POLYMERIC ADDITIVES USED IN MINERAL COLORED PLASTERS

Daniela FIAT[1], Mirela LAZĂR[2], Victoria BACIU[3], Gheorghe HUBCA[4]

This paper refers to obtaining mass colored, high performance mineral plasters by the use of polymer additives. The study revealed the influence of the nature and concentration of polymeric additives on the physico-mechanical properties of the obtained mortars.

Keywords: mineral plaster, redispersible powders, cellulose ethers

1. Introduction

Recent advances in the field of constructions include the development of new materials and technologies, together with higher quality requirements, the need to respect shorter deadlines, reducing the costs, increasing the productivity by mechanized application of mortars, the need to obtain a constant quality of the materials. All these have imposed significant changes of **traditional mortars** [1]**.**

Using polymer additives (redispersible powders, cellulose ethers) in mortars based on mineral binders, several properties are considerably improved, such as: adhesion to the substrate, open time, water retention capacity, flexibility, durability. Today one cannot conceive dry-mix mortars without addition of polymer additives.

The advantages of the dry-mix mortars are: they do not require the water transport, it eliminates the problems linked to metering the products on the site, the destruction and recycling of packaging materials is more effective, they are not affected by frost, storage is easy and a constant quality of the products can be ensured. The requirements for the hardened plasters are: good substrate adhesion, low water absorption and a good water repellent effect (i.e. low liquid water permeability), good drying characteristics (high water vapor transmission rate).

[1] Eng., Research Institute for Construction Equipment and Technology - ICECON SA, Bucharest, Romania, e-mail: fiatdaniela@yahoo.com
[2] Eng., Research Institute for Construction Equipment and Technology - ICECON SA Bucharest, Romania
[3] Eng., Research Institute for Construction Equipment and Technology - ICECON SA, Bucharest, Romania
[4] Prof., Faculty of Applied Chemistry and Material Science University POLITEHNICA of Bucharest, Romania

2. Redispersible powders

Redispersible powders are obtained by spraying aqueous dispersions, generally based on copolymers such as ethylene-vinyl acetate, copolymers based on vinyl esters, vinyl chloride-vinyl laurate-ethylene terpolymer, vinyl acetate-vinyl versatate, acrylic copolymers [3]. Ethylene-vinyl acetate (EVA) copolymer, as latex or redispersible powder, is added to mortars in order to improve the impermeability and substrate bond strength.

It was proven [4] that the vinyl acetate groups in the EVA undergoes hydrolysis in alkaline medium producing polyvinyl alcohol and acetate anions (CH_3COO^-) [5]. These anions combine with Ca^{2+}, released from cement dissolution (the first step of cement hydration) and form calcium acetate ($Ca(CH_3COO)_2$) [6].

The amount of additives added is generally between 1 and 10 % with respect to the mineral compounds.

3. Cellulose ethers

Various types of methyl cellulose are used in the construction industry to adjust consistency and water retention and to improve adhesion properties of the mortars. Cellulose ethers are used as thickeners and water retention agents in dry mortars, in very low quantities (0.02 to 0.7 %0. The main cellulose ethers used in dry mortars are: methyl hydroxyethyl cellulose (MHEC) and methyl hydroxy propyl cellulose (MHPC).

Cellulose ethers can adjust workability of the fresh mortar to the desired level (by controlling the moisture content) and help the improvement water retention (thus preventing rapid drainage of water from the mortar to the substrate [8]).

4. Experimental results

Twelve formulations of plasters have been obtained, consisting of mineral plaster, mass colored, with addition of cellulose ether, redispersible powder, hydrophobic agent and inorganic pigment.

The following materials have been used:

- cement type CEM I 42,5 R (HOLCIM Romania SA);
- redispersible powder (polymer additive) DLP 212 [9] based on vinyl acetate - ethylene copolymer, (DOW Chemical Company);
- redispersible powder (polymer additive) [10] based on vinyl acetate - ethylene copolymer, with hydrophobic effect (DOW Chemical Company);
- Walocel MKX 25000 PF 25 L [11] modified hydroxy methyl cellulose (cellulose ether), (DOW Chemical Company, Germany);

- ESASIL 300 P [12] water repellent agent based on siloxane (SILICONI COMMERCIALE SPA, Italy);
- CHROM OXIDGRÜN GN [13] inorganic pigment Cr oxide green, (LANXESS AG, Germany);
- hydrated lime;
- quartz sand 0-2,5 mm.

The basic and additivated formulation are presented in Table 1

Table 1

Basic (M0) and additivated (R1...R2) formulation

Material	Basic formulation M0	Additivated formulation R1.....R12
	Dosage [%]	Dosage [%]
Cement CEM I 42,5 R	15	15
Hydrated lime	5	5
Sand (0-2,5 mm)	78.5	78.5-77.6
Cellulose ether (MC)	-	0.2
DLP 212/2141	-	0.8/1/1.5
Water-proofing (H)	-	0/0.2
Pigment	0.5	0.5

Two types of redispersibile powders, DLP 2141 (with hydrophobic properties) and DLP 212 have been used. The concentration of the additives has been of 0.8%, 1% and 1.5% respectively. The amount of cellulose ether has been of 0.2%. Some formulations included a water-proofing agent (0.2%). All the formulations include a pigment (5%). The main characteristic of the polymer additives used are presented in Table 2.

Table 2

Polymer additives characteristics

Additiv type	Characteristics	Value
DLP 212	White powder obtained by spray drying of an aqueous vynil acetate-ethylene copolymer dispersion	
	Residual moisture	max. 2 %
	Bulk density	0.400 - 0.550 g/ml
	Ash content	10 - 14 %
	MTFT*	0^0C
	pH	5.5-7.5
DLP 2141**	White powder obtained by spray drying of an aqueous vynil acetate-ethylene copolymer dispersion	
	Residual moisture	max 2 %
	Bulk density	0.400 - 0.550 g/ml
	Ash content	10 - 14 %
	MTFT*	0^0C
	pH	7.5
Walocel MKX 25000 PF 25 L	Wihte powder, modified hydroxyethyl cellulose, water solube-	
	Viscosity	22000-28000 mPa s
	pH	neutral

		(2 %solution)
	Moisture content	max. 7 %
ESASIL 300 P	White powder, water-proofing agent based on siloxane	
	Active substance	50 %
	Density	0.45 g/cm^3
	pH	8-9

* minimum film formation temperature;
** hydrophobic effect

The mortars obtained, both freshly prepared and hardened, have been submitted to a series of tests as follows: bulk density of fresh mortar SR EN 1015-6:2001, dry bulk density of hardened mortar SR EN 1015-10:2002/A1:2007, flexural and compressive strength of hardened mortar SR EN 1015-11:2002/A1:2007, adhesive strength of hardened mortars to substrate SR EN 1015-12:2001, liquid water permeability SR EN 1062-3:2008 and water-vapor transmission rate (permeability) SR EN ISO 7783-1:2002.

5. Results and discussion

Test results are shown in the Table 3 (for mineral plaster with DLP 2141), Table 4 (for mineral plaster with DLP 212) and Table 5 (for mineral plaster without additive).

Table 3

Characteristics of polymeric additive mineral plasters DLP 2141

Redispersible powder/Dosage	**DLP 2141**					
	0,8 %	**0,8 %**	**1,0 %**	**1,0 %**	**1,5 %**	**1,5 %**
Water-proofing agent/Dosage	**-**	**0,2 %**	**-**	**0,2 %**	**-**	**0,2 %**
Celluose ether/Dosage	**0,2 %**	**0,2 %**	**0,2 %**	**0,2 %**	**0,2 %**	**0,2 %**
Characteristic/Recipe code	**R1**	**R2**	**R5**	**R6**	**R7**	**R8**
Density, kg/m^3 (fresh mortar)	1728	1768	1748	1788	1768	1758
Adding water, %	19	17	15,5	15	15	15
Consistency (standard cone), cm	8	7	8	8	8	8
Density, kg/m^3 (hardened mortar)	1575	1646	1606	1750	1652	1664
Flexural strength, N/mm^2	0.392	0.809	0.538	1.227	1.044	0.960
Compressive strength, N/mm^2	4.16	5.93	5.42	7.56	6.46	6.71
Adhesive strength (concrete), N/mm^2	0.52	0.69	0.65	0.26	1.36	0.87
Water permeability (W), kg/(m^{2}h$^{0.5}$)	0.3995	0.0962	0.2667	0.1027	0.1430	0.0825
Water-vapor permeability (V), g/(m^{2}day)	174	126	170	113	142	120

Table 4

Characteristics of polymeric additive mineral plasters DLP 212

Redispersible powder/Dosage	**DLP 212**					
	0,8 %	**0,8 %**	**1,0 %**	**1,0 %**	**1,5 %**	**1,5 %**
Water-proofing agent/Dosage	**-**	**0,2 %**	**-**	**0,2 %**	**-**	**0,2 %**
Celluose ether/Dosage	**0,2 %**	**0,2 %**	**0,2 %**	**0,2 %**	**0,2 %**	**0,2 %**
Characteristic/Recipe code	**R3**	**R4**	**R9**	**R10**	**R11**	**R12**

Density, kg/m^3 (fresh mortar)	1748	1748	1748	1748	1728	1748
Adding water, %	16	16,5	15	15,5	15	15
Consistency (standard cone), cm	8	8	8	7	8	8
Density, kg/m^3 (hardened mortar)	1627	1633	1675	1647	1602	1632
Flexural strength, N/mm^2	0.871	0.454	0.649	1.169	0.723	0.989
Compressive strength, N/mm^2	7.02	6.11	6.84	7.12	6.97	6.79
Adhesive strength (concrete), N/mm^2	0.91	0.72	0.54	0.39	0.84	0.71
Water permeability (W), kg/(m^{2}h$^{0.5}$)	0.4678	0.2099	0.4355	0.1486	0.3153	0.2647
Water-vapor permeability (V), g/(m^{2}day)	129	164	115	106	141	148

Table 5

Characteristics of the basic formulation M0 (without additives)

Characteristic/Recipe code	**M0**
Density, kg/m^3 (fresh mortar)	2128
Adding water, %	17
Consistency (standard cone), cm	8
Density, kg/m^3 (hardened mortar)	1949
Flexural strength, N/mm^2	4,51
Compressive strength, N/mm^2	14,8
Adhesive strength (concrete), N/mm^2	0,49
Water permeability (W), kg/(m^{2}h$^{0.5}$)	2,41
Water-vapor permeability (V), g/(m^{2}day)	223

Acording to the data, the water amount needed to obtain the same consistency, respectively 7-8 cm (determined using standard cone) diminishes when polymer additives are used in higher dosage.

It is observed that hardened mortar **density** without additives M0 (basic formulation) are about 1950 kg/m^3 and hardened additivated mortars have the density about 1500 - 1700 kg/m^3. The additivated mortars are lighter and the mechanical properties are smaller (Fig. 1 and Fig. 2). It was proven that the addition of cellulose ethers in mortar leads to a decrease in apparent density of hardened mortar [14], as a result of stabilization of the air entrained during mixing [15]. According to Jeni at al [16] mortars with cellulose ethers have a volume of air greater than 20% while those without cellulose ethers have only a few percent of entrained air.

Also when the redispersabile powder added in mortars, are mixed with water, they yield the original aqueous dispersion, with its typical properties and function [2]. After the water evaporates, the resin particles form a polymeric film [17], and the mortars become more flexible, so the compressive strength decrease.

Flexural strength was determined according european standard SR EN 1015-11:2002/A1:2007, by applying a three-point load, until breaking prismatic specimens of hardened mortar prismatic specimens.

For additivated mortars, the results show an increase in flexural strength with the amount of polymer additive (Fig. 1, Table 3, 4).

Adding the DLP 2141 polymeric additive resulted in an increase of the flexural strength from 0.392 N/mm^2 (for 0.8% additive) to 1.044 N/mm^2 (for 1.5% additive). For DLP 212 polymeric additive the flexural strength increased from 0.871 N/mm^2 (0.8% DLP 212) to 1.169 N/mm^2 (1.0% DLP 212).
With introduction of 0.2% Esasil the flexural strength increased slightly with a maximum at 1% polymeric additive added, shown in Fig. 1.

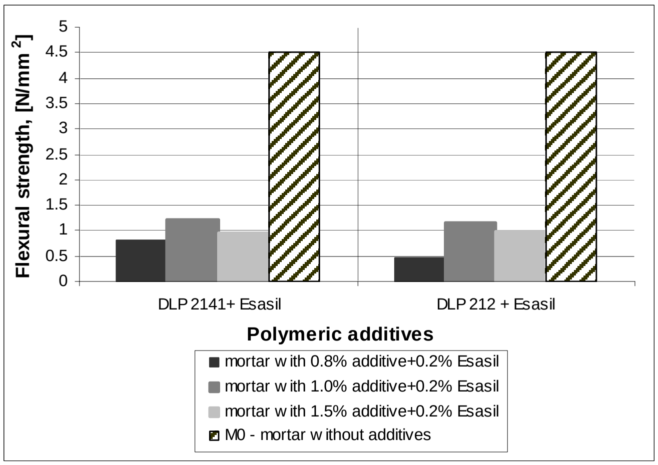

Fig. 1 - Relation between flexural strength (28 days) of the hardened mortar and the amount of polymer additive and water repellent agent Esasil

Compressive strength was determined according 1015-11:2002/A1:2007 by applying a load on the top side of the prismatic specimen, a load perpendicular to the casting direction. The load application was smooth and increased progresively. The resistance was computed as the ratio between the maximum load applied and the cross-section of the specimen.

According to figure 2, table 3 and 4, an increase of the compressive strength was noticed with the amount of the DLP 2141 additive (5.93 N/mm^2 for 0.8% additive, as compared with 6.46 N/mm^2 for 1.5% additive), while the presence of DLP 212 had no significant influence on the compressive strength (7.02 N/mm^2 for 0.8% DLP 212 as compared with 6.97 N/mm^2 for 1.5% DLP 212).

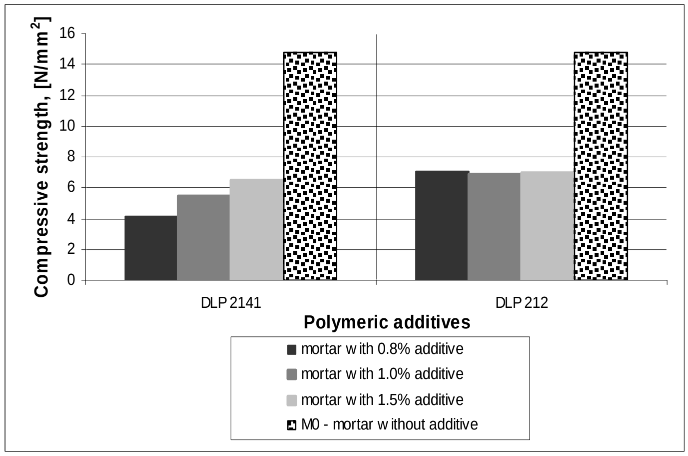

Fig. 2 - Variation of the compressive strength with the nature and the amount of polymer additive (mortars without Esasil)

Adherence between the mortar and the concrete support was determined according SR EN 1015-12:2001 by measuring the tensile strength of the concrete-mortar joint (Fig. 3); a normal effort was applied using a metallic plate fixed on the mortar surface. The effort was applied until the failure of the joint.

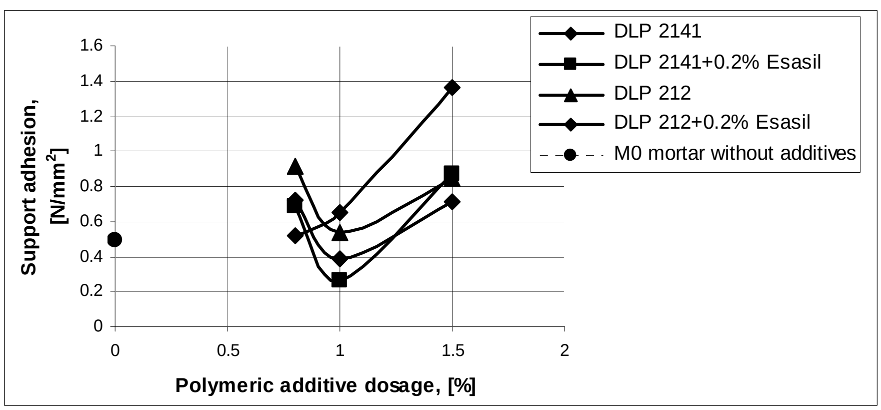

Fig. 3 - Test of the concrete (support)-mortar adhesion.

A significant increase of adhesion to the substrate was measured when DLP 2141 additive was used, from 0.52 N/mm^2 (0.8%) to 1.36 N/mm^2 (1.5%).

The increase in tensile strength value and property of waterproofing is achieved, as a result of the improved adhesion at the substrate interface and by improved the cohesion of the mortar due to the formation of the polymeric film [2].

Permeability to liquid water (W), was determined according SR EN 1062-3:2008. Test samples have been immersed in water face down, about 1 cm under the water surface, at $(23\pm2)^0$C. After 10 min., 30 min., 1 h, 2h, 3h, 6h , 24 h etc., the samples have been removed and weighted after the excess water was wiped out.

The dependence between the mass increase (in kilograms) divided at the test area of the test specimens (in square metres) and the square root of time was plotted, see figure 4 (example for the plaster mortar code R5).

The slope of the linear part of the curve represents the water permeability (W), according standard.

$$W = \frac{\Delta m}{S\sqrt{t}} \quad \text{(from the graph)}$$

w = liquid water permeability, kg/($m^2h^{0,5}$);
Δm = the rate of change in mass, kg;
S = surface, m^2;
t = time, h.

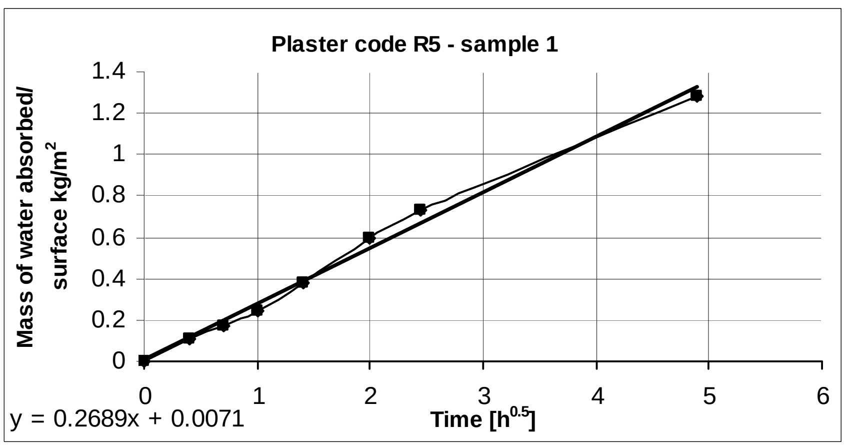

Fig. 4 - Dependence between the increasing mass divided at area of testing and the square root of time (example for the plaster mortar code R5)

The relation between the coefficient W (liquid water permeability) and the type/amount of additives is given in figure 5.

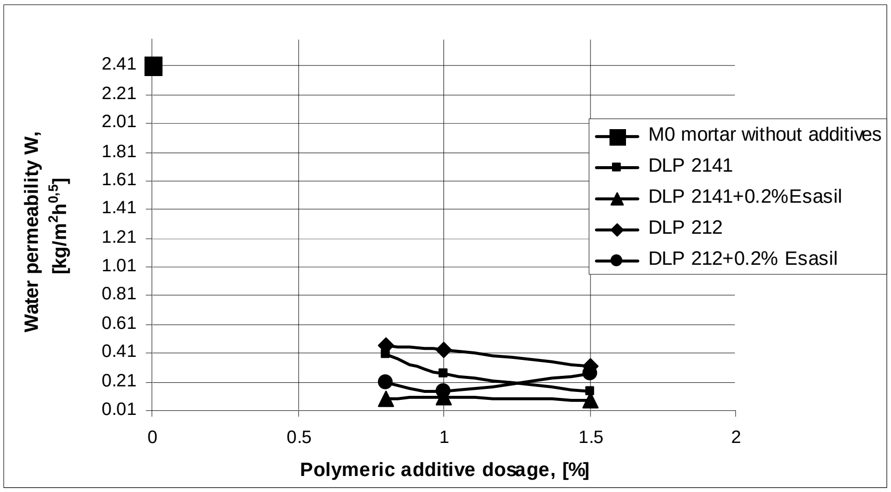

Fig. 5 - Variation of coefficient W depending on the nature and amount of polymeric additives.

The water permeability W decreases when the hydrophobic additive DLP 2141 is added to the mortar (from 0.3995 kg/($m^2h^{0,5}$) to 0.1430 kg/($m^2h^{0,5}$) for an increase of the amount of the DLP 2141 additive from 0.8% to 1.5%). The effect is significantly enhanced by the use of 0.2% Esasil 300 (with hydrophobic effect): for the same amount of DLP 2141 additive (0.8%), the water permeability decreased from 0.3995 kg/($m^2h^{0,5}$) to 0.0962 kg/($m^2h^{0.5}$) when EASIL 300 was added.

Permeability to water vapour

A test assembly consisting of a self-supporting coating (colored plaster) sealed to the rim of a cup is placed in a test enclosure kept at a specified temperature (23^0C) and relative humidity (85%), according SR EN ISO 7783-1:2002. By weighing the test assembly at suitable time intervals, the change in mass of the test assembly is followed. Plot the change in mass (grams), against time (hours). The test is considered to be complete when three or more points lie in a straight line, showing a constant rate of passage of water vapor.

- the water-transmission rate, V (g/m^2day), is calculated with the formula:

$$V = \frac{240x\Delta m}{A}$$

V = water-vapour transmission rate of the plaster mortar, g/(m^2x day);
Δm = the rate of change in mass, determined from the graph (the slope) mg/h;
A = the area of the test surface of the test piece, cm^2.

In fig. 6 it is presented an example of the rate of change in mass with time for plaster mortar code R5.

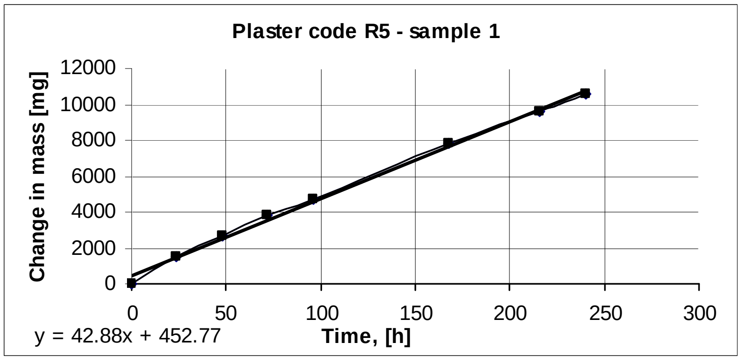

Fig. 6 - Rate of change in mass as a time function

The variation of the water-vapour transmission rate as a function of the quantity of polymer additives used is presented in Fig. 7. Compared with a usual cement mortar (without additives) and a cement-lime mortar M0 (without additives), the tested samples showed mostly a medium water vapour coefficient.
- regarding water-vapour permeability the tested mortars these are classified in medium water vapor permeability class V_2 (150 g/m^2 day ≤ V > 15 g/m^2 day) according SR EN 1062-1:2004 [18] and high water-vapor permeability class V_1 (V ≥ 150 g/m^{2}day), when using the polymeric additive DLP 2141.

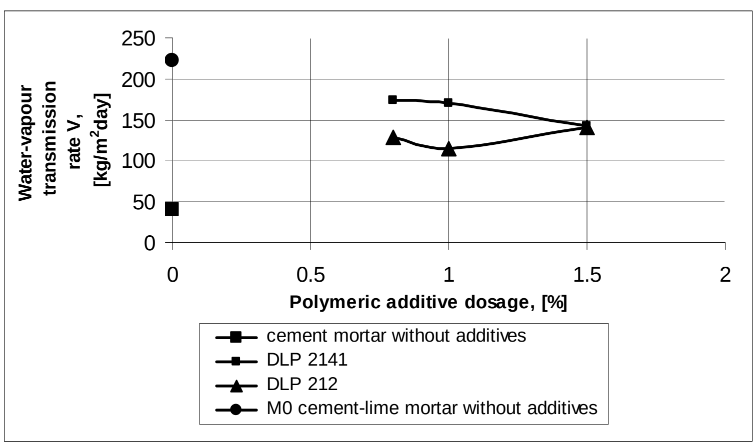

Fig. 7 - Variation of the water-vapour transmission rate V (without Esasil addition) as a function of the type and amount of polymeric additives.

6. Conclusions

Characterization of mortars with polymeric additives by physical and mechanical tests has shown the following:

- all compressive strengths comply the requirements provided according european standard SR EN 998-1:2011 [19] which classify rendering and plastering mortars thus: class CS I 0.4-2.5 N/mm^2;
  - class CS II 1.5-5 N/mm^2;
  - class CS III 3.5-7.5 N/mm^2;
  - class CS IV $\geq$ 6 N/mm^2.

  It is observed that are not required high mechanical strength.
- the use polymeric additives improves very much the adhesion to substrate, comparing with basic formulation M0;
- plastering mortar have a medium liquid water permeability W_2 - class ($W \leq 0.5$ kg/m^{2}h$^{0.5}$), according SR EN 1062-1:2004, in presence of polymeric additives and W_1-class (low) liquid water permeability ($W \leq 0.1$ kg/m^{2}h$^{0.5}$) in presence of the DLP 2141 additive (with hydrophobic effect) and water-proofing agent ESASIL 300 P; the water-proofing property is much improved compared to the conventional mortars (without additives);
- the mortars studied are permeable water-vapour class V_2 (medium) and class V_1 (high) according SR EN 1062-1:2004;

Cellulose ether content must be related to the redispersible powders content to achieve a good balance between the properties of mortars. Mortars with added cellulose ether has a higher content of entrained air, there are lighter, but redispersible powders enhance adhesion to the substrate and impermeability to water.

Water repellent additives are mainly used in cement based mortar for exterior applications. Redispersible powders with hydrophobic action have the advantage of an better sustainability, since they are not washed by rain from the mortars (over time) and they increase the adhesion between the mortar and the support.

R E F E R E N C E S:

[1] *V. Baciu, D. Fiat*, “Mortars based on mineral binders with addition of polymeric compounds”, Tribune Building Magazine no. 8, 2004;

[2] *H. Lutz*,”Modification of Mineral Plasters with Hydrofobic Polymeric Binders“, Wacker Polymer Systems GmbH&Co KG;

[3] *R. Bayer, H. Lutz*, “Dry mortars - from Ullmann’s Encyclopedia of Industrial Chemistry”, 2003;

[4] *A.M. Betioli, J. Hoppe Filho, M.A. Cincotto, P.J.P Gleize, R.G. Pileggi*, "Chemical interaction between EVA and Portland cement hydration at early-age", Construction and Building Materials, **23** (2009), pp. 3332-3336;
[5] *Y. Ohama*, "Polymer-based admixture", Cem. Concr. Copos., 1998, **20**, pp. 189-212;
[6] *D.A Silva, H.R Roman, P.J.P Gleize*, "Evidences of chemical interaction between EVA and hydrating Portland cement", Chem. Concr. Res, 2002, **32**, pp. 1383-90;
[7] *Feller, R. F., Witt, M.*, "Evaluation of Cellulose Ethers for Conservation", The Getty Conservation Institute, 1990;
[8] *J. Pourchez. P.Grosseau, B. Rout*, "Changes in C_3S hydration in the presence of cellulose ethers", Cement and Concrete Research, **40** (2010), pp. 179-188;
[9] Technical Data Sheet DLP 212, DOW Chemical Company;
[10] Technical Data Sheet DLP 2141, DOW Chemical Company;
[11] Technical Data Sheet Walocel MKX 25000 PF 25 L, DOW Chemical Company;
[12] Technical Data Sheet ESASIL 300 P, SILICONI COMMERCIALI SPA;
[13] Technical Data Sheet CHROM OXIDGRÜN GN, LANXESS Deutachland GmbH;
[14] C. Ciobanu, S. Iluc, I. Lazău, C. Păcurariu, "Some physico-mechanical properties of dry mortars containing cellulose ethers", Romanian Jurnals of Materials, 2011, **41**(1), 30-41;
[15] *J. Pourchez, B. Ruot, J. Debayle, E Pourchez, P Grosseau*, „Some aspects of cellulose etehers influence on water transport and porous structure of cement-based materials", Cement and Concrete Research, 2010, **40**, 242;
[16] *A. Jeni, L. Holzer, R. Zurbiggen, M. Herwegh*, "Influence of polymers on microstructure and adhesive strength of cementious tile adhesive mortars", Cement and Concrete Research, 2005, **35**, 35;
[17] *J. Schulze*, "The use of redispersible powders in cement mortars", Journal Tonindustrie-Zeitung, **9**, 1985, 698;
[18] SR EN 1062-1:2004, Paints and varnishes - Coating materials and coating systems for exterior masonry and concrete - Part 1: Classification;
[19] SR EN 998-1:2011, Specification for mortar for masonry - Part 1: Rendering and plastering mortar.