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THE EFFECT OF WATER-SOLUBLE SALTS ON THE MOISTURE REGIME OF SEALING STRUCTURES

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Abstract

This article examines the calculation of the moisture regime in building envelope structures under the influence of water-soluble salts. Existing methods for assessing moisture conditions are analyzed, highlighting their limitations in aggressive environments where salts alter vapor permeability and sorption processes. The study focuses on lightweight expanded clay aggregate concrete panels and evaluates the effectiveness of organosilicon hydrophobizing additives (sodium ethylsiliconate (ESNK) and polyphenyl-ethoxysiloxane (FES)) in enhancing durability and thermophysical properties. Results indicate that these additives improve resistance to salt-induced moisture accumulation and corrosion.

Keywords: building envelope structures, moisture regime, water-soluble salts, vapor permeability, sorption processes, hydrophobizing additives, aggressive environments, lightweight concrete.

Introduction

The rapid development of the chemical industry has increased the exposure of building envelope structures to water-soluble salts and aerosols, significantly altering their moisture regime. This exposure accelerates deterioration, reducing the long-term durability of structures, particularly in industrial facilities with aggressive environments.

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In such conditions, external walls experience not only typical temperature and humidity variations but also chemical interactions with salts, leading to salt corrosion rather than purely physical degradation. Standard building thermal engineering norms are often inadequate for these scenarios, as salts modify key parameters like vapor permeability and moisture sorption.

Previous research by scholars such as V.O. Machinsky, G.A. Maksimov, K.F. Fokin, and F.V. Ushkov has provided foundational methods for moisture assessment in envelopes. However, these approaches insufficiently account for salt effects on diffusion, sorption, and capillary transport. Limited studies exist on vapor permeability in salt solutions of varying chemical compositions.

This research adapts K.F. Fokin's graphical-analytical method for stationary vapor diffusion under salt influence, incorporating additions for constant-concentration salt solution adsorption in material pores and alignment with aerosol compositions in production spaces.

The objective is to evaluate moisture regime calculations in salt-affected envelopes and assess hydrophobizing additives for mitigation in aggressive media [1-5].

Methods

The present study primarily utilizes K.F. Fokin's well-established graphical-analytical method as the foundational approach for evaluating moisture regimes in building envelope structures. This classical technique, originally developed for analyzing stationary vapor diffusion and condensation risks under typical environmental conditions, has been carefully adapted and enhanced to better accommodate the specific influences of water-soluble salts in aggressive environments.

Key modifications introduced include the explicit consideration of adsorption processes involving concentrated salt solutions within the material's pores and capillaries. This accounts for the hygroscopic behavior induced by salts, where

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moisture is actively bound and retained at lower relative humidities than in salt-free conditions. Additionally, the chemical composition of the salt solutions was aligned to closely mimic the aerosols typically present in indoor air of industrial production facilities, ensuring greater relevance and accuracy in simulating real-world aggressive exposures.

For the experimental component, a standard Type II wall panel with an overall thickness of 300 mm was deliberately selected from centralized design institute albums for buildings in humid and aggressive conditions. This choice was based on criteria emphasizing the use of non-scarce, widely available, and thoroughly studied construction materials to facilitate practical applicability and reproducibility.

The panel configuration features a multilayer design: the primary insulating layer consists of lightweight expanded clay aggregate concrete with a bulk density of 580 kg/m³ and a water saturation capacity of 22%, providing excellent thermal insulation properties due to its porous structure. Complementing this is an outer protective layer made of dense heavy concrete, which offers enhanced mechanical strength and resistance to external environmental impacts.

This combination leverages the lightweight and insulating benefits of expanded clay aggregate while relying on heavy concrete for surface durability, making it particularly suitable for industrial settings exposed to medium-level chemical aggressiveness as defined by relevant construction norms and standards.

When assessing the moisture condition of an enclosing structure, V.O. Machinsky recommends using the limits of moisture accumulation during the winter period and drying during the summer period.

The general limiting condition is determined by the following formula:

$$K_O = \varphi_в^2 \frac{\beta_3 \cdot t_3}{\beta_\Lambda \cdot t_\Lambda} \left(\frac{W_н}{W_e} \right) \qquad (1)$$

Here:

$\varphi_в$ – relative humidity of indoor air, %;

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β_3 – duration of the heating period, years;

β_{Λ}– duration of the non-heating period, years;

t_3– average temperature difference between outdoor and indoor air during the heating season, °C;

t_{Λ} – average temperature difference between outdoor and indoor air during the non-heating season, °C;

$W_н$ – total vapor diffusion resistance of the outer part of the enclosing structure, m²·h·mm Hg/g;

$W_в$ – total vapor diffusion resistance of the inner part of the enclosing structure, m²·h·mm Hg/g.

Such a limiting condition mainly depends on two factors:

1. **Dependence on** $\varphi_в$:

Therefore, external enclosing structures of humid rooms are damaged due to moisture originating from indoor air.

2. **Dependence on the ratio** $\mathbf{W_n / W_v}$:

When $\mathbf{W_н = \infty}$ ($k_0 = 0$), no influencing factor exists;

when $\mathbf{W_н > W_в}$, the design solution of the enclosing structure is incorrect;

when $\mathbf{W_н = W_в}$, homogeneous enclosing structures with identical surface finishes become critical for use in humid rooms.

According to the observations of **V.D. Machinsky**, the general limiting value is equal to or less than **1.2**; however, this limiting condition does not reflect the complex process of moisture accumulation within the enclosing structure [6-10]. In the modifications introduced by **G.A. Maksimov**, the general limiting condition was calculated as **0.365**. He showed that the moisture condition of enclosing structures depends not only on vapor permeability but also on the ability to absorb and release liquid moisture. This limiting condition can be applied in combination with field (in-situ) observations, since the general moisture accumulation limit was determined based on an analysis of operational performance indicators.

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To determine whether moisture condensation occurs within the thickness of an enclosing structure, **K.F. Fokin** proposed a graphical method based on the construction of the actual water vapor pressure curve and the maximum vapor pressure curve. If these curves intersect, moisture condensation occurs within the structure. However, this method does not account for temporal changes in moisture content within the enclosing structure.

Material compositions are detailed in Table 1.

Table 1. Material Consumption for 1 m³ of Concrete

Concrete type	Material consumption for 1 m³ concrete					Water, l
	Cement kg	Quartz sand, kg	Granite gravel, (5mm) kg	Ceramzitic sand, l		
				1,2-5 mm	0-1,2 mm	
1	2	3	4	5	6	7
Heavy concrete	220	660	1310	-	-	180=(В/ц=0,8)
Expanded clay concrete	363	-	-	450	790	285=(В/ц=0,78)

Aggressiveness level: medium (per construction norms). Volumetric hydrophobization was applied using organosilicon compounds: sodium ethylsiliconate crystals (ESNK) and polyphenyl-ethoxysiloxane (FES) oligomers.

ESNK enhances mixture fluidity, reduces cement consumption, promotes air entrainment, and improves frost resistance. FES provides excellent hydrophobization.

Tests examined the impact of these additives on thermophysical properties and long-term durability of expanded clay concrete in salt-exposed conditions [11-15].

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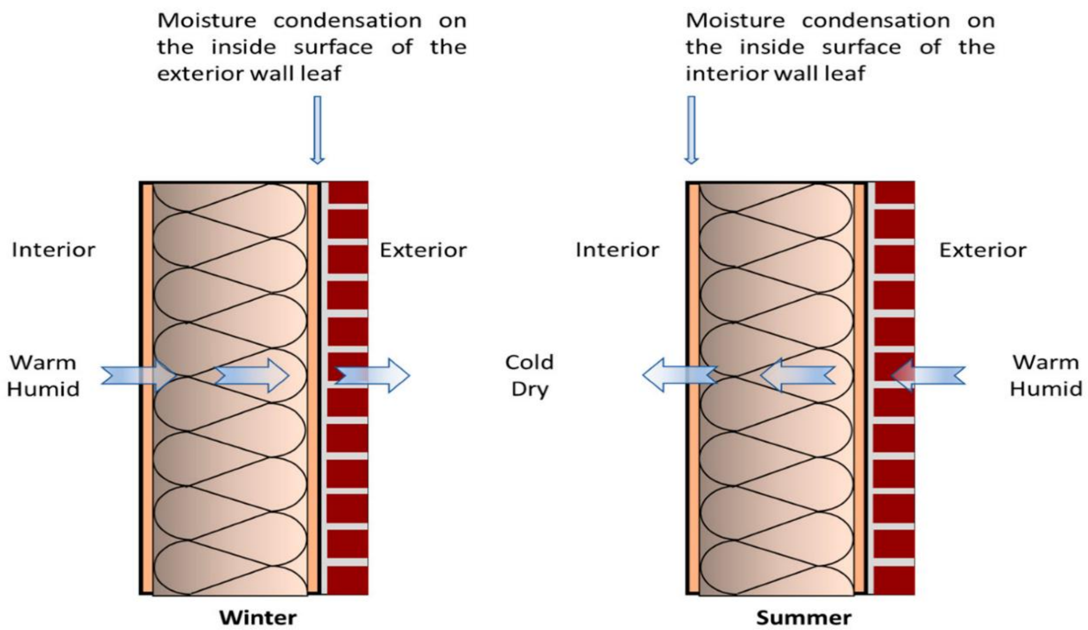
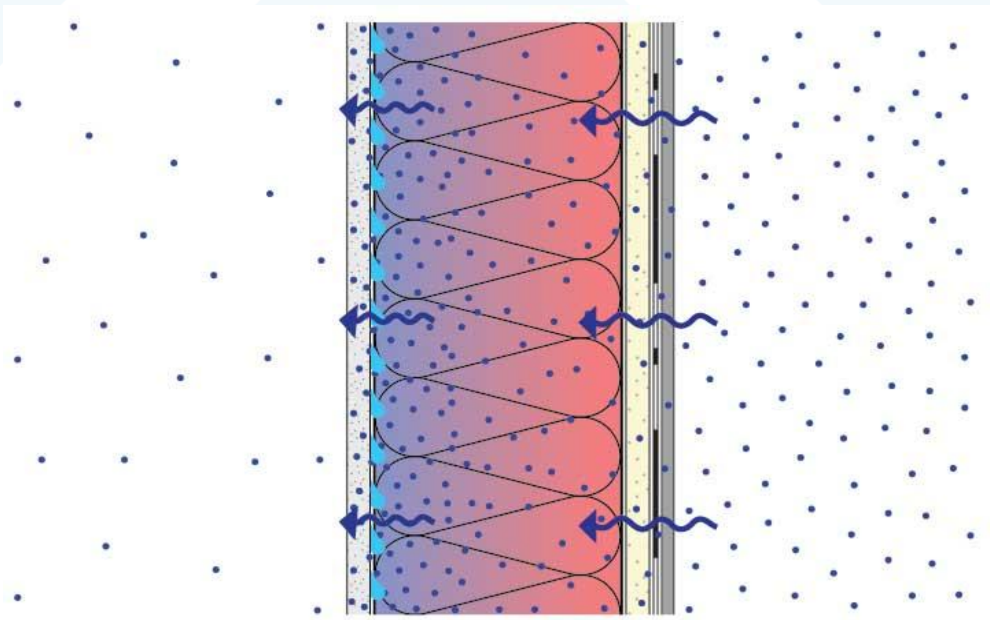


Pic. 1 Humidity movement in structures.

Pic. 2



Movement of moisture flow.

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Results

A detailed analysis of the classical methods developed by Machinsky, Fokin, and Ushkov for assessing moisture regimes in building envelopes reveals significant limitations when applied to environments contaminated with water-soluble salts. These traditional approaches primarily focus on vapor diffusion and condensation under standard temperature and humidity gradients, but they often underestimate the complex interactions introduced by salts. Specifically, soluble salts in pores and capillaries lower the vapor pressure over saturated solutions, leading to expanded condensation zones and accelerated moisture accumulation. This results in heightened vapor pressure gradients, promoting rapid moisture displacement and potential capillary transport, which can exacerbate physical degradation such as scaling or cracking.

Calculations conducted by V.A. Obyedkov further substantiate this phenomenon, demonstrating that the presence of salts elevates equilibrium vapor pressure within material pores, particularly over saturated salt solutions. This elevation intensifies diffusion-driven moisture ingress and can trigger hygroscopic moisture retention even at lower relative humidities. Literature confirms that salts amplify drying heterogeneities in porous materials, reducing overall vapor permeability while increasing the risk of crystallization pressure buildup. The quantification of moisture ingress—whether through vapor diffusion or direct condensate formation—was effectively addressed using R.D. Mirkin's methodological framework, which accounts for dynamic flux rates and provides a more accurate estimation of accumulated moisture volumes under salt-influenced conditions.

In the context of the selected expanded clay aggregate concrete panel, the incorporation of organosilicon hydrophobizing additives—namely sodium ethylsiliconate (ESNK) and polyphenyl-ethoxysiloxane (FES)—yielded notable improvements. ESNK promotes air entrainment during mixing, leading to a uniform distribution of micro-voids that enhance concrete density without

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compromising workability. This results in superior frost resistance by mitigating expansive forces during freeze-thaw cycles. FES oligomers, on the other hand, exhibited exceptional hydrophobization performance, forming a robust water-repellent lining on pore walls that significantly reduces capillary water absorption.

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moisture

Discussion

Standard methods inadequately predict moisture regimes under salt influence due to altered sorption and permeability. The modified Fokin approach, with adsorption inclusions, better forecasts stationary diffusion.

Hydrophobizing additives reduce capillary moisture transport, enhancing durability in aggressive media. Adding salts (e.g., table salt or sodium nitrate) to winter masonry mixtures increases hygroscopic moisture, causing efflorescence and stains—such practices should be avoided.

Although conditions are challenging, hydrophobization proves straightforward and effective.

Literature supports these findings: soluble salts amplify drying heterogeneities, reduce vapor permeability, and increase hygroscopic moisture retention.

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Hydrophobic treatments significantly lower water absorption (up to 80%) and ion permeability, improving corrosion resistance.

Conclusion

Water-soluble salts adversely affect the moisture regime of building envelopes, reducing durability. Identifying moisture sources (construction, ground, atmosphere, operation, hygroscopic, condensation) is essential for prevention.

Hydrophobizing additives (ESNK, FES) provide effective protection in aggressive environments. Avoiding salt additions to masonry mixtures is recommended to prevent hygroscopic issues.

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