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THERMAL PERFORMANCE AND RESOURCE EFFICIENCY OF GYPSUM CONCRETE CONTAINING LIME WASTE AND REDISPERSIBLE POLYMER POWDER

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Abstract. The study evaluates the thermal performance and resource efficiency of gypsum concrete produced with G-6 gypsum, lime waste generated during technical water treatment, and Redispersible Polymer Powder (RPP). Thermal conductivity was determined for specimens containing 25% lime waste and 0–0.20% RPP. The lowest thermal conductivity coefficient, 0.118 W/(m·°C), was recorded at 0.10% RPP. The experimentally selected composition contained 75% G-6 gypsum, 25% lime waste and 0.10% RPP relative to the mass of dry components. For industrial testing, 750 kg of G-6 gypsum, 250 kg of lime waste and 1.0 kg of RPP were used per 1000 kg of dry components. D900 gypsum concrete mixtures were produced under industrial conditions and 666×500×70 mm gypsum blocks were manufactured. The use of lime waste and RPP reduced G-6 gypsum consumption by up to 25%. The calculated economic effect was 91,940 sum per 1 m³ of modified gypsum concrete and 1,654,920,000 sum per year under the production regime stated in the dissertation.

Keywords: gypsum concrete, lime waste, Redispersible Polymer Powder, RPP, thermal conductivity, resource efficiency, gypsum block.

1. Introduction

Gypsum-based construction materials are characterized by relatively low-temperature production, rapid setting and hardening, light weight and good moldability. At the same time, the dissertation identifies low water resistance as one of the limitations of gypsum materials. The use of mineral and polymer components is considered as one of the directions for controlling the properties of gypsum-based composites [5–7].

The dissertation investigated the use of lime waste generated during technical water treatment together with G-6 gypsum and Redispersible Polymer Powder. The experimental program included determination of physical and mechanical properties, water absorption and thermal conductivity, followed by industrial testing of the selected composition.

The purpose of this article is to present the thermal conductivity results, the selected industrial composition, the production sequence and the resource and economic indicators reported in the dissertation without changing the original experimental data.

2. Materials and Methods

2.1. Materials and composition

The main materials were G-6 grade gypsum, lime waste generated during technical water treatment and Redispersible Polymer Powder (RPP). In the thermal conductivity tests, the lime waste content was 25%, while the RPP content varied from 0 to 0.20%. The amount accepted as optimal in the dissertation was 0.10% of the mass of dry components.

The final laboratory composition contained 75% G-6 gypsum, 25% lime waste and 0.10% RPP. For the industrial composition, 750 kg of G-6 gypsum, 250 kg of lime waste and 1.0 kg of RPP were used per 1000 kg of dry components.

2.2. Thermal conductivity testing

Thermal conductivity was determined in accordance with GOST 7076–99 using 300×300×60 mm specimens. Before testing, the specimens were dried to constant mass at 45–55 °C. The tests were performed using an XND-2-3030C thermal conductivity apparatus [1].

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2.3. Experimental production and economic calculation

In the industrial production sequence, the specified amount of lime waste was first mixed for 1 minute. RPP was then added and mixing continued for 15±5 s. G-6 gypsum was subsequently introduced and mixed for 20 s until a homogeneous plastic mixture was obtained. The mixer drum speed was (140±5) min^{-1} and the counter-rotating blade speed was (62±5) min^{-1}. After casting, the specimens were demoulded after 9±2 min and stored at 23±2 °C and at least 50±5% relative humidity.

The industrial test was performed using G-6 gypsum produced in accordance with GOST 125–2018. D900 gypsum concrete mixtures were prepared under the production conditions of “Ferghana Ceramics Industry” LLC and an experimental batch of 666×500×70 mm gypsum blocks was manufactured [2].

The economic calculation compared the resource costs of unmodified and modified gypsum concrete for 1 m^3 of product. The calculation included gypsum, lime waste, RPP, water, technical oil, electricity and labour.

3. Results and Discussion

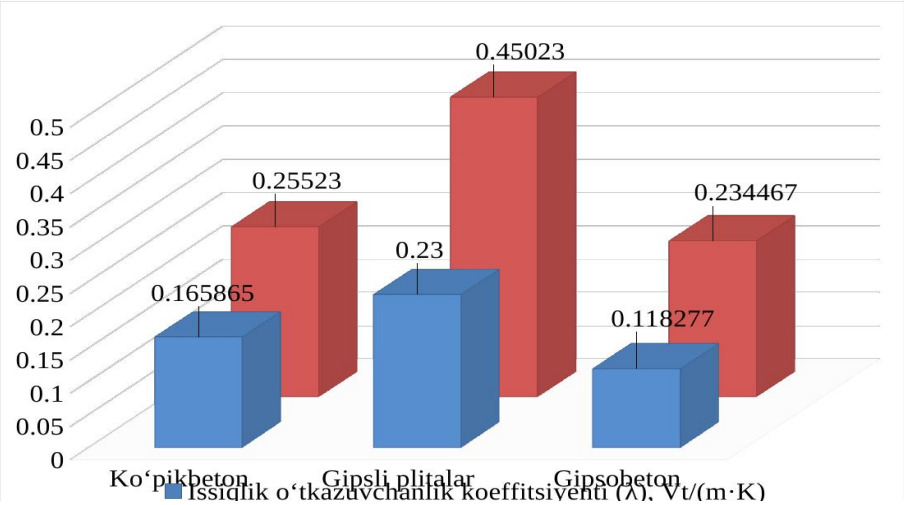
3.1. Effect of RPP content on thermal conductivity

The RPP content was varied from 0 to 0.20% at a lime waste content of 25%. The thermal conductivity coefficients reported in the dissertation are given in Table 1.

Table 1. Thermal conductivity coefficients of gypsum concrete specimens (dissertation Table 3.12).

No.	RPP, %	Average density, kg/m^3	Thermal conductivity λ, W/(m·°C)
1	0	915	0.171
2	0.06	930	0.156
3	0.08	912	0.133
4	0.10	923	0.118
5	0.15	901	0.127
6	0.20	887	0.145

The minimum thermal conductivity coefficient of 0.118 W/(m·°C) was recorded at 0.10% RPP. The dissertation therefore accepted 0.10% RPP as the thermally optimal amount within the investigated range.



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Figure 1. Comparative thermal conductivity and thermal resistance results reproduced from dissertation Figure 3.4.

Table 2. Comparative thermal test results (dissertation Table 3.13).

No.	Sample	Average density, kg/m³	Thermal conductivity λ, W/(m·K)	Thermal resistance, m²·K/W
1	Foam concrete	900	0.165865	0.255230
2	Gypsum boards	1100	0.23	0.45023
3	Gypsum concrete	900	0.118277	0.234467

According to the dissertation, the thermal conductivity coefficient of the gypsum concrete specimen was 0.047 W/(m·K), or 29%, lower than that of foam concrete. The obtained thermal conductivity values were used to characterize the thermal performance of the developed gypsum concrete and were considered applicable in thermal calculations for enclosure structures in accordance with ShNQ 2.01.04–2018 [3].

3.2. Industrial composition and production sequence

Three industrial compositions were considered. The compositions reported in the dissertation are reproduced in Table 3.

Table 3. Compositions of gypsum concrete containing lime waste and RPP (dissertation Table 4.10).

No.	Raw material	Unit	Composition No. 1	Composition No. 2	Composition No. 3
1	G-6 gypsum	kg	755	750	745
2	Lime waste	kg	245	250	255
3	Redispersible Polymer Powder (RPP)	kg / 1000 kg	0.8	1.0	1.2
4	Water	L	550	600	650

Among the experimental-industrial compositions, Composition No. 2 was accepted as the selected composition: 750 kg of G-6 gypsum, 250 kg of lime waste and 1.0 kg of RPP. The RPP consumption corresponded to 0.10% of the mass of 1000 kg of dry components.

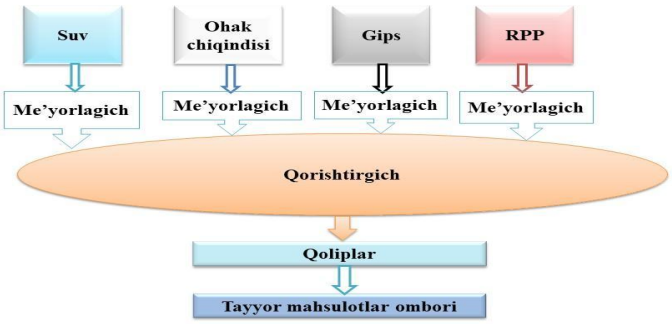


Figure 2. Energy-saving gypsum block production scheme reproduced from dissertation Figure 4.8.

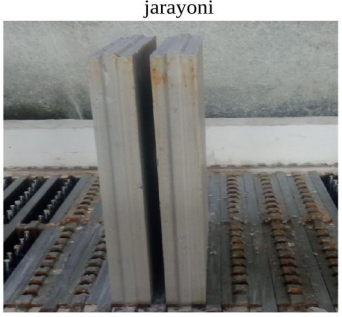
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a) gipsobeton qorishmasini tayyorlash jarayoni



b) gipsobetonlarini qoliplash jarayoni



v) gipsobetonlari, 666×500×70 mm.



g) gipsobetonlarini qoliplash jarayoni, 666×500×70 mm.



d) gipsobetonlarini montaj qilish 666×500×70 mm.



e) gipsobetonlarini montaj qilish. 666×500×70 mm.

Figure 3. Gypsum concrete preparation, moulding, products and installation reproduced from dissertation Figure 4.9.

The industrial test produced D900 gypsum concrete mixtures and 666×500×70 mm gypsum blocks under production conditions. The dissertation reports that the experimental batch was implemented using the developed production sequence.

3.3. Resource and economic efficiency

The dissertation reports that the introduction of lime waste and RPP into the gypsum concrete composition made it possible to reduce G-6 gypsum consumption by up to 25%. The economic calculation for 1 m³ of product is reproduced in Table 4.

Table 4. Economic calculation of materials and other resources for 1 m³ of D900 gypsum concrete (reproduced from the dissertation).

Material	Unit	Unmodified consumption	Modified consumption	Price, sum	Unmodified cost, sum	Modified cost, sum
G-6 gypsum	kg	1000	750	500	500,000	375,000
Lime waste	kg	0	250	30	0	7,500
Redispersible Polymer Powder	kg	0	1	25,560	0	25,560

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(RPP)						
Water	m³	0.600	0.600	2,600	1,560	1,560
Technical oil	kg	0.008	0.008	8,000	64	64
Electricity	kWh	2	2	1,000	2,000	2,000
Labour	unit	2	2	36,000	72,000	72,000
Total					575,624	483,684

The calculated economic effect from the use of lime waste and RPP was 91,940 sum per 1 m³ of gypsum concrete. At a production volume of 20 m³ per shift, the effect was 1,838,800 sum; at three shifts and 60 m³ per day, it was 5,516,400 sum. With 300 working days per year, the expected annual economic effect was calculated as 1,654,920,000 sum.

4. Conclusion

1. The effect of RPP content in the range of 0–0.20% on the thermal conductivity of gypsum concrete containing 25% lime waste was investigated. The lowest thermal conductivity coefficient, 0.118 W/(m·°C), was recorded at 0.10% RPP.

2. The selected composition contained 75% G-6 gypsum, 25% lime waste and 0.10% RPP relative to the mass of dry components. For industrial production, this corresponded to 750 kg of G-6 gypsum, 250 kg of lime waste and 1.0 kg of RPP per 1000 kg of dry components.

3. D900 gypsum concrete mixtures were prepared under industrial conditions and 666×500×70 mm gypsum blocks were manufactured using the production sequence reported in the dissertation.

4. The use of lime waste and RPP reduced G-6 gypsum consumption by up to 25%. The calculated economic effect was 91,940 sum per 1 m³ and 1,654,920,000 sum per year for the production regime stated in the dissertation.

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