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**TEXNIKA FANLARI DOKTORI, PROFESSOR  
MIRAXMEDOV MAXAMADJON MIRAXMEDOVICH  
TAVALLUDINING 80 YILLIGIGA BAG'ISHLANGAN  
“SAMARALI QURILISH MATERIALLARI, KONSTRUKSIYALARI VA  
TEKNOLOGIYALARI”  
MAVZUSIDAGI XALQARO ILMIY-AMALIY KONFERENSIYASI  
ILMIY ISHLARI TO'PLAMI**

Toshkent davlat transport universiteti RAASN akademigi, O'zbekistonda xizmat ko'rsatgan yoshlar murabbiyi, texnika fanlari doktori, professor Miraxmedov Maxamadjon Miraxmedovich tavalludining 80 yilligiga bag'ishlangan, ilmiy ishlar to'plami nashr etilishi ko'zda tutilgan «Samarali qurilish materiallari, konstruksiyalari va texnologiyalari» mavzusidagi Xalqaro ilmiy-amaliy konferensiyani o'tkazishni rejalashtirmoqda.

M.M. Miraxmedov kompozitsion qurilish materiallarining polistruktura nazariyasini rivojlantirishga salmoqli hissa qo'shgan. Uning qurilish materialshunosligi sohasidagi ilmiy hissi e'tirofi sifatida 1995-yilda Rossiya arxitektura va qurilish fanlari akademiyasining (RAASN) xorijiy a'zosi etib saylangan. M.M. Miraxmedov 6 ta monografiya, 200 dan ortiq ilmiy maqolalar va 25 ta ixtiroga mualliflik guvohnomalari muallifidir.

Ushbu konferensiyaning asosiy maqsadi - qurilish materialshunosligi, bino va inshootlarni loyihalash va qurilish sohasidagi ilmiy tadqiqotlar natijalarini, shuningdek, muhandislik ta'limini takomillashtirish yo'llarini muhokama qilishdan iborat.

Konferensiya ishida ishtirok etish uchun oliy o'quv yurtlari va ilmiy tadqiqot institutlari olimlari, O'zbekiston Respublikasi va xorijiy davlatlarning ishlab chiqarish vakillari, ilmiy tadqiqotlarda salmoqli natijalarga ega bo'lgan mutaxassislar taklif etiladi.

**“Samarali qurilish materiallari, konstruksiyalari va texnologiyalari”** mavzusidagi xalqaro ilmiy-amaliy konferensiyaning asosiy yo'nalishlari quyidagilardan iborat:

1. Resurs va energiya tejovchi qurilish materiallari va texnologiyalari.
2. Atrof-muhitning transport infratuzilmasiga ta'siri va uni himoya qilish usullari.
3. Bino va inshootlarning qurilish konstruksiyalari: hisoblash va loyihalashning zamonaviy usullari.
4. Arxitektura, shaharsozlik va shahar muhitini rivojlantirish.
5. Qurilishni tashkil etishning innovatsion usullari va qurilish jarayonlari texnologiyalari.
6. Transport obyektlarini loyihalash va qurishda raqamli texnologiyalar hamda sun'iy intellekt.
7. Temir yo'l transporti infratuzilmasi obyektlarini loyihalash, qurish va ekspluatatsiya qilish.
8. Zamonaviy muhandislik ta'limi tizimini takomillashtirish.

Mazkur konferensiya ilmiy hamjamiyatning turli vakillarini bir joyga jamlab, qurilish materialshunosligi sohasidagi zamonaviy muammolar va istiqbollarni muhokama qilish uchun qulay platforma vazifasini bajardi.

# Design-Based Assessment of Hybrid Thermal-Insulating Dry Plaster Mortars for Aerated Concrete Walls in Aral Sea Region Conditions

A. Ismaylova<sup>1</sup><sup>a</sup>

<sup>1</sup>Urgench State University, Khorezm, Uzbekistan

Abstract

The paper presents a design-based assessment of thermal-insulating dry plaster mortars intended for aerated concrete and other porous wall materials under the dry, windy and salt-aerosol affected conditions of the Aral Sea region. The study focuses on the simultaneous compatibility of the plaster layer with the porous substrate in terms of thermal resistance, vapour permeability, capillary water absorption, adhesion and crack resistance. Five mortar variants were compared: a reference cement-sand plaster, perlite-based and vermiculite-based lightweight plasters, a hollow-microsphere modified plaster and a hybrid perlite-vermiculite-microsphere composition. A multi-criteria approach was used to evaluate the balance between low thermal conductivity, sufficient compressive strength, low water absorption and vapour-open behaviour. The calculated screening indicators show that the hybrid composition can reduce thermal conductivity to 0.116 W/(m·K), decrease capillary water absorption to 0.26 kg/(m<sup>2</sup>·h<sup>0.5</sup>), and maintain adequate adhesion to aerated concrete. The results confirm that the best solution is not the composition with the lowest density alone, but the one that combines closed and open pore systems with a compatible lime-cement matrix and hydrophobic modification. A minimal laboratory testing program is proposed for further verification before pilot application.

Keywords:

Aerated concrete, dry plaster mortar, thermal insulation, perlite, vermiculite, hollow microspheres, vapour permeability, capillary water absorption, Aral Sea region, salt aerosol, multi-criteria assessment

## 1. INTRODUCTION

Aerated concrete is widely used in energy-efficient wall systems because its cellular structure reduces density and improves the thermal performance of building envelopes. However, the same porous structure also makes the material sensitive to capillary suction, vapour accumulation and surface damage when the finishing layer is selected incorrectly. In dry continental regions, especially in territories affected by dust and salt aerosols, the external plaster must not only protect the wall from rain and mechanical action but also maintain a safe moisture balance inside the wall section.

Traditional cement-sand plasters are relatively dense and strong, but their thermal conductivity is high and their deformation compatibility with aerated concrete is limited. A hard and low-vapour layer can increase the risk of interfacial cracking, efflorescence and local detachment. For this reason, dry thermal-insulating plaster mortars containing lightweight fillers, polymer modifiers, hydrophobizing agents and microfibrils are becoming an important direction for façade systems based on aerated concrete blocks.

The purpose of this paper is to develop and compare several thermal-insulating dry plaster mortar compositions for porous wall substrates. The comparison is based on a multi-criteria framework in which thermal insulation, moisture transport and

mechanical compatibility are assessed together rather than separately.

## 2. MATERIALS AND METHODS

The designed mortar system contains Portland cement, hydrated lime, fine mineral filler, lightweight porous fillers, polymer powder, cellulose ether, hydrophobizer and dispersed microfibrils. Expanded perlite and vermiculite were selected as open-pore lightweight fillers, while hollow mineral microspheres were used as a closed-pore component. The lime-cement binder was chosen to improve vapour openness and reduce stiffness compared with a purely cement matrix.

Five compositions were analysed. M0 is a reference cement-sand plaster. M1 and M2 contain perlite and vermiculite respectively. M3 contains hollow mineral microspheres, and M4 is a hybrid composition combining perlite, vermiculite and microspheres. The numerical values in the tables are design-screening indicators intended for formulation selection and laboratory planning.

The basic thermal and moisture criteria were expressed using the following relationships:

$$R = d / \lambda \quad (1)$$

$$R_0 = R_{si} + \sum(d_i / \lambda_i) + R_{se} \quad (2)$$

$$sd = \mu \cdot d \quad (3)$$

$$W = (m_t - m_0) / (A \cdot \sqrt{t}) \quad (4)$$

$$S = \sum w_i \cdot x_i \quad (5)$$

<sup>a</sup> <https://orcid.org/0009-0000-4596-0759>



Here  $R$  is the thermal resistance of a layer,  $d$  is the layer thickness,  $\lambda$  is the thermal conductivity coefficient,  $R_0$  is the total thermal resistance of the wall section,  $s_d$  is the equivalent air layer thickness,  $\mu$  is the vapour diffusion resistance factor,  $W$  is the capillary water absorption coefficient,  $A$  is the wetted surface area, and  $S$  is the integral multi-criteria score obtained from normalized indicators  $x_i$  and weights  $w_i$ .

#### Composition design

The composition design was aimed at reducing density and thermal conductivity while keeping the plaster mechanically compatible with an aerated concrete substrate. The amount of cellulose ether and polymer powder was kept moderate because excessive polymer content may reduce vapour permeability. The hydrophobizer was increased in lightweight compositions to compensate for the open-pore structure of perlite and vermiculite.

**Table 1**  
Designed compositions of dry thermal-insulating plaster mortars

Component	M0	M1	M2	M3	M4
Portland cement, wt. %	28.00	25.00	24.50	23.00	22.00
Hydrated lime, wt. %	8.00	9.00	9.00	10.00	9.00
Fine quartz/limestone filler, wt. %	62.35	46.40	46.00	44.60	38.60
Expanded perlite, wt. %	0.00	17.00	0.00	6.00	10.00
Expanded vermiculite, wt. %	0.00	0.00	18.00	6.00	8.00
Hollow mineral microspheres, wt. %	0.00	0.00	0.00	7.60	9.40
Redispersible polymer	1.00	1.60	1.50	1.60	1.70

Cellulose ether, wt. %	0.25	0.30	0.30	0.35	0.35
Organosilicon hydrophobizer, wt. %	0.20	0.35	0.35	0.45	0.50
Polypropylene/basalt microfibrils, wt. %	0.15	0.25	0.25	0.30	0.35
Air-entraining stabilizer, wt. %	0.05	0.10	0.10	0.10	0.10
Recommended water/dry mix ratio	0.23	0.29	0.31	0.27	0.28
Polymer powder, wt. %					

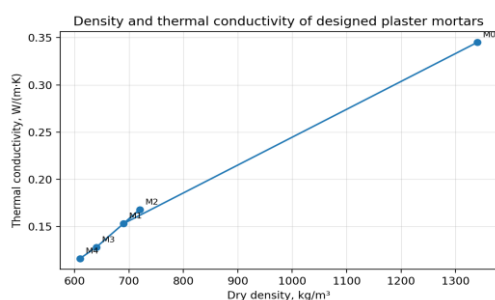
Note. The water/dry mix ratio is given for mortar preparation and is not included in the 100 wt. % dry composition balance.

**Table 2**  
Design-screening performance indicators for the compared compositions

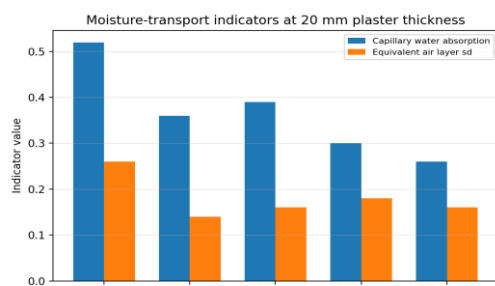
Mix	M0	M1	M2	M3	M4
Density, kg/m <sup>3</sup>	1340	690	720	640	610
$\lambda$ , W/(m·K)	0.345	0.153	0.168	0.128	0.116
$\mu$	13	7	8	9	8
$s_d$ at 20 mm, m	0.26	0.14	0.16	0.18	0.16
$W$ , kg/(m <sup>2</sup> ·h <sup>0.5</sup> )	0.52	0.36	0.39	0.30	0.26
Compressive strength	8.2	2.8	3.2	3.8	3.5



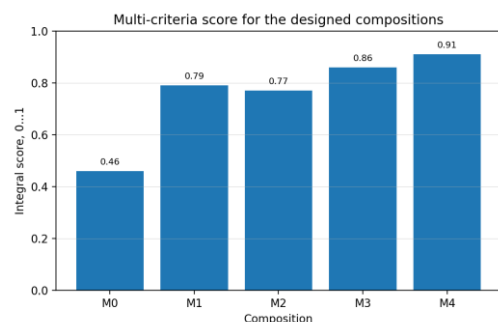
<b>h, MPa</b>					
<b>Adhesion, MPa</b>	0.42	0.31	0.34	0.37	0.39
<b>Shrinkage, mm/m</b>	1.25	0.91	0.86	0.74	0.69
<b>Score</b>	0.46	0.79	0.77	0.86	0.91



**Fig. 1. Relationship between dry density and thermal conductivity of the designed mortars**



**Fig. 2. Moisture-transport indicators used to check vapour-open and water-resistant behaviour**



**Fig. 3. Integral multi-criteria score of the designed compositions**

### 3. RESULTS AND DISCUSSION

The reference composition M0 has the highest density and thermal conductivity. Although it provides high compressive strength, the strong and dense cement-sand matrix is less favourable for aerated concrete because it can restrict vapour

movement and increase stress at the interface. This is confirmed by the highest capillary water absorption coefficient and the lowest integral score.

The perlite and vermiculite compositions reduce density by nearly one half compared with M0. Perlite gives a lower thermal conductivity than vermiculite in the proposed design, while vermiculite slightly improves compressive strength. However, both materials contain open pores; therefore, the hydrophobizer and polymer-cellulose system are important to prevent uncontrolled capillary suction.

The microsphere-modified composition M3 demonstrates a better balance between low thermal conductivity and mechanical resistance. Hollow particles create a closed-pore contribution to thermal insulation, while the fine mineral matrix keeps sufficient adhesion to the substrate. The hybrid composition M4 achieved the highest score because it combines the thermal efficiency of lightweight fillers with lower water absorption and acceptable vapour openness.

For façade use in the Aral Sea region, the most important result is the balance between water resistance and vapour permeability. A hydrophobic but vapour-open plaster reduces rain and aerosol solution ingress, while allowing moisture accumulated in the wall to dry outward. Such compatibility is especially important for aerated concrete because its thermal conductivity and durability are strongly affected by moisture content.

#### Recommended laboratory verification

Before industrial implementation, the proposed compositions should be verified using a minimal but complete testing program. The program must include thermal, hygric, mechanical and durability tests, because a single indicator such as thermal conductivity cannot fully describe façade performance.

**Table 3**

#### Recommended minimal testing program for plaster compatibility with aerated concrete

Indicator	Purpose	Method / reference direction	Recommended target
Thermal conductivity	Evaluate insulation efficiency	Steady-state heat flow test; comparison with EN 998-1 T classes	$\leq 0.20$ W/(m·K), preferably $\leq 0.12$ W/(m·K)
Compressive strength	Check mechanical stability	Prism compression test after 28 days	CS I-CS II range; avoid excessive stiffness
Adhesion to aerated concrete	Prevent delamination	Pull-off test on prepared aerated concrete blocks	$\geq 0.25$ MPa with cohesive or mixed failure



Vapour permeability	Control drying capacity	Vapour diffusion resistance and $s_d$ calculation	$s_d \leq 0.20$ m at 20 mm layer thickness
Capillary water absorption	Limit rain and salt solution intake	Capillary uptake test on dried specimens	$\leq 0.40$ kg/(m <sup>2</sup> ·h <sup>0.5</sup> )
Drying shrinkage	Estimate crack risk	Length-change measurement on prisms	$\leq 1.0$ mm/m for façade plaster
Salt aerosol / wet-dry cycles	Assess Aral Sea durability risk	Cyclic wetting with salt solution and drying	No visible scaling; mass loss $\leq 5\%$
Freeze-thaw resistance	Check seasonal durability	Cyclic freezing and thawing after water conditioning	Strength loss $\leq 15\%$ and no delamination

#### 4. CONCLUSION

A design-based comparative assessment of dry thermal-insulating plaster mortars for aerated concrete walls was prepared. The results show that the optimal façade plaster for porous wall materials should be selected using a multi-criteria approach that combines thermal conductivity, vapour permeability, capillary water absorption, adhesion and shrinkage.

Among the compared compositions, the hybrid system M4 showed the best balance of properties. Its calculated thermal conductivity was 0.116 W/(m·K), capillary water absorption was 0.26 kg/(m<sup>2</sup>·h<sup>0.5</sup>), and the integral score reached 0.91. The hybrid approach is promising because perlite and vermiculite reduce density, microspheres add closed-pore insulation, and the lime-cement-polymer matrix maintains compatibility with aerated concrete.

The proposed compositions can be used as a basis for laboratory trials and pilot production of lightweight plaster mortars for dry and salt-aerosol affected regions. Further work should focus on real specimen testing, cyclic durability assessment and optimization of the hydrophobizer dosage under local climatic conditions.

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#### INFORMATION ABOUT THE AUTHORS

**Ismaylova Aysuliu** Basic doctorant, Urganch state university  
E-mail: [ismaylovaaysuliu676@gmail.com](mailto:ismaylovaaysuliu676@gmail.com)  
Tel.: +998942946564  
<https://orcid.org/0009-0000-4596-0759>



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