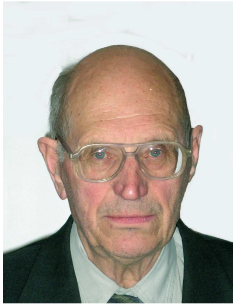
STRATEGY FOR SUSTAINABLE DEVELOPMENT IN THE BUILDING SECTOR OF RUSSIA, KAZAKHSTAN, AND UKRAINE



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Summary

The Russian Federation, the Republic of Kazakhstan, and the Republic of Ukraine continue to make important advances in developing and implementation of energy codes, market transformation, and design innovation in the building sector. A new generation of federal and regional codes on energy efficiency in buildings has taken effect in Russia. These codes, which mandate a reduction of at least 40 percent in energy consumption for heating, have led to the need for an increase of 2.5 to 3 times in thermal performance in new and renovated buildings. Since 2003 Kazakhstan and 2006 Ukraine have been explicitly following Russia's lead in moving to adopt and implement energy-saving building codes. As a result, a fundamental transformation has taken place, toward the production, sale, and use of energy-efficient construction materials and products, and changes in building design methods. Over the period from 2002 to 2006, the overall energy savings in Russia totaled more than 375 PJ. This has led to an almost 25.5-million-tonne reduction in carbon dioxide emissions. In the period from 2002 to 2010, the cumulative reductions are anticipated to rise to almost 1,200 PJ and more than 80 million tones of carbon dioxide in Russia alone. The paper describes these achievements and problems in implementation of these new systems and technologies.

Keywords: Building codes, energy efficiency, residential buildings, building envelope, thermal insulation

1 Introduction

Increasing energy efficiency of the buildings sector of Russia is a complex problem. Its successful resolution can be viewed in terms of national energy security and environmental protection, rational use of non-renewable natural resources, as well as mitigating the "greenhouse effect" by curtailing emissions of carbon dioxide and other substances into the atmosphere. The resolution of this problem is possible by combining work on energy efficiency in buildings [1], and work on energy efficiency in ventilation, heat delivery, and heat supply of buildings [2]. Such an approach corresponds with Russian policy, as the state has an interest, ultimately, in reducing consumption of primary fuel and energy resources – the strategic bases of its long-term existence and sustainable development.

2 A short history of the creation of building energy codes in Russia

The Research Institute for Building Physics of the Russian Academy of Architectural and Construction Sciences (known by its Russian initials as NIISF), together with an array of Russian organizations, the Russian State Construction Committee (Gosstroi RF) and regional executive agencies, has developed, approved, and implemented new approaches to building energy codes. First, in 1992-93, with the participation of specialists from the United States, a new ideology of building codes was developed from the point of view of energy [3], then in 1994 Russia's first regional code was developed and approved, for the city of Moscow. In 1995, fundamental amendments were introduced into the federal code on building thermal engineering, providing for a 20 percent reduction in energy consumption for heating, and 40% starting in 2000. From 1998 to 2003, NIISF and the Institute for Market Transformation (IMT) [4] and regional specialists around Russia developed and implemented regional building energy codes in more than 50 regions of Russia. Among these, a new edition of the energy code was developed and confirmed for the city of Moscow (MGSN 2.01-99). On the basis of the experience gained in the regions of Russia, a new national building code, SNiP 23-02-2003, "Thermal Performance of Buildings" [5] was developed and adopted in 2003, as well as the accompanying design manual Code of Practice SP 23-101-2004 "Design of Thermal Performance of Buildings " [6].

As a result, a new generation of the system of codes and regulations was created on the design and operation of buildings with efficient use of energy, providing for a reduction of 40 percent in energy consumption for heating, starting in 2000. This has led to the need for an increase of 2.5 to 3 times in thermal performance in new and renovated buildings in Russia. An array of standards and energy documentation requirements (“Energy Passports”) have provided for energy audits and verification of code compliance. The new codes are harmonized with international levels and, in particular, their parameters for energy efficiency have been made consistent with the requirements of the laws (directives) of the European Union - directives 2002/91/EC [7] and 93/76 SAVE.

3 Fundamentals of Russian building energy codes

Four principles are key for creation of energy-efficient buildings:

- first, selection of a geometric shape for the building that reduces heat losses;
- then reduction of demand for energy by selecting thermal-performance level, including reduction of air permeability;
- provision of required air exchange with the help of organized air intake;
- and, finally, meet remaining needs for energy in the most effective manner.

In selecting the level of thermal performance for a building, one must observe code requirements for specific energy consumption by the building over the heating season which are from 70 to 85 kJ/($m^2 \cdot {}^oC \cdot day$) depending of a number of storey of the buildings

[5]. According to the underlying principles, it is a completely new document in its structure and area of applicability, as well as the criteria established by it for thermal performance, methods for oversight, the character and level of energy auditing, and its correspondence with European standards. In design of thermal performance, in each case the following calculation tasks are carried out in sequence:

1. For a given category of energy efficiency of the building, ***A***, ***B*** or ***C*** [8], the code-stipulated value for specific energy consumption is determined for the type of building being designed, and degree-days are calculated for the relevant region.

2. Through a variety of options, the code-stipulated level of thermal performance is calculated for separate elements of the building envelope, either on the basis of a whole-building energy consumption requirement, or on the basis of a prescriptive table of thermal-resistance values or formulae for individual elements. In either case, the design value of specific energy consumption for the heating season is defined, and an Energy Passport is completed for the building for verification of compliance of calculated values with code-stipulated values.

3. The overall thermal resistance of the designed building envelope is calculated, the result is compared with the level defined in task 2 (see preceding paragraph), and changes to the design are carried out as necessary. In addition, moisture protection (vapor barrier) and air permeability are determined and compared with code-stipulated values.

4 The level achieved

Real results have already been achieved in the direction of energy efficiency. The codes provide for a 40 percent reduction in demand for energy for heating by newly introduced and renovated buildings, since 2001. The building sector has been completely transformed and has made the transition to observance of these codes. Over the period from 2001 to 2004, 235.9 million square meters of residential housing were introduced, including: in 2001 – 31.1, in 2002 – 33.7, in 2003 – 36.3, in 2004 – 41, in 2005 43.6, and in 2006 50.2 million square meters. All buildings built over this period were designed in compliance with new federal and regional energy-conserving codes. Over the period from 2002 to 2006, the calculated overall energy-conserving effect in terms of fuel constituted almost 375 PJ (10.5 million tonnes in coal equivalent), which has also led to an overall reduction in emissions of greenhouse gases at a volume of 25.5 million tonnes of carbon dioxide. With the growth in the residential building stock, growth in energy expenditures for heating these buildings is inevitable. The opportune development of the new generation of energy-conserving codes and their implementation has put the brakes on this growth. Annual consumption in terms of fuel expended for the generation of heat energy in the heat-supply system up to the end of 2006 grew only by 201 PJ in comparison with 336 PJ, if these codes had not been introduced.

5 Codes of the Republics of Kazakhstan & Ukraine

New code has also been developed, and approved in the Republic of Kazakhstan (RK), and have introduced on November, 2004 [9] — one of the most successfully developing central Asian republics of the post-Soviet sphere. The rate of GDP growth of this republic over the past few years has not fallen below 10 percent per year, in comparison with 7 percent in Russia. Thanks to economic reforms and liberal laws, foreign investment in this republic has grown without cease, especially from western countries. The building sector is also growing mightily. But the RK has practically no base of codes of its own for the building sector. Buildings are being built in accordance with the expertise of construction companies hired by the future owner or investor, often according to the codes of the country where hired companies are based, or according to Russian codes. In this light, the government of the RK has set forth a goal of creating its own code for energy efficiency in buildings. The new code also includes performance targets for residential and commercial buildings that correspond to world levels, as well as methods for oversight and enforcement.

We have been developing this code in close collaboration with the Department of Technical Codes and New Construction Technologies of the Committee for Construction Affairs of the RK, under the support of the U.S. Environmental Protection Agency.

Ukraine too has developed, approved, and introduced on January, 2007 a new national code for energy efficiency in residential and commercial buildings [10]. This process was under the direction of the Ukrainian Ministry of Construction, Architecture and Communal Residential Services and Ukraine's Institute for Building Construction (Farenuk G.). NIISF, and IMT, under the support of the U.S. EPA, have offered consultation and training to assist this process.

Ukrainian authorities have integrated many of the resulting suggestions into the code. Because of these recommendations, the new Ukrainian code has included a performance-based compliance option, a calculation methodology similar to that of the Russian and Kazakhstani codes, energy-performance rating systems, and an Energy Passport documentation system. Expected energy savings relative to existing building stock will be about 40 percent, as in Russia and Kazakhstan.

6 Building envelope materials and design approaches

From a thermal-engineering point of view, people conventionally make a distinction between two general types of walls: single-layer and multi-layer.

In single-layer walls, appropriately lightweight aggregate concretes are used both for monolithic and for piece-by-piece applications with protective layers inside and out. As seen in work [11], such walls, with modified polystyrene- aggregate concretes applied to low thermal conductivity and low-sorption active composite binders (MPSB), are used for buildings in regions that have up to 6000-7000 degree-days in the heating season with wall thicknesses not more than 350-400 mm. The basic advantage of single-layer walls made of lightweight aggregate concrete is its high thermal homogeneity, as well as an expected service life of not less than 100 years. Its deficiency is limitation of applicability, based on degree-days in the heating season.

Multi-layer walls have achieved widespread market proliferation. These walls differ in the positioning of thermal insulation material – internally (three-layer) and externally (two-layer). The thermal-performance properties of multilayer wall elements depend to a large degree on the equilibrium moisture content of the thermal insulation; therefore it is necessary to proceed with great caution in determining the arrangement of insulation and water vapor-retarder layers. As a consequence of the difference in water vapor pressure across the wall unit, water vapor diffuses to the outside. Therefore the task in design of multilayer building envelopes is to weaken the diffusion of water vapor into the interior layer of the wall and to avoid the formation of moisture emerging inside the envelope.

With this goal, designers design water vapor retarder such that they must be positioned as close as possible to the interior surface of the wall. Use of thermal insulation starting from the interior wall is allowed only where there is a reliable water vapor retarder on the side facing the occupied area, which in practice is difficult to implement.

Three-layer walls with a thickness of 350-450 mm with polystyrene or mineral wool insulation 200-300 mm thick in the middle, with flexible ties, may be used in regions where the heating season has 6000-7000 degree-days. Multiple calculations to define the overall thermal resistance, taking account of three-dimensional temperature fields have shown that the coefficient of thermal homogeneity of such envelope elements is 0.67-0.8. The disadvantage of three-layer walls is their inapplicability to restoration.

Another type of three-layer walls is monolithic lightweight aggregate concrete with inside and outside lagging. This type is according to the Swiss technology by the “Plastbau” system. The specific of the construction system is the use of an encasement from cellular polystyrene, which is not removed after construction; hence the construction of the wall is three-layered, with the middle layer from the lightweight aggregate concrete. The width of the external primary lagging from cellular polystyrene is 150 mm; the internal layer (additional lagging) is 50 mm. From the inside the cellular polystyrene is protected by two layers of gypsum cardboard with width of 25 mm, from the outside – by a plaster with the width of 35 mm over the reinforcing fabric. The external and internal layers of the lagging are connected by still rods with the diameter of 2-6 mm at a distance of 200 mm from each other.

The basic advantage of two-layer walls is their usefulness for buildings built in regions without degree-day limits (up to 12000 degree-days). Two-layer walls are suitable for use in restoration, which is another advantage. A deficiency of two-layer walls, as with three-layer walls, is their low thermal homogeneity, because of the presence of thermal bridges. Another deficiency is that the expected useful service life of thermal insulation is not less than 30 years. But international experience shows that this service life may be doubled.

Two-layer walls have been developed in facade systems. Two variants of facade systems are generally used: 1) systems with external plaster layer or a protective outer layer of brick without an air space; and 2) systems with a ventilated air space, so call double wall.

Variant 1 is based on the use of thermal-insulation materials of a thickness up to 150 mm (mineral-wool or fiberglass slabs) and up to 250 mm (polystyrene slabs), affixed to the wall by rivets with steel tie elements and polyamide cartridges. Thermal insulation is protected from weather by a vapor-permeable fixative layer, equipped with a fiberglass net, and a decorative vapor-permeable layer (plaster or paint), or brick too. One peculiarity of this variant is the necessity of the use of safe, durable, compatible components, partially or completely eliminating cracking or breaking of insulation layers of the building façade. Stringent requirements also apply to corrosion protection of the rivets. A disadvantage of these systems is the necessity of assemble their only in positive Celsius outdoor air temperatures, which limits their use in warm season across Russia.

Variant 2 differs from variant 1 because of the absence of any limitation on the thickness of the insulation layer -- mineral wool or fiberglass slabs, which are also affixed to the wall with rivets. The insulation layer is protected by facade panels made of any of various materials, installed on metal elements affixed to the wall (steel, aluminum alloy, or a combination of the two). These metal elements substantially affect thermal homogeneity (thermal bridges). In addition, insulation is protected by a vapor-permeable sheet such as

TYVEK, installed on site. For organization of air movement throughout the space, intake and exit openings are included. Moreover, between the facade panels and the insulation there is an air space with a thickness of between 60 and 150 mm. To prevent the spreading of fire, every three stories the air space is closed with a non-flammable material. Another trait that makes such systems worthwhile is that they can be assembled year-round, which is very important for many regions of Russia, even though these systems are 20-25 percent more expensive than systems of variant 1.

The new generation of windows is based on the use of one- and two-chamber sealed glass units, which make it possible to increase the level of thermal performance relative to previously-produced fenestration. The use of windows with separated frames with a single pane and single-chamber sealed glass with selective coatings and argon fill increases the reduced thermal resistance of window units to as much as 0.65-0.72 $m^2 \cdot {}^oC/W$, and the very same window block with a two-chamber sealed glass unit, up to a 0.81-0.82 $m^2 \cdot {}^oC/W$. The code requirement in regions with 12,000 degree-days in the heating season is 0.8 $m^2 \cdot {}^oC/W$, and thus these windows satisfy the requirements of SNiP 23-02. On a qualitatively different level, the problem of sealing off drafts is solved, as a rule, by three bands of weather-stripping.

The brightest example is new technology for the production of windows with vinyl frames and sealed glass units made of K-glass (glass with a selective coating). Thus, for example, in the city of Moscow over one million square meters of mass residential construction is being introduced each year with windows with vinyl frames and sealed glass units. In comparison with solid wood-framed windows, windows with vinyl frames can provide for increased thermal performance properties as well as required levels of air permeability, and therefore are promising for construction of energy-efficient buildings.

Implementation in Russian construction practice of vinyl-framed windows with increased thermal performance has carried in its wake an array of errors in thermal-engineering design of facades of buildings and installation of window openings. One mistake of initial implementation of these windows was linked to the small (50-55 mm) thickness of window frame. In connection with this, on the internal surfaces of window slopes there emerge zones with lowered temperatures, which leads to the formation of condensate or even freezing. To eliminate this problem, it is necessary to choose a window with greater thickness of the frame (not less than 100 mm) and to place it in the window opening at one-quarter depth in from the facade of the wall (125 mm), filling the space between the window block and the internal surface of the "quarter" with foam insulation material.

7 Conclusions

As a result of the implementation of the new codes and standards, a fundamental transformation has taken place in the Russian building sector, toward the production, sale, and use of energy-efficient construction materials and products, and changes in building design methods. Kazakhstan and Ukraine have also started down the path blazed by Russia regarding energy codes. A new architectural form of widened buildings with a lower surface-area-to-volume ratio; buildings with monolithic-frame construction using lightweight aggregate concrete; energy-efficient windows with energy-efficient glass; external insulation systems with use of efficient thermal insulation; the double wall system; the use of regulated air intake systems; energy-efficient heating and ventilation equipment;

heat delivery systems for individual apartments – this is far from a complete list of design solutions under the influence of the new set of codes.

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