UDC 624.15

METHODS OF ENSURING THE STRENGTH OF A CONTACT JOINT OF THE COMPOSITE CONCRETE STRUCTURES

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This article is devoted to the influence of material science, technological and engineering measures on the strength of contact joints. The necessity of all three aspects to achieve optimum adhesion of the concrete layers is determined. The expediency of actions from the point of view of labor and material costs is considered.

Providing of collaboration of the layers of concrete and reinforced concrete in composite structures is an important issue not only in precast-monolithic and monolithic construction, but also in the reconstruction and modernization of buildings and structures. Quality adhesion of concrete is based on the unity of material science, technological and engineering measures to ensure the strength of the contact joint.

The impact on the joint of material science aspects is, first of all, in the structure of the materials itself and especially in the properties of the new concrete, and as it makes contact with the old one. Decisive role in this process is played by the type of binding agent. The concrete based on cement binding agents (Portland cement, slag Portland cement, portland pozzolan cement, aluminous cement) has unique properties and is used in load-bearing and enclosing structures, if they are not subject to special requirements. So during the study of adhesion of concrete with cement binding agents, it was found that the use of Portland cement gives the highest strength, the adhesion of alumina cement in comparison with Portland cement showed strength by 20-50% less [1].

The most important property for a binder is grinding fineness. With the increase of cement grinding fineness the rate of hydration and cement strength increase. The average specific surface area of the Portland cement is 2500–3000 cm^2/g. The particles that comprise such cement react chemically with water only by a quarter of its volume. The remaining volume of the particles performs the function of an inert aggregate in the hardened cement mixture [2]. Modern technologies allow to produce special cement of much finer grinding. However, fine ground cement causes increased shrinkage that may adversely affect the strength of the contact joint.

Nowadays there is a wide use of special concretes, but at the same time their use doesn't always have a positive effect on the adhesion strength. Increased strength and durability under special conditions can greatly complicate the adhesion process, and that requires additional actions.

A water-cement ratio of concrete mixture plays an important role in strength of concrete adhesion. The use of low-slump concrete and stiff mixtures may adversely affect the joint performance, as even using concrete vibration it is difficult to achieve soundness of concrete adhesion. The use of flow concrete mixtures is also not recommended due to the significant difference between the shrinkage of concrete, which leads to disruption of adhesion bonds and the reduction of adhesion [3].

To increase the plasticity of the mixture with less water consumption it is recommended to use modifying additives. In modern construction modified concrete is widely used in practice. Of most interest is plasticizer: the super - and hyper plasticizers.

There are a great variety of plasticizers. Typical additives with pronounced plasticizing properties are additives on the basis of the waste and by-products of the pulp and paper industry (ССБ, СДБ, ЛСТ) and super plasticizers (С-3, 10-03, МФАС-100Р), etc. Plasticizers lead to the increase in the specific surface of cement, due to whit the density of the cement paste increases and its viscosity decreases [4]. A lot of researches are devoted to the study of the influence of additives on the flocculation of cement grains, as on the basis of Polotsk State University the investigation of plasticizer С-3 was carried out and its positive effect was detected, figure 1 [4].

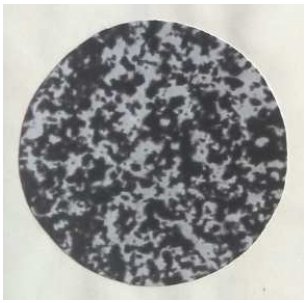

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Fig. 1. Influence of additives on the flocculation of cement grains:
1 – without additives; 2 – with the additive С-3

The rate of cement hydration in the presence of additives depends on the chemical composition of the additive and its concentration, it is not clear how different plasticizers will affect the strength of the contact joint.

In Vitebsk region the additives like C-3, СПС, various modifiers of the Stakhem's company have found application. Table 1 shows the most common current plasticizers and the recommended dosages for them.

Table 1 – Modifying additives

Name	Recommended dosage in % from cement mass
Stakhement F super plasticizer	0,5–1,5
Stakhement 2000M hyper plasticizer	0,3–1,2
Stakhement hyper plasticizer	0,5–1,8
Stakhement 2010 hyper plasticizer	0,8–1,5
C-3 super plasticizer	0,9–2.5

A lot of researches done on the basis of Polotsk State University, Brest State Technical University, Kryvyi Rih National University are dedicated to the study of the concentration of a particular chemical additive in the concrete mixture [3, 5–7]. Modified concrete has been widely used in monolithic construction, but in precast-monolithic construction and renovation the question of the influence of modifying additives on the strength of the contact joint remains unstudied. So in the research [3] the use of C-3 was studied, and in the researches [5–7] the use of the additive СПС and Stakhement-2000M. Table 2 shows experimental data obtained by the authors of these researches.

Table 2. – The change of shear strength of prefabricated samples depending on a concentration of chemical additive in new concrete

Name of used additive	Cone slump, sm	Test shearing resistence depending on additive ratio, MPa		
		0,4	0,7	1,0
Stakhementт-2000M	12	0,972	3,377	1,954
C-3	10	1,4	1,96	1,16
СПС	12	1,04	1,27	1,06

From the above table it is seen that the optimal concentration for the studied additives can be considered as 0,7% [3, 5, 7].

However, for large volumes of work the use of modifying additives can be very costly and not advisable, as the cost of modified concrete is bigger than the cost of conventional concrete. In these cases it is possible to use layers or impregnations on the basis of modified cement systems. As the adhesive layer colloidal cement glue is used. But the adhesive layers and impregnations should be used carefully and only after appropriate studies. In the study conducted in [1] the glues made on the basis of cement, grinded until the specific surface of 5000–7000 cm^2/g showed high strength of joints.

It is also worth noting that recently to improve the adhesion and to increase the strength of the joint of old concrete with new one various polymeric adhesives and composites have been applied. When choosing adhesives it's necessary to consider not only their strength, but also reliability and durability. Cohesive and adhesive properties of various adhesives and their physicochemical properties have been thoroughly studied. The recommendations for the use of the proposed chemicals for corresponding building structures have been developed. Epoxy adhesives have been widely spread. In Belarus today, there is a big variety of these materials, however their cost is quite high. That's why, the use of polymeric adhesives to connect concrete is suitable for minor areas of gluing, determined by technological and strength characteristics of the adhesive. However, polymer adhesives and compositions are increasingly used in construction and their properties are improved.

Technological activities depend mostly on the plasticity and formability of the concrete mix, the wetting of the surface of the old concrete and surface preparation method, and the actions on new and old concrete curing.

In Belarus and abroad there is some experience in the adhesion area treatment. There are several surface preparation methods. Their choice depends mainly on the volume and surface requirements for the job. These methods can be divided into four main groups: water and water-air treatment, dry mechanical, chemical and flame cleaning [8].

The most common and safe are water, water-air and dry mechanical treatment. A structural element subjected to flame cleaning can change its properties, which may affect its future work. Chemical treatment is based on the use of organic and inorganic removers and as a rule these removers are made from acidic chemical compounds. In the result of such process the concrete structure is broken and after that the remains of the concrete are simply washed off under the water pressure. The means for removal of concrete are flammable, some of

them emit harmful gases during the process and almost all compositions require extra individual protective measures. In addition, it is impossible to determine if chemical substances are fully washed away from the surface or have remained, and it is also unknown how the remnants of chemical agents will influence the strength of adhesion.

There are studies of the reliability of the adhesion of old concrete with new one in compliance with appropriate technology of laying of new concrete and surface preparation of old concrete [9, 10]. A special feature of the technology involves laying of the new concrete on clean, rough, wet surface, possibly by vibrating the concrete mix. However, in terms of reconstruction, during structural reinforcement it is impossible to use vibration because of tight working space or structure condition. So in the course of studying of the effect of the method and the nature of the surface treatment on the strength of the contact joint [11] the following conclusions have been made:

– cleaning of the surface to the filler with the help of cuts to the depth of 5 mm and with the pitch of not less than 40 mm increases the strength of contact joint by 1.5 times in comparison with the adhesion strength on a smooth surface. The difference values of the adhesion strength of the contact joint for samples having a smooth or intermediate between smooth and very smooth surface, not significant, therefore, during surface treatment in certain cases it may be enough just to remove cement milk;

– samples with layer-by-layer compaction of concrete by joint grouting with vibration give much higher results of the shear resistance of the composite structures than the samples with layer-by-layer compaction of concrete by joint grouting with ramming.

It should also be noted that differential of shrinkage of new and old concrete has adverse influence on the adhesion, that's why much attention is paid to the new concrete maturing and old concrete watering. It is necessary to lay the concrete on a damp but not wet surface, as excess of water reduces the strength of the adhesion. The adhesion strength is significantly higher during the hardening of the samples in wet conditions than under normal storage conditions [9]. During slow curing of new concrete ultimate strength of the joint has generally higher strength than during rapid solidification [12].

Structural measures include an increase in the actual area of contact joint, which can be reached through holes and slots, the anchor protrusions and curves, or by the device of keys of different shapes. However, such activities require high labour cost and are not always necessary. Their application depends on the requirements of the construction design and its overall condition.

According to the above mentioned information the following conclusions can be made:

– it is possible to achieve the required adhesion strength through a combination of material science, technological and engineering activities: 1) by increasing the actual contact area by stripping the surface roughness, to reduce labor costs it can be limited to a simple surface cleaning with the removal of cement milk; 2) through the use of modifying additives, in particular СПС, С-3, Stagement-2000M in the amount of 0.7% from the weight of cement; 3) and treatment of new and old concrete;

– the possibility of applying the impregnation or the layers with the use of modified cement systems requires detailed study, as perhaps a more cost-effective option for improving the strength of contact joint, in comparison with the use of modified concretes.

Today, on the basis of Polotsk State University a scientific study on the investigating of the possibility of applying of surface treatments or impregnations on the basis of modified cement systems is conducted.

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