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SECTION 2.
CHEMICAL TECHNOLOGY

2.1 Change of physical and mechanical properties of reinforced concrete at heating depending on a kind of the protective covering

For high-temperature and fire protection of reinforced concrete structural materials, effective thin-layer coatings on an organic basis have been widely used, which are conventionally divided by the method of protection into low-combustible and intumescent [73, 74]. Intumescent coatings are more effective, the high-temperature and fire action of which are achieved due to the intumescence of the initial composition at relatively low temperatures with the formation of a porous heat-resistant heat-insulating layer which is more than 1 cm thick [75,76].

Intumescent high-temperature fire-retardant coatings are compositions of organic and inorganic components. They consist of a bonds, filler, flame retardant and intumescent additives.Polymers areused as bonds because they are capable of cyclization, condensation, crosslinking and formation of non-volatile products, for example copolymers of vinyl, polyester, epoxy and organosilicon resins, etc. Dextrin, starch, sorbitol, salts of phosphate, boric and other acids can be used as intumescent agents [77, 78].

Intumescent coatings outperform others because, when applied to a reinforced concrete structure in a thin layer, they do not increase its weight, but significantly increase the temperature resistance, fire resistance and have a wide range of technological methods of application and are available in exploitation.

An important characteristic feature of building materials is their resistance to temperature effects on changes in physical and mechanical properties of coated reinforced concrete samples (Fig. 18). The strength characteristics of materials based on Portland cement (PC II / A-III), Portland slag cement (PSC III / A) at high temperatures have been studied. The study was performed after heating to a temperature of 473, 673, 873, 1073, 1273 K [79, 80].

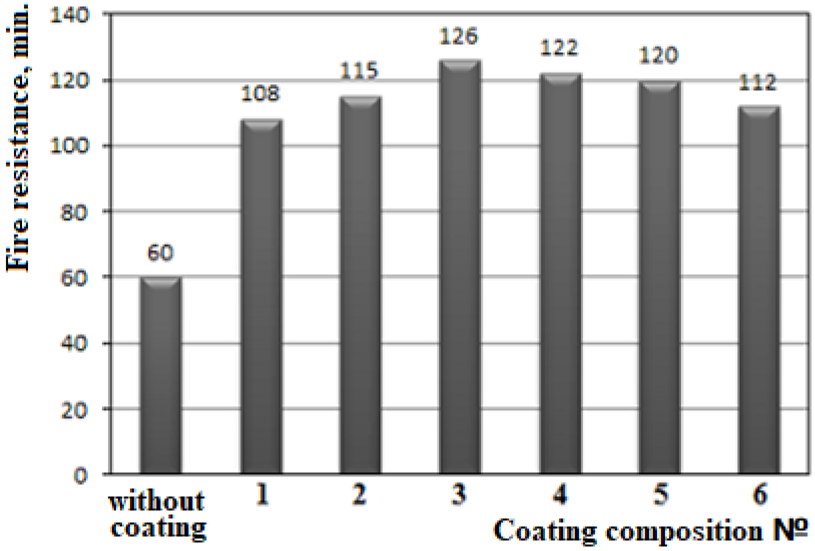

Fig. 18. Fire resistance of protected reinforced concrete samples

The characteristics of changes in the strength of reinforced concrete when heated after using the proposed composition of the coating are shown in Fig. 19.

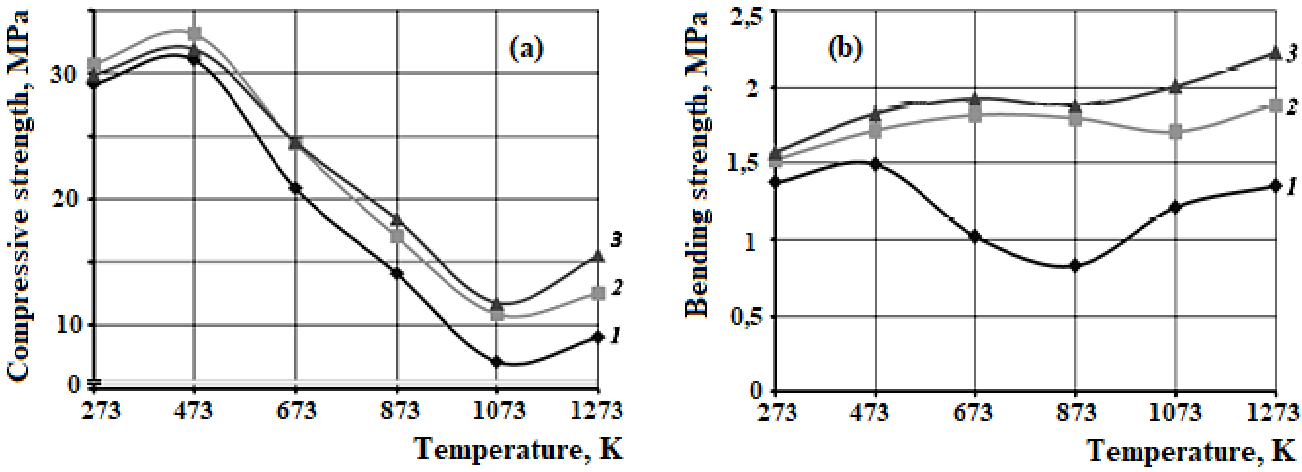

Fig. 19. Dependence of compressive strength (a) and flexural strength (b) of reinforced concrete on the heating temperature: uncoated (1); coated with a protective composition based on PC II/ A-III (2) and PSC III/ A (3)

It is discovered that when heated to a temperature of 473 K, the compressive strength of the samples increases by 4.5...5.0%, and the flexural strength by 7...12% due to the compaction of the reinforced concrete structure. In addition, water is released from the gel-like components of the binder and the crystallization of calcium hydroxide, which is formed during the hydration of cement. Heating to a temperature of 673 K reduces the compressive strength of reinforced concrete at almost stable flexural strength. Such a significant decrease in compressive strength (25...50%) is observed when heated in the temperature range of 673...873 K, which is explained by the dehydration of the hardening products of cement. Meanwhile, the minimum reduction in compressive strength is observed for reinforced concrete based on Portland slag cement. It can be noted that the flexural strength of the samples decreases by 40% for unprotected coatings and by 12.5...25% for protected ones.

Further heating of the samples to a temperature of 1073 K leads to a decrease in the compressive strength of unprotected reinforced concrete by almost 85%, which can lead to its destruction.

It has been visually revealed that the surface of the samples is covered with cracks ranging in size from 3 to 30 mm. Further heating to a temperature of 1273 K leads to a slight increase in the compressive and flexural strength of the samples due to partial sintering of the material as active calcium oxide is formed from the sintered material.

The study of the deformable characteristics of reinforced concrete showed that when heated to 573 K, the modulus of elasticity of concrete (Fig. 20) decreases by almost 2 times due to the uneven expansion of its components due to the difference in temperature coefficient of linear expansion.

The largest decrease in E_0 (by 2.5 times) occurs in unprotected reinforced concrete. Heating in the temperature range of 573...873 K due to the large difference in the rate of thermal expansion of cement stone, its destruction due to dehydration reduces the modulus of elasticity to $0.12 \cdot 10^4$ MPa for ordinary concrete. For protected reinforced concrete, this figure is by 2.0...2.6 times higher. Further heating to 1173 K due to the destruction of the crystalline hydrate structure and the appearance of frame defects reduces the modulus of elasticity to $0.03...0.18 \cdot 10^4$ MPa. Therefore, the indicator E for protected reinforced concrete ($0.03 \cdot 10^4$ MPa) indicates its practical destruction, while the protected samples have the appropriate strength, which is confirmed by the modulus of elasticity.

While heating the coated reinforced concrete, its porosity is changed and it significantly affects the physical and mechanical properties of the material. According to Fig. 21, the porosity of reinforced concrete begins to actively increase when heated to temperatures above 673 K.

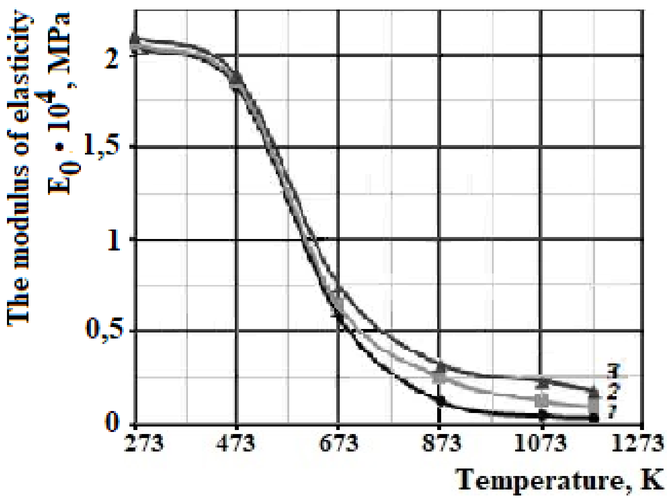

Fig. 20. The dependence of the elasticity modulus of reinforced concrete on the heating temperature:
without coating (1); coated on the basis of PC II/A - III (2) and PSC III/A (3)

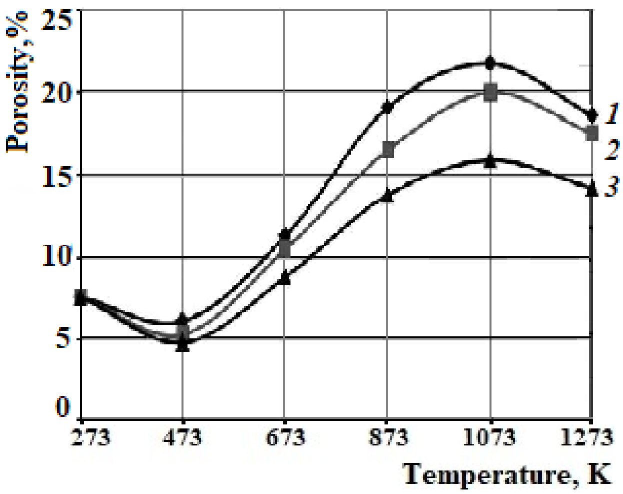

Fig. 21. Change of porosity of reinforced concrete protected by a covering when heated:
not protected original (1);
protected on the basis of PC II/A - III (2);
protected on the basis of PSC III/A (3)

It was found that in the temperature range from 673 to 1073 K, there is an increase in the porosity of reinforced concrete by 40...52% for reinforced concrete with non-reinforced and reinforced kaolin fiber.

Reinforced concrete based on Portland slag cement with a protective coating changes the porosity when heated in a less extreme way. Meanwhile, the increase in porosity in this range of heating temperatures is only 6%, which is explained by the formation of dehydrated particles of a thin film of glassy phase from the cement slag component and stabilization of structurally active components on its surface.

Due to the phenomenon of adsorption modification of the surface of individual components of reinforced concrete, protective coating may get favorable conditions for the formation of minimally tensed microstructure, resulting in higher strength, compared with samples based on Portland cement binder [80].

Heating of all test samples in the temperature range from 1073 to 1273 K leads to a decrease in porosity by 10...18% due to partial melting of the coating surface.

The effectiveness of fire protection of the developed compositions of protective coatings of reinforced concrete structures has been experimentally proved. It has beendiscovered that the fire resistance for heat insulating ability of protective materials is 108-126 minutes, which is 1.8-2.1 times higher than of unprotected ones.

Protective coatings based on filled polymethylphenylsiloxane (PMFS) increase the compressive and flexural strength of reinforced concrete by 2.0...2.4 times in the temperature range of 673...1273 K. The modulus of protected reinforced concrete elasticity in the temperature range from 573 to 873 K is 2.0...2.6 times higher than the original.

Taking into account the results of the study, it can be argued that the compositions based on kaolin and aluminum, zirconium oxides of PMFS can be used as a high-temperature protective coating for reinforced concrete, which allows to further improve the protective properties of coatings for reinforced concrete structures.