ISSN 1846-6168 (Print), ISSN 1848-5588 (Online)
ID: TG-20170816141410

Original scientific paper

ANALYSIS OF POROUS AND CHEMICAL ADDITIVES EFFECTS ON THE CEMENT-LIME MORTAR PROPERTIES

Khrystyna MOSKALOVA, Marin MILKOVIĆ, Goran KOZINA

Abstract: Cement-lime (CL) mortar has a number of properties and most important property of this mortar type is dependent on the admixtures and aggregates. By varying the ratio of ingredients, the characteristics of CL mortar can be adapted to specific mortar applications. This paper discusses those mortar properties that EU standards and engineers consider important. For each of these properties, the influence of admixtures and aggregates in the mortar is explored. Properties detailed in the paper include bond strength, compressive strength and workability.

Keywords: admixtures; cement; hydrated lime; mortar; workability

1 INTRODUCTION

The main components that form a strong structure of solid plasters based on the dry building mixes (DBM) are binders and fillers. Cement of various brands and lime in hydroxyl form are predominantly used as binders for coating materials. Fillers with rationally selected grading, dispersion and the optimum ratio in the texture composition contribute to the improvement of the quality of the plaster. They also contribute to minimization of added chemical additives, which are the most expensive component. In case the material is a complex system consisting not only of binders and fillers, but also of high molecular substances, its structure will be unique due to the structure and properties of polymer modifiers. This system will not obey the generally accepted idealized laws of recoverability, plasticity, which proceed from the theory of an ideal model of a body possessing the properties of continuity, homogeneity and isotropy.

2 RESEARCH AND RESULTS

The ability to quantitatively describe and analyse the multidimensional relationships between the parameters of mixtures, operating conditions, ratio and technological factors and the properties of materials - the properties of the mixture, characteristics of the structure, operational properties with the purpose of controlling the structure and properties of the material - it is expedient to use computer material science tools based on the concept of property plains [1, 2].

The cement-lime light plaster on the basis of perlite was adopted as a baseline mixture, which is developed by the company "Henkel-Bautechnik (Ukraine)". The composition consists of a polymer-cement mixture containing perlite sand, redispersible powders Vinnapas, as well as water-retaining and air-entraining additives.

The experiment was carried out according to the optimal 18-points plan [3]. Four factors of the composition were varied (relative to 1000 weight parts (w.p.) of a premised plaster):

X_1 - powdered to S_{ss} = 400 m^2 / kg limestone rock, 80 ± 20 w.p.;

X_2 - expanded perlite sand of mark 100, 40 ± 10 w.p.;

X_3 - methylhydroxyethyl cellulose Tylose 60010 (water-soluble, non-ionic cellulose ethers), 1.15 ± 0.15 w.p.;

X_4 - polymer redispersible powder Vinnapas RE 5034N (copolymer of vinyl chloride, ethylene and vinyl laurate), 1.5 ± 0.5 w.p.

Table 1 Generalized parameters of plaster mortar

Parameter Y		W/C		W_{OUT}, %		R_A, MPa	
		min	max	min	max	min	max
Y_{exp}		0.92	1.2	99.7	99.9	0.08	0.49
Coordinates Y_{exp}	x_1	−1	0.99	0.37	1	−1	−1
	x_2	1	0.99	1	1	1	1
	x_3	1	1	−1	1	−1	−1
	x_4	0.41	−1	−1	−1	−1	−1
ΔY		0.28		0.2		0.41	
δY		1.3		1		6.1	
S		0.03		0.03		0.03	

Based on the results obtained in the experiment, four-factor experimental-statistical (ES) models were constructed describing the explored quality criteria (1-3). For the construction of ES models, the COMPEX system [4] created in the Odessa State Academy of Civil Engineering and Architecture is quite effective, which is used to process experimental-statistical models data, optimize and make engineering decisions. The COMPEX program provides interaction with Windows, and allows the construction of models with a generated experimental error [5], calculation of generalized indices of the material properties fields [6], etc. The fields which were described by these models can be characterized by generalizing indicators that facilitate their comparative analysis, Tab. 1. The basic generalizing exponents of the property Y in the boundaries of the field under study are the minimum Y_{min} and the maximum Y_{max} levels, as well as their coordinates x_{min} and x_{max}.

3 PROPERTIES OF CEMENT-LIME MORTARS

3.1 Workability

One of the most important properties of plastic mortar is its workability. Lime is the primary contributor to workability of cement-lime mortars. The lack of workability of mortar mix makes it difficult to align the surface of the plaster coatings, reduces the adhesion properties, reduces the degree of hydration of the binder in the mortar, and leads to the shedding of the surfaces of the plaster coating.

Water requirement of dry mortars was attributed to the cement as a water-cement ratio and was determined at different water-cement relations chosen so that all proportions had the same workability.

The workability of the mortar mixture was determined by the European standard DIN 18555 on a jolt-table. According to the standard, all plasters mortar mixes are divided by diameter of flow into: rigid <14 cm; plastic - 14÷20 cm and soft > 20 cm. To ensure equal workability all the examined plasters should have the same workable consistency. As a result, the flow diameter of all mixtures corresponded to 16÷17 cm and this classifies all mixtures as plastic. This condition is chosen based on the results of the analysis of the behaviour of produced dry mixtures and equipment parameters. Equal workability of all mixtures was ensured by the selection of mixing water.

The diagram (Fig. 1) in the form of squares on a square is shown; it represents the influence of composition factors on the water demand of the mixture. Factors - methylhydroxyethyl cellulose (x_3) and polymeric redispersible powder (x_4) were chosen as square-bearing. The fields that show the effect of limestone (x_1) and perlite (x_2) are constructed at nine points. In the squares on the square, the isolines of the maximum values of water demand W/C_{max}, water-cement ratio are shown, which can be achieved with a fixed ratio of methylhydroxyethyl cellulose and polymer redispersible Vinnapas powder, with varying amounts of limestone and perlite. Analysis of the diagram allows saying that the water requirement of a plaster mixture of equal mobility slightly increases as the amount of porous components - limestone (x_1) and expanded perlite (x_2) in the formulation increase.

Varying the dosage of methylhydroxyethyl cellulose within the factor space of the experiment does not produce significant effect on water requirement. The minimum of water-cement ratio shows compositions with an average (about 1.5 w.p.) amount of redispersible powder Vinnapas. In general, it is possible to establish a slight (up to 16 %) change in water requirement and, respectively, water-cement ratio (W/C) mixes of equal mobility with varying composition factors, which is explained by a rather "narrow" range of factors, approximating to the baseline composition.

3.2 Water retention

The water retention ability plays an important role in the formation of a strong adhesion of the mortar to the base. With insufficient water retention capacity in the contact area with a base, the liquid phase is formed, which leads to a complete disruption of the adhesion. The water-retaining capacity of the compositions was estimated by water loss in %,. As a result, an ES model was obtained (1).

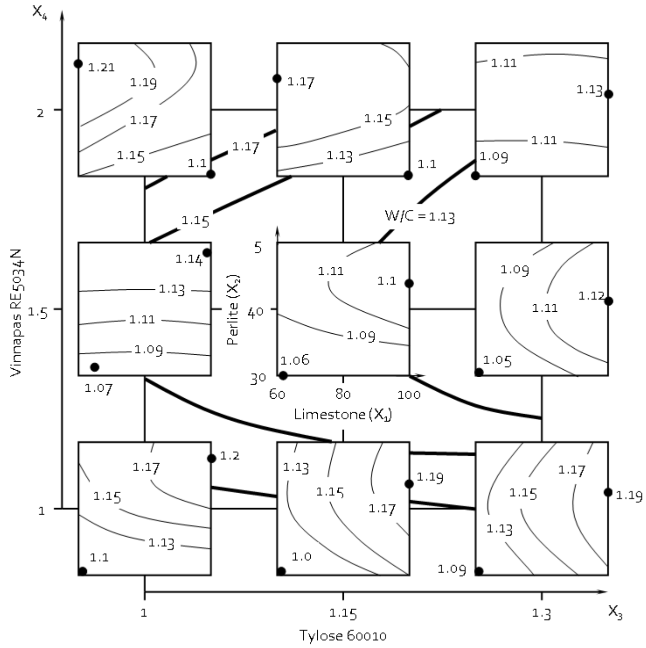

Figure 1 The diagram of change in the water requirement of the W/C plaster compositions of the same workability under the influence of composition factors

$$W_{out} = 99.8 \pm 0x_1 + 0.06x_1^2 + 0.03x_1x_2 + 0.04x_1x_3 + 0.03x_1x_4 \pm 0x_2 \pm 0x_2^2 + 0.02x_2x_3 + 0.01x_2x_4 \pm 0x_3 - 0.04x_3^2 - 0.08x_3x_4 \pm 0x_4 + 0.3x_4^2 \quad (1)$$

The water-retaining capacity of all 18 compositions proved to be higher than the regulatory requirements and it is within W_{out} = 99.65÷99.9 %, which is achieved by adding high-molecular compounds into the mixture. However, as expected, the greatest positive effect on the mixture is provided by the water-retaining additive Tylose, with growth of which the water-retention is increased.

3.3 Hardened mortar property

3.3.1 Adhesion

One of the most important quality indicators for all types of plaster mixture, including lightweight ones, is adhesion to the base [7]. The adhesion was measured on DYNA Z16 instrument, and based on the results of its determination, the following experimental statistical model (ES) was constructed for 18 experimental compositions (S_e = 0.0307):

$$R_A \text{ (MPa)} = 0.304 \pm 0x_1 - 0.06x_1^2 - 0.04x_1x_2 - 0.02x_1x_3 - 0.02x_1x_4 + 0.04x_2 \pm 0x_2^2 + 0.04x_2x_3 + 0.07x_2x_4 \pm 0x_3 - 0.04x_3^2 \pm 0x_3x_4 + 0.05x_4 \pm 0x_4^2 \quad (2)$$

According to the model (2), the diagram shown in Fig. 2 was constructed in the form "Squares on a square", reflecting the influence of variable factors on the adhesion of light-weight plaster composition. In this case, in the field of each small square, as in Fig. 1, the effect of the amount of ground limestone and perlite is shown, and depending on the coordinate of the small square on the carrier square, the amount of methylhydroxyethyl cellulose and Vinnapas changes.

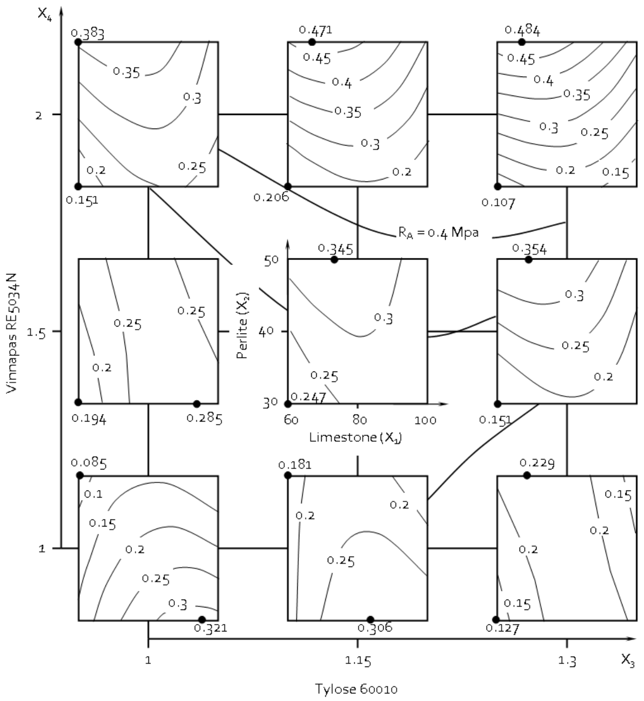

Figure 2 Influence of the composition factors of the on the adhesion of the light-weight plaster mixture

Analysis of the diagram allows saying that the adhesion of the plaster mixture to the base significantly increases with the increase of the amount of redispersible powder Vinnapas, which is a quite expected effect. At the maximum dosage of Vinnapas, an adhesion level above 0.4 MPa is achieved, which can be considered desirable for the durable work of the solution in real conditions. The change in the amount of methylhydroxyethyl cellulose affects the adhesion less significantly. This increase of the amount of this component increases the level of adhesion for the compositions with the maximum dosage of Vinnapas and slightly reduces for formulations with a small amount of redispersible powder.

It is important to note that almost for all of the examined compositions, with the exception of the zone with $x_3 = x_4 = -1$, the adhesion was increased with increasing of perlite amount and reached a maximum at a dosage of limestone close to 70 w.p.

4 CONCLUSION

From the presented materials it can be noted that water requirement of mortar was maximally reduced and slightly increases with increasing of porous components; water requirement can also be reduced by rational dosage of redispersible additive Vinnapas.

Water retention ability of compositions is increased to almost 100 % (due methylhydroxyethyl cellulose and redispersible powder with optimal amount content of fillers), which reduces the risk of shrinkage and peeling of plaster layer during the migration of water in the porous base from the lower layers and evaporation from the upper layers at higher temperatures.

Adhesion of plaster to the base is significantly increased by increasing the ratio of redispersible powder Vinnapas, which purposefully affects this property. At the maximum dosage of Vinnapas the level of adhesion is achieved above 0.4 MPa, which can be considered a satisfactory mark for such building materials.

Note: This investigation was presented at the International Conference MATRIB 2017 (29. 6. - 2. 7. 2017, Vela Luka, Croatia).

5 REFERENCES

[1] Lyashenko, T.: Fields of properties of building materials (concept, analysis, optimization), Abstract of the thesis for degree Doctor of technical sciences, 2003.

[2] Lyashekno, T.: The concept of the fields of properties is the methodological basis for extracting information from ES models in computer material science, Bulletin OSACEA, 12 Edition (2003) 171–179.

[3] Kazarnovskyy, Z.; Omelchenko, L.; Saville, G.; Warming of enclosing structures, sanitation and waterproofing with the use of dry mixes, Building materials, No. 3 (1999) 24–25.

[4] Voznesenskiy, V.: Modern methods of optimization of composite materials, Budivelnik, Kiev, 1989.

[5] Voznesenskiy, V.: Models with a generated experimental error for special quality criteria of composites, A collection of scientific articles, Odesa: Building materials, structures and engineering systems (1996) 144–155.

[6] Lyashekno, T.: The Generalizing properties of fields for the development of effective composites, A collection of scientific articles, Odesa: Building materials, structures and engineering systems (1996) 172–186.

[7] Popov, O.; Moskalova, K.: Technology influence of the mineral and polymer additives on adhesion of plaster solutions, Tehnički glasnik, Vol. 1, No. 9, (2015) 33−34.

Authors' contacts:

Khrystyna MOSKALOVA, PhD, Assistant Professor
Odessa State Academy of Civil Engineering and Architecture
4 Didrihsona St., Odessa, Ukraine
krisogasa@gmail.com

Marin MILKOVIĆ, Ph.D, Professor
Goran KOZINA, Ph.D, Associate Professor
University North
104. brigade 3, Varaždin, Croatia
rektor@unin.hr
goran.kozina@unin.hr