 3.0% instead of part of quartz sand, wherein density of the concrete mix, production costs have declined, indicators for frost resistance and water segregation improved.

Analysis of the results of researchers shows that water treatment sludge SCHWT as a finely divided filler can be used in the production of self-compacting concrete, but it is necessary to investigate the effect of its introduce for properties of the concrete mix and the concrete.

To determine the influence of the dispersed filler content – sludge of Novopolotsk thermal Electrical Station in the binder composition "cement-dispersed filler", we investigated normal consistency of the composition, the strength of the cement stone and kinetics of a set of its strength when filler and hyperplastisizer are included together.

For research Portland cement brand PC 500-D0 production of «Krasnoselskstroimaterialy», $R_ц$ = 50 MPa; $\rho_ц$ = 3200 kg / m^3; $K_{нг}$ = 0,27 was used.

Quartz sand career «Borovoe» $M_{кр}$ = 2,5, $S_{уд.м.}$ = 7,5 m^2/ kg; $W_м$ = 0,8%; $\rho_{мз}$ = 2650 kg /m^3. The content of the dispersed filler in the sand is 2% by weight.

Granite crushed stone of Republican Unitary Production Enterprise «Granit» with a grain size of 5 to 20 mm, $S_{уд.к.}$ = 0,36 m^2/ kg; $W_к$ = 0,45%; $\rho_{кз}$ = 2700 kg /m^3. The content of the dispersed filler in the crushed stone is 1.1% by weight.

As the dispersed filler carbonate containing water treatment sludge of thermal power stations - Technical Conditions BY 300220696.050 was used. $S_{уд.д\ н.}$ = 1240 m^2/ kg; $\rho_{дн}$= 2510 kg /m^3, dense loaded density of filler 870 kg /m^3 . Maximum particle size -80 mkm. The main components of the slag, 2/3 of the dry matter weight of calcium carbonate (CaC03).

Chemical additive - hyperplasticizer Stahement - 2000 - M ZH 30, Limited Liability Company «Stahema M», $K_{нг}$ = 0.2%, $K_{нг}$ = 0.223 (when added in an amount of 0.3% by weight of the binder composition).

Normal consistency of taste determined in accordance with GOST 310.3-76, the strength of the samples-cubes normal hardening size 20x20x20 mm as per GOST 310.4-81.

Investigated the properties of five compositions: no filler, filler, respectively, at a rate of 10, 20, 30, 40% by weight of cement.

The results are shown in Figures 1, 2, 3.

Analysis of the results allows us to establish, that an increase in the dosage of filler leads to an increase indicator of normal density in comparison with the composition without additives and reduction of strength cement compositions with filler. So the strength of the compositions is 2-5, containing a filler in an amount of 20–40% by weight of cement, at the age of 28 days decreased by 11, 18, 24, 31%. For further researches we accepted the composition number 3.

The choice is due to the optimum combination of the amount of particulate carbonate filler, which is defined by numerous previous research, the need for Recycling of waste. Increased water consumption with the introduction of the sludge may be compensated by the use of SCC in hyperplasticizers.

Researches of the effect of the content of dispersed filler and hyperplasticizer on the kinetics of a set of durability of the cement stone were fulfilled.

For research additive Stahement-2000-M ZH30 with a dosage of 0.25-0.35% was accepted.

The amount of sludge is accepted of 20% instead of injected cement. Compositions were prepared with the same cement paste with relative water content of 1. The results are shown in Figure 4.

As can be seen from Fig. 4, the use of high dosage supplements Stahement of 0.35% does not provide desired effect of gain strength. The maximum dosage of superplasticizer accepted is 0.3%.

The research suggests the possibility of effective application of filler, based on the sludge in conjunction with hyperplasticizer in the cement composition. Based on the obtained results limits to the percentage of sludge and hyperplasticizer at dosages of 20% and 0.3% respectively have been proposed. Assessment of the results of research was carried by the estimated composition of the SCC.

The calculation of the composition of self-compacting concrete was done in two stages as described [1].

The first stage is designed to approximate composition of conventional concrete monolithic reinforced concrete wall thickness of 240 mm, reinforced by two reinforcing mesh. The class of the concrete compressive strength – $C^{25}/_{30}$ was adopted , the coefficient of variation of strength SCC– V = 13,5%, grade on the workability of the concrete mix – P-2 ($РК_{тр}$ = 60 sm).

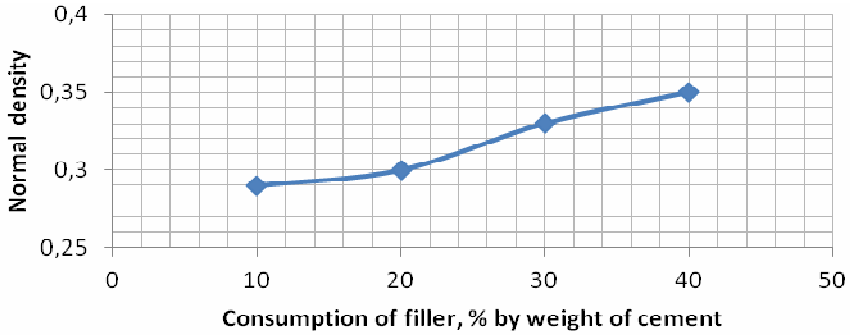

Fig. 1. Change of the normal consistency depending on the flow of filler

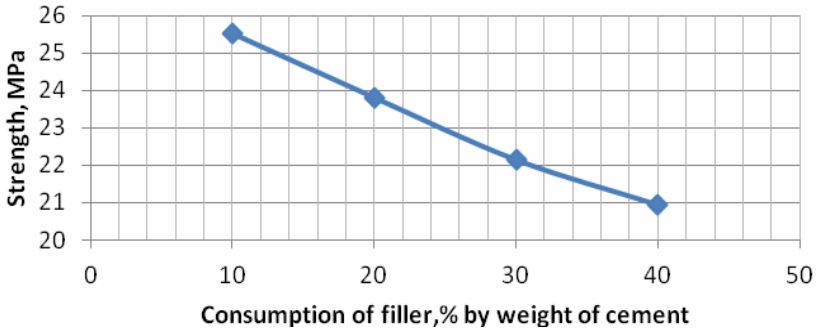

Fig. 2. Changes in strength depending on the flow of filler (7 days)

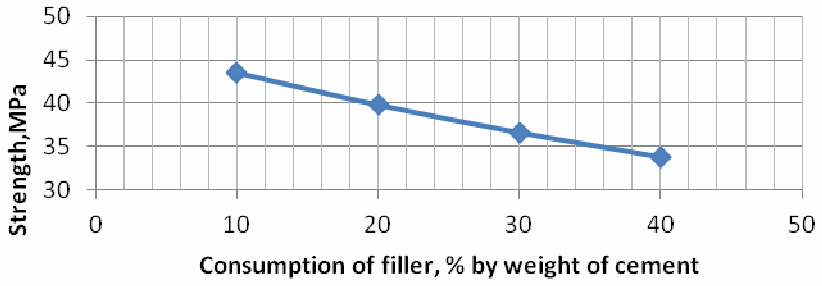

Fig. 3. Changes in strength depending on the flow of filler (28 days)

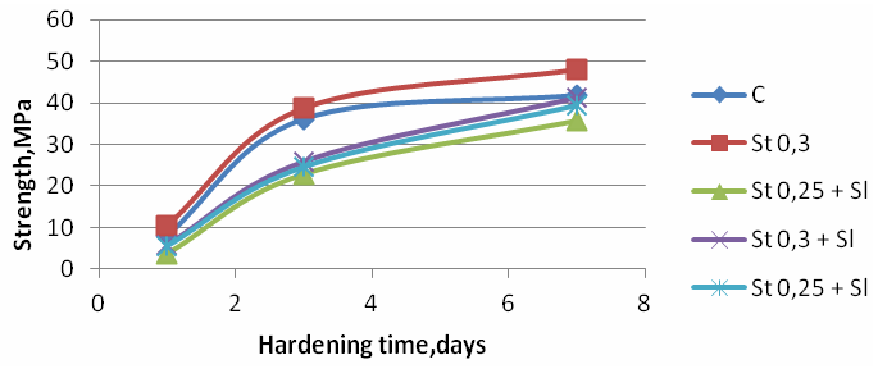

Fig. 4. Kinetics of a set of durability cement paste, modified by various chemical additives when exposed to normal-humidity conditions

At the second stage by the approximate values of components of SCC the structural characteristics of $W_т$, W, $m_{вим}$, $S_{уд.з}$, $X_т$, $m_{т2}$, $m_{т1}$, $РК_с$ и $РК_р$ were defined, and the check of the compliance with the conditions of the ТКР 45-5.03-266-2012 was carried out [1].

$$РК_р = РК_{тр-з}^{+4}, \quad (1)$$

where $P_{кр}$, sm – estimated value of diameter flow cone. 90,93 см ≥ 60 sm. The condition is not complied.

$$f_{c\ cube\ тр} = {}^{+1,10}_{-0,95} f_{c\ тр} \quad (2)$$

where $f_{c\ cube\ тр}$ - calculated strength SCC on compression at age τ, MPa;

$f_{c.пр}$ – required strength SCC on compression, MPa.

28,876 MPa ≤ 1,1$f_{c.пр.}$ = 1,1 x 27,02 = 29,9 MPa.

The condition is complied.

We compare the content of cement required for STB 1544: $G_ц \geq G_{ц.min}$, (3)

where $G_ц$ – content cement in SCC mix, kg;

$G_{цmin}$ – the minimum content in SCC mix of cement, kg;

$G_ц$ = 529 kg /m^3≥280 kg /m^3. The condition is complied.

$$X_т = 1{,}269 \leq 0{,}98\, X_{тmax}, \quad (4)$$

where $X_т$ – characteristic of the relative water content of the cement paste;

$X_{тmax}$ – the maximum value of the characteristic relative water content cement paste within the coherence SCC mix. 1,24 ≤ 1,303. The condition is complied.

$$m_{т1} = 0{,}234 \geq 0{,}225\ , \quad (5)$$

$m_{т1}$ - bulk concentration of cement paste, providing extendable grain fillers. The condition is complied.

Increase $РК_р$ is associated with a high normal density of dispersed filler - sludge (0.47). To obtain the optimal composition of the SCC the content of the binder composition should be increased while maintaining the values of W, effective water-binder ratio of concrete equal $G_{вк}$/B.

The conducted research suggests possibilities of effective application of filler on the basis of chemical water treatment sludge thermal Electrical Station with a dosage of 20%, together with a superplasticizer with a percentage of 0.3% in cement compositions of self-compacting concrete on the condition conducting further studies, aimed at obtaining the optimal composition of self-compacting concrete using a considered additions.

REFERENCES

1. Бетонные и железобетонные изделия и конструкции из самоуплотняющегося бетона. Правила изготовления : ТКП 45-5.03-266-2012.
2. Медяник, Ю.В. Смешанное вяжущее с наполнителем из шлама водоумягчения для сухих штукатурных смесей : дис. … канд. техн. наук : 05.23.05 / Ю.В. Медяник. – Казань, 2003. – 158 л.
3. Величко, Е.Г. Физико-механические и методологические основы получения многокомпонентных систем оптимизированного состава / Е.Г. Величко, Ж.С. Белякова // Стр. материалы. – 1996. – № 3. – С. 27–30.
4. Повышение свойств композиционных строительных материалов введением минеральных микронаполнителей / Г.И. Бердов [и др.] // СтройПРОФИ. Рубр. Бетонные технологии и жбк. – 2012. – № 3. – С. 57–60.
5. Лазаренко, О.В. К вопросу о снижении себестоимости самоуплотняющегося бетона / О.В. Лазаренко, Н.Л. Шпилевская // Актуальные проблемы архитектуры белорусского Подвинья и сопредельных регионов : материалы респ. науч.-практ. семинара, Новополоцк, 2015 / Полоцк. гос. ун-т. – Новополоцк : ПГУ, 2015. – С. 184–188.
6. Марданова, Э.И. Многокомпонентные цементы с добавками из местного минерального сырья : дис. … канд. техн. наук : 05.23.05 / Э.И. Марданова. – Казань, 1995. – 224 л.
7. Будников, П.П. О гидратации алюмосодержащих минералов портландцемента в присутствии карбонатных наполнителей / П.П. Будников, В.М. Колбасов, А.С. Пантелеев // Цемент. – 1961. – № 1. – С. 5–9.
8. Вишнякова, Ю.В. Строительные растворы с карбонатосодержащим наполнителем из вторичного продукта водоподготовки : дис. … канд. техн. наук : 05.23.05 / Ю.В.Вишнякова. – Новополоцк, 2014. – 166 л.
9. Влияние шлама химической водоочистки в комплексе с суперпластификатором на физико-механические свойства цементного камня / В.И. Авксентьев [и др.] // Изв. КГАСУ. – 2014. – № 4. – С. 249–254.
10. Величко, Е.Г. Об оптимальной технологии изготовления вяжущих материалов с применением минеральных добавок / Е.Г. Величко, В.А. Пискарев, В.М. Лукьянович // Журнал ВХО им. Д.И. Менделеева. – 1984. – Т. 29. – № 3. – С. 111–113.
11. Бетонная смесь : пат. № 2258052 [Электронный ресурс] / В.Б. Чупшев. – 2015. – Режим доступа: http://bd.patent.su/2258000-2258999/pat/servl/servletd2f6.html. – Дата доступа: 12.10.2015.