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Lime Based Dry Mixes with Carbonate Aggregates

Y.V. Pukharenko, T.V. Kharitonova

***Abstract*: The use of carbonate rocks as aggregates for cement concretes and mortars is limited due to their insufficient strength and the threat of corrosion. The use of quarry dust from crushing carbonate rocks are technically and economically feasible in building compositions based on air-hardening lime. The results of the study of the effect of replacing a part of quartz sand in lime mortar by limestone and dolomite fine aggregates on the basic physical and mechanical properties of lime mortars for restoration are presented in the paper. The matrix of planning experiments, which allows increasing the informativity of the research results in order to reduce the number of experiments in the search for optimal values, is proposed. The efficiency of replacement of the quartz sand with quarry dust of carbonate rocks in the production of dry mixes for restoration is shown.**

Key words: air lime, limestone, dolomite, dry mixtures for restoration.

I. INTRODUCTION

The main binder in the composition of restoration mortars is air lime. This is due to the observance of the principle of historicism in relation to these materials as well as the design features of architectural monuments – cultural heritage [1-3]. High deformability and vapor permeability of lime-based mortars as well as their good adhesion to the ceramic brick determine the operational reliability of plaster and masonry mortars in the construction and finishing of massive structures of artificial and natural stone [4,5].

The modern practice of restoration is characterized by the active development of the direction of dry mixtures produced in accordance with the requirements for restoration materials – the authenticity of the material composition as well as physical and mechanical properties [6]. It should be noted that the economic component (minimizing the cost of production) and the high relevance of increasing the durability of materials is important to consider in addition to the need to ensure the principles of restoration in the production of dry mixtures [2, 7-10].

The main task in the design of dry mixes for restoration is the selection of components that meet the following requirements: low cost, year-round availability, technical and historical validity of their use in the composition of restoration renders [11-13]. Based on the above-mentioned the use of quarry dust from crushing carbonate rocks namely limestone and dolomite as fine aggregate in lime renders for restoration is appropriate. The developed deposits of limestones and dolomites are widespread in the territory of the Russian Federation and, in particular, in the Northwest region [14,15]. Dolomite and limestone quarry dust can be attributed to the affordable and inexpensive potential raw materials. Drying and classification is required for dry mix technology. But these operations are also necessary for the traditional fine aggregate for renders – quartz sand [15-17].

The use of carbonate rocks in the composition of the aggregate of mortars was noted by a number of researchers in terms of compliance with the principle of historicism with respect to the material composition [18-21]. The validity of the widespread use of carbonate aggregates in the composition of lime dry mixtures consists in the affinity of the matrix and filler grains as well as lower density of carbonate rocks in comparison with quartz sand [22]. Historical masonry and plaster mixes, as a rule, are characterized by the strength class from M25 to M75. Accordingly the use of limestone is not limited to its lower strength in comparison with quartz sand [23-27]. Thus, the use of quarry dust of carbonate rocks as a fine aggregate in restoration dry mixtures seems reasonable from the historical, technical and economic side. The aim of this study is to assess the effect of limestone and dolomite introduced instead of the quartz sand on the properties of the lime dry mixture.

II. MATERIALS AND METHODS OF RESEARCH

Hydrated lime from Rosizvest Company (Rossosh city), limestone of fractions 0-2,5, quartz-feldspar sand, dolomite flour with grain size of 0.01-0.1mm were used in experiments.

Quantitative assessment of the effect of replacing quartz sand with carbonate fine aggregates was carried out on the basis of three-level two-factor experiment. Limestone consumption in per cent of the aggregate mass (X1) and dolomite consumption in per cent of the aggregate mass (X2) were considered as the studied factors. Limestone consumption has varied from 0 to 80% with the variation step of 40%. Dolomite consumption has varied from 0 to 20% with the step of variation of 10%.

III. FULL-FACTOR EXPERIMENT PLANNING MATRIX

The developed matrix of planning full-factorial experiment, which allows to obtain the regression equation as well as to differentially assess the impact of individual factors at each level of variation, is a feature of this study.

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***Correspondence Author(s)**
Y.V. Pukharenko, Dr. Sci. Tech., Professor, Saint Petersburg State University of Architecture and Civil Engineering, Saint-Petersburg, Russia
T. V. Kharitonova, PhD-student, Saint Petersburg State University of Architecture and Civil Engineering, Saint-Petersburg, Russia.

The large informativity of the results obtained with minimum number of experiments is achieved according to Table 1.

The limit of compressive strength (R_{comp}, MPa), adhesion to brick (Ad, MPa) and water vapor permeability (PR, mg/m·h·Pa) were determined as functions of the response. The change of the workability of mixtures by cone immersion was estimated depending on the ratio between the fine aggregates since all mixtures were carried out at the constant water-to-solid ratio equal to W/S=19%. The amount of hydrated lime was 15% by weight of the dry mixture.

Table 1 Planning matrix of two-factor three-level experiment

No.	X_1	X_2	№	X_1	X_2	№	X_1	X_2
Chart at X_2 at the lower level			Chart at X_2 at the middle level			Chart at X_2 at the top level		
1	-1	-1	7(5)	-1	0	13(6)	-1	1
2	0	-1	8	0	0	14(12)	0	1
3	1	-1	9	1	0	15	1	1
Chart at X_1 at the lower level			Chart at X_1 at the middle level			Chart at X_1 at the top level		
4(1)	-1	-1	10(2)	0	-1	16(3)	1	-1
5	-1	0	11(8)	0	0	17(9)	1	0
6	-1	1	12	0	1	18(15)	1	1

Note: repeated experiments are shown in parentheses to improve the accuracy of the variance determination. Number of parallel experiments are 6.

IV. RESULTS AND DISCUSSION

The use of carbonate aggregates causes the proportional decrease of the workability of the compositions. Complete replacement of quartz sand with the fine aggregate of limestone (80%) and dolomite (20%) is accompanied by the decrease of the amount of cone immersion from 8.5 mm to 15 mm. Replacement of sand by 20% of dolomite leads to the decrease of the workability up to 2.5cm. Mixture with the content of 60% of quartz sand and 40% of limestone is characterized by the decrease of the workability of 1.8 cm as shown in Figure 1. Thus, the use of dolomite fine aggregate is associated with more intense decrease of fresh mortar workability.

The increase of lime mortar strength is observed in case of quartz sand amount decreases. Thus, the strength increases in two times with the introduction of 10% of dolomite and 80% of limestone instead of quartz sand. The same result can be achieved with the introduction of 20% of dolomite and 40% of limestone instead of quartz sand as shown in Figure 2.

Determination of adhesion to the brick surface was made using full-bodied ceramic brick with strength class of 125 and water absorption of 10% by weight. The brick surface was previously polished and the brick was kept in water until full saturation before applying the fresh mortar.

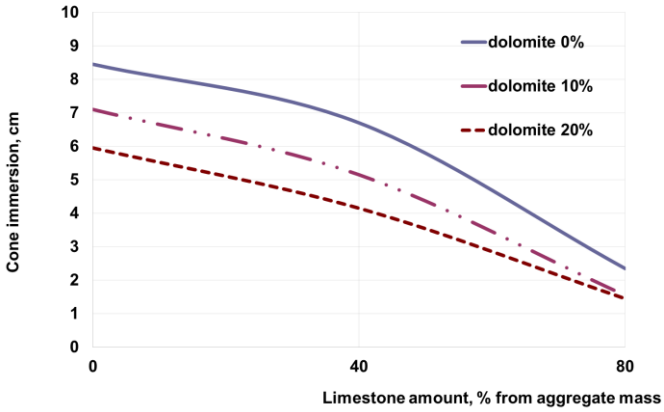

Figure 1. Influence of limestone and dolomite ratio on fresh mortar workability

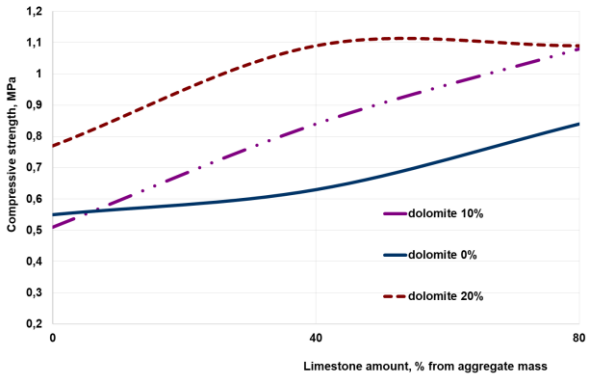

Figure 2. Influence of limestone and dolomite ratio on the compressive strength

Increasing the proportion of carbonate rocks in the aggregate mix has positive effect on the adhesion strength to the brick surface as shown in Figure 3. The greatest increase of adhesion takes place at the maximum content of limestone of 80%. The share of dolomite effects the increase of adhesion as well.

It should be noted that the nature of the separation of the mortar from the brick at the values of the adhesion strength up to 0.06 MPa is adhesive and at larger values of the adhesion strength is cohesive.

Unambiguous dependences could not be identified in relation to the vapor permeability of the studied mortars. It can be argued that the influence of the type of filler on the vapour permeability is not traced and the observed changes in numerical values are associated with the error of the method of determination as one can see in Figure 4. This conclusion is confirmed by high dispersion of values in each series of experiments.

The regression equation for the compressive strength of the compositions studied can be considered to demonstrate the advantages of the proposed experimental planning matrix and to find the best decisions.

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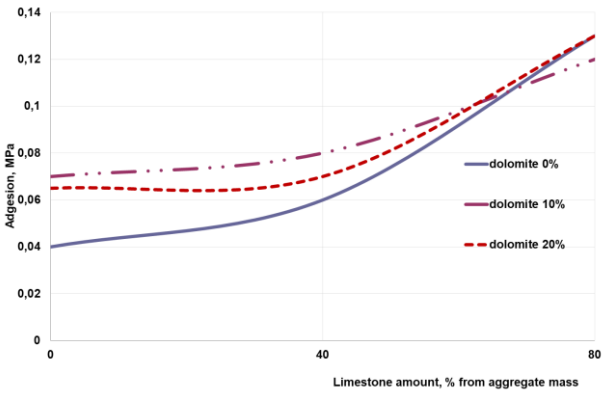

Figure 3. Influence of limestone and dolomite ratio on adhesion strength to the brick surface

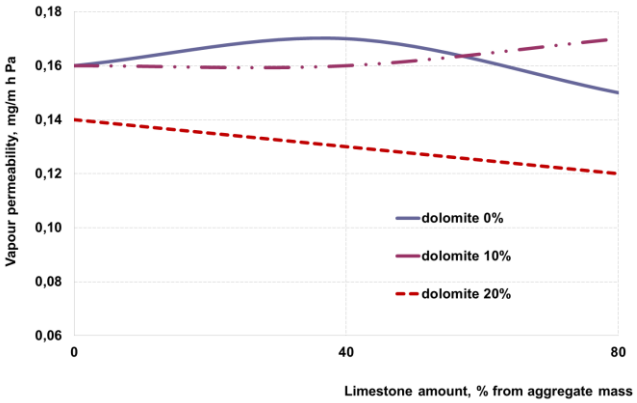

Figure 4. Influence of limestone and dolomite ratio on the vapour permeability of the studied mortars

The regression equation of a full-factorial experiment of type 3^2 for estimation of the ultimate strength taking into account the significance of the coefficients is as follows:

$$R_{comp}=0.82+0.2\cdot X_1+0.16\cdot X_2 \quad (1)$$

The analysis of the obtained regression equation shows that the strength of the samples increases with increasing amount of both limestone and dolomite. The influence of factors on the strength, estimating by the coefficients, is almost the same. Maximum strength is achieved when the values of the factors corresponding to the upper level. Similar conclusions were obtained earlier in the analysis of strength dependence graphs at the fixed value of one factor and the variation of the other according to Figure 2. Such graphical analysis can be used in the search for rational compositions reducing the cost of experiments through the step study. In case of early detection of the lack of the required result, the search in the intended direction can be stopped without conducting the experiment in full.

In addition, one can note another feature of the use of graphical analysis of the results of the experiment. Smoothing of the results (the model does not exactly repeat the experiment) occurs at building a mathematical model in the form of a regression equation. It is almost impossible to reproduce the family of dependencies obtained experimentally. In particular, the maximum value of strength is obtained at the values of the factors when one of them is at the upper level and the second at the main (zero) level in our case of consideration.

V. CONCLUSION

The efficiency of replacement of quartz sand with quarry dust of carbonate rocks in the production of dry mixes for restoration was shown. The results of replacing a part of quartz sand in lime mortar by limestone and dolomite fine aggregates on physical and mechanical properties of lime mortars were obtained in the paper. The matrix of planning experiments, which allows increasing the informativity of the research results in order to reduce the number of experiments in the search for optimal values, was proposed. Thus, the use of limestone and dolomite as fine aggregate for lime mortars (dry mixtures) can increase the compressive strength in two times, the strength of adhesion to ceramic bricks in three times. In this case, the vapour permeability remains unchanged and it is characterized by high values (about 0.15 mg/m·h·Pa).

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AUTHORS PROFILE

Y.V. Pukharenko, Dr. Sci. Tech., Professor, Head of Department Building Materials and Technology, Saint Petersburg State University of Architecture and Civil Engineering, Saint-Petersburg, Russia. Author and co-author of more than 282 published scientific and educational papers including 4 collective monographs, 240 scientific papers, 19 educational works, 26 inventions.
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T.V. Kharitonova, PhD-student, Saint Petersburg State University of Architecture and Civil Engineering, Saint-Petersburg, Russia. Research interests: technology of dry mixes, restoration materials