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Design solutions for thermal insulation of exterior walls of cast-in-place concrete high-rise residential buildings in central regions of Afghanistan

The article discuses the issue of high-quality performance of the technical and thermomechanical characteristics of the external walls of monolithic multi-storey residential buildings in the central regions of Afghanistan from the point of view the location of insulation and various methods of installing insulation systems. Several methods were considered (external wall with insulation located inside the structure, design of external walls with insulation located outside the building, design of external walls with insulation located inside the building). It is concluded that the structure of external walls with insulation outside the building has advantages in the construction of monolithic multi-storey residential buildings and is recommended in new buildings or reconstruction of residential buildings.

Keywords: constructive solutions, thermal engineering, energy efficiency, monolithic, residential buildings, foamglass, Afghanistan, exterior walls.

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ПРОЕКТНЫЕ РЕШЕНИЯ ДЛЯ ТЕПЛОИЗОЛЯЦИИ НАРУЖНЫХ СТЕН ВЫСОТНЫХ ЗДАНИЙ В ЦЕНТРАЛЬНЫХ РЕГИОНАХ АФГАНИСТАНА

В статье рассмотрен вопрос качественного выполнения технических и термомеханических характеристик наружных стен монолитных многоэтажных жилых домов в центральных регионах Афганистана с точки зрения расположения утеплителей и различных способов установки систем утепления. Рассмотрено несколько методов (внешняя стена с изоляцией, расположенной внутри конструкции, проектирование внешних стен с изоляцией, расположенной снаружи здания, проектирование внешних стен с изоляцией, расположенной внутри здания). Сделан вывод, что конструкция наружных стен с утеплителем, находящаяся вне здания, имеет преимущества при строительстве монолитных многоэтажных жилых домов и рекомендуется в новостройках или при реконструкции жилых домов.

Ключевые слова: конструктивные решения, теплотехника, энергоэффективность, монолитный, жилые дома, пеностекло, Афганистан, наружные стены.

Introduction

Residential construction in the central regions of Afghanistan features with congestion and high energy costs for building maintenance, thus, improving the energy efficiency of multi-story residential buildings is relevant for construction.

A significant part of the total heat loss premises make up heat loss through the building envelope (enclosing structures). According to experts, the surface area of external walls with thermal insulation is approximately 65% of the total area building envelopes of a multi-story residential building, because of this, insulation of external walls is one of the main measures for thermal insulation of a building, since depending on the design of the walls through them, up to 45% of heat is lost during operation of the building [1]. Thermal protection of the exterior walls of buildings is a key issue in ensuring the thermal characteristics of the enclosing structures of multi-story residential buildings. Thermal protection of building envelopes is carried out by various methods, using various materials and technologies.

Waste heat from various parts of the building can see in Illustration 1.

As you can see from the above figure that heat loss from external walls, In one-story residential building, about 30% with the increase in floors, the building also increases Up to 45% heat loss from external walls. So to prevent heat loss in buildings Exterior walls must be heat insulated, Therefore,

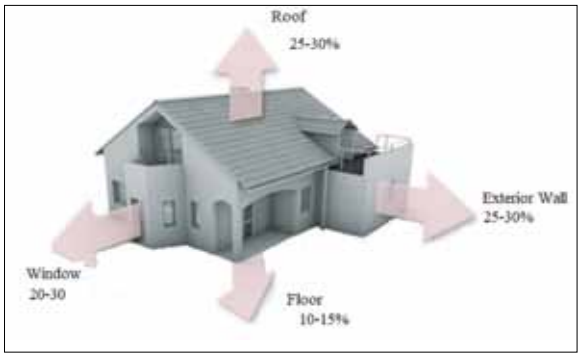

Illustration 1. Approximate information about heat loss from the various structures of the building a residential constituency. Course lecture Architecture and building physics. Aauthor: M. Sliman Osmankhil. Source: http://afg-eng.blogfa.com/post/26

for this purpose, it is necessary to insulate the external walls properly, so I started researching on the topic.

The suitable method of thermal insulation of external walls monolithic multi-storey building in Afghanistan

It is noteworthy that already had been work on this issue. We followed the work that was done before us like O.L. Bancerova, Li Juysin, O.G. Chesnokova, B.D. Chesnokova, T.F. Cherednichenko, Mohammad Omar Temori — How to use energy in residential buildings.

Research Methods:

The amount of heat that goes through the hard wall Which is surrounded by two parallel surfaces is obtained by the following formula

$$Q = K\left(t_B - t_H\right)\cdot F \cdot Z$$

Q — The amount of heat in Kcal
t_B — Air temperature inside is surrounded by 0 °C
t_H — Air temperature on the outside is around 0 °C
Z — Heat transfer time to hr
F — The area of the leading surface is surrounded by m²

K — Heat transfer coefficient surrounded by $\frac{KCal}{M^2 \cdot hr \cdot °C}$

Heat transfer coefficient is the amount of heat (Kcal) that per hour passes through one square meter of 1 m² area if the difference in air temperature from both sides of the area is equal to one degree Celsius.

$$K = \frac{Q}{\left(t_B - t_H\right)\cdot F \cdot Z} = \frac{KCal}{M^2 \cdot hr \cdot °C}$$

The inverse quantity of the heat transfer coefficient «K» is called the heat transfer resistance and is denoted by the letter «R0».

$$R = \frac{1}{K}\cdot\left[\frac{M^2 \cdot hr \cdot °C}{KCal}\right]$$

In the case of heat transfer through the enclosure from the inner surface to the outer surface, heat degradation occurs not only in the enclosed building material but also near the surfaces.

The explanation for this is that the process of heat transfer consists of the following three sequential steps:

1 — Obtaining heat
2 — Heat penetration
3 — Heat dissipation

Using the listed formulas and graphical methods of a building physicist we found Illustration 2.

In accordance with the location of the insulation, structural solutions for thermal protection of external walls are classified according to three main types:

1 — Design of external walls with insulation located inside the building.

2 — External wall with insulation located inside the structure.

3 — Designof external walls with insulation located outside the building (Illustration 1) [2].

Currently, in the central regions of Afghanistan, the above types of thermal protection of the external walls are used. Next, we consider their heat engineering and technical features.

The design of the exterior walls with insulation located inside the building

Currently, this type of thermal protection of the outer walls is most often used in the central regions of Afghanistan. With this location of the insulation various materials are used: calcareous solutions, polymer solutions, etc. This technology is widespread in Afghanistan, but it has the following disadvantages: Due to the temperature difference and dew point displacement, cracks in the plaster are formed [3]. In addition, this location of the insulation negatively affects the architectural and artistic organization of the interior of the room. Insulation placed indoors must meet the following requirements [4]:

a) be made of non-combustible or hardly combustible materials;

b) have good characteristics of ensuring the health of residents;

c) to have low density, strength and hardness for fixing embedded parts in the bearing layer of the outer walls.

According to the method of installation of insulation from the inside of the room two methods are distinguished: gluing and anchoring (Illustration 2) [4].

When bonding insulation, the following heat-insulating materials are used: autoclaved aerated concrete blocks, foam glass, extruded polystyrene foam (XPS), expanded polystyrene foam (EPS), etc.

Expanded polystyrene is an effective heat-insulating material in the installation of insulation indoors and is widely used throughout the world, but in central Afghanistan, XPS has not yet found use.

According to this method, based on the experience of large cities in Afghanistan (Kabul, Mazar, Hirat), are offered the following designs with different insulation (Table 1, 2).

Installation of insulation with the help of anchors is carried out on a profile frame with an additional protective plate. Mineral and vegetable fibrous heat-insulating materials are used as insulation, which are characterized by a low coefficient of thermal conductivity λ (not more than 0.05 W/m · K) and a flame-retardant property [5].

Previously, gypsum board was used as a protective layer of the plate, now the following materials are widely used: cement fiber (fiber cement) panel (FC), panel calcium asbestos-free silicates (NALC), asbestos-free fiber cement board (NAFC) and non-tensile fiber cement board (LCFC) (Table 3).

Requirements for the anchoring of insulation: when using profiles of wood or gypsum materials, installation of profiles (width 50 mm) in increments of 600 mm on one or both sides. Wood profiles must be treated against corrosion; when using gypsum plasterboard, its thickness should be at least 100 mm, and for NALC and NAFC boards — at least 60 mm; when performing high-quality putty on protective boards for drywall, masking tape (width not less than 100 mm) at the joints of the boards should be applied. On the FC, NALC,

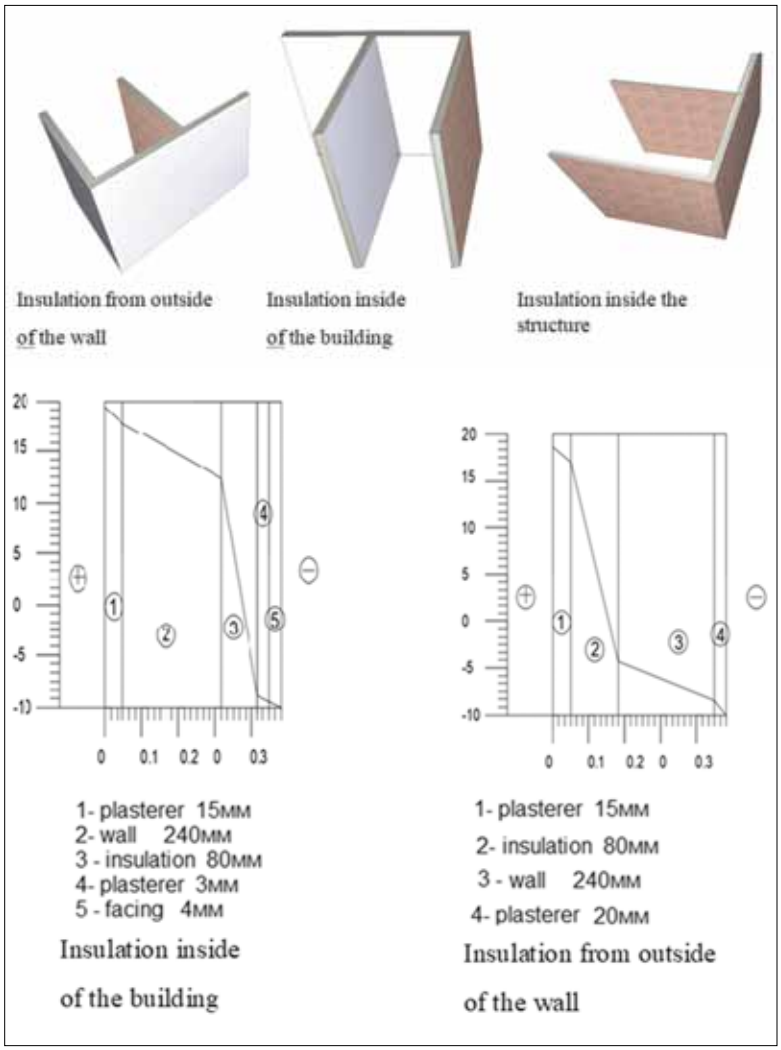

Illustration 2. Types of insulation distribution for exterior walls. Source: developed by the author

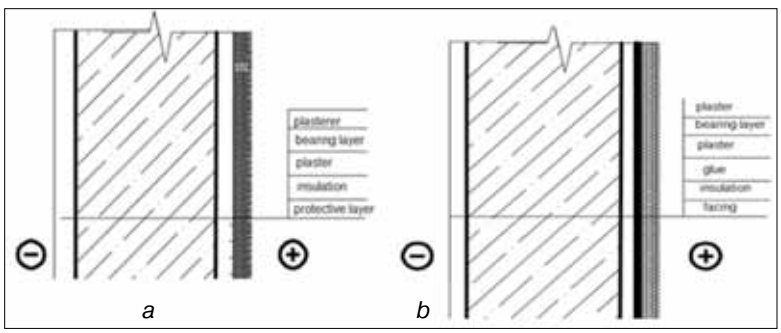

Illustration 3. Methods of installation of insulation: gluing (a) and anchoring (b). Source: developed by the author

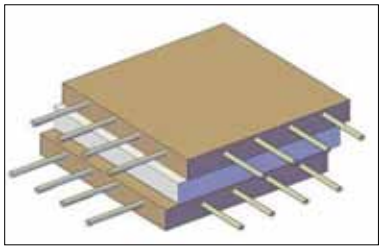

Illustration 4. Fixed formwork EVG-3D. Source: developed by the author

NAFC, and LCFC boards, masking nets (60 mm wide) should also be attached to the gaps between the boards [7].

External wall with insulation located inside the structure

There are two options for ensuring the required thermal characteristics of the external walls: wall without insulation made of autoclave concrete and the EVG-3D panel with insulation.

If the creation of such a multilayer wall is successfully implemented in new construction, then for existing buildings it's difficult because it causes an increase in the thickness of the structure, which often requires reinforcing the foundation. In the first embodiment, such walls are made of cellular concrete blocks or panels in a special solution. Due to the fact that the walls themselves have high coefficients of resistance to heat transfer and thermal inertia, the installation of insulation on the outside or inside the walls is optional.

Autoclaved concrete blocks have a small coefficient of thermal conductivity and a large coefficient of heat absorption. Thus, the effectiveness of thermal protection of the outer walls of autoclaved aerated concrete is confidently ensured when the standard thickness is achieved. YTONG insulation product for exterior walls is the most common in Afghanistan at present (Table 4).

This method meets the minimum requirements for heat transfer resistance of building envelopes in the conditions of the city of Kabul and was used in the last century, but it does not take into account the energy saving of a residential building and is not recommended in construction. In the second embodiment, the EVG-3D fixed formwork is carried out. The technology of construction using the three-layer panel «3D» is the use of wall panels (3D panel), representing a spatial truss,consisting of reinforcing mesh and galvanized or stainless steel rods, welded at an angle to the nets, a core of polystyrene foam and two concrete layers deposited by shot Crete (Illustration 3).

The heat engineering property of EVG-3D is given in Table 5.

The design of the exterior walls with insulation located outside the building

With this method of thermal protection at present in large cities of Afghanistan (Kabul, Parvan) the following heat-insulating materials for external heat insulation are distributed: extruded polystyrene foam (XPS), expanded polystyrene foam (EPS), mineral wool, foam glass, warming solutions, etc. According to the technology of building an external insulation, the method of gluing, installation and monolithic concreting is distinguished. Thermal insulation materials for outdoor installation should be characterized by high heat transfer resistance R, weak thermal conductivity λ (less than 0.06 W/m · K) and good hygroscopicity.

Table 1. Minimum thickness dimensions of thermal insulation materials
Source: O. L. Bantserova, Li Juysin

№	Wall layer material	Thickness mm	Minimum thickness of heat-insulating material, mm		
			EPS	XPS	Foam glass
1	Silicate hollow brick	240	30	20	20
2	Concrete block with one row of voids	190	30	20	30
	Concrete block with two rows of voids	190	30	20	50
	Concrete block with three rows of voids	190	30	20	40
3	Concrete hollow block (8 voids)	240	30	20	25
		190	30	20	45
	Concrete hollow block (6 voids)	190	30	20	45
4	Reinforced concrete	200	30	20	40
		250	30	20	30

Table 2. Minimum thickness dimensions of autoclaved aerated concrete blocks
Source: O. L. Bantserova, Li Juysin

№	Degree of density		B04			B05		
	The ratio of the area of the blocks to the outer walls		≧ 0,70	≧ 0,50	≧ 0,30	≧ 0,70	≧ 0,50	≧ 0,30
	Wall layer material	Thickness mm	Block thickness, mm					
1	Silicate hollow brick	240	50	60	75	60	75	75
2	Concrete block with one row of voids	190	75	75	75	100	100	100
	Concrete block with two rows of voids	190	60	75	75	75	100	100
	Concrete block with three rows of voids	190	60	75	75	75	75	100
3	Concrete hollow block (8 voids)	240	50	60	75	60	75	75
		190	60	75	75	75	75	100
	Concrete hollow block (6 voids)	190	75	75	75	75	100	100
4	Reinforced concrete	200	100			100		
		250	75			100		

Table 3. Characteristics of protective plates [7]
Source: O. L. Bantserova, Li Juysin

Name of materials	Plate FC	Panel NALC	Plate NAFC	Plate LCFC	Plasterboard plate
Density ρ, kg/m^3	1600…1700	900…1100	1500…1900	1100…1300	800
Tensile strength, MPa	17…20	8…12	10…13	10…16	> 50 kg longitudinally; > 25 kg transverse
Impact strength, kJ/m^2	2,0…2,5	2,0…2,5	≧ 2,7	≧ 2,0	10 kg from a height of 1 m
Shrink %	—	≦ 0,20	—	—	—
Extension %	—	—	—	≦ 0,20	—
Water absorption, %	20…24	—	20…24	—	—
Fire Resistance Category	Grade A in accordance with GB8624				0,15…0,25 h
Thickness mm	4…25	6…12	4…25	5…25	9; 12

Table 4. Characteristics of the materials of the YTONG system in accordance with DBJ/CT018–2008 [8]

The degree of density of blocks and slabs of autoclaved aerated concrete	B05	B06
Density in the dry state ρ, kg/m^3	≦ 550	≦ 650
Estimated coefficient of thermal conductivity λ, W/(m · K)	0,18	0,20
Estimated heat absorption coefficient S, W/(m^2 · K)	2,73	3,28

Table 5. Characteristics of the EVG-3D system in accordance with DBJ/CD01–2004 [9]

Construction	Wall thickness mm				*K*, $W/m^2 \cdot K$	*Kav*, $W/m^2 \cdot K$	*D*	Facade glazing coefficient f
	Expanded polystyrene	Concrete layer		Plaster on both sides				
		Outside	Inside					
Exterior wall	100	50	40	by 15	0,627	1,40	2,16	≦ 0,31
	100	50	40	—	0,641	1,47	1,79	≦ 0,27

Table 6. The minimum thickness of insulation with various wall designs
Source: O. L. Bantserova, Li Juysin

№	Wall layer material	Thickness mm	Minimum thickness of heat-insulating material, mm				
			EPS	*CIR	XPS	Mineral cotton wool	Foam glass
1	Silicate hollow brick	240	30	20	25	30	25
2	Concrete block with one row of voids	190	30	25	25	30	25
	Concrete block with two rows of voids	190	30	40	25	35	35
	Concrete block with three rows of voids	190	30	35	25	35	35
3	Concrete hollow block (8 voids)	240	30	20	25	30	25
		190	30	35	25	35	35
	Concrete hollow block (6 voids)	190	30	30	25	35	25
4	Reinforced concrete	200	30	30	25	30	30
		250	30	25	25	30	25

Note. *CIR — cement-lime mortar with polystyrene granules

Table 7

Type of thermal protection	Advantages	Disadvantages
The design of the exterior walls with insulation located inside the building	1. Simplicity of construction technology. 2. Underestimated requirements for the strength of insulating materials. 3. Low cost	1. The emergence of the bridge of cold. 2. Reducing the volume of premises. 3. The lack of external protection of the building envelope. 4. The appearance of cracks on the surface of insulating materials indoors
External wall with insulation located inside the structure	1. Good protection of thermal insulation materials. 2. Application of industrial construction methods	1. The emergence of the bridge of cold. 2. Large wall thickness. 3. Decrease in structural strength under seismic effects
The design of the external walls with insulation located outside the building	1. A wide range of applications. 2. Protection of the main structure of the wall and increase the degree of durability of the building. 3. Elimination of the cold bridge. 4. Ensuring temperature stability in the room. 5. Convenience during reconstruction. 6. Reducing the cost of heat-insulating materials. 7. In order to avoid damage to the insulation layer from finishing work	1. High requirement for the choice of thermal insulation materials. 2. High requirement for the compatibility of omponents. 3. High demands on durability and weather resistance. 4. The complexity of the work

Thus, you can select the following materials: extruded polystyrene foam (XPS), expanded polystyrene foam (EPS), mineral wool, glass wool, etc. (Table 6). In an external insulation system, expanded polystyrene foam (EPS) is more often used [10].

The insulation layer is fastened to the carrier layer with glue or hardware. To create a reliable adhesion of the bonding layers, a primer must be applied to the surface of the main wall. Also, to increase the stickiness and stability of gluing during the hardening period after installing heat-insulating materials, additional reinforcement with plastic dowels and nails can be carried out. In monolithic structures, the insulation is installed inside the wall formwork, and concreting is performed simultaneously with the installation of insulation. The creation of cladding on the surface of the insulation layers is carried out in different situations by various materials: polymer-cement mortar, cement mortar, facade tiles. Polymer-cement mortars with a thickness of 4... 7 mm are applied to the surface of the insulation with a reinforcing layer (paint mesh, metal mesh) [11]. Strengthening layer helps to increase the strength and stability of the plaster to avoid stress concentration and cracking on the surface. Cement mortars are applied with plaster on the surface of the insulation (mineral wool) 25... 30 mm with a reinforcing layer (metal woven mesh 50 × 50 × 1.8

mm). Cement plaster is applied in three layers. The lower and middle layers are made with a thickness of 10 mm, for the upper layer it is better to use a polymer-cement mortar with a thickness of 5... 10 mm [11]. The reliability of the cladding by gluing due to the influence of weather conditions is reduced. Therefore, facing with ceramic tiles is not recommended. Based on the experience of other large cities, Afghanistan and Russia offer the following structures for the construction of external walls.

A comparison of the advantages and disadvantages of these types of thermal protection is given in Table 7.

Conclusion

As a result of comparing the options, we see that the design of the outer walls with insulation, located outside the building, has advantages in the construction of monolithic multi-storey residential buildings and is recommended in new residential buildings or reconstruction of residential buildings.

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