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MAIN SOURCES OF MOISTURE IN MODERN BUILDINGS AND METHODS OF SOLVING THIS PROBLEM

ABSTRACT

The article generalises the main aspects of the moisture hazard in modern buildings and outlines possible ways to solve this problem. Most residential buildings in the Republic of Belarus are designed and exploited with natural air exchange. Provided that, the moisture of both outdoor and indoor air is actually equal under summer conditions. In winter, the air outdoors is considerably drier than indoors and the air moisture in the rooms increases considerably unless the air change is arranged. Not without reason, the special devices, i. e. valves allowing filtering the outdoor air coming into rooms have to be installed after installation of the windows meeting the today's strict requirements for airtightness. The article justly points out the increased moisture of construction materials to be the main cause of worsening of the durability and deterioration of service properties of the building constructions. This article reveals the main sources of the constructions moistening and considers some of the moisture transfer processes in buildings. The article presents the results of investigations of the gypsum-based moisture-regulating plasters. The use of porous fillers capable to collect the moisture quickly and then return it slowly represents an interesting method of moisture regulation in living premises. The performed investigation has resulted in the development of gypsum-based plaster compositions with moisture-regulating capability, allowing to reduce the risk of water steam condensation on the walls.

Keywords: gypsum plaster, moisture-regulating plaster, moisture sorption, moisture desorption, porous filler.

INTRODUCTION

One of the most powerful destructive factors affecting a construction is moisture. High humidity of structures exerts a destructive effect on the durability and decorative properties of these structures. In addition, the climate in the room changes as well, which leads to a change in the quality of a person's life and their well-being.

One of the most important tasks is to keep a suitable indoor microclimate. The humidity level in the room should not be more than 60% for a comfortable microclimate.

At the same time, high humidity of both external and internal air is one of the causes of damage and destruction of buildings.

The following problems may occur as a result of high humidity:

- corrosion of metal products (air ducts, building frame, reinforcement steel in reinforced concrete structures);
- chemical damage to materials used;
- change in colour, the appearance of spots and stains;

- shrinkage, swelling, the appearance of cracks and deformation of construction materials;
- the appearance of fungi and mould formation.

Moreover, fungal damage is given special importance, since these phenomena can affect not only the condition of structures and the appearance of buildings but the health of people as well.

In real conditions, it is necessary to consider the potential for moistening as well to minimize undesirable consequences.

Thus, in order to minimize the risk of the above-mentioned problems, a deliberate choice of building materials and their combinations in structures is required, as well as accounting and control of moisture sources in buildings, which will ultimately reduce operating costs.

Moisture-regulating gypsum-based plasters will certainly win their popularity thanks to the cheapness of the material and ease of use. Gypsum plasters do not have harmful impurities in their composition and they are quite eco-friendly.

It should be noted that the surface of the above moisture-regulating plasters perfectly accumulates heat, they are highly vapour-permeable and gypsum-based plaster layer is able to absorb moisture and, if necessary, return it, which ensures a healthy microclimate in the premises.

SOURCES OF MOISTURE IN BUILDINGS

There are four main sources of moisture in buildings:
- moisture from the penetration of atmospheric precipitation and pipelines leaks;
- water vapour from the outside and inside air;
- water and water vapour from the soil adjacent to the building;
- moisture contained in materials of building structures.

Inside the buildings, there are quite many sources of moisture. Nevertheless, the main reason for the appearance of moisture in the premises is the allocation of it to humans, animals and plants during physiological processes, during cooking, wet cleaning, washing and drying, defrosting of refrigerators, etc. [1]. In addition, plaster, paint, floor coverings and other components contribute their share as sources of moisture emissions. At the same time, the supply of water vapour from different sources is very different. So, for example, the exudation of moisture by building materials depending on the construction of the building is from 3 to 8 litters/day and when washing floors and dishes are from 0.2 to 0.5 litters/day. [2].

In case there is balance made between moistening and drying, moisture does not accumulate over time, and problems do not arise. Therefore, when assessing the risk of damage to structures caused by moisture, it is always necessary to determine the amount and duration of moisture, moisture accumulation and drying.

It should be noted that increasing the humidity of enclosing structures, in turn, leads to increased heat losses, lower temperatures in the facility and, consequently, deterioration of living conditions.

Most moisture control methods are designed to reduce the flow of moisture by sealing the enclosing structures, protection against the penetration of rainwater and its absorption by the materials of the structures. Nevertheless, it is possible to prevent the emergence of problems caused by moisture only

theoretically. It is practically impossible to eliminate all sources of moisture and all the driving forces of moisture transfer, as it is impossible to build a waterproof building.

With reference to the above mentioned, more and more attention is paid to the water-accumulating ability of the finishing materials and the possibility of their drying.

GYPSUM PLASTERS WITH MOISTURE-REGULATING ABILITY

All types of moisture transfer, which can lead to problems caused by moisture, can also help during drying if building materials. Consequently, attempts to block the mechanisms of moisture transfer are not always the best solution for dampness overcoming. Sensible combinations of actions to reduce moisture sources, control and regulate moisture transfer, as well as to stimulate drying processes are recommended.

Modern building codes and regulations provide that to preserve the thermal energy, the residential buildings must be airtight. At the same time, the moisture formed during cooking or using a shower can lead to a strong increase in air humidity in the room, which can cause the appearance of fungi and mould formation.

Currently, scientists at the German Fraunhofer Institute for Silicate Research (ISC) have found a way to regulate moisture in living premises by adding the porous glass in the plaster mixtures used for premises finishing. This simple and inexpensive addition proved to be very effective in maintaining the optimum moisture regime in energy-efficient houses, characterized by a high degree of tightness. As a result of the studies carried out, it has been shown that a plaster mixture with the addition of glass particles can absorb significantly more moisture than, for example, materials such as zeolite or fibreboard, and then release it again. For example, in a room with a volume of 30 m^2, approximately 40 m^2 occupy walls and ceilings, which can be covered with plaster that regulates humidity. In order to reduce the humidity in such a room from 72% to 47%, about 180 ml of water should be absorbed. At the same time, the plaster with glass scales developed by the authors can actually absorb more than 500 ml of water.

One of the ways to regulate the moisture in living premises is to use plaster compositions with moisture-regulating properties for decorating walls. It should be noted that the use of these plasters reduces the risk of condensation of water vapour on the walls.

In work [1] it is established that moisture-regulating plaster on a cement base sorbs excess moisture from the air, and then releases back into the room after a few hours. As a result, the air humidity in the room remains relatively stable, which has a huge impact on the health of residents and energy consumption in the home. It is known that the drier the air, the less heat it takes to heat the room.

A distinctive feature of moisture-regulating plasters is reduced density in comparison with “usual” plasters, practical absence of shrinkage, high vapour permeability and strength of adhesion to the substrate.

To develop humidity regulating gypsum-based plasters the following components are applied: gypsum binder brand G-4 (hemihydrate of calcium sulphate β-modification), the gypsum binder retarder (citric acid), lime hydrate, complex modifying additives (water-retaining and air-entraining additives, cellulosic fibres), fine-dispersion filler (calcium carbonate), fillers (quartz sand with a grain size from 0.08 to 0.315 mm, sand for construction work with a grain size from 0.63 to 1.25 mm), porous fillers (expanded vermiculite, expanded pearlite, porcelain, expanded polystyrene).

It should be noted that in terms of their technical and economic indicators, gypsum binders are related to effective building materials, which is due to the huge reserves of natural raw materials, relatively low fuel consumption during their production, short terms of setting and hardening.

The experience in the production and use of gypsum mixtures shows that the main properties of gypsum mortars depend on the type of gypsum binder used in the dry mixes. It should be noted that in contrast to cement mortars, gypsum compositions contain a small amount of fine and porous fillers. The amount of gypsum binder in the mixtures is in the range of 55-70% by weight and the properties of the binder used determine the quality of the dry gypsum mixture.

The main specifications of gypsum binder grade G-4 are presented in Table 1.

Table 1

The main specifications of gypsum binder

Indicator name	Indicator values
Degree of grinding (sieve residue percentage 02), %	12.4
Normal consistency, %	58.0
Packed density, kg/m^3	900
Humidity, %	0.7
Setting time, min beginning end	 4.4 8.1
Tensile strength, MPa bending compression	 2.1 4.2

A distinctive feature of gypsum solutions in comparison with cement mortars of similar purpose is a lower material consumption, which makes possible to process a 2-2.5 times larger area from the same mass of the gypsum-based mixture. In addition, the use of gypsum mixtures for finishing provides labour costs reduction by more than 2 times compared with cement mortars. Gypsum plaster mixtures dry much faster than cement, thus shortening the duration of the work. Therefore, the use of gypsum plasters can significantly increase labour productivity.

The use of gypsum materials for interior finishing provides a favourable indoor climate due to the ability of these materials to easily absorb moisture at moisture excess and on the contrary, at moisture lack to give away the accumulated moisture.

Gypsum-based plaster has a reduced density, which makes it possible to reduce the load on the intermediate concrete slabs.

It is known that gypsum binders are seized very quickly and in connection with this, the goal of increasing viability is the correct choice of special additives-retarders. The action of retarders of gypsum binders hardening is based on the creation of a pH-medium, which slows the solubility of hemihydrate of calcium sulphate. The most well-known additives retarding the setting time include various animal-based glues in powder form, modified lignosulphonates, tartaric and citric acids and their salts. In the work, citric acid was used as a setting retarder in an amount not exceeding 0.1%, at injection of which the viability of the gypsum binder was more than 60 minutes.

One of the main ways to regulate moisture in living premises is to use porous fillers, since their very important property is the ability to absorb a large amount of moisture quickly and then slowly give it away. As a result, these compositions using various porous fillers are very effective in maintaining the optimum moisture regime in the interior premises. Besides, the presence of porous fillers in plaster compositions reduces heat loss, allows better retention of heat in the facility and reduces the load on the walls and fuondation of the house.

The porous fillers used in this work differ by grain size and shape, composition, content of fine particles and porosity.

The characteristics of the porous fillers used in this work are presented in Table 2.

Table 2

Porous fillers specification

Filler		Density kg/m³	Thermal conductivity W/mK	Grains size, mm
Open porosity	expanded pearlite	100-150	0.05-0.08	0.1-0.3
	expanded vermiculite	100-150	0.05-0.08	0.5-1.0
Closed porosity	porover	150-200	0.06-0.09	0.2-0.5
	expanded polystyrene	20-30	0.05-0.06	1-2

A very important characteristic of the structure of the moisture-regulating gypsum solution is porosity. The pore space of the solidified gypsum solution consists of pores formed as a result of the crystallization process, evaporation of free water and air involvement. The amount of absorbed free water by the hardened gypsum binder depends on the pore space volume. Moreover, because of the macroporous structure, the free water is not only absorbed well, but it is also well removed under good conditions.

The porosity of the gypsum solution can be determined by the formula:

$$П = (В-\omega_{ch.b.}Г)\ 100 / 1000,$$

where В is the water discharge, kg/m³;
Г is the gypsum discharge, kg/m³;
$\omega_{ch.b.}$ is the chemically bound water content, % from gypsum mass.

Therefore, gypsum solution porosity is equal to:

$$П = (550\text{-}0{,}18 \times 1000)\ 100 / 1000 = 37\ \%$$

Based on the results obtained, the porosity of the plaster composition on the gypsum binder containing 10% of expanded pearlite will be equal to 60%; 15% of expanded pearlite will be 73%; 10% of the expanded vermiculite will be 45%; 15% of expanded vermiculite will be 52%; containing 5% of the foamed polystyrene will be 45%; 10% of expanded polystyrene will be 52%; 20% of the porover will be 59%.

In addition, for porosity of plaster gypsum solutions by involving air and the formation of air pores directly in solution, Berolan LPW 1 blowing agent in amount of 0.01 to 0.04% of the dry mixture mass was used.

When the content of the blowing agent is 0.015%, the air involvement of the gypsum solution increases from 8 to 25%. It should be noted that moisture regulating gypsum plaster possesses the greatest air involvement, in which expanded vermiculite is used as a porous filler.

Since the porosity can be determined quite accurately, it is possible to regulate effectively the humidity in the facility.

The possibility of changing the porosity adapts the material for use in various temperature regimes and premises of various purposes.

When applying a gypsum mortar mixture to a brick, cellular concrete, aerated concrete and other bases that absorb water quickly, the mortar becomes tough and unsuitable for further work. This loss of workability makes work difficult and significantly reduces the strength of the mortar.

To prevent the effect of the "drying" of the gypsum solution, Machellose FMC22501 methylcellulose was introduced into the plaster composition, which belongs to the group of water-retaining additives. In the contact with the porous base, the water retention capacity of mortar mixtures is their ability to retain the water in their composition necessary to ensure the plasticity of the mixture and the course of the hardening reactions of the gypsum binder. The necessary high level of water retention is impossible without the use of additives only due to astringents and fillers [3].

It should be noted that with the introduction of methyl cellulose in amount of 0.2-0.3%, the water retention capacity of the plaster gypsum solution reaches 98.9%.

Arbocel PWC500 cellulose fibres in amount of 2.0-2.5% of the dry mixture mass were introduced into the plaster gypsum mixes to reduce cracking and shrinkage deformations.

Thus, the modifying additives in the composition of gypsum moisture regulating plasters regulate the setting and hardening of the mortar, improve water retention, promote air involvement and air pores formation, create a special pore structure, increase mobility, ductility and reduce the risk of cracking.

In the present work, calcium carbonate was used as the finely dispersed filler. An important feature of carbonate rocks is that when entering into an active physicochemical interaction with gypsum, these fillers participate in the formation of the structure. Having a significant specific surface in a system with a low degree of filling (from 5 to 10%), fine carbonate fillers serve as a plasticizer, without changing the water requirement of the binder. At a higher degree of filling (from 10 to 30%) the water requirement rises slightly and the strength index of the binder filled with carbonate filler is higher approximately by 20% than the control composition. This can be explained by the fact that fine carbonate particles fill the voids between gypsum grains and together with it participate in the formation of the microstructure of the matrix base. Advantages of the gypsum binders structure with finely dispersed fillers is that internal defects – microcracks are localized in it, their number and dimensions decrease, the stress concentration decreases [4].

The most important, from a practical point of view, is the vapour permeability effect.

Walls are laminated structures in which, in addition to the main wall material, there are heaters, decorative and finishing coatings that either reduce or retain the vapour permeability of the basic

building materials. Moreover, very much depends on the characteristics of the vapour permeability of different layers of the wall.

It should be considered that a significant influence on the vapour permeability value exerts the influence of the moisture content of materials. Diffusion processes practically cease when the material reaches a certain threshold of moisture saturation. Relative air humidity in living premises is approximately 50%, depending on the season in wet premises, for example, in showers and kitchens is about 97%.

For the correct organization of water vapour movement, there is a rule that the resistance of the vapour permeability of the layers located on the cold side should be less than those located on the warm side. Otherwise, the moisture formed in the wall can move only inside the wall, which leads both to the danger of mould formation and to the damage of the interior finish, for example, to the detachment of the paint composition or wallpapers.

The essence of the method for determining the vapour permeability is to create a stationary flow of water vapour through the sample discovered and determination of the set of this flow.

The coefficient of vapour permeability of moisture-regulating gypsum-based plaster with the content of porous fillers from 10 to 20% varies from 0.075 to 0.085 mg/ m·h·Pa.

Thus, the above plasters have a sufficiently high vapour permeability, which will also help maintain a balance of humidity in the premise and exclude the formation of mould and fungi in the premise.

It should be noted that in absolutely dry material the pores and capillaries are filled with air. In the case where the building material is in air containing water vapour, a certain amount of air vapour penetrates into the pores of the material and condenses on their walls until an equilibrium moisture is established, which depends on the partial pressure of the vapour in the ambient air.

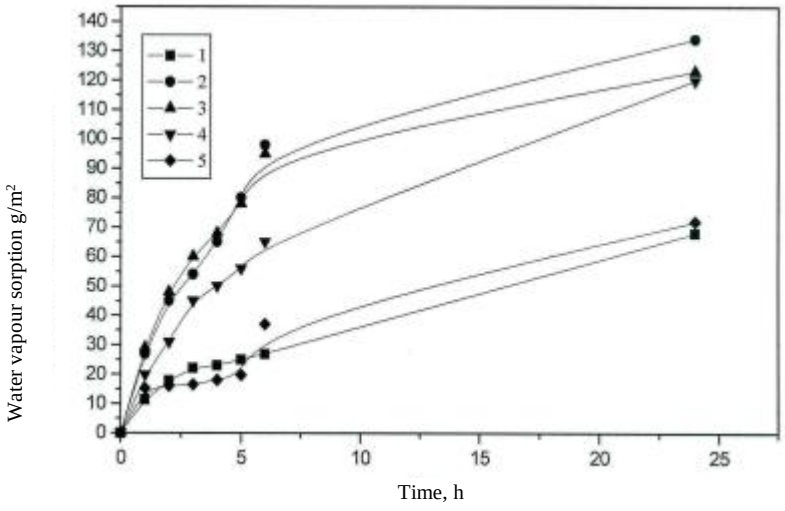

Figure 1. Water vapour sorption by gypsum-based moisture-regulating plaster at air humidity (98±2) % and temperature (20±2) °C:
1 – control composition; 2 – expanded pearlite; 3 – expanded vermiculite; 4 – porover;
5 – expanded polystyrene

Water vapour sorption in the gypsum-based moisture-regulating plaster, which contains various porous fillers in its composition, is shown at Figure 1.

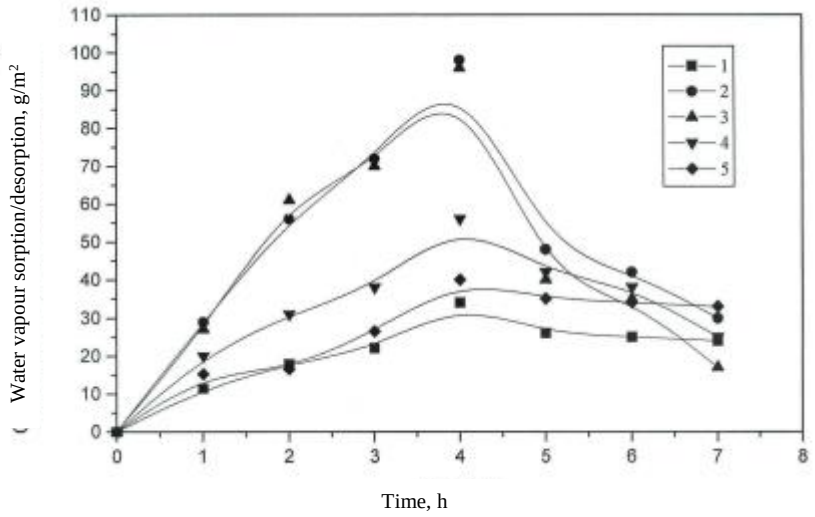

Figure 2. Water vapour content change depending on time: (0-4) hours – moisture sorption, (4-7) hours–moisture desorption;
1 – control composition; 2 – expanded pearlite; 3 – expanded vermiculite; 4 – porover;
5 – expanded polystyrene

The developed moisture-regulating gypsum-based plasters with expanded vermiculite and perlite, at air humidity of (98 ± 2) % and temperature (20 ± 2) °C, in 4 hours get almost the maximum amount of moisture, which reaches 100 g/m^2. In this case, as is known, the moisture sorption of the moisture-regulating plaster walls coating should be about 90 g/m^2 [1]. Moisture desorption begins with a change in the humidity in the premise to (60 ± 5) %, and after 3 hours the residual moisture content on the gypsum-based plaster with the expanded vermiculite becomes 15-18 g/m^2 and with expanded perlite – 30-33 g/m^2.

CONCLUSION

Humidity control in buildings is a key condition for increasing their durability, effective use and a healthy microclimate. Knowledge of moistening sources and moisture transfer mechanisms in the building and in the enclosing structures will allow specialists improving the design solutions of buildings and air conditioning systems. This knowledge must be based on a strategy to overcome the high humidity.

It is most advisable to regulate the humidity in the premises not only through the operation of air conditioning systems that consume a significant amount of energy but also with building materials accumulating and easily releasing moisture.

As a result of this study, a moisture-regulating gypsum-based plaster was developed using porous fillers, which allows reducing the risk of water vapour condensation directly on the walls, fungi and mould formation in the premises.

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