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Study of Effects of Redispersable Latex Powders On Hardening Kinetics of Cement-Sand Composites.

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ABSTRACT

Redispersable polymer powders act as boosters of the physical and mechanical properties in the cement-sand composite. For the studies the most typical redispersable polymer powders were used – Rhoximat PAV 22 and Rhoximat PAV 23 latex powders, by Rhodia. The analysis of the micrographs showed that the new formations of the cement rock had a pronounced needle-like form, and the cements with the additives were partially covered with the polymer film of the redispersable particles. The resulting polymer bridges and cords in the structure prevented growth of the cracks which were formed due to shrinkage and applied external force. Film-forming latex of redispersable powder can increase fracture energy of the cement-sand composite significantly. In view of this, of great significance is strength of the polymer itself. The higher strength polymer has, the greater force one should apply to fracture modified mixture. The basic components of Rhoximat PAV 22 and Rhoximat PAV 23 are vinyl acetate and vinyl versatate. Vinyl resins in the cement composites are known to develop a lattice which penetrates the structure formed by the cement gel, and, thus, act as an additional binder in the material.
Keywords: redispersable latex powders, cement-sand composites

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INTRODUCTION

Nowadays, polymer modifiers are widely used for dry mortars to increase the material strength. The thickening agents such as methyl hydroxyethyl cellulose, ethyl hydroxyethyl cellulose and redispersable powders are the polymer materials which are added to dry mortars as powder components. Their key difference is that in the presence of water thickening agents either fully swell and gel, or completely or partially dissolve, while redispersable polymers swell on their surface to a limited extent and mainly remain crystalline polymer capable of transferring the external load [1-22].

Thus, redispersable polymer powders act as boosters of the physical and mechanical properties in the cement-sand composite. In order to test the boosting effect of redispersable polymers the kinetic studies of strength development were carried out on cement-sand composites, both common and modified with powder boosters [23-24].

MATERIALS AND RESEARCH METHODS

For the studies the most typical redispersable polymer powders were used –Rhoximat PAV 22 and Rhoximat PAV 23 latex powders, by Rhodia [25].

Redispersable latex powder Rhoximat PAV 22 is a vinyl acetate (80%) and vinyl versatate (20%) copolymer, in the form of white powder with bulk weight 0.45÷0.6 g/cm^3 and mean particle size 80±10 µm (figure 1). The dispersion characteristics (50% of dry extract) are the following: Brookfield viscosity 200÷400 mPa·s; pH 5÷6; particle diameter 1÷5 µm.

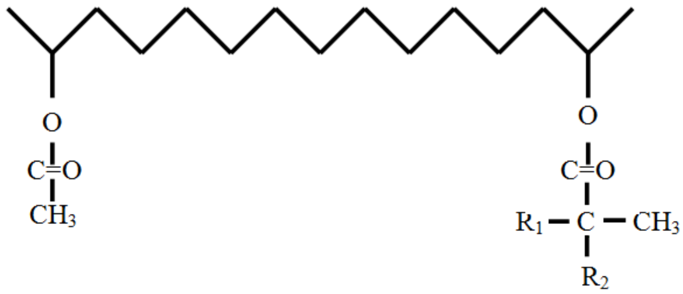

Figure 1: The empirical formula of vinyl acetate / vinyl versatate copolymer (R_1 and R_2 are alkyd radicals).

The film forming temperature is ~ 5 °C. Rhoximat PAV 22 is added to dry mortars to improve their mechanical properties. It is used for tile adhesives, self-leveling compounds, gypsum compounds, cement repair compounds [25, 26].

Redispersable latex powder Rhoximat PAV 23 is a vinyl acetate and vinyl versatate copolymer, in the form of white powder with bulk weight 0.45÷0.60 g/cm^3 and mean particle size 90±10 µm. The polymer is used in composite materials to increase their adhesion to common substrates and improve their physical and mechanical properties. Rhoximat PAV 23 contains solid matter (99±1%); anticaking agent (12±2%); protective colloid – polyvinyl alcohol (PVA). Rhoximat PAV 23 has the same empirical formula as PAV 22. The dispersion characteristics (50% of dry extract) are the following: Brookfield viscosity of aqueous solution 200÷400 mPa·s; pH 5÷6; particle diameter 1÷5 µm. The film forming temperature is ~ 5^{0}C. Rhoximat PAV 23 was developed specifically for self-leveling floor compounds. It can also be used to prepare screed mixes for small-sized floors, ceramic tile adhesives, gypsum plaster [25, 26].

Redispersable latex powders are spray-dried dispersions. During mixing a dry mix and water the powders pass into the dispersed phase with the features comparable to the ones of the original polymer dispersion. The mixture contains the redispersable powder which acts as an additional bonding agent and increases adhesion with organic and inorganic substrates. In these polymers PVA stabilizer increases water retention capacity.

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For the experimental studies on dry mortars the cement with identical chemistry and compound composition was used. The cement manufacturer is Oskoltsement, ZAO (Stary Oskol, Russia). The characteristics of cement PTs 400 D0 (ПЦ 400 Д-0; Portland cement, 28-day compressive strength 400 kg/cm^3, plain) according to standards GOST 310.1-76-310-3-76, GOST 310-4-81, GOST 310-5-81, GOST 310-6-85 were defined by the values: S_{sp}=290 m^2/kg, normal consistency=25.2%, setting time: initial – 4 h 50 min, final – 5 h 50 min, 28-day flexural strength – 7.3 MPa, compressive strength – 41.2 MPa.

The specifications of the sand obtained from the Svetlaya Polyana sand pit, Penza, Russia were the following: silt/dust content – 0.22%, FM=1.36 mm, true density – 2720 kg/m^3, bulk density – 1510 kg/m^3, void ratio (loose sand) – 43%, bulk density (packed sand) – 1670 kg/m^3, void ratio (packed sand) – 31.2%. According to GOST 8736-93, by silt/dust content the natural sand used belongs to class 1, and by grain size – to the group "very fine".

The compressive strength development was investigated by testing the 70.7×70.7×70.7 mm samples according to GOST 5802-86. The cubes were manufactured from the cement-sand mixture (1/3). The water/solid ratio was 0.25. The samples were molded by vibration on the standard vibrator VS-1 (ВС-1) at frequency 3000 rpm and amplitude 0.35 mm. The mixtures were hardened according to GOST 310.4.-81 at fixed temperature 20$\pm$2 ^{0}C and relative humidity 95÷100 %.

RESULTS

The strength development was analyzed for cement-sand mixtures with Rhoximat PAV 22 and Rhoximat PAV 23 redispersable powders (Figure 2, 3). As seen in Figure 2, Rhoximat PAV 22 latex powder with 0.1% concentration increased the unconfined compressive strength of the cement-sand rock by 30% after 24 hours. In 7 days it gained 20% strength, in 28 days – 20% strength. From 7 days through 28 days the strength of modified mixtures 1, 2 and 3 was 10÷30% higher than the strength of the check mixtures (figure 2).

Rhoximat PAV 22 powder with 2% concentration lowered the strength over all the 28-day kinetic area of the mixture hardening in comparison to the check mixtures (figure 2). It can be associated with PVA stabilizer present in Rhoximat PAV 22 additive.

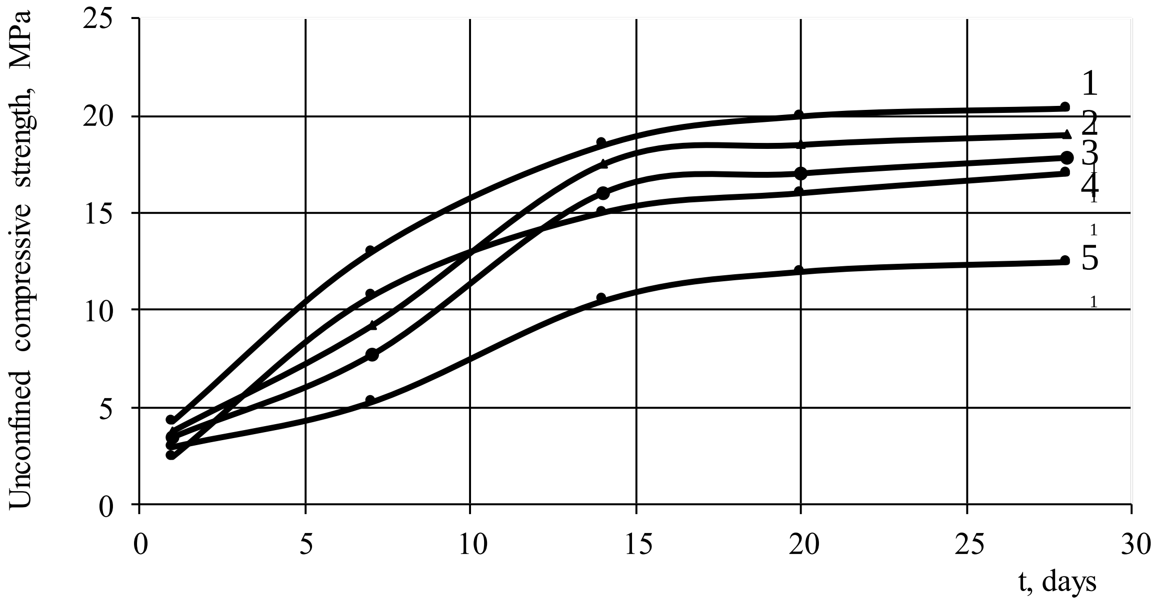

Figure 2: Strength development for cement-sand mixtures with Rhoximat PAV 22 redispersable powder added: 1, 2, 3, 5 – mixtures with Rhoximat PAV 22 added, 0.1%, 0.5%, 1%, 2% respectively; 4 - check mixture.

At high concentrations, a water-soluble PVA additive acted as a stabilizer and thickener, and lowered the strength of cement/sand rock. The strength development of the mixture with 2% Rhoximat PAV 22 exhibited the relationship that was close to linear, it indicated that hydration rate of the cement-sand system decreased in 7÷28 days and is a negative effect. From hardening kinetics analysis of the cement-sand composite it follows that the maximum optimum Rhoximat PAV 22 content is 1%.

The concentration of Rhoximat PAV 23 powder also varied from 0.1 to 2%. Throughout the range of 0.5÷1.0% concentrations the mixtures modified with Rhoximat PAV 23 showed the gain in strength up to 28 days in comparison with the mixtures containing 1% and 2% additives (figure 3). When Rhoximat PAV 22 and Rhoximat PAV 23 concentration increased from 1 to 2% or higher the unconfined compressive strength of the cement-sand composites decreased.

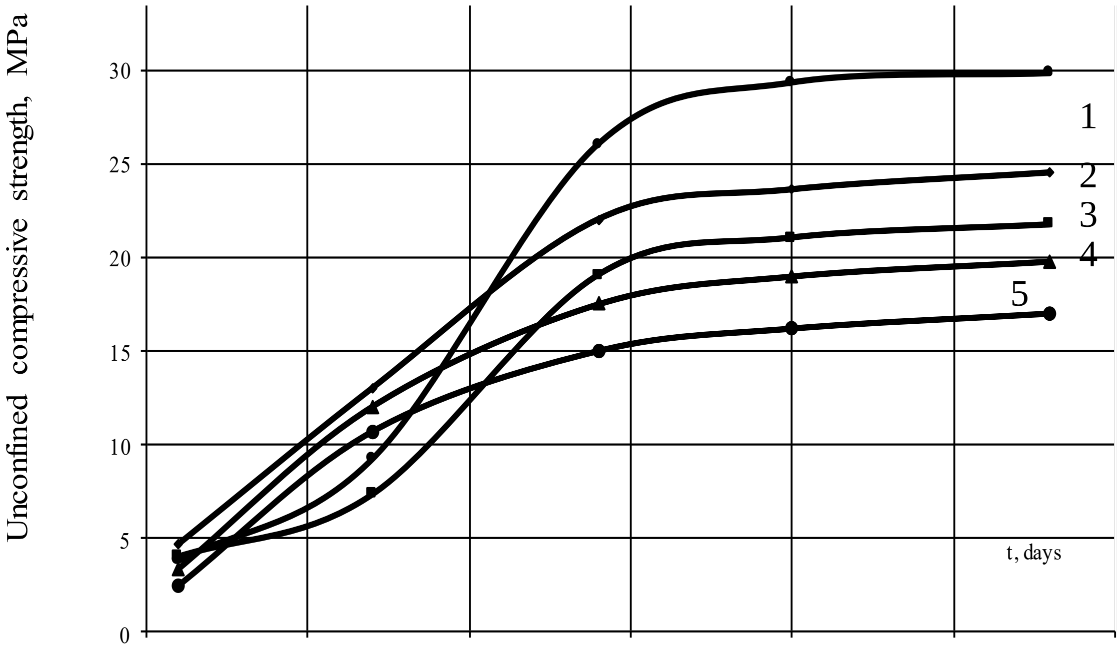

Figure 3: Strength development for cement-sand mixtures with Rhoximat PAV 23 redispersable powder added: 1, 2, 3, 4 - mixtures with Rhoximat PAV added, 1%, 0.5%, 2%, 0.1% respectively; 5 - check mixture.

DISCUSSION

Higher compressive strength of the cement-sand composite modified with latex powders can be explained by the following factors [27]:

- additional bonding in cement-sand mixture;
- lower porosity due to lower air entraining and defects of cement-sand rock structure;
- no blocking effect of polymer on hydration of cement particles.

The impact of the above mentioned factors was analyzed in more detail. A latex powder particle in the aqueous phase of cement-sand mixture can be shown as a model (Figure 4), the average particle diameter can be taken as 1.0÷5.0 µm. The limited surface swelling of latex powder particles resulted in a partial bulk of the polymer particles (“adjacent to the surface”) passing into the viscous film state (figure 4). Tensile strength of such viscous films exceeded 5.0 N/mm^2 that is higher than tensile strength of cement rock [22].

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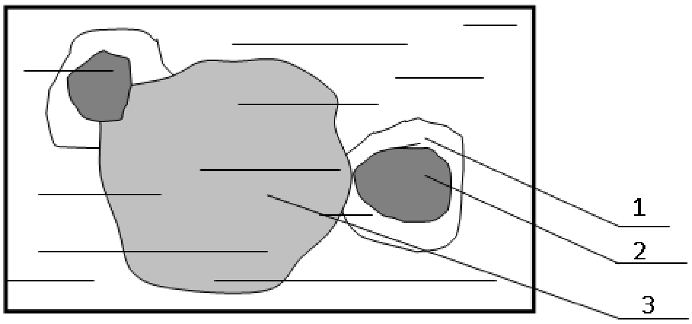
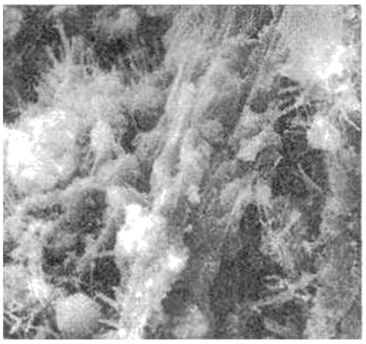


Figure 4: Particles of latex powder and cement in aqueous phase: 1 – surface-swollen viscous film part of particle bulk; 2 – crystalline part of latex powder particle; 3 – cement particle.

Also, the inner bulk of the particle retained its crystallite state and could transmit the external force in the structure of cement-sand composite while being a particulate filler with viscoelastic behavior. In the condensed cement-sand system the latex powder particles interacted with the immediate environment, cement particles, sand grains via their viscous films, they did not fully screen the surface of cement particles and prevent hydration. By adhering with their viscous layers to the particles around, the latex polymer particles became a part of the rigid body and started transmitting the external force.

It is possible that redispersable polymer is mainly present where the added water is concentrated, for example, in the pockets between the relatively smooth surface of a facing tile and comparably rough ingredients of a mortar mix. The water which has redispersed the powder is then used to hydrate cementing material except for the part which has been evaporated or absorbed by the base [22-24, 26-29].

Figure 5 shows the structure micrographs of the common cement composite (Figure 5, a) and composite modified with redispersable powder (figure 5, b, c). It should be mentioned that the areas with the redispersable polymer present are observed to have less defect areas of the cement new formations (figure 5). It is likely to be related to gradual usage of the water by the cement particles which has been retained by the surface-swollen polymer particles.



a)

b)

c)

Figure 5: Micrographs of cement rock structure (x100): a) structure of common cement rock; b) structure of cement rock modified with redispersable powder; c) structure of cement rock with redispersable powder as cementing medium.

Thus, the structure body as a whole obtained the viscoelastic properties, which had a direct effect on the physical and mechanical performance of the cement-sand composite. Compressive strength, transverse strength, flexural strength, peel strength increased, mainly, because of higher fracture toughness. Thus, when redispersable latex polymer powders were added to stiff cement-sand composite a fracture mode shifted from the brittle fracture area to the viscoelastic fracture area. The latter is believed to be a favorable condition for a hardened cement-sand mixture.

The fractographic evaluation of the fractures of the cement-sand samples with Rhoximat PAV 22 and Rhoximat PAV 23 additives indicates that fracture behavior of the modified mixtures differs from fracture behavior of the common mixtures. The fractured modified cement samples with a 0.1÷2.0% concentration of the redispersable latex powder had minimum microdefects and pores. The pores were smaller than ones in the check mixture. The mixture density did not decrease lower than 1800 kg/m^3.

The mixtures modified with Rhoximat PAV 22 and Rhoximat PAV 23 had higher fluidity and workability. It indicates that at certain concentrations redispersable powders partially act as water reducers and fluidifiers for mortars. The fluidifying effect of latex powders in the cement-sand mixture resulted in closer packing of cement particles and sand grains than the check samples had. The density study of the dried hardened cement-sand mixtures modified with the redispersable powders showed that the mixture density decreased slightly at the concentrations when the fluidifying effect was observed in the mortars. For Rhoximat PAV 22 and Rhoximat PAV 23 modifiers with a concentration of 1.5% from dry ingredients the density of the modified cement-sand mixtures with Rhoximat PAV 22 and Rhoximat PAV 23 was equal to 1810÷1890 kg/m^3 while the density of the check mixture was equal to 1980 kg/m^3.

CONCLUSION

Redispersable powders in a mineral mixture contribute to more thorough water wetting of the composite particles, resulting in higher quantity of hydrated cement particles. It should also be noted that the low quantities (up to 1.0%) of the polymers from a redispersable powder group favor the formation of ettringite which affects the early strength during hardening of cementing materials [27, 30].

The comparative analysis of the micrographs showed that the new formations of the cement rock had a pronounced needle-like form, and the cements with the additives were partially covered with the polymer film of the redispersable particles. The resulting polymer bridges and cords in the structure prevented growth of the cracks which were formed due to shrinkage and applied external force. The picture (Figure 5, Б) clearly shows that the system “cement-dispersing powder-filler” has the hydrated cement as well as the dispersing polymer as a cementing medium [22]. Therefore, film-forming latex of redispersable powder can increase fracture energy of the cement-sand composite significantly. In view of this, of great significance is strength of the polymer itself. The higher strength polymer has, the greater force one should apply to fracture modified mixture [31]. It should also be noted that the basic components of Rhoximat PAV 22 and Rhoximat PAV 23 are vinyl acetate and vinyl versatate. Vinyl resins in the cement composites are known to develop a lattice which penetrates the structure formed by the cement gel, and, thus, act as an additional binder in the material [31].

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