Features of Calculation of Consumption of Fuel and Energy Resources for Heating of Temporary Buildings and Structures on Construction Area

Oleg Korol 1, Anna Dudina 1
1 Moscow State University of Civil Engineering, Yaroslavskoe shosse 26, Moscow, 129337, Russia

mr.korol@gmail.com

Abstract. The main issue of the study is the problem of increasing the efficiency of fuel and energy resources for heating temporary buildings and structures on the construction site. The current state system does not ensure adequate efficiency of the housing stock, which is increasingly manifested in the growing gap between the cost of operation of temporary buildings and structures aimed at ensuring the quality of their functioning and the real state of this quality. The aim of the study is a systematic integrated approach to solving problems to improve the efficiency of the block-container office and household purposes, which allows you to objectively, fully and accurately assess the relationship of economic and technical indicators. All the combined socially significant technical and climatic indicators of operational measures can become the basis of legislative regulation in the industry. On the basis of the analysis, it can be concluded that the design and space-planning features are slightly different from each other and retain the element composition of all the structures of the block-container. Thus, the generalized technical characteristics of the block-container for office and household purposes for further calculation of heat losses during heating of this type of construction are formed. Conclusions: the criteria for assessing the effective and safe operation of temporary buildings and structures on the construction site begin from the moment of design, on the principle of connecting several block-containers horizontally and vertically. Thus, the total consumption of fuel and energy resources for heating temporary buildings on the construction site will depend on the variable solutions for the combination and arrangement of block-containers among themselves.

1. Introduction

In the preparatory period of construction, one of the important points of the construction site is the installation of temporary buildings and structures for the needs and maintenance of construction production, [1-5].

The structure of temporary buildings and structures includes the following buildings: household buildings for recreation, heating, and drying of workers’ clothes, a dressing room building, a building for eating (dining room), an administrative block, toilets, buildings of material and technical warehouse heated and unheated, a security post. The temporary building is a mobile collapsible construction of individual elements – typical block-containers of factory production. Due to the unified fastening and connecting elements, container blocks are formed into a modular building in the longitudinal and transverse direction, as well as installed on several floors, [6-10].
Modular buildings are provided with the possibility of installing utility networks when docking a block-containers: power supply, heat supply, water supply, sewage, ventilation [11], thereby addressing one of the major energy consumers of the infrastructure elements of the construction site, [12-17].

2. Materials and methods
To analyze thermal characteristics of block-containers, home and office purpose used the most common technical solution based on the study design features of block-containers of various manufacturers, [18-19].

On the basis of the analysis, it can be concluded that the design and space-planning features are somewhat different from each other and retain the elemental composition of all the structures of the block-container. Thus, the generalized technical characteristics of the block-container for office and household purposes (table 1) for further calculation of heat energy losses for heating of this type of construction.

**Table 1. Technical characteristics of re-use of block-containers for office and household purposes**

| Name of characteristic | Description |
|------------------------|-------------|
| Space-planning         |             |
| characteristics        |             |
| External size (m):     |             |
| - length – 6.000       | - length – 5.768 |
| - width – 2.430        | - width – 2.198 |
| - height – 2.590       | - height – 2.295 |
| Internal size (m):     |             |
| Construction volume, m³ | 37.76        |
| Walls                  |             |
| - external cladding – shaped galvanized sheet C-8, 0.5 mm thickness; | |
| - wind moisture protection (film 80 MKR); | |
| - mineral wool, 100 mm thick (density 37 kg/m³), laid in a crate (board 40x100 mm); | |
| - vapor barrier Izospan; | |
| - interior finish – laminated chipboard 10 mm thick (density 690 kg/m³). | |
| Ceiling (roof)         |             |
| - external cladding – shaped galvanized sheet C-8, 0.5 mm thickness; | |
| - wind moisture protection - plastic film; | |
| - mineral wool, 100 mm thick (density 37 kg/m³), laid in a crate (board 40x100 mm); | |
| - vapor barrier Izospan; | |
| - interior finish – laminated chipboard 10 mm thick (density 690 kg/m³) or PVC panel. | |
| Floor                  |             |
| - external cladding – shaped galvanized sheet C-8, 0.5 mm thickness; | |
| - wind moisture protection (film 80 MKR); | |
| - mineral wool, thickness 100 mm (density of 37 kg/m³) laid in a crate (board 40x100 mm); | |
| - vapor barrier Izospan; | |
| - floor plate – cement particle board, thickness 20 mm; | |
| - floor covering – PVC floor covering (linoleum) soldered at the joints, thickness 2.0 mm. | |
| Window                 | - frame is PVC, one-part, 945x1200 mm, thickness: 24 mm (4-16-4). |
| Door                   | - double-sided plating galvanized, painted steel sheet, 2100x900 mm. |

To calculate the heat transfer resistance of the enclosing elements of the averaged model of a block-container for office and household purposes and heat loss through 1 m² fencing structures for the heating period was used software thermal Calculator enclosing structures, [20].

Operational requirements for the location of the block-container office and household premises are considered in relation to the following climatic conditions:
- cold five-day temperature with security 0.92: -25 °C;
- duration of the heating period: 205 days;
- average air temperature of the heating period: -2.2 °C;
- indoor temperature: 20 °C;
- operating condition of the room: B;
- number of degree-day heating period (GSP): 4551 °C•day.

**Figure 1.** Layer-by-layer construction elements of Wall

**Figure 2.** Layer-by-layer construction elements of Ceiling

**Figure 3.** Layer-by-layer construction elements of Floor
3. Results and discussions

The results of calculations on the values of heat transfer resistance are presented in table 2.

Table 2. Resistance to heat transfer of elements of repeated application of designs of block-container of office and household appointment

| Name of the block-container element | The calculated heat transfer resistance R, m²•°C/W |
|-------------------------------------|-----------------------------------------------|
| Wall                                | 1.75                                          |
| Ceiling                             | 1.75                                          |
| Floor                               | 1.82                                          |
| Window                              | 0.35                                          |

Next, the calculation of heat loss through 1 m² each of the enclosing structure during the entire heating period.

Due to the fact that the block-containers act as single elements, which are later completed in different ways in modular buildings of different space-planning forms, it is necessary to calculate the specific characteristic of the heat consumption of the block-container / modular building, which shows how much heat is lost per 1 m³ of heated building volume per unit time with a temperature difference of one °C – q (W/(m³•°C)).

The software used in the calculation of heat losses for the heating period does not take into account the allowance for the location of the enclosing structures in relation to the cardinal directions. For the calculation as an example, we take the location of the block-container according to figure 5.

Figure 5. Location of the block-container model in relation to sides of light
Calculation of heat loss of block-containers of office and household purpose for the coldest five-day period is made according to the formula (1) and is given in table 3:

\[ Q = F \times \left( \frac{1}{R} \times (t_{\text{int}} - t_{\text{ext}}) \times n \right) \]  

(1)

where:
- \( F \) – area of enclosing structures, m\(^2\);
- \( t_{\text{int}} \) – internal air temperature, °C;
- \( t_{\text{ext}} \) – the temperature of the coldest five days, °C;
- \( n = 1 \) – is the coefficient taken according to the position of the outer surface of the cladding relative to the outer air (according to table 4 STO (standard of organization) 00044807-001-2006 «Heat-shielding properties of building envelopes»);
- \( R \) – design resistance to heat transfer of structures (according to table 2).

### Table 3. Calculation for heat loss of block-container size 6000x2430x2590 for cold decreases

| Name       | Filler structure | Orientation | F, m\(^2\) | \( t_{\text{int}} \) | \( t_{\text{int-}t_{\text{ext}}} \) | Allowance, % | R, m\(^2\) °C/W | Q, W |
|------------|-----------------|-------------|------------|----------------------|-----------------------------|---------------|-----------------|------|
| Block-container | Ceiling 1 | 12.68 | 20 | 45 | 0% | 1.75 | 326.01 |
| Floor 6 | 12.68 | 20 | 45 | 0% | 1.82 | 313.47 |
| Wall 3 | S | 5.69 | 20 | 45 | 0% | 1.75 | 146.39 |
| Wall 4 | N | 5.69 | 20 | 45 | 10% | 1.75 | 161.03 |
| Wall 5 | W | 15.54 | 20 | 45 | 5% | 1.75 | 419.58 |
| Wall 2 | E | 13.27 | 20 | 45 | 5% | 1.75 | 358.34 |
| Window (2 pcs.) | E | 2.27 | 20 | 45 | 5% | 0.35 | 306.18 |
| Total building heat loss | 2030.99 |

The specific characteristics of the consumption of thermal energy in W/(m\(^3\)•°C)

\[ 1.195 \]  

\[ (=2030.99/(4\times5\times37.76) \]

Next, we will calculate the heat loss for the entire heating period (table 4) on the basis of the data obtained using the software thermal Calculator enclosing structures (figure 6).

### Table 4. Calculation for heat loss of block-container size 6000x2430x2590 for whole heating period

| Name       | Filler structure | Orientation | F, m\(^2\) | Heat losses during the heating season, kW•h per 1 m\(^2\) | Allowance, % | Heat losses during the heating season, kW•h |
|------------|-----------------|-------------|------------|----------------------------------------------------------|---------------|----------------------------------------|
| Block-container | Ceiling 1 | 12.68 | 62.36 | 0% | 790.60 |
| Floor 6 | 12.68 | 59.86 | 0% | 758.91 |
| Wall 3 | S | 5.69 | 62.36 | 0% | 355.00 |
| Wall 4 | N | 5.69 | 62.36 | 10% | 390.50 |
| Wall 5 | W | 15.54 | 62.36 | 5% | 1017.53 |
| Wall 2 | E | 13.27 | 62.36 | 5% | 869.02 |
| Window (2 pcs.) | E | 2.27 | 315.81 | 5% | 752.07 |
| Total building heat loss during the heating season | 4933.64 |
Modern economic conditions require construction companies to promptly prevent, identify and manage risks in various fields of activity. At the same time, the results of the study demonstrate the availability of opportunities for further development. Among the key areas for development are the following: the process of integrating risk management into the company's development strategy, the collection and accumulation of statistical data, interaction between departments, the involvement and active participation of key stakeholders, as well as the quality of information about key risks, [21-27].

The calculations and analysis of heat loss for different types of enclosing structures of temporary buildings from block-containers used on the construction site during the construction of objects revealed that the greatest heat loss occurs through the Windows and is almost twice the total heat loss through the walls, ceiling, and floor (figure 6).

![Figure 6. Heat losses during heating period per square meter of various types of enclosing structures, kWh](image)

In comparison with traditional one-storey residential buildings, the closest the space-planning, and constructive solutions, for example, a total area of 50 m², the specific characteristics of the consumption of thermal energy which is 0.579 W/(m²•°C), the building of block-containers have specific consumption of thermal energy per 1 m³ is equal to 1.195 W/(m³•°C), which is 2.06 times more.

4. Conclusions
Temporary office and commercial buildings on the construction site during the construction of buildings are most often a model of block-containers. Due to the features of space-planning and design solutions, these buildings have significant heat losses during operation, especially in winter. The consumption of fuel and energy resources for heating of one block-container with a total area of 15 m² and 37.76 m³ area for the whole heating period average 4933.64 kW, which is several times higher than the required values for the traditional low-rise buildings of a permanent appointment.

Design of temporary buildings for the needs and provision of construction production can be carried out on the principle of connecting several block-containers horizontally and vertically. Thus, the total consumption of fuel and energy resources for heating temporary buildings on the construction site will depend on the variable solutions for the combination and arrangement of block-containers among themselves.

References
[1] A. Pleshivtsev, O. Korol, R. Barkhi, Risks on optimization of life cycle of technology of installation of transformed low-rise buildings from sandwich panels, MATEC Web of Conferences, Volume 251, 06024 (2018),
DOI: https://doi.org/10.1051/matecconf/201825106024.

[2] E. Lyapuntsova, Yu. Belozerova, I. Drozdova, O. Korol, Safety in construction in the field of investment in urban infrastructure, E3S Web of Conferences, Volume 97, 06034 (2019), DOI: https://doi.org/10.1051/e3sconf/20199706034.

[3] O. Korol, The impact of energy-corrective measures at the design stage of construction projects, MATEC Web of Conferences, Volume 193, 05057 (2018), DOI: https://doi.org/10.1051/matecconf/201819305057.

[4] M. E. Dement’eva, Metodologiya prinyatya resheniy pri ekspluatatsii ob”ektov nedvizhimosti [Methodology of decision-making in the course of using real estate objects], Vestnik MGSU – MSUCE Bulletin, 2015, No. 4. Pp. 158–165.

[5] O. Korol, N. Shushunova, D. Lopatkin, A. Zanin, T. Shushunova, Application of High-tech Solutions in Ecodevelopment, Journal MATEC Web of Conferences, Volume 251, 06025 (2018). DOI: https://doi.org/10.1051/matecconf/201825106002.

[6] E. A. Korol, S. V. Komissarov, P. B. Kagan, S. G. Arutyunov, The solution of problems of organizational and technical modeling of construction processes, Industrial and civil construction, № 3, pp. 43-45, 2011.

[7] V. Burkov, I. Burkova, R. Barkhi, M. Berlinov, Qualitative Risk Assessments in Project Management in Construction Industry, Journal MATEC Web of Conferences, Volume 251, 06027 (2018), DOI: https://doi.org/10.1051/matecconf/201825106027.

[8] V. G. Borkovskaya, D. L. Passmore, Behavioral engineering model to identify risks of losses in the construction industry. In D. B. Solovev (Ed.), Smart Technologies and Innovations in Design for Control of Technological Processes and Objects: Economy and Production - Proceeding of the International Science and Technology Conference “FarEastCon-2018”, Volume 1, pp. 243-250, 2019 (Smart Innovation, Systems and Technologies; Vol. 138). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-3-030-15577-3_24.

[9] V.G. Borkovskaya, Complex models of active control systems at the modern developing enterprises, Advanced Materials Research (Volumes 945-949). Chapter 22: Manufacturing Management and Engineering Management, 3012-3015 (2014), DOI: 10.4028/www.scientific.net/AMR.945-949.3012.

[10] V.G. Borkovskaya, Environmental and economic model life cycle of buildings based on the concept of "Green Building", Applied Mechanics and Materials 467. Materials Science and Mechanical Engineering. Chapter 2: Building Materials and Construction Technologies, pp 287-290, December 2013, DOI: 10.4028/www.scientific.net/AMM.467.287.

[11] http://zavodmz.ru/catalog.php?i=9 online: 06/2019.

[12] S. D. Sokova, N. V. Smirnova, A. V. Smornov, Mathematical approach to solving the problem of the choice of waterproofing of underground parts of buildings and structures, Moscow: Nauchnoe obozrenie, no 9, pp. 35-39, 2017.

[13] V.G. Borkovskaya, The concept of innovation for sustainable development in the construction business and education, Applied Mechanics and Materials, Volumes 475-476, Chapter 15: Engineering Management, December 201, Pages 1703-1706, DOI: 10.4028/www.scientific.net/AMM.475-476.1703.

[14] V.G. Borkovskaya, E. Degaev, I. Burkova, Environmental economic model of risk management and costs in the framework of the quality management system, MATEC Web of Conf., Volume 193, 05027 (2018), DOI: https://doi.org/10.1051/matecconf/201819305027.

[15] V.F. Kas’yanov, V. Danilchenko, V. Amelin, V. Tolmacheva, Environmental risk management. Forecasting and modeling of emergency risk management situations, Matec Web of Conferences, Volume 251 (2018), DOI: https://doi.org/10.1051/matecconf/201825106030.

[16] V.G. Borkovskaya, Project Management Risks in the Sphere of Housing and Communal Services, Journal MATEC Web of Conferences, Volume 251, 06025 (2018), DOI: https://doi.org/10.1051/matecconf/201825106025
[17] V. Borkovskaya, D. Passmore, Application of Failure Mode and Effects Analysis in Ecology in Russia, *MATEC Web of Conf.*, 193, 05027 (2018). DOI: https://doi.org/10.1051/matecconf/201819305026.

[18] http://zavodmz.ru/ online 06/2019.

[19] http://www.modul.org/ online 06/2019.

[20] https://www.smartcalc.ru online 06/2019.

[21] V. Polyakova, E. Degaev, P. El Haddad, Reduction of Ecological and Economic Risks in Utilization of Solid Domestic Wastes and Construction Waste, *MATEC Web of Conferences*, Volume 251, 06017 (2018). DOI: https://doi.org/10.1051/matecconf/201825106017.

[22] E. Degaev, A. Orlov, P. El Haddad, A. Pleshivtsev, Ecological and Economic Risks of Fire Protection of Warehouses and Tank Parks, *MATEC Web of Conferences*, Volume 251, 06013 (2018). DOI: https://doi.org/10.1051/matecconf/201825106013.

[23] E.A. Korol, The choice of the rational parameters of three-layer reinforced concrete inclosing structures with monolithic bond of layers by computer simulation, *IOP Conference Series: Materials Science and Engineering*, Volume 456, 012075 (2018), DOI: https://iopscience.iop.org/article/10.1088/1757-899X/456/1/012075.

[24] E. Korol, D. Mostovoy, A. Pleshivtsev, Technological parameter optimization of multilayer enclosure structures with the multiple-criteria decision analysis., *MATEC Web of Conferences*, Volume 170, 03031 (2018), DOI: https://doi.org/10.1051/matecconf/201817003031.

[25] E. Korol, Yu. Gaydysheva, D. Passmore, Integration of organizational-technological and social aspects in the realization of the program of renovation of residential development, *MATEC Web of Conferences*, Volume 251 (2018), DOI: https://doi.org/10.1051/matecconf/201825106031.

[26] V.O. Evseev, R. Barkhi, A. Pleshivtsev, A. Scrynnik, Modeling the Influence of Weather and Climatic Conditions on the Safety Characteristics of the Construction Process, *E3S Web of Conferences*. Volume 97 (2019), DOI: https://doi.org/10.1051/e3sconf/20199703035.

[27] A. Davidyuk, I. Rumyantsev, Risks in housing and communal services and major repairs program for apartment buildings in Moscow. Experience of the first years of implementation, *MATEC Web of Conferences*, Volume 251 (2018), DOI: https://doi.org/10.1051/matecconf/201825106022.