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INFLUENCE OF DENSITY ON SHRINKAGE, FROST RESISTANCE AND THERMAL CONDUCTIVITY OF NON-AUTOCLAVED FOAM CONCRETE

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Abstract: *This paper investigates the operational properties of non-autoclaved foam concrete with density grades ranging from D400 to D600. Particular attention is given to shrinkage, frost resistance, and thermal conductivity as the key performance indicators affecting the durability and energy efficiency of foam concrete products. Experimental studies were conducted on compositions containing cement, fly ash, sodium sulfate, and chemical admixtures. The results showed that shrinkage values depend on density, curing conditions, and binder composition, while frost resistance decreases with decreasing density due to thinner inter-pore partitions. Thermal conductivity was found to decrease as density decreases, providing improved thermal insulation performance. The study demonstrates that achieving optimal operational properties requires a balanced relationship between density, strength, pore structure, and moisture resistance. The obtained results can be used for the*

development of energy-efficient and durable non-autoclaved foam concrete materials for building applications.

Keywords: *non-autoclaved foam concrete, shrinkage, frost resistance, thermal conductivity, density grade, fly ash, pore structure, durability, thermal insulation, operational properties.*

The developed low-water foam concrete compositions make it possible to obtain thermal-insulating and structural-thermal-insulating products with density grades from D400 to D600. The strength values satisfy the target functional requirements for the corresponding density classes. However, operational properties must be considered together because low density, strength, shrinkage, frost resistance and thermal conductivity are interconnected.

Shrinkage depends primarily on density, water content, fly ash content and curing conditions. The maximum shrinkage is typical for normally cured specimens, while heat-moisture-cured specimens have lower shrinkage. The minimum shrinkage among the studied compositions was obtained for composition No. 2, based on 50 % cement and 50 % fly ash with Chemix Art-2 and sodium sulfate. Its shrinkage was 0.82 mm/m under normal curing and 0.65 mm/m after heat-moisture curing.

Frost resistance was evaluated by strength and mass loss after freezing and thawing cycles. Compositions No. 1 and No. 2 correspond to frost-resistance grade F35, while compositions No. 3 and No. 4 correspond to F25. The decrease in frost resistance at lower density is expected because thinner inter-pore partitions and higher moisture sensitivity make the material less resistant to cyclic freezing.

Thermal conductivity decreases with decreasing density. The D400 composition has the lowest thermal conductivity, 0.093 W/(m*K), while D600 compositions have values around 0.133-0.135 W/(m*K). However, the presence of moisture can significantly increase thermal conductivity; therefore, foam concrete products used in exterior envelopes must be protected from wetting.

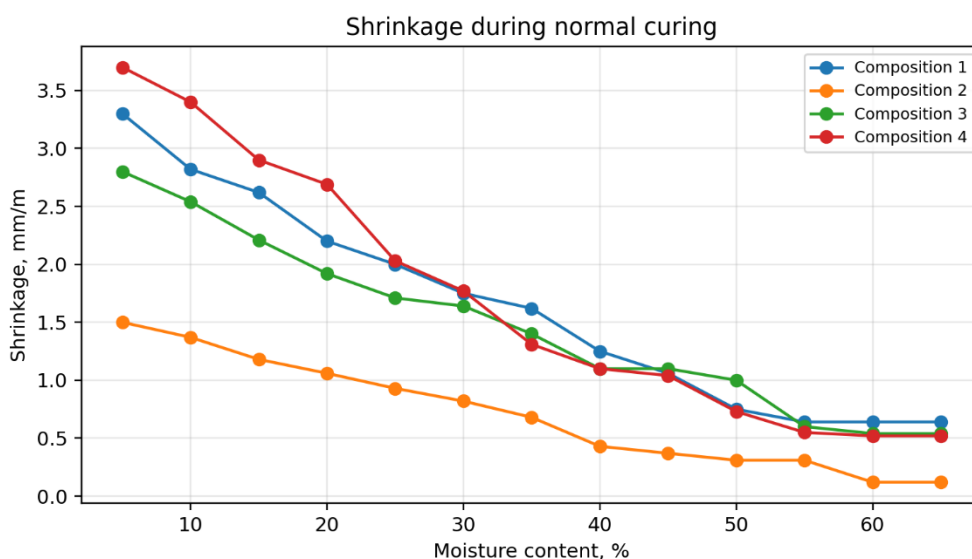


Figure 1 - Shrinkage of foam concrete during normal curing

Table 1 - Frost resistance by strength criterion

Composition	R0, MPa/%	R25, MPa/%	R35, MPa/%	Frost-resistance grade
No. 1	3.30/100	3.20/98	3.00/91	F35
No. 2	2.00/100	2.00/100	1.92/96	F35
No. 3	1.10/100	1.03/94	0.90/82	F25
No. 4	0.65/100	0.59/91	0.51/79	F25

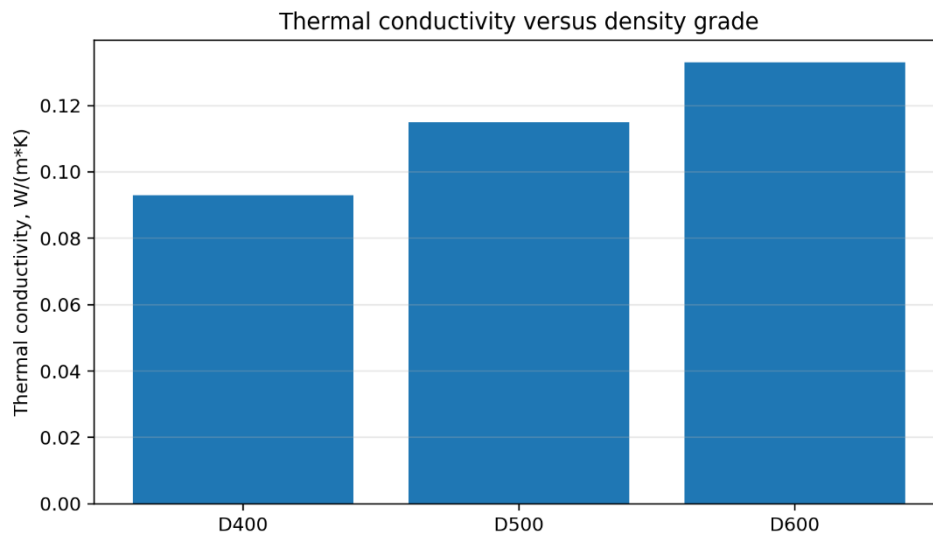


Figure 2 - Thermal conductivity depending on density grade

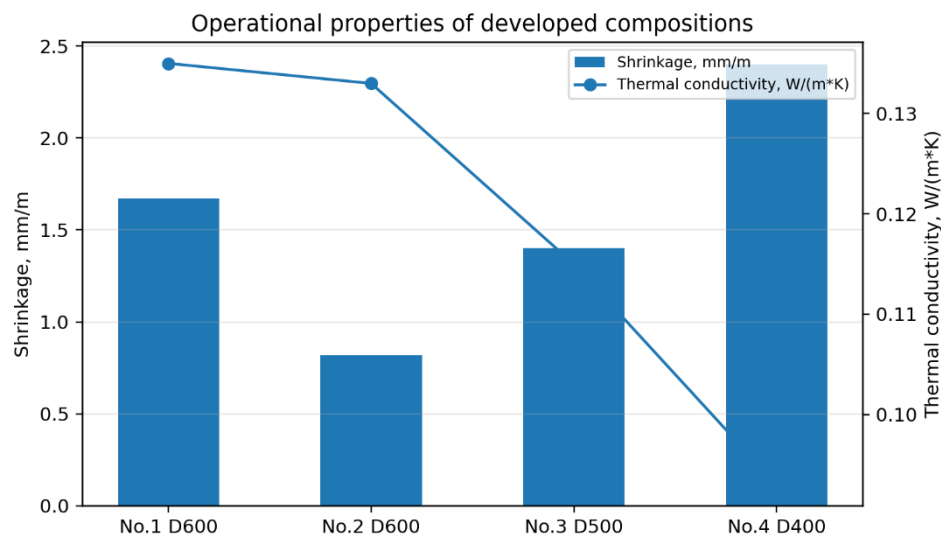


Figure 3 - Operational properties of the developed compositions

In relation to operational properties, the most important technological task is to maintain a stable connection between the composition of the mixture and the final properties of the hardened material. The parameters shrinkage, frost resistance and thermal conductivity must therefore be considered not separately, but as mutually dependent factors. When one factor is changed without

correcting the other two, the apparent improvement in workability may be accompanied by loss of foam stability, increased capillary porosity or excessive shrinkage.

The analysis of operational properties shows that the quality of non-autoclaved foam concrete is governed by the quality of the cement matrix around the air pores. A low-density structure is useful only when the inter-pore partitions remain dense enough to resist mechanical loading and moisture migration. For this reason, the technological interpretation of shrinkage and frost resistance should always include their influence on both fresh mixture behavior and hardened-state performance.

A practical feature of operational properties is the need to operate within a narrow technological window. If shrinkage is insufficient, the mixture becomes stiff and does not distribute air uniformly. If it is excessive, segregation, foam collapse or increased drying shrinkage can appear. The role of thermal conductivity is to compensate for these deviations and to make the mixture reproducible under laboratory and production conditions.

From the point of view of production control, operational properties requires a simple set of measurable indicators. The density of the fresh foam concrete mixture, the flow spread, the stability of the foam and the setting time provide rapid feedback. These indicators are not final quality criteria by themselves, but they help to predict whether the selected composition will form a uniform pore system after hardening.

The technological significance of operational properties becomes especially clear for compositions with a low water-to-solid ratio. Such mixtures can provide higher strength and lower shrinkage, but they are more sensitive to dosing errors and mixing time. Therefore, the use of

Leadcrete LA40, a water-reducing admixture and an accelerator must be coordinated as a single system rather than as independent additives.

For the interpretation of operational properties, it is also important to distinguish between the density of the composite and the density of the material in the inter-pore partitions. A reduction in average density is not always a positive result if it is achieved by forming large or connected pores. A rational composition should form many closed pores with a smooth near-pore layer and with partitions that are sufficiently uniform in thickness.

The experimental program related to operational properties therefore combines technological, structural and performance indicators. This approach makes it possible to explain not only what value of strength or density was obtained, but also why the result was achieved. The same numerical density may correspond to different structures; consequently, the method of foam formation and the compatibility of admixtures are decisive factors.

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