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COMPARATIVE CHARACTERISTICS OF MODERN THERMAL INSULATION TECHNOLOGIES OF BUILDINGS

Thermal insulation materials and technologies for thermal insulation of houses were investigated. The widespread use of such materials is due to the saving of fuel and energy resources, in particular, during the operation of buildings and structures. The subject of the analyzed stage of the research is the use of modern thermal insulation materials in construction, comparative characteristics of materials and processes associated with thermal insulation technologies.

A list in the form of a table of the most used on the Ukrainian thermal insulation materials with comparative characteristics was considered. The most optimal from the point of view of ecology are ecowool, foam glass and mineral wool. The disadvantages of materials are the high cost of work and installation. Polyurethane foam, relative to other heat-insulating materials, has a minimum thermal conductivity. Also, along with glass wool, it is an excellent sound insulating material. The main requirements for thermal insulation materials are fire resistance. All listed materials correspond to this characteristic, except for expanded polystyrene.

The construction industry in Ukraine is dependent on the country's economic factors. Back in 2015, there was a sharp decline in the market volume associated with an unstable political and economic situation. However, a year later, the pace of construction work has noticeably accelerated by 13,1%. This is due to the growth of the real estate market, the level of purchasing power, the popularization of energy-efficient

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construction in the country, and, therefore, the latest technologies and innovations in the direction of energy-saving materials.

Keywords: technologies of thermal insulation, thermal insulation materials, energy saving, thermal conductivity, ecology, durability

1. Introduction

Among the rich variety of thermal insulation materials, the most important issue is their systematization and development of highly efficient materials. Many years of experiments and experience in this field are the result of the development of effective materials that meet all the requirements of insulation, low thermal conductivity of buildings and structures of residential, industrial and agricultural, industrial equipment and units and more. In recent years, many new heaters have appeared on the Ukrainian market, thanks to which there has been a real breakthrough in the field of energy saving.

2. Analysis of recent researches and publications

Many works and scientific researchers are devoted to the basic heat-insulating materials and technologies of thermal insulation of houses. It is necessary to note such authors: L. P., Gorchakova G. I.[1], Gorlova Y. P.[2], E. O. Igokhina [3]. The authors of these works studied building insulation materials, technologies and methods of their installation.

3. Formulation of the problem

To date there has been an active increase in energy resources prices. For most buildings in our country, including historic sites, the percentage of heat loss is about 40% due to insufficient insulation of buildings. This means that for reconstructed buildings and for new construction it is necessary to install high-quality insulation. In all regions of Ukraine much attention is paid to energy-saving technologies in construction. For example, in the central-eastern regions of the country tens of millions of square meters of previously built housing do not meet modern requirements for thermal resistance to heat transfer of enclosing structures. Such residential buildings require insulation with the use of effective insulation methods.

The main purpose of this work to analyze the properties of thermal insulation materials with the definition of their disadvantages and advantages, to characterize and compare modern technologies for insulation of buildings.

4. Statement of main material and results

In the book *Building Materials* studying heat-insulating materials state: "Inorganic and organic low-heat-conducting materials intended for thermal insulation of building constructions, industrial equipment and pipelines are called heat-insulating. Accelerated development of such materials is necessary to solve a key economic problem – saving fuel and energy resources in industrial processes as well as in the operation of buildings and structures" [1]. In modern construction, the use of energy-efficient insulation materials allows to enlarge the structural elements (wall panels, coatings, blocks), thereby increasing the degree of industrialization of construction while reducing the weight of the building and reducing material consumption.

There are three main ways to insulate houses according to the spatial position of the material:

- external (insulation is located outside);
- internal (insulation is located on the side of the room).

To maintain comfortable conditions in the house, it is important not only to choose the right insulation materials, but also the thickness and thermal conductivity of the insulation. Incorrect thermal calculation will lead to the destruction of the structure and the formation of condensate. With the help of diagrams of the position of the dew point in the insulated walls, we will analyze the importance of the correct choice of insulation and its location (Figure 1–3).

On examples of schemes it is possible to analyze that in the first case position of a dew point is correct, the wall remains dry, while the insulation is outside. In the second case the insulation inside, the dew point is in the wall thickness.

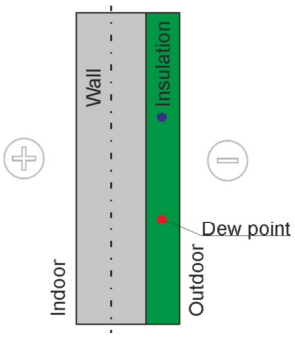


Fig. 1. The location of the dew point in the insulated wall (insulation outside)

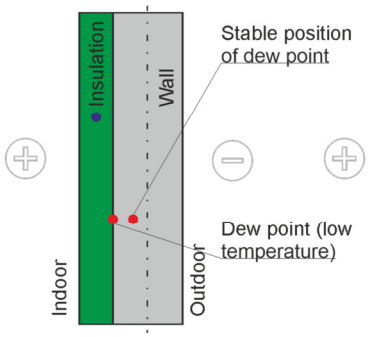


Fig. 2. The location of the dew point in the wall thickness (insulation inside)

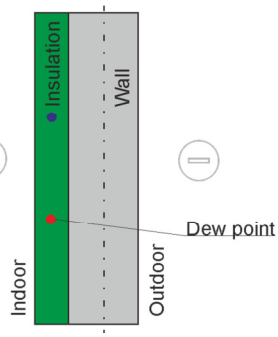
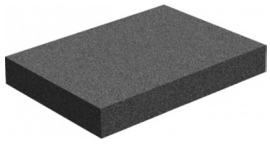
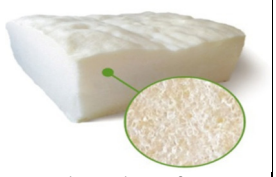


Fig. 3. Location of the dew point in the insulation (the wall is insulated inside)

Below is Table 1 of the most energy-efficient insulation materials.

Table 1. Comparative characteristics of thermal insulation materials

Insulation	Max heating temp. °C / Density, kg/m^3	Thermal conductivity W/m*K	Advantages	Disadvantages
 Glass wool	+500 / 9–13	0,044	Elasticity, heat-, sound insulation, no fire hazard	Low service life, the presence of formaldehyde
 Ecowool	+1000 / 30–60	0,036	Long service life, not prone to rot, non-toxicity	Risk of shrinkage, additional equipment required
 Basalt mineral wool	+600 / 35	0,039	High strength, resistance to fungus, mold, non-flammable	Dust formation, non-environmental, high cost
 Styrofoam	+60 / 25	0,037	Resistance to fungus, mold, low thermal conductivity	Flammability, risk of rodents, low sound insulation, fragility
 Foam glass	+485 / 100–400	0,048-0,08	Durability, resistance to deformations, steam and water, nonflammable, biostability	High cost, weight, fragility
 Polyurethane foam	+500 / 40–80	0,029–0,041	Heat and noise insulation, long service life, non-flammability, low hydroscopicity	Color change under ultraviolet light, high cost, caustic smoke in case of fire

In this case the wall is dry, but can get wet when it cools down sharply (the temperature is lower than the estimated DBN), due to which the dew point can move to the inner surface of the wall. In the third case, the wall and insulation are soaked throughout the winter. Therefore, based on the above, we can conclude that the best option for wall insulation is external.

The peculiarity of the manufacture of fiberglass (glass wool) is due to the chemical composition of the glass. Both alkaline and non-alkaline glass compositions containing boron are used to obtain fiberglass. For the production of glass fibers (cotton wool) use the following raw materials: as acid oxides – sand, alumina, boric acid; as alkaline oxides – soda, sodium sulfate, potash; as alkaline earth oxides – limestone, chalk, dolomite [1]. Depending on the form of release it is possible to use glass wool for horizontal surfaces, and also for cracks, niches, walls outside and inside the house. The technology of work on the insulation of the house with fiberglass begins with the preparation of the walls: the surface is carefully cleaned, remove fragments of putty or plaster. Then a waterproofing film is attached to the wall to prevent moisture from entering the wall. On top of the film the base is attached to the wall – wooden beams (25×50, 50×50), and the distance between the man beams is determined by the dimensions of the glass. Next, the glass is mounted: there are unfolded rolls of insulating material between the bars. This process should be carried out from top to bottom. Work with glass wool carefully, firstly, because of the fragility and fragility of the material, and secondly, the particles of the substance can affect the skin, eyes and respiratory system. On top of the glass is arranged vapor barrier, and then finishing the walls. Therefore, glass installation is easy, but it requires mandatory protective equipment against the smallest particles of material. Over the last few years, with the improvement of technology, models of safer fiberglass have been developed, but this does not invalidate the recommendations for the protection of specialists during installation.

Ecologically clean material is ecowool, which has excellent heat and sound insulation properties. To prevent flammability and the tendency to damage the material by rodents, ecowool is treated with flame retardants and bioprotective compounds. The total composition of ecowool: within 80% consists of recycled pulp; 12% is boric acid, which has a special antiseptic property, aimed at protecting against the effects of fungal microorganisms and preventing the development of bacteria; sodium tetraborate is 8% of the total weight of the material and is a strong flame retardant [2]. There are two ways to insulate your home with ecowool:

- Wet method. The adhesive filler is lignin. Wet fibers adhere well to any substrate. The insulation layer should be in the range of 50–60 kg/m^3. This method is good to insulate block or brick walls. The lattice is made of a bar or a profile (the first option is better). Insulation is applied using a professional installation. Loose cotton wool at the outlet of the nozzles is impregnated with water and under pressure is given to the surface. Wet method

easy and fast, indispensable in large volumes. The only drawback is the availability of professional equipment. For complex surfaces such as the ceiling on the underside in the water for strength dissolve the adhesive compositions, which help the lignin to strengthen adhesion[4].

- The dry method involves filling the cells of the lattice on the wall, floor, overlap. You can loosen the insulation with a nozzle for mixing solutions in a container of appropriate size. All surfaces are filled with embankment, compacting cotton wool to the damping of forces.

Mineral wool consists of thin vitreous fibers with a diameter of 5–15 μm, obtained from an alloy of low-melting rocks (marl, dolomite, basalt, etc.), metallurgical and fuel slags, ash TPP[1]. Insulation of a frame house with basalt wool begins with the installation of a cornice made of metal. It is attached to the wall with dowels in the base. The eaves are intended for simplification of laying of a heater and protection of material against rodents. Next, fix the insulation boards with polymer-cement glue, which provides a secure attachment of the plates to the wall. The insulation is mounted in the direction from the bottom up and from right to left. First of all, fix the whole plates, and after covering large areas, the insulation is mounted on small ones, for which the plates must be cut. A layer of vapor barrier is placed between the insulation and the decorative layer and there is a gap of 1–3 mm to ensure air circulation. The final layer applied to this insulation can be absolutely any: all types of plaster, siding, imitation timber, or an effective ventilated facade. When working with basalt wool cannot be neglected basic protection - gloves and respirator[5].

Styrofoam is used in the form of thermal liners in wall panels, roofing. They can be used to fill voids in reinforced concrete and other structures. Thermal insulation boards are made of beaded polystyrene, which contains isopentane as a gasifier and is produced by the chemical industry in the form of granules with a diameter of 0.5…0.3 mm. Thermal insulation boards are made by two-stage heat treatment [3]. Insulation technology begins with cleaning the surface of the walls from dirt, fragments of paint or plaster. The prepared surface is primed depending on the condition of primers, which increase adhesion. Slabs are installed on the prepared surface using an adhesive that can be applied both to the slab and to the wall. Mechanically expanded polystyrene plates are fastened by means of plastic dowels at the rate of not less than four pieces on a plate which installation should be carried out in days after gluing on a solution. On the surface of the plates is applied a special reinforcing composition, which «wet» is laid a layer resistant to alkalies of the reinforcing glass mesh with a cell of 4–7 mm. At the final stage, a decorative layer is applied: facade paint or structural facade plaster with subsequent painting. Thus, the installation of polystyrene foam is characterized by easy installation, but during the construction stages the material emits a harmful chemical – styrene. Also, if it is heated to 75° C, there is a release of vapors: ethylbenzene, toluene, carbon monoxide and benzene, which will harm the human body.

Porous glass is a highly porous heat-insulating material of porous structure, in which the pores are evenly distributed by thin partitions made of glassy substance. The material got its second name - foam glass - due to its appearance, which resembles frozen foam. There are several ways to obtain porous glass: the introduction into the charge of substances that abundantly emit gaseous products during the cooking of glass; blowing glass races with air or gases; swelling of the softened glass under vacuum as a result of expansion of the air contained in glass wool, etc. [3]. Foam glass is used for all types of roofs, walls, partitions. Consider several stacking technologies:

- Wall with heavy cladding. Foam glass is glued to a reinforced concrete or brick surface. Additional fixing is carried out mechanically (4–5 dowels per plate). After all perimeter will be put pass to installation of the metal profile intended under a facing stone. This option is also applicable to the installation of the base.
- Plaster wall. Foam glass mats are attached to brickwork or walls made of foam or aerated concrete blocks with the help of an adhesive composition. Before applying the finishing material, the plates are covered with a mesh overlap (not less than 100 mm). It is fixed with disc dowels with clamping washers. The thickness of the plaster layer can be up to 30 mm.
- Wooden roof. On rafters the continuous flooring is equipped. A layer of bitumen-based waterproofing materials is laid on top of it, which is fastened mechanically. Then the foam glass is mounted, then the waterproofing material. The surface is completely ready for laying of any roofing material.

Thus, foam glass today is one of the best heat and sound insulation materials. When installing, it is important to take into account its low absorbency and apply polymer acetate adhesive to ensure high adhesion.

A variant of polymeric material for thermal insulation of houses is polyurethane foam. It is applied by spraying, which provides a minimum number of cold bridges as well as a uniform structure of the insulation over the entire surface. Before starting work in the house or around the house pull the hoses through which the gun is fed components for the formation of foam. Workers who spray thermal insulation are dressed in protective suits with a respirator (foam components are toxic before hardening), gloves and goggles to protect the skin from PPU, which then cannot be torn off. The foam is applied from the bottom up, in small portions. Fill everything without gaps trying to prevent the formation of shells. As the foam expands, make sure that the thickness of the layer is not less than necessary. After the foam hardens the excess can be cut off. The end result strongly depends on the equipment used and experience of the worker, and also at full observance of technology.

Below are the processes of insulation of buildings with thermal insulation materials (Fig. 4–9).

Fig. 4. Glass wool insulation

Fig. 5. Ecowool insulation

Fig. 6. Basalt mineral wool insulation

Fig. 7. Styrofoam insulation

Fig. 8. Foam glass insulation

Fig. 9. Polyurethane foam insulation

5. Conclusions

The materials on their characteristics (thermal conductivity, maximum allowable temperature, density, advantages and disadvantages), technologies of thermal insulation of buildings were investigated in the work. Based on the study of thermal insulation materials, we note that polyurethane foam, polystyrene foam, glass wool, basalt wool emit toxic substances, are not completely safe for humans and during installation require additional equipment and protection. Foam glass, ecowool and basalt wool are the most optimal in terms of thermal, operational, physical and mechanical properties. In addition, they are environmentally friendly. The market of thermal insulation materials in Ukraine shows the potential of the pace of development for today, because given the current Ukrainian trends in energy efficiency and individuality, innovations in construction will develop in the direction of energy-saving materials and individual architectural developments.

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