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TEXNIKA FANLARI DOKTORI, PROFESSOR MIRAXMEDOV MAXAMADJON MIRAXMEDOVICH TAVALLUDINING 80 YILLIGIGA BAG'ISHLANGAN "SAMARALI QURILISH MATERIALLARI, KONSTRUKSIYALARI VA TEXNOLOGIYALARI" 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 hissasi 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.

Optimization of Foam Concrete with Fly Ash and Silica Fume for Energy-Efficient Wall Blocks

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Abstract: The article presents a design-screening approach for non-autoclaved foam concrete intended for thermal-insulating and structural-thermal-insulating wall blocks. The proposed mixtures combine Portland cement, fine quartz sand, fly ash, silica fume, a polycarboxylate superplasticizer and preformed foam. The main objective is to obtain a rational balance between dry density, compressive strength, thermal conductivity and water absorption without excessive cement consumption. A five-level density series from D500 to D900 was analyzed. The results show that mixtures in the D650-D750 range provide the most balanced performance: thermal conductivity remains below 0.16 W/(m·K), while the predicted 28-day compressive strength exceeds 3.0 MPa. The paper also proposes an integral score method that can be used for selecting foam concrete compositions for wall products in dry and hot climatic regions.

Keywords: Foam concrete, preformed foam, fly ash, silica fume, thermal conductivity, dry density, lightweight wall blocks, water absorption, energy efficiency

1. INTRODUCTION

Foam concrete is a lightweight cementitious material containing a system of uniformly distributed artificial air pores. Compared with ordinary dense concrete, it has lower dry density, reduced thermal conductivity and improved technological flexibility. These characteristics make it suitable for non-load-bearing wall blocks, monolithic insulation layers, roof screeds and fill materials [1]–[3].

The main difficulty in producing reliable foam concrete is the simultaneous control of pore structure and cement matrix quality. Excessive foam content reduces density and thermal conductivity, but it can also decrease strength and increase shrinkage. On the other hand, increasing cement content improves strength but worsens economic and thermal indicators. Therefore, the development of foam concrete should be based on a multi-criteria balance rather than on a single target parameter.

The use of supplementary cementitious materials is one of the most effective ways to improve this balance. Fly ash contributes to particle packing and later-age pozzolanic hardening, while silica fume fills microvoids and promotes the formation of additional C-S-H phases. In combination with a superplasticizer, these components can reduce water demand and stabilize the cement paste around air pores.

The aim of this article is to develop and evaluate a series of foam concrete mixtures for wall blocks and to determine a rational density interval in which strength, thermal insulation and moisture resistance are simultaneously acceptable.

2. MATERIALS AND RESEARCH METHODS

The proposed material system includes Portland cement as the main binder, low-calcium fly ash as a mineral filler, silica fume as a highly reactive microfiller, fine quartz sand as a skeletal component, a polycarboxylate superplasticizer and preformed foam prepared from a protein-based foaming agent. Water dosage was selected to maintain paste flowability while minimizing the water-to-binder ratio.

Foam concrete mixtures were designed for five target density grades. The preformed foam was introduced at the final mixing stage in order to reduce mechanical destruction of air cells. The quality of foam was evaluated by foam density, half-life and visual stability. Hardened specimens were assessed by dry density, 28-day compressive strength, water absorption and thermal conductivity.

For comparative selection of the best composition, an integral score was calculated using normalized values of strength, thermal conductivity and water absorption. Higher strength increases the score, whereas higher thermal conductivity and water absorption decrease it. The simplified relation used for screening is expressed as:

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$$S = 0.40 \cdot Rs + 0.35 \cdot (1 - \lambda n) + 0.25 \cdot (1 - Wn) \quad (1)$$

where S is the integral score, Rs is normalized compressive strength, λn is normalized thermal conductivity and Wn is normalized water absorption.

Table 1

Proposed mix proportions for foam concrete wall blocks

Mix	Cement	FA/SF	Sand	W/B	Target D
FC-500	270	90/20	120	0.43	D500
FC-600	285	95/25	155	0.41	D600
FC-700	300	100/30	190	0.39	D700
FC-800	320	100/35	225	0.37	D800
FC-900	345	90/40	260	0.35	D900

Note: cement, fly ash (FA), silica fume (SF) and sand are given in kg/m³; W/B is water-to-binder ratio.

3. RESULTS AND DISCUSSION

The obtained screening results confirm the typical relationship between density and performance of foam concrete. A decrease in density improves thermal insulation but reduces mechanical strength. This trend is caused by the increase in total air volume and the reduction in the solid load-bearing frame of the cement-sand matrix.

The D500 mixture has the lowest thermal conductivity, but its strength is sufficient mainly for insulation products and non-load-bearing fills. Mixtures D600 and D700 demonstrate a more balanced structure because the amount of cementitious matrix is sufficient to form stable interpore partitions, while the pore volume remains high enough to provide thermal efficiency.

Table 2

Screening properties of foam concrete mixtures.

Mix	Density kg/m³	R28 MPa	λ W/(m·K)	Water %	Score
FC-500	515	1.34	0.112	38.5	63
FC-600	605	2.10	0.132	35.1	75
FC-700	695	3.08	0.153	31.7	86
FC-800	805	4.42	0.181	28.9	82
FC-900	910	5.76	0.212	25.3	69

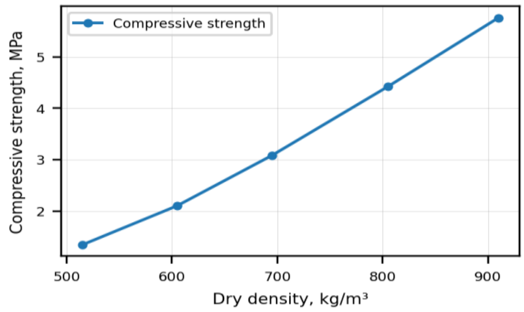

Fig. 1. Relationship between dry density and compressive strength

Figure 1 shows that compressive strength increases almost linearly in the considered density range. This confirms that the load-bearing capacity of foam concrete is mainly controlled by the thickness and continuity of interpore partitions. However, an increase in density above D800 reduces the thermal advantage of the material.

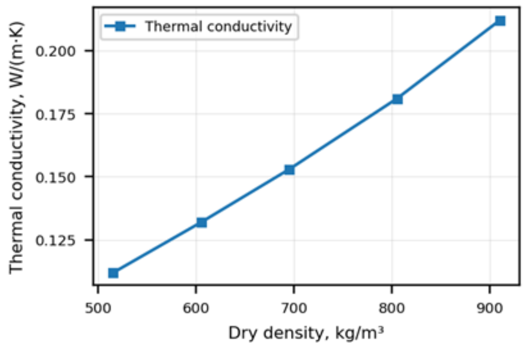

Fig. 2. Relationship between dry density and thermal conductivity

Thermal conductivity also increases with density, because the fraction of solid mineral phases becomes larger and the amount of air-filled pores decreases. For wall products intended to reduce heat losses, the D600-D700 interval is the most promising compromise between insulation and strength.

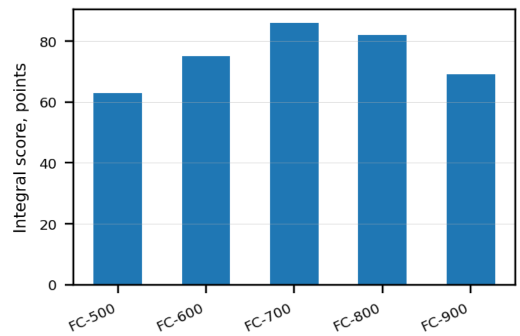

Fig. 3. Integral score of the designed mixtures

The integral score indicates that FC-700 is the most balanced composition. Although FC-800 has higher compressive strength, its thermal conductivity is noticeably higher. FC-500 and FC-600 are useful for insulation layers, whereas FC-700 can be considered for structural-thermal-insulating wall blocks after pilot verification.

Table 3

Recommended application range of selected mixtures

Density grade	Main advantage	Limitation	Recommended use
D500	Lowest λ	Low strength	Roof/floor insulation
D600	Low weight	Medium strength	Non-load walls
D700	Balanced	Needs curing control	Wall blocks
D800	High strength	Higher λ	Partitions/base layers

4. TECHNOLOGICAL RECOMMENDATIONS

The foam should be introduced only after the cementitious slurry reaches stable flowability. Overmixing after foam addition must be avoided because it destroys air cells and causes density deviation. The recommended mixing sequence is: dry blending of cement, fly ash, silica fume and sand; addition of water with superplasticizer; short homogenization; introduction of preformed foam; casting and protected curing.

In hot and dry climates, early moisture loss can cause shrinkage microcracking. Therefore, foam concrete blocks should be protected from wind and direct solar radiation during the first 24-48 hours. Curing under film or in a humid chamber is recommended until sufficient matrix strength is developed.

5. CONCLUSIONS

A five-level density series of foam concrete mixtures with fly ash and silica fume was proposed for energy-efficient wall blocks. The results show that the use of mineral additives and a superplasticizer makes it possible to improve the matrix quality and reduce thermal conductivity while maintaining acceptable strength.

The most rational composition in the screening series is FC-700, which combines a dry density of about 695 kg/m³, compressive strength of 3.08 MPa and thermal conductivity of 0.153 W/(m·K). This composition can be recommended for further laboratory verification and pilot production of structural-thermal-insulating wall blocks.

The proposed integral score method is convenient for comparing alternative foam concrete compositions because it simultaneously considers strength, thermal performance and water absorption.

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