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Efficient Binding Using Composite Tuffs of the Middle East

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Abstract: The paper discusses the properties of composite binders based on cement and tuff (Kingdom of Jordan), used to obtain fiber concretes on their basis for reconstruction and construction of buildings in regions of the Middle East. The research has been made to study the effect of the method of grinding of raw materials and plasticizer on physical, mechanical and technological properties of binders, a method of "internal curing" for hardening concrete in hot climate conditions has been developed.

Key words: Cement composites · Fiber concrete · Care of hardening concrete · Hot climate · Volcanic tuff

INTRODUCTION

The Middle East is one of the regions with high rates of development in construction. Unfortunately, a significant number of buildings and structures in some states of the Arab world has been destroyed and a part of it need repair and restoration, which is connected both with tense political situation, natural and climatic conditions and geological structure of the earth's crust. Fiber concrete is currently one of the most effective construction materials. Disperse reinforcement significantly improves the tensile strength of composite and inhibits the formation of cracks at all stages of the structure formation. The use of composite binders (CB), multi-component composition of which not only helps to reduce the clinker component in the mixture, but also to effectively manage the process of structure formation, will ensure high quality of concrete and products based on them [1-5]. Selecting the mineral structure for a composite binder with specific ratio of components can affect the structure and physico-mechanical properties of the concrete directly in the desired way [6-7].

In the conditions of a dry and hot climate it is necessary to ensure the proper cure of hardening concrete, primarily in order to block destructive phenomena which occur during the development of plastic shrinkage, eliminating the processes of moisture transfer in freshly mixed concrete and its escape into the environment [8]. There are many traditionally used methods to solve this problem (Fig. 1). All these methods are designed to protect the material from the outside.

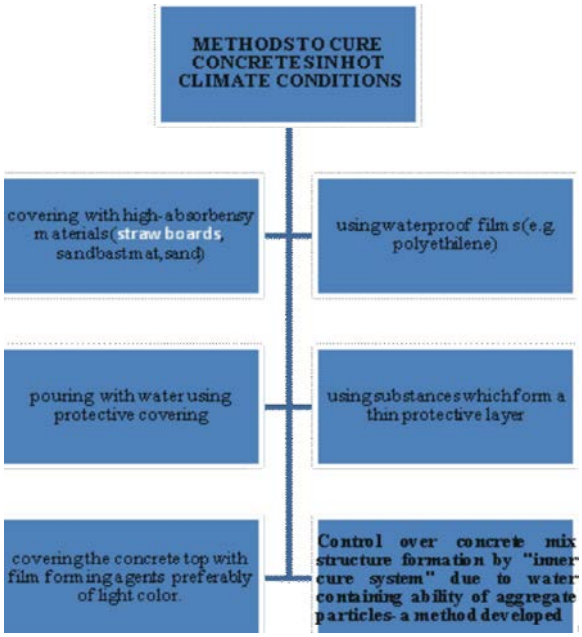

Fig. 1: Methods, used to concrete cure in hot dry climate conditions: traditional and developed by the authors

However, it is obvious that the traditional protection of concrete results in complication of technology and its cost increase, therefore it is necessary to develop alternative non-traditional ways of hardening concrete mixture curing (Figure 1). It seems that the most appropriate in the production of fiber concrete is the use of high-strength composite binder with the use of fine

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volcanic tuff (deposits in the Kingdom of Jordan). Specific structure of the tuff, as a part of the binder will help to ensure the so-called "internal curing" of concrete, which means the change of the balance of internal forces due to water retention ability of tuff particles, followed by the necessary H_2O doses in the process of hardening concrete, which will lead to reduction of stress in the hardened concrete and, consequently, will reduce the number and size of microcracks formed.

MATERIALS AND METHODS

To obtain composite binders a number of tests were made: in the first stage we obtained binders with optimal ratio between cement and mineral components (tuff deposits in the Kingdom of Jordan); then the optimal dosage of superplasticizer was chosen. Additionally we investigated the effect of the method of grinding of raw materials on physico-mechanical and technological properties of composite binders.

Preparation of composite binders was carried out in several ways: grinding the ingredients in a vibrating mill with the addition of a plasticizer and without it, as well as separate grinding and then mechanical mixing of the components [10].

As a basis for CB using Portland cement Type I 42,5 N produced at JOCM plant in Jordan meeting the requirements of GOST 31108-2003 (State Standard) and tuff from the deposits of Jordan with a density of 1560-1800 kg/m^3, water absorption - 8.53-10.8%, as a plasticizer a superplasticizer ASTM C494 - Type A was used.

Basic Part: X-ray diffraction analysis of volcanic tuff samples used showed that it is represented by the following: mainly β-oligoclase (d, Å = 2.21; 3.45; 2.95; 2.15;.83; 1.78) and cryptocrystalline quartz with defective structure (d, Å = 3,34, 4.24, 2.45, 2.28, 2.123, 1.813, 1.668, 1.539) and therefore more reactive.

To use the rock as aggregate in a composite binder tuff powder was prepared Sуд = 500 M^2/kg, grain shape of which is Is fractured and scaly, average length 2…5 mkm, also coarse polyhedron type particles 5…20 mkm long can be seen (Fig. 2).

It was established that introduction of 10 % tuff into the cement ñ with specific surface of 500 m^2/kg allows not only to save clinker, but leads to increasing compressive strength by 10 %.

Comparing radiographs binders prepared in different ways showed that joint milling provides the best conditions for hydration (Fig. 3).

Thus, when joint grinding of the components of the composite binder to 28 day age, the value of diffraction peaks intensity for the tuff minerals and portlantide becomes 2-2.5. times lower.

This testifies to emerging a better system conditions for interaction and binding of calcium hydroxide due to high activity of fine cement fractions and mechanically and chemically activated surface layer of mineral aggregate - tuff, which is confirmed by the results of physical and mechanical tests (Table 1).

It has been established that joint grinding method to obtain a composite binder increases its activity by 10.5% as compared to separate grinding. The use of plasticizing aggregate (1%) in CB preparation by joint grinding increases composite binder activity by 7.3% and compared to separate grinding - by 18.5%, which not only saves clinker, but also leads to an increase in compressive strength by 18.5% (Table 1).

Considering the dynamic water-cement ratio, it should be noted that the plasticizing additive introduced into the composite binder significantly reduces the amount of water (21%) compared with plain binders.

The study of micrographs of composite binders prepared by various grinding schemes recealed the following (Fig. 3).

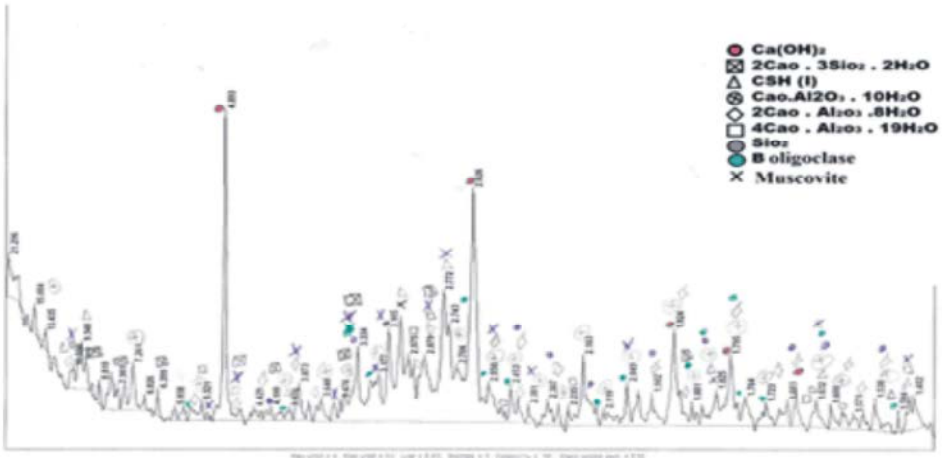
The structure of the composite binder produced by separate grinding and subsequent mixing of the components is characterized by heterogeneous composition. The presence of caving is seen, inside which intergrowth of acicular crystals up to 5 microns takes place, penetrating the entire volume of the material (Fig. 3a). Presence of large number of cavities is explained by worse mechanical activation and diffusion of tuff particles and binder. This reduces compressive strength by 9 Mpa compared to binders obtained by joint grinding.

CB Microstructure without plasticizing aggregate, obtained by joint grinding is more homogeneous, it is also observed intergrowth of acicular crystals is also observed, they penetrate the volume of the material structure (Fig. 3b), but to less extent. Firm new formations near the grain aggregate are present in great number.

The composite binder, obtained by joint grinding with plasticizing aggregate has more homogeneous compact texture, which is associated with decrease in water-cement ratio. In the whole of the hydration products, similar to CB without plasticizer we can reveal presence of dense formations near aggregate grains in the contact zones, which provide minimum content of pores and microcracks (Fig. 3c).

Table 1: Properties of composite binders depending on the composition

No	Composition, % Cement	Tuff	Aggregate	Finess of cement, M^2/kg	Finess of tuff, M^2/кГ	В/ц	Type of grinding	Compression strength, Mpa in the age, per day. 3	14	28
1a	90	10	-	500	500	0,30	Separate	45,2	60,4	80,3
2a	90	10	-	500	500	0,280	Joint	48,7	66,8	88,7
3a	90	10	1	500	500	0,225	Joint	53,2	74,3	95,2



Pic. 1: Methods, used to concrete cure in hot dry climate conditions: traditional and developed by the authors

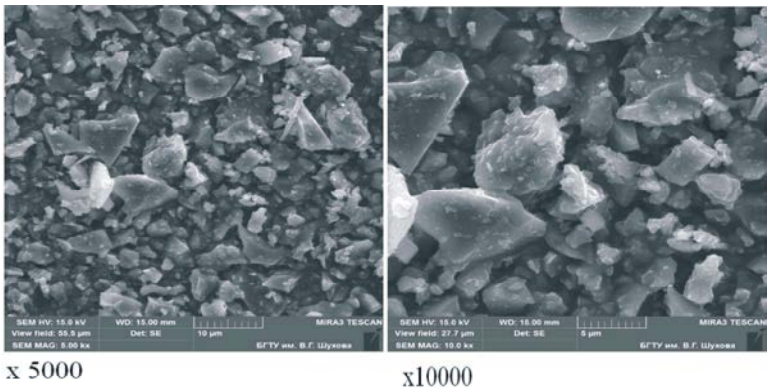
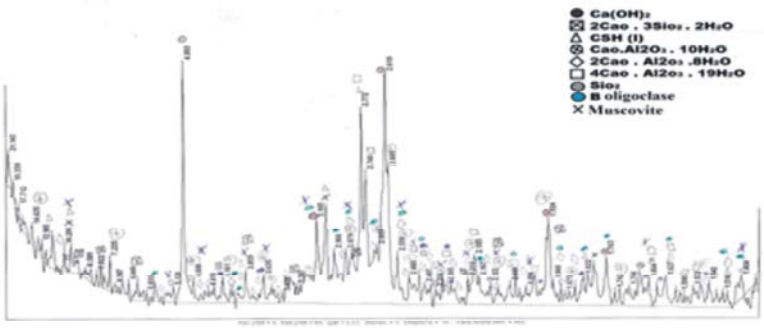


Fig. 2: Appearance of tuff power particles Sуд = 500 m^2/kg



Pic. 2: Radiographs composite binders: 1-derivedin a vibratory mill for grinding the cement, tuff,plasticized additive, 2 - resulting in a vibrating mill atseparate grinding of cement and tuff

(a)

(b)

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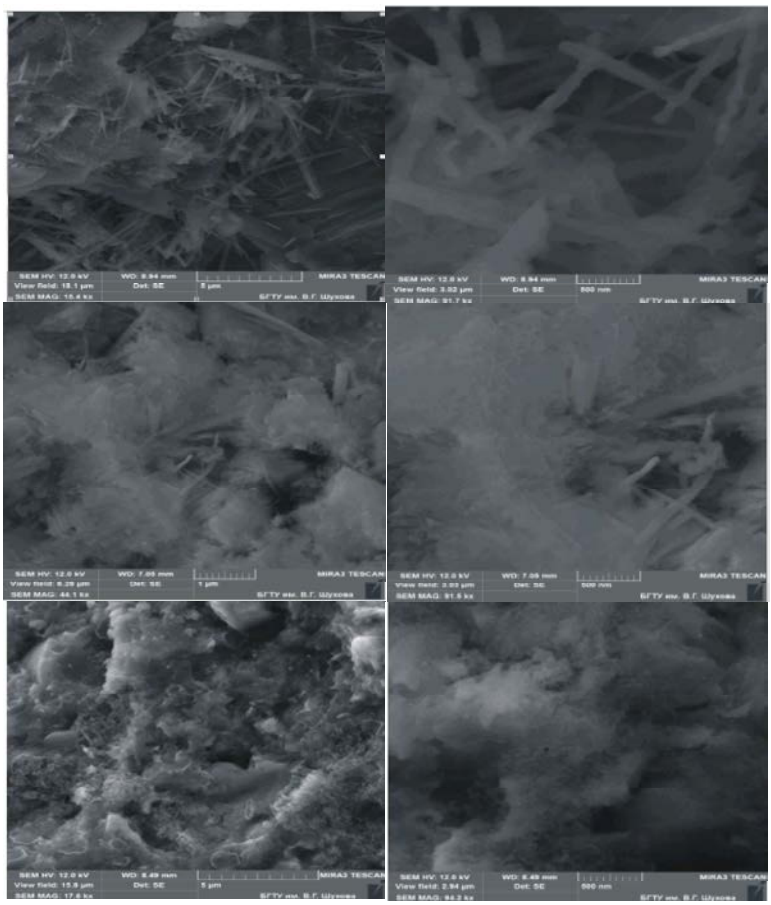
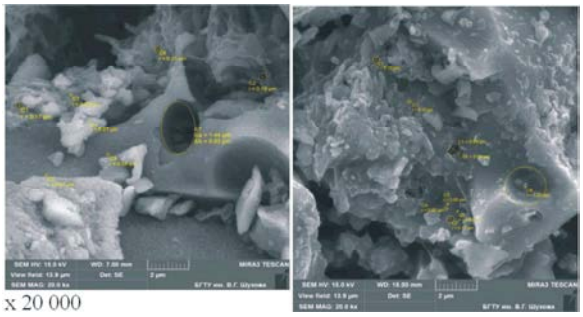


Fig. 3: Microstructure of 28 days composite binder: a - 90% cement and 10% tuff, separate grinding; B - 90% cement and 10% tuff, joint grinding; c - 90% cement, 10% tuff and 1% chemical aggregate, joint grinding



Pic. 4: Surface micrographs: a- volcanic tuff; b-tuff powder

This is explained by specific structure of fine tuff, allowing active new formations to emerge due to the use of water accumulated in the rock pores, as well as significantly contributing to the formation of contact zones microstructure and cement stone in general. To understand this process, let us consider in more detail the structure of the tuff aggregate.

It is known that volcanic tuff is a porous rock. The pore space of this rock is very complex by form and consists of a combination of different pore sizes (Fig. 4).

The micrographs clearly demonstrate that the rock is dominated by capillary pores $d_{ýô} = 10^{-7}10^{-4}$ m. You can also clearly see subcapillary pores ($d_{ýô} = 2*10^{-9}$-$1*10^{-7}$ m). It is the presence of pores of different shapes and sizes that provides good moisture retention capacity of tuffs.

The water in the rock is in a complex interaction with its mineral frame. It is known that the rocks are distinguished by four categories of water inside them, all these categories are present together, the boundaries and relations between them are conventional and are constantly changing: steam; chemically bound water, physically bound water (film and capillary retained), free or gravitational water [10].

Physically bound water (film and capillary retained) remains in the pore space of the rock due to the interaction of water molecules with the surface of the

mineral frame of the rock, as well as by the influence of capillary forces. Film water almost completely fills the volume of capillaries with a radius r <20 - 30 nm and capillaries with a radius r <1,5-2,0 nm are filled mostly with strongly bound water. Capillary water is characteristic to pores with a radius of 30-500 nm and also to the corners located near joints between the grains forming the rock frame and one-side open pores [10].

Thus, since tuff dispersibility contained in a composite binder is high, when the aggregate particles are mixed with water, they form a colloid adhesive and physically bind large amounts of water. By this they facilitate compaction and hardening of concrete particularly in the contact areas with the aggregate. Subsequently, in conditions of the shortage of the liquid phase, typical for hot climate, the aggregate particles begin to release, previously retained water by relevant dosages, reducing stress in hardening composite and as a result, reducing the amount and size of microcracks. This is confirmed by the results of physical and mechanical tests according to which compressive strength of the binder I s twice the strength plain cement - 95 MPa.

CONCLUSION

Thus, the results of the research have shown that volcanic tuffs of the Middle East represent effective mineral component for composite binders. It is established that the joint method of grinding when obtaining composite binder is more efficient compared to separate grinding and increases the activity of a binding agent by10.5%. Therefore, it is most efficient for obtaining fiber concrete for renovation and construction of buildings in the Middle East.

The work revealed the character of the influence of composition, fineness of composite binders containing volcanic tuff from Jordan and superplasticizer on the processes of structure formation of concrete mix in conditions of hot, dry climate, which is based on "internal curing", due to water retention capacity of tuff particles during mixing and molding, followed by release of relevant H_2O doses during concrete hardening. This reduces the stresses in hardening composite and, consequently, reduces the number and size of microcracks, which is determined by increasing the performance property of reconstructed buildings.

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