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№ 32

July-September 2001

ENERGY EFFICIENCY

Quarterly Bulletin *CENEf*

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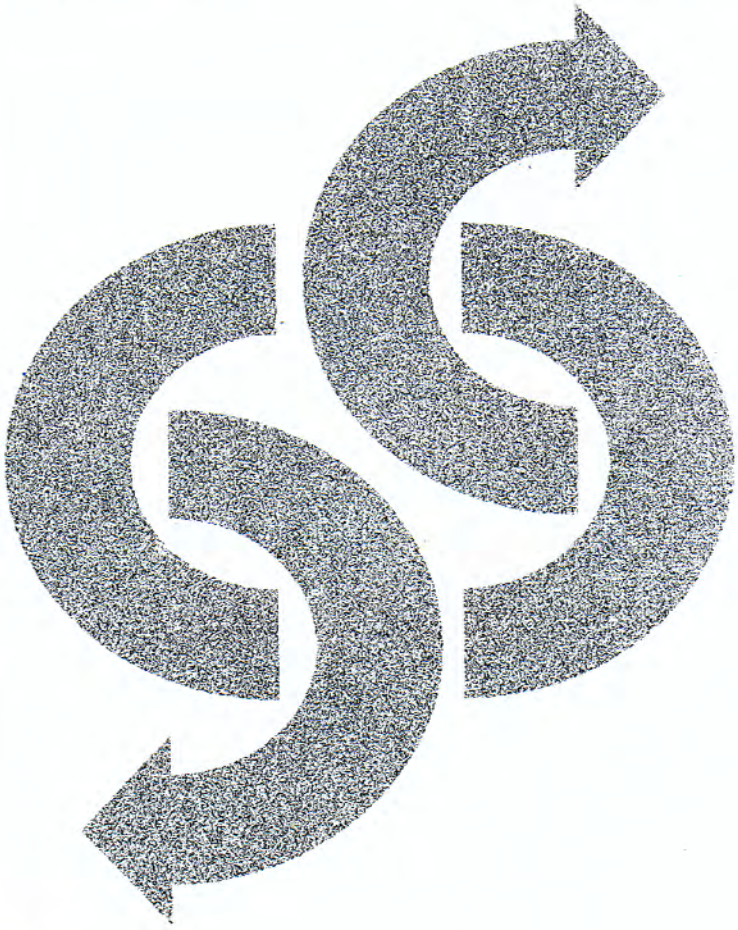

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Statistical Data. Reviews

NEW TECHNOLOGIES IN THERMAL PERFORMANCE OF BUILDINGS: PROBLEMS AND SOLUTIONS

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High requirements to thermal performance of buildings complying with today's energy saving objectives and reflected in new regulations pertaining to thermal performance of buildings dictate the necessity to develop and introduce energy efficient walling structures using high-quality effective thermal-insulated materials.

Basic principles regulating thermal protection of buildings were formulated in construction norms and specifications (SNiP II-3-79*). No problems arise from the revised rules and regulations in designing of coatings, attic and ground floors, while designing of exterior walls necessitates looking for qualitatively new engineering approaches.

Designing of exterior walls with allowance made for new requirements to thermal performance

It is common knowledge that from thermotechnical viewpoint three main types of exterior walls are conditionally distinguished by the number of basic layers: one-layer, two-layer and three-layer ones. Thermal performance properties of the walls, which ultimately define heat consumption for heating of a building, pertain to climatic characteristic of locality expressed in degree-days of heating period (DDHP). Practicability of employment of this or that structure is limited by the highest value of DDHP, at which the structure provides the necessary level of thermal performance, being reasonably thick.

One-layer walls

One-layer walls are the most customary for Russian designers and constructors and they are the simplest in manufacture and, when the necessary thermal performance properties are assured – in operation, as well. The one-layer walls are manufactured from structurally thermal– insulated materials and products combining load-bearing and thermal performance functions. The required parameters of indoor microclimate, i.e. necessary comfort, are provided, if the walls materials are of appropriate quality.

Bearing in mind current requirements to thermal performance, walls made of cellular concrete blocks manufactured according to diverse technologies, are the most acceptable ones. When maximum density of the material is 500 kg/m^3, wall thickness is 500 mm and calculated value of thermal conductivity coefficient is 0.15 W/(m*°C) at most, its use in the areas with DDHP up to 6000-6500 is practicable. Extension of the cellular concrete material application to areas with DDHP in excess of 6500 is also possible, but the wall thickness shall be increased to 700-750 mm. More often than not, walls of cellular concrete blocks are designed as self-supporting walls with by-floor leaning against the floors elements and mandatory protection against external atmospheric effects (facing, plaster layer, etc.).

Production of the structurally heat-insulated blocks from cellular concrete was arranged at Tobolsk, Orenburg, Golitsyno plants, Kaluga house-building combine (HBC) and at other enterprises, while production of blocks of particularly light-weight polystyrene concrete (its density 150-550 kg/m^3) – at 10 enterprises in construction industry.

For the one-layer walls the use of other concrete materials is advisable, when their density is not in excess of 600-700 kg/m^3 (light-weight concrete, foamed concrete, etc.), however, for the wall thickness of 500 mm their use is restricted by areas with DDHP 2000.

Under certain conditions one-layer walls made of clay hollow bricks proved efficient.

Two-layer walls

The two-layer walls contain load-bearing and thermal-insulated layers, which can be arranged both inside and outside. Internal insulation shall provide protection against damping and moisture accumulation in the bulk of thermal insulation, which necessitates special thermal engineering calculation and careful manufacture. Systems with outside heat insulation feature a number of essential advantages (high thermotechnical homogeneousity, maintainability, variety of architectural approaches to facade, preferable for the walls reconstruction) and nowadays they found extensive use in construction practices. Currently, two main variants of the systems are used: variant 1 – systems with external plaster layer; variant 2 – systems with an air gap.

In variant 1 thermal-insulated materials meeting special requirements are used: mineral wool batt insulation thickness is up to 150 mm, that of expanded polystyrene plates – up to 250 mm; they are fixed to the wall by dowels with steel stay elements and polyamine cylinders. From external atmospheric

effects the insulation is protected by a basic glue film reinforced by a glass net and ornamental layer (plaster, painting). Safe to handle, durable and compatible components, preventing partial/full cracking or failure of the thermal-insulated layers on facades of buildings shall be used. Accordingly, components, materials and products used shall undergo technical appraisal of their fitness. Recommendations on the choice of materials and products contained in the code of practice SP 12-101-98, shall be reviewed with allowance made for the appraisal mentioned.

Nowadays, by results of the relevant verification 20 foreign and national companies were granted certificates issued by State Committee for Construction (Gosstroy) of Russia for the products and systems they employ, which served in different regions of the country with DDHP 6000.

Variant 2 differs from variant 1 by the absence of restrictions for thickness of the thermal insulation materials used – mineral wool batts, which are also fixed to the wall by dowels. The thermal-insulated layer is protected by facade plates made of diverse materials installed on light-weight structures of metal profiles (steel, aluminum alloys and their combinations) fixed to the wall. The thermal insulation layer is additionally protected by a vapour-permeable film fixed under factory or building conditions. Besides, an air gap 60 mm thick is envisaged between the facade facing and thermal insulation layer.

Safety and durability of the variant depends on many factors, including compliance with requirements of anticorrosion protection of fasteners and their joints.

At present 12 organizations submitted materials for technical appraisal of their systems fitness to Gosstroy of Russia.

The use of dowels 400-450 mm long for fixing mineral wool batts to the wall according to variant 2 can find application in areas with DDHP > 9000.

Nowadays systems with outinsulation are employed in most of buildings under construction with a cast-in-situ ferroconcrete frame and in modernization of bearing-wall and brick buildings.

Three-layer walls

The three-layer walls erected on construction site using all kinds of small-pieces products and thermal insulation arranged between external and internal layers, were previously used in construction as a "well brickwork". Low thermotechnical homogeneousity (less than 0.5), stemming from the brick cross pieces splitting the thermal insulation, along with problems in the brickwork quality control, hampered its application, bearing in mind the new requirements to energy saving.

Walling made by small-pieces items shall provide a high thermotechnical homogeneousity of the walls – up to 0.64-0.74. For flexible ties in the walls mentioned, steel reinforcement, featuring the relevant anticorrosion properties of the steel or protective coating, is used. Employment of the structures is restricted by the wall thickness of 2.5-3 bricks.

In prefabricated house-building three-layer concrete walls have been long in use, featuring lower reduced thermal resistance (R-value) than the one necessary according to today's requirements. To improve their thermotechnical homogeneousity the rigid ties between external and internal layers were replaced by flexible steel ties in the form of separate rods or their combinations. For the same purpose plate-filling or filling insulation materials are used. Numerous calculations for ascertaining the reduced thermal resistance made by Research Institute for Building Physics (NIISF) and Central Research Institute of Experimental Design of Dwellings (CNIIEP) and other organizations, bearing in mind three-dimensional temperature fields, suggest that thermotechnical homogeneousity coefficient of the structures makes up 0.67-0.8, which is quite acceptable for coping with the task assigned.

Three-layer walls 350-450 mm thick with a thermal insulation layer 200-300 mm thick made of flexibly bonded expanded polystyrene and mineral wool can be used in regions, where DDHP reaches 6000-7000.

Today we have numerous examples of three-layer enveloping structures manufacture complying with requirements set for the second stage of the SNiP II-3-79* introduction. Thus, Moscow HBC and construction materials manufacturers on the basis of energy saving design approaches have mastered erection of dwelling houses of the P44T, P3M, KOPE, P46M, Pd4 series, their total area exceeding 2.2 mln. m^2 a year, with the wall panels reduced thermal resistance of 3.16-3.28 m^2*^oC/W, which compares favorably with requirements for the second stage (3.15 m^2*^oC/W). Similar three-layer panels are used for erecting buildings by HBC in Podolsk, Shchelkovo, Tuchkovo, Elektrostal, Orekhovo-Zuevo, Chelyabinsk, Republic of Tatarstan, Buryatia, Karelia, Khabarovsk territory, Sverdlovsk, Leningrad, Arkhangelsk, Orel, Pskov, Novgorod, Tomsk and Samara regions.

Evaluation of safety and durability of discrete ties (bushing keys) of diverse modifications and glass-fiber-reinforced plastic flexible ties required additional information along with their approval with issue of a technical certificate by Gosstroy of Russia.

Clearly, the lack of a new revision of State Standard GOST 11024 "Exterior concrete and ferroconcrete panels for dwelling and public buildings. General technical specifications" restricts the development of this promising trend.

Walls made of light-weight sandwich-panels continue to be extensively used, primarily in industrial construction. Here, as in the previous case, the regulatory base is the decisive factor, development of a standard for sandwich panels with mineral wool insulation, first of all.

Application of the building materials designed thermal values

It is a well-known fact that there is an essential difference in thermal conductivity of certain materials in a dry state and the same materials within the enveloping structures. For instance, expanded polystyrene plates, their density 40 kg/m^3, in a dry state feature thermal conductivity of 0.038 W/(m*°C), while within the enveloping structure of a building constructed in central Russia, allowance made for the wall moistening during service, the same coefficient has the value of 0,05 W/(m*°C), i.e. 30% higher. Foreign and national manufacturers, when selling thermal-insulated materials, often inform purchaser of their materials characteristics obtained in the course of laboratory testing in a dry state and the value, by mistake and in violation of SNiP II-3-79*, is sometimes used in designing.

SNiP II-3-79* requires that only design values of thermal conductivity coefficient for thermal-insulated materials are used in designing for operation conditions A and B. Table values in the SNiP were defined on the basis of materials manufactured by national industry. Nowadays thermal-insulated materials, manufactured according to the state-of-the-art technologies and featuring improved thermal insulation characteristics, appeared on the Russian market of building materials, so, the necessity arises in the development of a standardized method for determining the design thermal values for the materials under service conditions. The method was developed and provided in Code of Practice SP 23-101-2000 "Designing of thermal performance for buildings" approved by Gosstroy of Russia. The method is intended for test laboratories accredited by Gosstroy of Russia, delineating the procedure of defining the designed values for specific makes and types of building materials, including the foreign ones.

A similar approach to determining the designed values is used abroad. Hence, the International Organization for Standardization (ISO) has developed standard 10456 "Procedures for determining declared and design thermophysical values" of thermal-insulated materials. In FRG standard DIN 4108, p.4, is currently effective, which contains a table of design values of termal conductivity coefficients of building materials and products. In 1997 leading manufacturers of thermal-insulated materials, research and other organizations in Denmark set up independent organization (VIK), which supervises over application of design thermal conductivity values in designing on the basis of Danish standard DS 418. Similar approaches are used in the standards of Norway (NS 3031), Sweden (BBR 99), Estonia (EVS 724:1996), Lithuania ((STR 2.01.03:1999) and other countries.

Thermal insulation of exterior walls

There is an opinion that arrangement of an insulation layer outside the load-bearing part of a wall will bring about reduction of its durability due to moisture accumulation near outside finishing layer and alternate freezing and thawing in the process of service in cold and intermediate seasons of year.

Nonetheless, results of calculations and full-scale tests of moisture conditions of the walls carried out by some research institutes indicate that, if they are designed correctly, no intolerable moisture accumulation near the outside finishing layer occurs. Hence, at CNIIEP comprehensive research of structural durability of the exterior walls insulated by basalt-fiber base mineral wool batt plates with a finishing plaster layer was conducted. Outinsulation of one-layer walls was performed in dwelling houses of series 1-515 in Moscow. The system of outinsulation resulted in improvement of heat and moisture conditions in the apartments and in the walls; operation of the buildings for quite a long time revealed no defects.

Similar results for outinsulation were obtained in Research Institute of Construction in Lithuania, where the structure withstood 70 cycles of freezing and thawing that did not impair its properties. Experience in large-scale service of outinsulation in Poland and Germany for more than 25 years did not reveal any deterioration of service properties of the outinsulation and its facing layers.

Protection of multi-layer walls against vapour diffusion

Heat insulation properties of a multi-layer structure depend on the thermal insulation steady state moisture content. Due to partial pressure difference of vapour outside and inside a building, vapour diffuses through the enveloping structure towards outside. When designing the multi-layer enveloping structure, the problem consists in reducing vapour diffusion into internal layers of the wall and in removing moisture that penetrated inside the structure. With this end in view vapour-insulated layers are designed, which should be arranged as close as possible to the internal surface of the wall. It is permissible to use thermal insulation on internal side solely, if a reliable vapour barrier on indoor side is available, which is difficult to attain in practice.

Translucent enveloping structures

The new generation of window structures is based on the use of single and double chamber window insulating glass units, which permit essential increase in the level of thermal performance compared to previously manufactured translucent structures. The use of glasses with selective coating in the glass units increases the window unit thermal resistance to 0.6-0.65 m^2*^oC/W. Problems of the folds sealing are solved at a qualitatively new level.

Introduction of windows in plastic sash, featuring improved thermal performance, into the practices of domestic construction resulted in a number of blunders in thermotechnical designing of facades and mounting of translucent openings. One of blunders made during initial introduction of the windows stems from a low, within 50-55 mm, thickness of plastic sash pulleys, resulting in zones with decreased temperatures on internal surfaces of window jamb giving rise to condensate settling out or even freezing. Selection of a thicker translucent structure, at least 80 mm thick, and its arrangement in the sash pulley to the depth of the frame "quarter" from the wall facade plane, filling the space between the window casing and internal surface of the quarter by foaming thermal insulation material, were necessary to eliminate the blunder made.

Other errors pertain to insufficient account of the windows air permeability. Rated air permeability for filling translucent openings with windows in wooden sash equals 6 $kg/(m^2*h)$, in plastic sash – 5 $kg/(m^2*h)$ at 10 Pa pressure drop, moreover, the value was set, bearing in mind the air permeability of the window casing adjoining the wall. Results of certification tests of windows in plastic sash suggest that air permeability of the folds of the window opened elements is within 0.5 – 2 $kg/(m^2*h)$. Decreased air permeability of folds in the windows in plastic sash (as well as in the newest types of windows in wooden sash) and high degree of sealing the windows adjoining the wall involve insufficient air exchange and, accordingly, increased humidity in the apartments. Periodic aeration of the rooms is necessary to avoid the phenomenon; opening of a window or window leaf for 10-15 min assures the required air exchange and does not involve a noticeable heat loss. Meanwhile, today's window structures are already fitted out with ventilation controls (soundproof valves, specially arranged apertures in window contour, turn-drop devices, holders), which can provide any variant of the room aeration by the user wish.

For evaluating the influence of the enveloping structures on indoor air exchange the currently effective normative documents pertaining to the methods for defining the air permeability (GOST 25891-83, GOST 26602.2-99) shall be supplemented by new standards. The methods were taken up abroad, being reflected in some standards of foreign countries and in new standard ISO 9972.

Introduction of novel engineering approaches to thermal performance of buildings

The experience gained and outlooks for the development and introduction of new thermal– performance structures of buildings can be summed up by the following conclusion:

– New structural approaches to the enveloping structure, relying on the newest technologies including outinsulation systems, ventilated structure, punctual tie three-layer structures, along with experience gained in regions of the RF during the approaches implementation in practice, confirm their energy efficiency.

– New normative requirements stimulated national industry for manufacturing new promising building materials and products meeting the world standards and, specifically, for increase in output of high-quality effective thermal-insulated materials, energy saving enveloping structures and new types of energy efficient windows.

– Essential part of subjects of the RF, having comprehended the necessity to solve energy saving problems, is actively engaged in re-structuring of their construction industry, considering the new normative requirements. Regional standards, assuring the same energy saving effect as the one stipulated by federal standards, and taking into consideration the climatic, energy, construction and other regional features and potentialities of local construction industry, were elaborated and enforced. Approbation of the new rate setting ideology takes place in the regions.

– There are certain problems in the development and assimilation by production of the new engineering approaches relating to thermal insulation of exterior walls, providing low-cost but high-quality domestic thermal-insulated and other building materials in the regions. Overcoming of the difficulties necessitates systematic efforts.