Construction and insulation of agricultural buildings and structures

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Abstract. The article covers different application aspects of the products made of polyethylene foam within the scope of insulation systems of framed and frameless constructions used in the quality of storage premises, logistic objects, agricultural storage facilities and livestock facilities as well as framed residential buildings. Agricultural storage facilities, livestock facilities, covered parking areas for agricultural machinery and some types of storage premises represent the agricultural construction facilities which require the established protection systems against excessive heat losses as well as monitoring of the state of the internal environment - its temperature and humidity. These structures are built based on one of three schemes: frameless type, framed type with a rigid coating and framed type with a tent coating. The insulation of buildings constructed before 2010 is predominantly characterized by usage of mineral wool plates (with a protective facade covering) or sandwich panels. The main problem of suchlike coverings is the impossibility of creating an insulating coating without joints, seams or gapless junctions to the base. Mineral wool plates, in case of destruction of the waterproof coating, contact with water and firstly lose their thermal and physical properties, and then – come to the destruction themselves. Sandwich panels are more resistant to weather impacts, but create a coating with huge quantity of cold bridges and paths of convective air transfer through gaps or openings.

1 Introduction

The situation began to change when the development of insulation systems of agricultural facilities using polyethylene foam has started. The material itself was neither new nor innovative. For decades products made of polyethylene foam have been used within the scope of pipeline insulation, in the quality of substrate layer for laminate, as sealing gaskets, etc. The two inventions patented by the Russian company TEPOFOL made this material reasonable in the construction area: introduction of technology of manufacturing of the products up to 150 mm in thickness and introduction of technology of creation a seamless junction of separate sheets [1–3].

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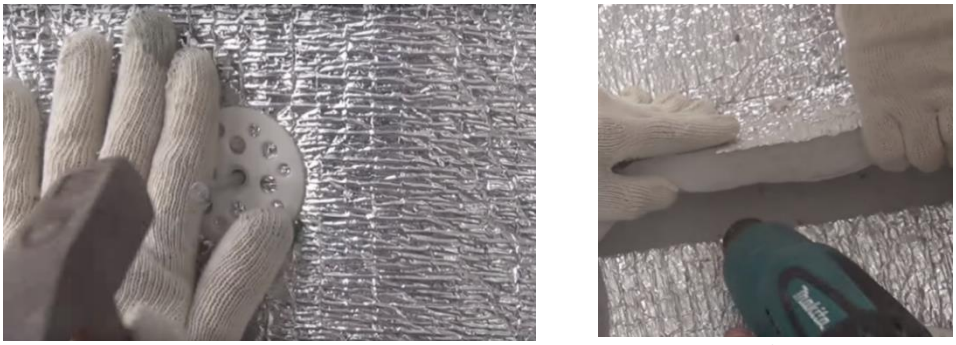
Despite the different functional purpose of the objects, their insulation system is based on two general principles. The thermal, vapour and air insulating coating is created with the help of mechanical fixation of polyethylene foam rolls on the load-bearing structure with subsequent connection of the separate sheets into the locking joint and welding them with the hot air by means of a heat gun (Fig. 1). In frameless systems, the insulating material is mounted on the inside of the galvanized metal profiled sheet; in framed systems, the insulating coating is installed on the outside of the load-bearing frame [4–6].



a b

Fig. 1. Installation of thermal insulation: a – mechanical fixation of the insulator sheet; b – welding of joints of the polyethylene foam rolls.

Various aspects of the usage of polyethylene foam within the frame of insulation systems of rural houses and cottages were studied in the process of contracts implementation with NRU MGSU (Research Moscow State University of Civil Engineering), as well as NIISF RAACS (Research Institute of Building Physics). The studies concerned typical design options, determination of the operational characteristics of the material and performance of the on-site inspections of rural houses insulated by means of polyethylene foam [7–9].

2 Experimental

Studies of the properties of polyethylene foam (with metallized reflective coating and without coating) were carried out in the laboratories of NRU MGSU and NIISF RAACS in the following areas:

- assessment of the possibility of using polyethylene foam to work in conditions of negative and alternating temperatures and its operational durability;
- assessment of the strength characteristics of polyethylene foam and welded locking connection of individual sheets of polyethylene foam;
- assessment of water absorption and sorption humidity of polyethylene foam.

Evaluation of tensile strength in the longitudinal direction was carried out in accordance with GOST EN 1608-2011 “Heat-insulating products used in construction. Method for determining the tensile strength parallel to the facial surfaces”. Evaluation of diffusion water absorption of polyethylene foam was carried out in accordance with GOST EN 12088-2011 “Heat-insulating products used in construction. Method for the determination of diffusion moisture absorption for a long time”. Water absorption of samples (with and without coating) with partial or full immersion was determined in accordance with GOST EN 1609-2011 “Heat-insulating products used in construction. Methods for determination of water absorption during short-term partial immersion“.

Results

Studies carried out at NRU MGSU and NIISF RAACS have established the following characteristics of foamed polyethylene: average density 18–20 kg/m3; diffusion water absorption of polyethylene foam without coating – 0.44 kg/m2; diffusion water absorption of polyethylene foam with a metallized coating – 0.37 kg/m2; water absorption after partial immersion in water for 24 hours – 0.013 kg/m2; water absorption by volume with full immersion for 28 days – 0.96%.

The tensile strength in the longitudinal direction for polyethylene foam products with a metallized coating is 80–92 kPa, without a metallized coating – 80–87 kPa, and for a welded seam – 29–32 kPa. The destruction of the "polyethylene-metal" contact surface is going by adhesive layer and the ultimate breaking stress was 12–17 kPa.

According to the results of climatic tests and determination of operational durability, it was established that there are no damage to the samples. The decrease in the strength characteristics of foam polyethylene samples after climatic tests does not exceed 4–6%. The material could be recommended as a thermal insulation of objects, operated at temperatures above -60°C.

When cooled to -60°C, the air density in the cells of polyethylene foam rises to 1.60–1.65 kg/m³, and this causes condensation of water vapor and their conversion into ice. The air density in closed cells of polyethylene foam increases by 1.3 times, pressure in the cells becomes lower than atmospheric, which implies a linear compression of polyethylene foam to 3-5%. Polyethylene has a low vapor permeability, therefore, the relaxation of compression deformation occurs gradually, as the air pressure in the cells is equalized with the atmospheric air pressure.

3 Discussion

In frameless buildings, the load-bearing structure is represented by the metal coating of the construction which is usually made of profiled galvanized metal. The assembly sequence is demonstrated in the figures 2 and 3.

Fig. 2. Preparation of a roll of metallized polyethylene foam.

The operating temperature of polyethylene foam is from -60 to +80 ° C what creates all the necessary conditions for performance of all-season installation. The works on storage thermal insulation do not depend on the outside air temperature and can be performed 365 days a year. Furthermore, the rolled polyethylene foam itself is not prone to destruction under the influence of seasonal temperature fluctuations what makes it multifunctional and

suitable for regions with extreme temperature conditions, including severe climatic conditions of use [10–12].

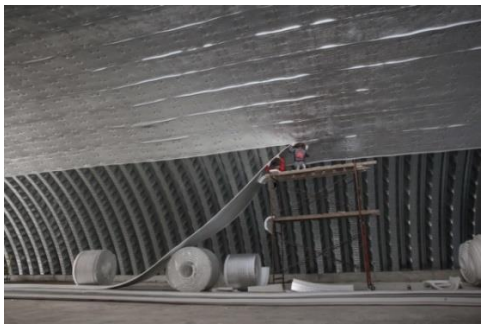



Fig. 3. Installation of the insulating coating of a hangar.

Insulation system of vegetable storehouses should contribute to the implementation of the following tasks: providing maximum thermal resistance of the insulated metal structure, minimization of the cold bridges and external air infiltration paths, reduction of mechanical loads on the metal frame, contribution to long-term exploitation of the construction simultaneously maintaining all basic thermal physical properties.

Specialized vegetable storehouses represent frameless metal structures (less often framed constructions), the internal space of which is often zoned for various functional purposes (drying, sorting, production storage). Storage conditions for finished agricultural products are rather critical: acceptable temperature of 3-5°C, optimum moisture content of 95% - for observance of such conditions the automated climate control systems are often required [13–15].

Standard equipment of vegetable storehouse should include various ventilation systems and other engineering systems (humidification, refrigeration, drying, etc.) which provide and maintain definite all-season and long-term storage conditions for agricultural products. However, the provision with the most modern equipment does not guarantee the long-term preservation of the products - this task is solved exclusively by means of high-quality thermal insulation of hangar-type vegetable storehouses.

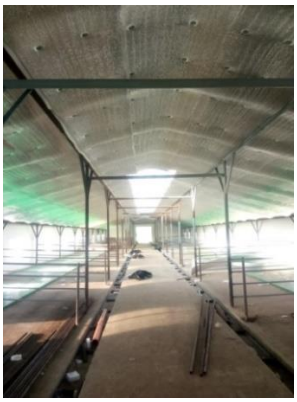



Fig. 4. Insulation of a framed structure. Calf house.

During the reconstruction of objects intended for livestock keeping facilities, the walls and the ceiling are insulated with rolled materials by means of mechanical fixation on the surface and creation of a seamless coating. The usage of air exchange ventilation and

climate control (in terms of humidity and temperature) is recommended in light of large premises what will ensure an optimal regime of animal management.

Framed (Fig. 4) or frameless (Fig. 5) structures with an interior arrangement of roll insulation on the basis of polyethylene foam are used in the quality of facilities for wintering of the livestock within the scope of a new construction.

Fig. 5. Insulation of a frameless structure. Covered stockyard.

Seamless insulation of hangar-type vegetable storehouses using rolled material Tepofol® with a heat-reflecting covering provides an effective insulation system of the vegetable storehouse by forming an integral hermetic coating of the building (Fig. 6). Proper insulation and selection of heat-insulating material that meets all the requirements and objectives minimize heating costs, ensure efficient usage of energy resources and regulate the indoor environment, maintaining the optimal temperature and humidity conditions inside the storage facility [16–19].

Fig. 6. Insulation of the end face of a vegetable storehouse.

The environmental friendliness and harmlessness of the insulator becomes an important aspect of choice for the storage facilities where long-term storing of agricultural products is foreseen. Polyethylene foam is absolutely safe for people and plants, it will not inflict any damage on animals and food products. It does not emit toxic substances during the exploitation, particularly at high temperatures. Resistance to aggressive biological environments and chemical neutrality of the material allow using of special detergent compositions and solutions during periodic sanitary and hygienic treatments of the premises.

Insulated hangars can also be used as garages for storage of vehicles. The temperature maintained indoors thanks to this technology of insulation enables a quick, easy and convenient start of the vehicles. This is especially important and actual in regions that are

characterized by a large variation of daily temperatures caused by the rapid change of day and night temperature values.

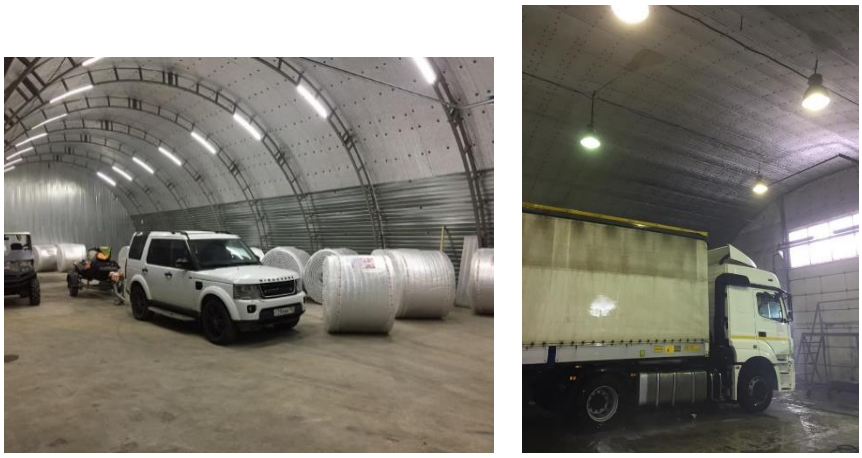


Fig. 7. Interior of heat-insulated parking areas.

A challenging task remains creating of the insulating coating within the scope of large garages or objects used for long-term storage of equipment located on large areas (Fig. 7). In this case, additional aspects related to the large-scale factor emerge along with the architectural and configuration tasks, the assessment of thermal resistance of the insulating coating, implementation of climate control engineering systems, etc. At the same time, the goals of protective measures remain the same: keeping the equipment in working condition, creating favourable working conditions for personnel, energy saving, reduction of operating costs for both facilities and equipment exploitation.

MGSU experts have performed a thermal-imaging inspection of insulated surfaces within the scope of one of suchlike production facilities insulated with polyethylene foam according to Tepofol technology. As a result, the temperature field on the surface of the enclosing structures was homogeneous, with no sources of losses.

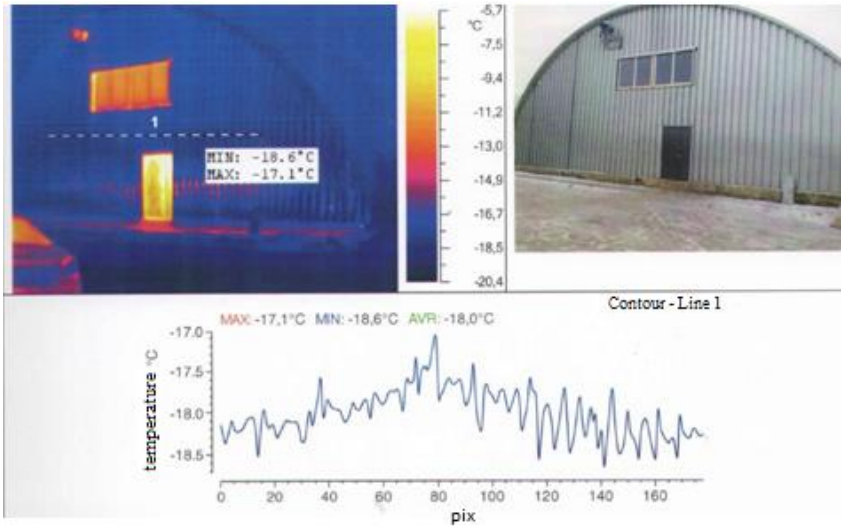


Fig. 8. Thermal-imaging filming of an insulated hangar. Legend: [Contour - Line 1], [Temperature °C],[pix.].

It becomes very important to bring vehicles into operating state under the conditions of severe frosts. The experience of the current winter for the majority of Russian regions and constant practice for regions where negative temperatures appear to be a normal climatic factor show that even to start the car in the freezing cold is either difficult, or impossible, or is worth the money or dangerous. And at the same time, motor transport should be ready for operation at any time. The usage of winter heated parking areas with effective thermal insulation allows solving all these problems.

Tented structures, as a rule, of framed type allow creating a thermal efficient insulating coating and are used in the building of long span structures: sports facilities, storage facilities, and warehouses. Systems made of profiled metal and light metal structures are used as a framework.

The installation of the tented thermal insulation system in accordance with the Tepofol technology is performed in the following sequence. The lath is mounted on the load-bearing frame; rolled polyethylene foam is laid out on the lath, the sheets are fixed mechanically; the lock connection of the sheets is built up and their subsequent welding is performed. Further, the tent covering is stretched and mechanically fixed along the perimeter and stiffening ribs of the structure. Such a tented covering protects the system well from all types of weather impacts, but becomes no obstacle for an unauthorized entry. Therefore, suchlike tent structures are recommended to be installed in protected areas.

The usage of polyethylene foam makes it possible to insulate the framed cottages along the outline (Fig. 9). NXLPE rolls (any length of the roll can be manufactured in compliance with the technical requirements) are unfolded around the perimeter of the building and fixed to the timber posts with cap screws. The rolls on the contact surfaces are connected in a butt-joint and welded with hot air.

The implementation of the lock welded joint of polyethylene foam rolls in accordance with the Tepofol technology (patent No. 2645190) enables obtaining an insulating coating of a pitched roof without using of additional windscreen and vapour barrier. At the same time, the roofing strip should be placed directly under the insulation locking system in order to achieve a reliable seamless welding of the joints.

a b c

Fig. 9. Thermal insulation of a cottage: a – unfolding of the NXLPE roll; b – fixing of the thermal insulation and seaming of the NXLPE roll; c – creating of an insulating contour and window apertures.

Foiled polyethylene foam rolls is laid on the entire surface of the roof and fixed with screws and washers and then welded with hot air along the joint lines. Thus, an integral insulating coating is created, which does not have cold bridges on the surface. Further, the internal lathing is mounted by means of self-tapping screws, to which the interior furnishing sheets are attached.

Hangars, warehouses, livestock facilities of both framed and frameless type are successfully used in the quality of agricultural buildings of various functional purposes. A significant disadvantage of any quick-mounting structures - heat losses during the cold season - is solved by an efficient insulation system capable of maintaining the necessary

indoor microclimate throughout the year without reference to the location region. In the Russian Federation, already dozens of residential cottages have been built or reconstructed (additionally insulated) using TEPOFOL technology and construction or insulation of the objects in the Polar Region is implemented as well.

4 Conclusion

The operational characteristics of foamed polyethylene, as well as insulating shells based on it, fully comply with the requirements for materials and systems operating at negative and alternating temperatures. From the point of view of maintaining the temperature regime in the insulated volume, the best way is to form a seamless joint as a result of the lock connection of individual rolls of polyethylene foam using heat welding.

Systems based on foamed polyethylene is a clear example of the implementation of the principles of energy efficiency, which can be formulated as follows: reducing the cost of heating the room; the use of materials and structures that allow quick and energy-efficient construction of structures; creation of optimal conditions for the work of personnel, the preservation of insulated materials and a comfortable stay of people.

Various aspects of the use of polyethylene foam in the insulation systems of rural houses and a cottage were studied in the process of implementing agreements with the Moscow Building University and the Institute of Building Physics. The studies concerned typical design decisions, determining the operational characteristics of the material, as well as conducting a field survey of rural houses insulated with foamed polyethylene.

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