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Strength Properties of The Polymer – Cement Systems

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Generally, the polymer–cement systems consist of three main interacting components: polymer, cement, and water. However, other components, i.e. various fillings and additives, also affect the structure and properties of the central system. The paper aims at the investigation of the impact of the polymer type and its ratio in cement on the properties of the product.

The acrylatic copolymer water dispersion (ACD) as well as such familiar polymeric materials as polyvinyl acetate dispersion (PVAD) and butadiene - styrene latex SKS-65 G P (b) have been used. After a certain amount of time, the strength by pressure and bending, the layer flexibility, the sample deformations during the process of hardening, and strength alterations caused by water and frost have been determined. According to the dependency of the strength alteration in the polymer–cement mixtures, the acrylate copolymer dispersion by its operation resembles the polyvinyl acetate dispersion and butadiene - styrene latex. However, the hardened mixtures essentially differ by their elasticity and flexibility. Besides, with the increase of the amount of the PVAD in the mixture, the deformations of the sample contraction also increase. On the other hand, the growing amount of the acrylatie dispersion decreases the contraction. The authors present their opinion regarding the applicability of such systems in the sphere of repairing the building constructions, their protection, and trimming.

Keywords: cement mortar, compressive strength, softening in water, polymer dispersion.

1. INTRODUCTION

The majority of the polymer–cement mortars are well-known and successfully used in practice. The most widely known and examined are the cement mortars with the additives of polyvinyl acetate dispersion und butadiene–styrene latex [1 – 3]. They are successfully used for the building finishing, hydro isolation, and other purposes. Obviously, the chemical industry offers new polymeric products. Actually, it is important to examine and apply them for the protection and repairing of the building constructions. Such mortars have already been described [4 – 6]. However, no data was introduced regarding their strength by pressure, bending, and the comparison with other familiar polymer–cement mortars.

The aim of the paper is the examination of the dependency of the strength changes on the type of polymeric dispersion, composition of mortars, and conditions of their hardening and preservation.

2. MATERIALS AND METHODS

The CEM II A-M 42.5 portlandcement, acrylate copolymer dispersion ACD, polyvinil acetate dispersion PVAD, latex SKS-65 GP (b), and fine (up to 0.6 mm size) quartz sand from Anykščiai were used for the experiments. Both unplasticized and plastised (15 % of plasticizers) acrylate dispersions were used.

The cement–paste and cement–sand mixtures were produced. It appeared that the hardening process of the cement paste including polymeric additives was long and complicated. Very small samples (2×2×2 cm) were made in order to have lower contraction and a smaller cracking possibility. In the case of cement and sand samples the 4×4×16 cm prisms were formed. The samples hardened both in the open air and under laboratory conditions. Some samples after 21 days of hardening in the open air were put into water for 7 days for the determination of the degree of water saturation and the coefficient of softening. Further, several samples were left in water, others were frozen following the LST 1413.11 method. During freezing, after saturation, the samples were kept in a special chamber under –15 °C (and more). Then, in order to speed the process of decay, they were melted in the 5 % NaCl solution. In 24 hours a full freezing–thawing cycle was achieved.

During the process of hardening deformations were determined with the special indicators according to the LST 1413.9 method.

In should be mentioned that the data regarding the strength by pressure has an exclusively referential comparative meaning since, during the pressure, the samples because of their plasticity, get deformed not reaching the degree of decay. That's why it was difficult to determine the exact point of decay.

3. RESULTS

The dependence of the strength to pressure of the cement paste samples after 28 days hardening on the amount acrylate and polyvinyl acetate dispersion as well as butadiene–styrene latex are presented in Fig. 1. Other properties, such as the density of the samples, water saturation, the softening coefficient, etc. are presented in Table 1. The properties of the samples of cement mortars including the ACD additives are introduced in Table 2 and Table 3.

The curves in Fig. 1 show that the additive with 10 – 20 % latex SKS–65 GP(b), 20 – 30 % PVAD and

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20 – 40 % acrylate considerably increases the compressive strength of the samples which harden in the open air. The strength decreases when the samples are saturated with water. The data in Table 1, Table 2, and Table 3 show the changes of water saturation and softening coefficient ($R_{\check{S}}/R_S$).

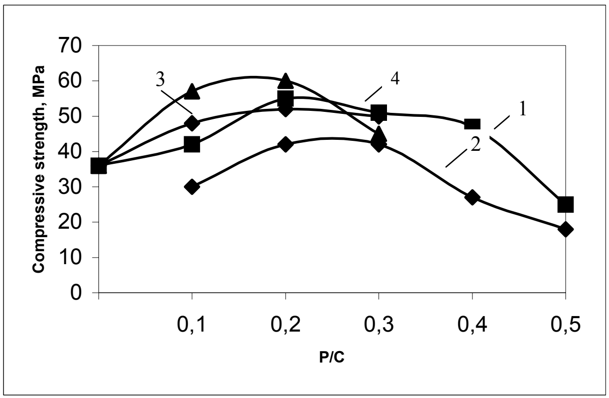


Fig. 1. The effect of types and content of polymer additives on the compressive strength specimens cement parts. 1 – ACD, 2 – ACD with 15 % plastisizer, 3 – lateks SKS–65GP(b) and 4 – PVAD

However, the regularity of the strength alteration remains the same (Fig. 1 and Table 1). It is characteristic of the majority of cement mortars including polymeric dispersion additives [1]. Most often, when in water, the strength of the samples decreases with the use of the plasticized dispersion (Table 1). Water saturation in the samples decreases with the increase of the amount of dispersion. In fact, water saturation afters similarly both with the use of the plasticized and unplasticized dispersions. However, the acrylate copolymer dispersion increases the elasticity and flexibility of a thin layer (it is not achieved by the PVAD or latex). The greatest flexibility is achieved with the use of the plasticized dispersion.

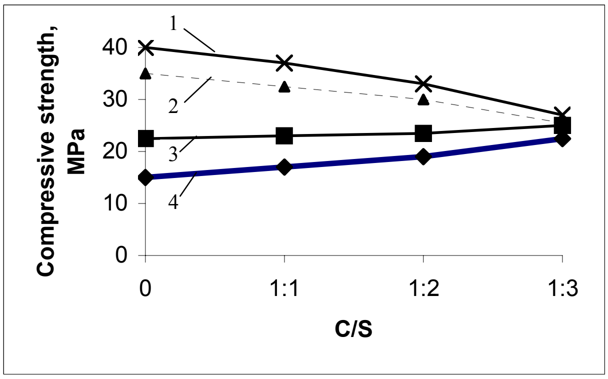


Fig 2. The effect of proportions of cement and sand (/S) on the compressive strength specimens polymer cement mortars. 1 – without polymers, 2 – 20 %, 3 – 30 % ACD, 4 – 50 % ACD

When testing the samples of cement and sand mortar with the polymeric additives 1:1 structure, the similar sample strength alteration has been discovered as in the case of the experiments with the cement – paste samples (Table 2).

When the ratio of cement (C) and sand (S) alters from 1:0 to 1:3, the compressive strength of the samples including typical amounts of the polymer dispersions (20 % PVAD, 30 % ACD alters inconsiderably. Fig. 2 demonstrates, the strength is smaller than that of the mortars without additives. The data shown in Fig. 2 was achieved with the use of the $4 \times 4 \times 16$ cm samples (Table 3). The test results regarding these samples differ from the results achieved with the $2 \times 2 \times 2$ cm samples which is determined by the different hardening speed and different contraction deformations (especially when the ratios are 1:0 and 1:1).

Table 1. The effect of additives ACD content on the properties specimens (2 × 2 × 2 cm) polymer cement pastes (C/S = 1:0)

No	Content ACD % by cement mass		$\frac{W+P}{C}$	Density, kg/m^3	Toughness and flexibility	Absorption of water, %	Softening in water (R_W/R_d)	Compressive strength at days:		
	Unplasticized	Plasticized						7	28	soaked
1	0	–	0.35	1870	Brittle, tough	14.6	0.93	31	35	33
2	10	–	0.35	1850	Brittle, tough	12.5	0.86	30	37	32
3	20	–	0.35	1870	Elastic	10.7	0.84	44	59	46
4	30	–	0.40	1780	Elastic, flexibility	4.1	0.82	44	57	46
5	40	–	0.50	1700	Elastic, flexibility	3.6	0.73	29	47	34
6	50	–	0.50	1690	Elastic, flexibility	2.8	0.96	25	26	25
7	–	10	0.40	1790	Brittle	12.00	0.60	29	31	19
8	–	20	0.40	1760	Elastic	7.60	0.58	36	43	25
9	–	30	0.40	1750	Flexibility	6.40	0.53	26	42	22
10	–	40	0.45	1670	Flexibility	5.60	0.70	15	25	18
11	–	50	0.45	1650	Very flexibility	3.80	0.92	13	19	17
12	PVAD	30	0.45	1800	Brittle	6.80	0.80	32	43	34
13	SKS-65GP(b)	20	0.40	1650	Brittle	5.10	0.89	–	44	38

Table 2. The effect of additives ACD content on the properties of specimens (2 × 2 × 2 cm) polymer cement mortars (C / S = 1:1)

No	Content ACD % by cement mass		$\frac{W+P}{C}$	Density, kg/m^3	Compressive strength at days:			Absorption of water, %	Softening in water (R_W/R_d)
	Unplasticized	Plasticized			7	28	soaked		
1	0	–	0.4	2000	24.00	25.00	28.60	7.10	1.1
2	5	–	0.4	1870	21.70	27.20	24.60	6.60	0.9
3	10	–	0.4	1840	30.00	37.20	26.90	5.80	0.7
4	15	–	0.5	1850	37.50	39.40	25.00	3.10	0.7
5	20	–	0.6	1740	17.70	18.40	11.10	4.30	0.6
6	20	–	0.5	1800	27.70	38.50	28.20	2.00	0.7
7	30	–	0.6	1750	17.10	18.20	10.70	0.70	0.6
8	–	5	0.5	1870	16.00	18.20	16.00	6.50	0.8
9	–	10	0.5	1780	10.70	16.30	14.30	6.50	0.9
10	–	15	0.5	1780	10.30	15.70	13.40	3.50	0.8
11	–	20	0.5	1760	14.00	15.60	11.40	3.60	0.7
12	–	30	0.6	1760	4.20	12.00	8.60	3.60	0.7

Table 3. Influence composition of mortars and content ACD of polymer cement mortars properties of specimens (4 × 4 × 16 cm)

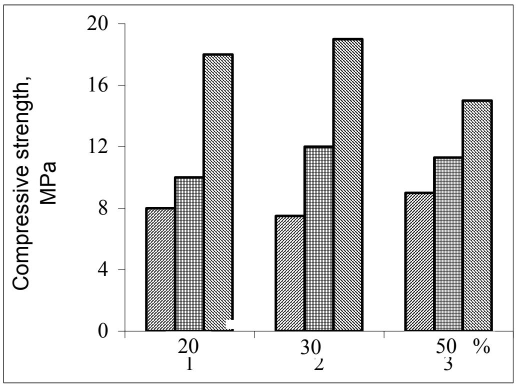
No	C/S	Content of ACD in %		$\frac{W+P}{C}$	Density, kg/m^3	Compressive/bending strength, MPa		Absorption of water, %	Softening in water (R_W/R_d)	Shrinkage/ expansion at 28 d mm/m
		Unplasticized	Plasticized			dry	wet			
1	1:0	0	0	0.33	1790	35.8/6.5	39.0/8.4	12.3	1.05/1.1	–0.7
2	1:0	15	–	0.53	1600	25.2/5.6	19.3/4.0	13	0.77/0.71	–0.6
3	1:0	30	–	0.53	1620	26.0/6.6	22.4/4.9	9.6	1.86/0.74	~0.0
4	1:0	50	–	0.53	1790	16.0/7.4	15.2/6.8	3.3	0.95/0.92	+0.1
5	1:1	0	–	0.40	2000	39.2/8.4	19.5/3.9	7.4	0.88/0.84	–1.0
6	1:1	15	–	0.62	1830	26.0/7.4	20.0/4.2	10.2	0.77/0.57	–0.6
7	1:1	30	–	0.62	1780	24.6/6.1	16.0/3.5	4.7	0.7/0.6	–0.6
8	1:1	50	–	0.60	1990	16.8/7.3	16.0/5.1	3.0	1/0.7	
9	1:3	0	–	0.50	1970	26.6/4.8	27.1/5.3	7.3	1.0/0.7	–1.1
10	1:3	10	–	0.52	1930	14.9/4.3	11.3/3.0	10.6	1.0/0.7	–0.9
11	1:3	20	–	0.57	1990	20.5/5.7	15.6/4.3	8.5	0.7/0.75	–0.6
12	1:3	30	–	0.62	1890	25.4/8.2	15.4/5.5	8.5	0.60/0.67	–0.25
13	1:3	50	–	0.75	1920	25.4/9.3	16.4/5.8	4.6	0.64/0.62	+0.1
14	1:3	–	20	0.75	1930	14.1/4.1	8.4/2.9	9.0	0.6/0.7	–0.22
15	1:3	–	30	0.65	2000	15.1/4.8	7.5/3.2	6.8	0.5/0.7	–0.11
16	1:3	–	50	0.75	1950	13.9/4.5	9.2/3.9	4.2	0.66/0.86	–0.08

The alterations of the properties of the cement mortars after the short–term (up to 7 days) and long – term (about 360 days) and cyclical freezing – thawing tests when the acrylate copolymer dispersion (ACD) was used, were examined.

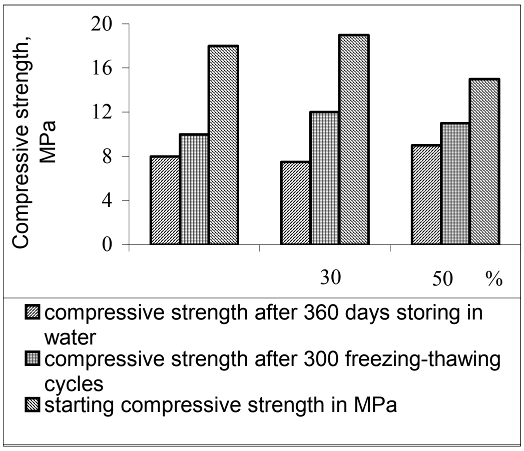
In most cases, the compressive strength and bending strength alters with the change of the amount of the ACD additive. With the increase of the ACD additive for about 30 % by the cement mass, the strength of the samples after soaking decreases. The ratio R_W/R_d increases up to 0.8 – 1.0. As it has been mentioned, some hardened samples were left in water up to one year (with occasional examinations), other ones, after having been saturated with water, were frozen in certain cycles. 300 freezing–thawing cycles were carried out. During a year, in either case, the decay signs did not occur. The test results demonstrated that the polymer–cement mortar samples hardened in the open air and then soaked in water first get weaker, but later they go on hardening and their mechanical strength increases. When cement and sand ratio (C/S) in mortars was 1:3, and in its composition was 20 – 50 % of the ACD, after one year of soaking in water, the strength increased about 40 % was compared to the initial state. The strength of the samples after 300 of freezing–thawing cycles also increased and, approximately, this increase made 24 % (Fig. 3).

An even greater effect is achieved with the use of the plasticized ACD. After freezing compression strength increased about 16 %, but after saturation the increase was 2.7 times (Fig. 3 b).

After freezing, the strength of the hardened cement–paste samples (1:0) altered insignificantly: it remained 90 % of the initial state, i. e. before freezing (Fig. 4 a). An average mortar (1:1) strength increase, in its turn, made around 20 %. From this it follows that the cement–paste samples because of their deformation increase during the process of hardening demonstrated a greater number of structural defects:



a



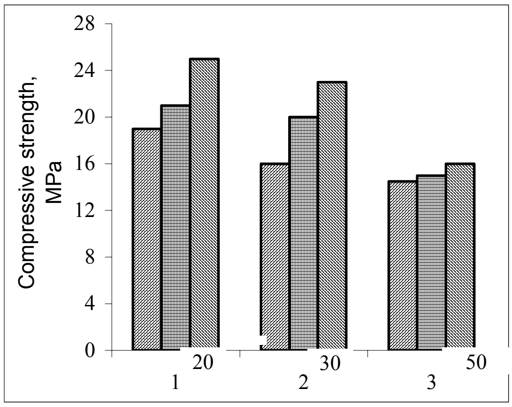
b

Fig. 3. The effect of the content of ACD on the compressive strength polymer cement specimens (1:3) after cyclic freezing – thawing and storing up in water: a – unplasticezed; b – with plasticised

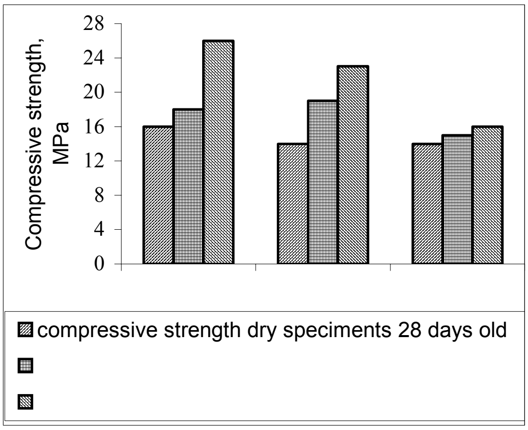
After freezing, the strength of the hardened cement–paste samples (1:0) altered insignificantly: it remained 90 % of the initial state, i. e. before freezing (Fig. 4 a). An average mortar (1:1) strength increase, in its turn, made around 20 %. From this it follows that the cement–paste samples because of their deformation increase during the process of hardening demonstrated a greater number of structural defects:

When measuring the sample ($4 \times 4 \times 16$ cm) contraction deformations during the mortar hardening, it has been determined that the ACD additives decrease the contraction (Table 3). It is lower than in the samples without additives. Moreover, when hardening in the open air, the samples with 50 % of the ACD additives get extended. The latter phenomenon will be examined in a more detailed research. The lowest contraction has been observed in the mortars with the plastificated ACD.

In summaty, all the achieved results point to the conclusion that the acrylate copolymer dispersion in cement mortars demonstrates the similar impact as observed in the case of the polyvinyl acetate dispersion. However, the main difference of both products is that, in the case of the PVAD additive, they are stiff, and in the case of the ACD additive, they are elastic, and their thin layers are flexible.



a



b

Fig. 4. The effect content (20, 30 and 50 %) on the compressive strength of specimen polymer cement 1:0 and 1:1 after cycling frost – thawing. Numbers at columns showing compressive strength in MPa: a – cement and sand ratio 1:0, b – C:S =1:1

Besides, in the process of hardening, they demonstrate lower contraction. With the latex SKS–65 GP (b) additive, the mortars are also stiff and hard. As it has been determined above, they may be used for the hydroisolation of the building construction.

The polymer-cement mortars including the ACD additive, with regard to their elasticity, flexibility, and resistance to frost, could be useful for the repair of the cracked building constructions and for the finishing of external walls.

4. CONCLUSIONS

1. According to the dependency of the polymeric mortar strength changes, the acrylate copolymeric dispersion by its operation in the mortar mixtures is similar to the polyvinyl acetate dispersion and the

butadiene-styrene latex. However, the greater amount of it in the mortar mixtures (up to 30 – 50 %) makes the cement mortars to be elastic and, in the case of thin layers, flexible.
2. During their hardening in the open air the polymer-cement mortars including the ACD additives demonstrate small contraction deformations.
3. The additives in the acrylate copolymeric dispersion decrease water saturation of the cement mortars. Even when big amounts of the mentioned dispersion are used (up to 50 %), the mortar softening index nearly does not change.
4. The polymer-cement mortars with the ACD additives that were hardened in the open air go on hardening in water and are steady. They also demonstrate high frost resistance

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