Abstract

The article deals with resource saving in the construction sector. The Russian Federation legal and regulatory requirements in the field of energy efficiency are analyzed. The necessity for applying resource saving construction technologies at different stages of the buildings and structures’ life cycle is proved. To ensure the energy efficiency, we suggest adoption of the technologies and materials based on the magnesia binder instead of traditional cement ones. It is especially useful in the field of insulation and finishing materials. The efficiency of the light frame enclosing structures based on gypsum sheet materials, significantly reducing the loads on the underlying supporting structures and the installation labor costs compared to with partitions and floors based on the traditional materials is shown. A new technology for construction of multistorey buildings with monolithic frames (“Early Loading” Technology), which takes into account the actual loads on the constructed load-bearing structures, and reduces the work periods significantly, is proposed.

Energy and resources saving is minimizing energy and resources consumption with the least negative structure impact on the environment. In construction, taking into account the principles of sustainable development, we should address all stages of the structure life cycle, from research and design to construction work, operation and disposal. Of course, at these stages, much attention should be given to the design. It is at the stage of design where, by choosing advanced design and technological concepts, we can achieve a significant reduction in total costs throughout the life cycle of the object.

The design stage which costs 5-9 % of the estimated project cost influences greatly (up to 50%) the construction stage and even more significantly the period of building operation. Detailed analysis of the design and construction

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stage degree influence on the building operation period is not carried out, but it is obvious that it is high enough; this is the case with the structure environmental impact assessment.

Unfortunately, little attention is paid to the construction processes design, both at drawing up flow charts and construction work planning stages.

According to statistics, the share of the construction is about 45% of the global energy consumption and 40% of the materials consumption.

There is a legal framework for the systematic work to improve buildings energy efficiency nowadays. Adopted on November 23rd, 2009, the Federal Law № 261 "On energy saving and energy efficiency improvements and on Amendments to the Certain Legislative Acts of the Russian Federation" outlined the legal regulation in the sphere of energy saving and energy efficiency. It is based on the following principles: effective and efficient use of energy resources; support and promotion of energy saving and energy efficiency; systematic and comprehensive events for energy saving and energy efficiency; energy saving and energy efficiency planning; using energy resources in the context of resource, production and technological, environmental and social conditions [1].

In 2011, the Russian Government issued a regulation "On approval of the Regulations, establishing energy efficiency requirements for buildings, structures and the rules for determining the class of apartment buildings energy efficiency". It establishes performance standards, which specify energy resources intensity in buildings, as well as requirements for the architectural, functional and technological, design and engineering works. Conditions, eliminating wasteful consumption of energy resources during buildings, structures and facilities construction should be provided. Based on the calculated and normative values of energy efficiency comparison (determining the deviation), the energy efficiency class included in the building energy performance certificate is determined.

As it was mentioned above, the current approach to energy efficiency in construction is one-sided and aims at resources conservation mainly at the stage of facility operation and does not take into account the design, construction and disposal stages. Thus, the problem is more complex and it cannot be solved by working only in one direction, for example, only reducing energy loss in buildings and structures operation [2-4].

To obtain notable results, complex solutions for building energy efficiency should be implemented throughout all stages of the structure life cycle. At the design stage, effective frames and materials should be applied, in particular, materials extracted and processed in the region that will significantly reduce transport and construction costs. The share of composites based on the traditional cement binder (concrete, mortar, etc.) should be reduced due to the high energy intensity of its production, in favor of alternative binders, such as gypsum or magnesia binder.

Magnesia binder is a two-component material. The first component is a caustic magnesite (MgO) which is a product obtained by natural magnesite (MgCO₃) calcination at the temperature of 750-1000 °C, followed by grinding to a powder. The second component includes water-salt solutions (MgCl₂, MgSO₄, FeSO₄, etc.) called mixing water. An artificial stone material, characterized by rapid hardening and high strength [3] is formed when mixing caustic magnesite with water-salt solutions [5-7].

Many domestic and foreign scholars point out that the properties of materials and products based on caustic magnesite are better than those based on the Portland cement [8,9]. They do not require humid storage under hardening; provide good fire resistance and low thermal conductivity, wear resistance, compressive and bending strength. Magnesium concretes have high elasticity, early strength, lightness, resistance to oils, greases, paints and lacquers, salts, they also possess bactericidal properties, etc. [10-12]

Magnesia binder is widely spread in construction as a material for the various building products manufacturing. Currently, insulating and finishing sheet materials are mainly produced, based on the magnesia binder. In particular, the production technology of thermal insulation materials based on magnesia binder and wood wool is widely known. These materials are widely used for the producing various kinds of finishing, facade and even concrete work, though the latter require special waterproofing.

Glass magnesium panels, which are the analogs for magnesia materials, such as gypsum panels and gypsum-fiber sheet, having lower physical and mechanical properties and long-term operating experience, are also widely used now.

However, the magnesia binder is widely used mainly as the basis for the durable and wear-resistant flooring. These floors have a wear resistance, dust-free and decorative properties, which provide a wide range of applications.
As for the raw materials, and particularly in Russia, it is unique in terms of total reserves and the size of some deposits. There are significant crystalline magnesite reserves in such Russian regions as: Chelyabinsk Region, Republic of Bashkortostan, Krasnoyarsk Territory, Irkutsk Region, Chita Region and others.

Despite the large number of the explored deposits in the Russian Federation, magnesia raw material extraction is carried out only in Satka, Kirigeysk and Kuldur fields. According to the data for 2010 only Satka deposit of crystalline magnesite (Chelyabinsk region) is used on an industrial scale [12].

Unfortunately, in spite of the huge reserves of primary minerals and secondary raw materials in the domestic construction sector, materials based on magnesia binders are not widely used for a number of reasons. First of all, it is the lack of domestic production of specialized construction magnesia binder, high production standards and application limited by low water resistance of many magnesia materials.

However, we can observe a completely opposite situation with building materials and technologies based on gypsum binder. Its major manufacturer and supplier in Russia is the KNAUF company, a leading European gypsum-based materials manufacturer.

The raw material, for producing KNAUF materials and products, is gypsum – an odorless natural mineral material, which contains no toxic components or substances. It is non-combustible and fire resistant, it has a high vapor and gas permeability, which increases the comfort for living and working in rooms decorated with gypsum products, and has the acidity pH = 5.5, which corresponds to the human skin acidity. Nowadays, the worldwide raw gypsum reserves, by various estimates, account for more than 7.5 bln. tons, and half of these reserves are extracted in Russia. This ensures the needs of construction sector, even with a substantial increase in the use of gypsum in building materials for many years to come [1].

An effective measure to reduce the consumption of materials in construction is the use of lightweight walling, which replaces the traditional masonry and reinforced concrete panels, significantly reducing the loads on the underlying supporting structures providing an opportunity to reduce the cross section of load-bearing elements or apply less durable construction materials. Thus, the dead loading in construction can be significantly reduced. In the case, a good example is the KNAUF complete systems in constructing a multistorey residential complex "Zapadnyj Luch" in Chelyabinsk. This project is a residential complex of four 24-storey buildings with complete infrastructure.

The main structural system of each building is a prefabricated monolithic frame with prefabricated reinforced concrete columns and openings at the level of ceilings, bearing monolithic reinforced concrete girders, binding monolithic reinforced concrete girders, prefabricated hollow flooring, stiffness diaphragms, precast elevator shafts, prefabricated staircases, ventilation units. The calculations produced have shown that the using Knauf lightweight walls instead of brick and cellular block, as well as the precast floor foundation instead of the screed of cement-sand mortar, reduces the dead load of the building structure by an amount sufficiently enough to add two more floors without strengthening the foundations and increasing the cross-section and improving physical and mechanical properties of the main load-bearing structural elements [13].

Further, in considering the construction stage of a building or structure, the most significant factor, influencing the power consumption, is the energy intensity and periods of production methods, so the preference should be given to building technology using complete systems with low labor intensity assembling, building composite materials gaining strength in the construction site without autoclave processing, as well as the energy-efficient methods of work production [15-18].

The technology of accelerated buildings construction with monolithic frame ("early loading" technology) can be considered to be the most promising one. It was developed at the Building Production Technologies Department of the South Ural State University [12,19]. The experimental studies on physical and mechanical properties of heavy concrete compositions, both in normal conditions and during early loading, the building construction simulation using the software complex "Lira" allowed to formulate the principles of the new construction method for multistorey reinforced concrete structures. The aim of this technology is accelerating the formwork turnover, work periods reduction and providing high quality of monolithic construction.

As a basic building material, concrete hardens rather slowly, it becomes a retarding factor in monolithic buildings construction. The study shows that the removal of columns and slabs shuttering in such buildings with subsequent structures loading is carried out in five to ten days after the concrete mix placement.
At the same time, modern technologies ensure the higher pace of floor level construction in multistorey buildings, compared to time requirements to achieve concrete stripping strength. Therefore, a possible pace of floor level construction is often at odds with the pace of concrete hardening and can lead to a situation when a few floor levels in a building have been erected, but the concrete strength is less than required. Moreover, it varies from floor level to floor level.

According to the design and construction specifications regulations (SP 63.13330.2012), structures should ensure bearing capacity, strength and stiffness of the building under loading in terms of the structural scheme changing and concrete strength [20]. Therefore, in addition to carrying out strength calculations in the design of load-bearing structures, especially columns (walls) and buildings ceilings, their load-bearing capacity should be checked at the construction stage [21]. It is determined by the sequence and pace of works, terms of concrete hardening, its physical and mechanical properties, types of formwork systems, climatic conditions, etc.

If we consider a specific example, according to the current technologies, it takes 23 days to erect a floor of a building, however, but the new technology requires 17 days with reducing the heat treatment and maturing time on each floor level to 2 days. While using the standard duration of a monolithic 11-storey building construction is 10 ... 12 months, the time reduction will be 26%.

Thus, the proposed technology allows to greatly reduce the cost of construction, as well as energy and labor cost, using the same technological equipment.

Nowadays, the problem of energy and resources saving is undoubtedly crucial for the future sustainable development of the civilization, and it cannot be solved without reducing energy and resources consumption in construction. The current approach to determining energy efficiency is based on the techniques of defining the power consumption during the construction operation, without regard to the cost of energy and resources at other stages of the building or structure life cycle. However, in the examples shown in this paper, you can see the way of significant resource savings using modern materials, designs and technologies. But in this case, the main problem is the developing the comprehensive methodology for evaluating and selecting optimal reduction of energy and other costs. The development of this technique is an urgent problem for modern construction science.

References