DOI:10.30857/1813-6796.2018.4.1.

UDC 620.91:697.1

PANASYUK I. V., KUZNETSOVA O. O.
Kyiv National University of Technologies and Design

THERMAL INSULATION PERFORMANCE OF STEEL FRAMED WALLS

Purpose. *To determine metal stud wall systems with improved thermal insulation performance.*

Methodology. *Thermal transmittance of steel framed walls was analyzed using heat-transfer simulation program THERM 7.6.*

Findings. *Thermal insulation performance of various configurations of metal stud walls has been evaluated.*

Scientific novelty. *Approaches to enhance thermal insulation performance of steel framed walls were determined.*

Practical value. *The work results can be used in designing new energy efficient building.*

Key words*: steel framed wall, U-value, thermal insulation, thermal insulation performance.*

Introduction. Commercial and residential buildings consume about one-third of world's energy [1]. To enhance energy efficiency and sustainability in the building sector, it is important to reduce the energy consumption of buildings, especially in their operational stage, since this represents 80%–85% [2] of total energy consumed during their life cycle. Therefore, it is fundamental to develop constructive solutions and methods that offer advantages in reducing buildings energy consumption during operational stage of their life cycle.

Over the last few years, alternatives to the traditional constructive methods have been developed. The lightweight steel framing (LSF) system, characterized by using cold-formed steel profiles and pre-fabricated non-structural panels, is an example of this new and growing trend.

The use of LSF system as a structural element in buildings has increased in recent years. Its various advantages [3] include high mechanical strength and lightweight, easy and rapid prefabrication and high potential for recycling and reuse.

However, LSF also presents some drawbacks [4]. Unfortunately, because the metal components in the walls can create significant thermal bridges, such walls, if not suitably designed, could lead to excessive heat transfer through building walls. Given this, in the recent years significant efforts to assess and improve the thermal behavior of constructive solutions with steel structures were undertaken. Kosny and Christian [5] showed that the use of continuous exterior thermal insulation is an effective way to reduce thermal bridges and enhance thermal performance of metal framed walls. Höglund and Burstrandb [6] studied an efficient way to reduce heat flow by reducing the area of the steel profile, with the insertion of slots in the web studs.

Objectives. The task of the work consisted in evaluation and comparison of thermal insulation performance of various types of metal stud walls. For that purpose three common types of metal stud walls were simulated, and three levels of insulation were included in the models for each type of wall. The comparison of thermal insulation performance of the simulated metal framed walls was done. The approaches to enhance the thermal insulation performance of such walls were outlined.

Research results. The wall model to be simulated is represented in Figure 1. The wall comprises a steel structure containing galvanized cold-formed steel studs with a "U" cross-sectional shape (8.9 cm depth and 4.1 cm flange (8.9x4.1 cm) or 10.2 depth and 4.1 cm flange (10.2x4.1 cm), 1.2 mm thick). The spacing between studs is 400 mm or 600 mm.

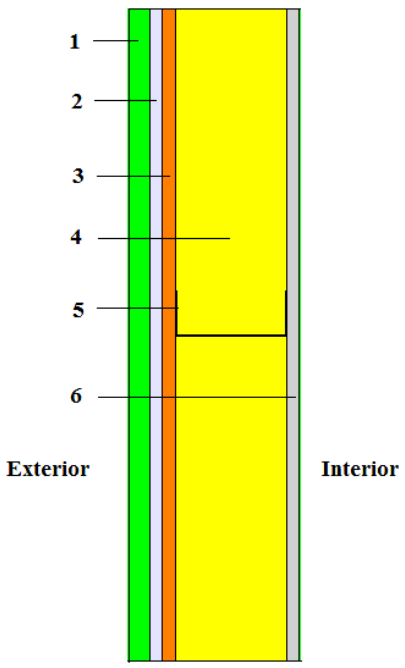

Fig. 1. **The scheme of a fragment of the steel framed wall.**
Materials: 1- external plaster; 2 - sheathing insulation (optional); 3 - oriented strand board (OSB); 4 - mineral wool; 5 – steel stud; 6 - plasterboard

Three common types of metal stud walls were simulated, and three levels of insulation were included in the models for each type of wall. The total number of simulated walls reached 9. Configurations of these walls are described in Table 1.

The thermal properties of the materials were assumed to be uniform for all simulated walls to aid the evaluation analysis. They are presented in Table 2.

Table 1.

Configuration and characteristics of simulated steel framed walls

Wall symbol	Size of steel studs; studs spacing	Insulation of wall cavity	Exterior/interior surface finish	Optional sheathing insulation between OSB and external plaster
A1	8.9x4.1 cm, 1.2 mm thickness, spacing 40 cm o.c.	Mineral wool	Interior – 1.25 cm plasterboard; exterior – 2 cm external plaster; sheathing insulation - optional	no
A2				1.2 cm of expanded polystyrene
A3				2.5 cm of expanded polystyrene
B1	8.9x4.1 cm, 1.2 mm thickness, spacing 60 cm o.c.	Mineral wool	Interior – 1.25 cm plasterboard; exterior – 2 cm external plaster; sheathing insulation - optional	no
B2				1.2 cm of expanded polystyrene
B3				2.5 cm of expanded polystyrene

Table 1.

C1	10.2x4.1 cm, 1.2 mm thickness, spacing 60 cm o.c.	Mineral wool	Interior – 1.25 cm plasterboard; exterior – 2 cm external plaster; sheathing insulation – optional	no
C2				1.2 cm of expanded polystyrene
C3				2.5 cm of expanded polystyrene

Table 2

Thermal properties of wall materials

№	Wall material	Thermal conductivity, λ, W/(m·K)
1	Plasterboard	0,21
2	Mineral wool	0,04
3	Oriented strand board	0,13
4	Expanded polystyrene	0,038
5	Steel	50

The following boundary conditions were set for external and internal environment: an external temperature equal to 0 ^oC and a convective surface heat transfer coefficient h_e=25 W/(m^2·K); the internal temperature was defined at 20 ^oC and a convective surface heat transfer coefficient h_i=7.69 W/(m^2·K). These convective surface heat transfer coefficients were established according to EN ISO 6946 [7] for a horizontal heat flow.

In order to calculate the U-value of the LSF facade walls, first it is necessary to identify a representative wall section to model. For a wall with a single layer of vertical steel studs and a frequency of 600 mm (or 400 mm) every two studs, standard ISO EN 10211 [8] suggest taking advantage of its symmetry to position the adiabatic plans (zero heat flow). Therefore, a cross-section of the wall measuring 600 mm (or 400 mm), with a steel stud in the core, was considered as a geometric model.

Thermal insulation performance of steel framed walls was analyzed with heat-transfer simulation program THERM 7.6 [9].

THERM is a state-of-the-art computer program developed at Lawrence Berkeley National Laboratory (LBNL) for use by building component manufacturers, engineers, educators, students, architects, and others interested in heat transfer.

THERM's two-dimensional conduction heat-transfer analysis is based on the finite-element method, which can model the complicated geometries of building products.

Temperature distribution maps obtained during computer modeling are represented in Figure 2.

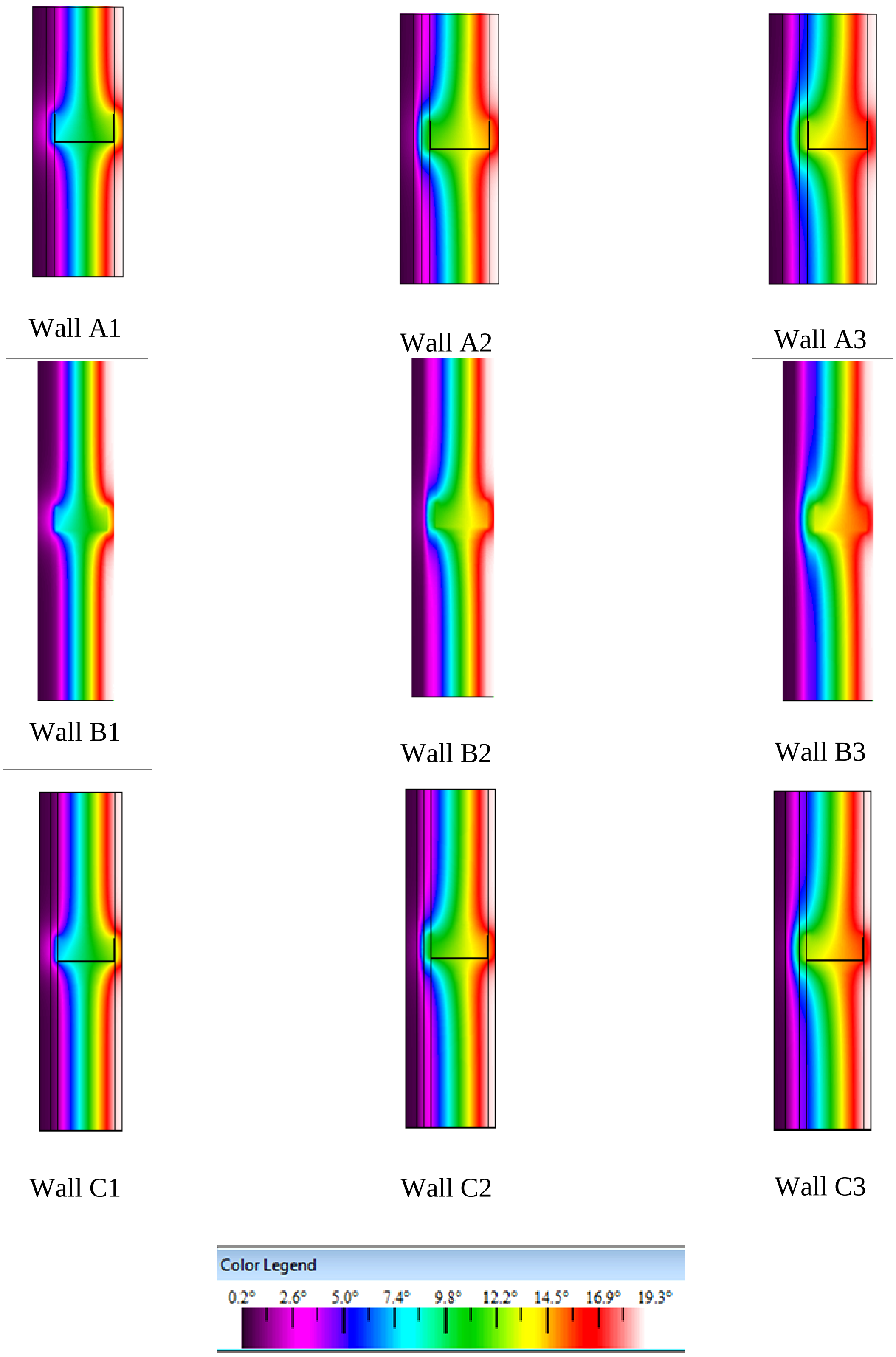

Fig. 2. **Temperature profiles**

These temperature maps were used to estimate average surface heat flux for all considered walls. A knowledge of heat flux values allowed U-value calculations. Table 3 represents all U-values calculated as a result of THERM 7.6 modeling. For three types of walls, three levels of exterior insulation were considered. In these cases (walls A, B, and C, without exterior EPS sheathing), U-values between 0.55 and 0.69 W/ m^2·K were obtained as a result of computer modeling. It can be observed from these models that 2.5 cm of EPS layer may lower U-value of the metal stud wall from 32 to 36 %.

Table 3

U-values of metal stud framed walls simulated

Wall symbol	U-value, W/(m^2·K)
A1	0,69
A2	0,53
A3	0,44
B1	0,59
B2	0,47
B3	0,39
C1	0,55
C2	0,43
C3	0,37

Changing stud spacing from 40 in. to 60 cm o.c. (walls A and B) decreased wall U-value. The highest improvement was observed at 15% for a wall without exterior EPS sheathing. The efficiency of this change decreases for the walls with additional exterior insulation. The decrease in U-value caused by the increased spacing was about 11% for walls with 1.2 cm of EPS and about 9.5% with 2.5 cm of EPS.

It can also be observed that additional layers of EPS sheathing of the same thickness may result in different decreases in wall U-values for various wall configurations.

Calculations for metal frame walls show that the simulated wall U-value can be considerably higher than the "ideal" U-value calculated, excluding the effects of thermal bridges caused by metal studs. However, those comparisons do not clearly show how effectively the wall materials are used. The data in Table 4 depict a comparison between U-values simulated by THERM 7.6 and "ideal" U-values calculated only for layers of the used materials (excluding the metal studs). The increase of wall U-value due to the metal studs is called the *framing effect*, (*f*). It can be described by the following formula:

$$f = \left(1 - \frac{U_{ideal}}{U_{simulated}}\right) \cdot 100\%$$

where $U_{simulated}$ - simulated U-value and U_{ideal} – “ideal” U-value calculated only for layers of the used materials (excluding the metal studs).

Table 4

The magnitude of framing effect *f*

Wall symbol	Framing effect, %
A1	44,2
A2	35,2
A3	30,0
B1	34,8
B2	26,9
B3	22,6
C1	37,9
C2	29,3
C3	25,1

For the wall with 8.9 cm metal studs, 1.2 mm thick, installed with 40 cm o.c., without sheathing insulation the increase in U-value compared with “ideal” U-value (excluding the metal studs) reaches 44.2 %. The framing effect is lowered with the increase in sheathing insulation thickness as well as spacing between studs. For wall B3 the framing effect is only 22.6 %. However, comparing walls B and C, it can be seen, that walls C have higher values of framing effect than walls B with the same amount of sheathing insulation. This phenomenon can be explained by higher depth (10.2 cm versus 8.9 cm) of metal studs installed in walls C.

Conclusions. In this study, thermal properties of 9 metal framed walls with various configurations of insulation and various metal stud sizes and spacing were examined analytically. The results obtained led to the following conclusions.

• Installing additional exterior sheathing insulation is an effective way to improve the thermal insulation performance of the metal framed walls.

• Changing stud spacing from 40 cm o.c. to 60 cm o.c. decreased wall U-value by nearly 15 % for a wall without exterior EPS sheathing. The efficiency of this change decreases for walls with additional exterior insulation sheathing. The decrease in U-value caused by the increased spacing was about 11 % with 1.2 cm of EPS and about 9.5 % with 2.5 cm of EPS.

• Changing the distance between metal studs from 40 to 60 cm o.c. reduced the value of the framing effect (caused by metal studs) by about 9.4 %. However, the framing effect can also be lowered by the addition of EPS sheathing - about 14 % for walls with 2.5 cm thick layer of EPS.

Література

1. Kuznetsova, E. A (2016). A review of definitions of zero energy buildings. *Metallurgical and Mining Industry*, *11*, 92 – 98.
2. Sharma, A., Saxena, A., Sethi, M., & Shree, V. (2011). Life cycle assessment of buildings: a review. *Renewable and Sustainable Energy Reviews*, *15(1)*, 871-875.
3. Murtinho, V., Ferreira, H., Correia, A., et al. (2010). Affordable houses: architectural concept of light steel residential house. In: ICSA2010 –

References

1. Kuznetsova, E. A (2016). A review of definitions of zero energy buildings. *Metallurgical and Mining Industry*, *11*, 92 – 98.
2. Sharma, A., Saxena, A., Sethi, M., & Shree, V. (2011). Life cycle assessment of buildings: a review. *Renewable and Sustainable Energy Reviews*, *15(1)*, 871-875.
3. Murtinho, V., Ferreira, H., Correia, A., et al. (2010). Affordable houses: architectural concept of light steel residential house. In: ICSA2010 –

International conference on structures and architecture, 1291–1297.
4. Santos, P., da Silva, L. S., & Ungureanu, V. *Energy Efficiency of Light-weight Steel-framed Buildings, European Convention for Constructional Steelwork (ECCS), Technical Committee 14– Sustainability and Eco-Efficiency of Steel Construction, N.129,2012.*ISBN 978-92-9147-105-8.
5. Kosny, J. & Christian, JE. (1995). Thermal evaluation of several configurations of insulation and structural materials for some metal stud walls. *Energy and Buildings 22(2)*, 157–163.
6. Höglund, T. & Burstrandb, H. (1998). Slotted steel studs to reduce thermal bridges in insulated walls. *Thin-Walled Structures*, *32*, 81–109.
7. EN ISO 6946:2008. Building Components and Elements—Thermal Resistance and Thermal Transmittance – Calculation Method; International Organization for Standardization: Geneva, Switzerland, 2008.
8. EN ISO 10211. Thermal bridges in building construction – Heat flows and surface temperatures – detailed calculations (ISO 10211:2007), CEN, 2007.
9. *THERM*. Retrieved from: https://windows.lbl.gov/software/therm

International conference on structures and architecture, 1291–1297.
4. Santos, P., da Silva, L. S., & Ungureanu, V. *Energy Efficiency of Light-weight Steel-framed Buildings, European Convention for Constructional Steelwork (ECCS), Technical Committee 14– Sustainability and Eco-Efficiency of Steel Construction, N.129,2012.*ISBN 978-92-9147-105-8.
5. Kosny, J. & Christian, JE. (1995). Thermal evaluation of several configurations of insulation and structural materials for some metal stud walls. *Energy and Buildings 22(2)*, 157–163.
6. Höglund, T. & Burstrandb, H. (1998). Slotted steel studs to reduce thermal bridges in insulated walls. *Thin-Walled Structures*, *32*, 81–109.
7. EN ISO 6946:2008. Building Components and Elements—Thermal Resistance and Thermal Transmittance – Calculation Method; International Organization for Standardization: Geneva, Switzerland, 2008.
8. EN ISO 10211. Thermal bridges in building construction – Heat flows and surface temperatures – detailed calculations (ISO 10211:2007), CEN, 2007.
9. *THERM*. Retrieved from: https://windows.lbl.gov/software/therm

PANASIUK IGOR
panasjuk.i@knutd.edu.ua
ORCID: 0000-0001-6671-4266
Researcher ID: 56672850100
Head of Department of heat and power engineering, resource saving and technological safety
Kiev National University of Technologies & Design

KUZNETSOVA OLENA
ekyznec@ukr.net
ORCID: 0000-0002-1786-314X
Researcher ID: 57143768700
Heat-and-Power Engineering, Resource Saving and Technogenic Safety Department
Kiev National University of Technologies & Design

ТЕПЛОЗАХИСНА ЕФЕКТИВНІСТЬ СТІН ІЗ МЕТАЛЕВИМ КАРКАСОМ

ПАНАСЮК І. В., КУЗНЄЦОВА О. О.
Київський національний університет технологій та дизайну

Мета. *Визначити конфігурації металокаркасних стін із підвищеною теплозахисною ефективністю.*

Методика. *Приведені коефіцієнти теплопередачі стін зі сталевими каркасами були визначені за допомогою прикладної комп'ютерної програми для моделювання теплопередачі THERM 7.6.*

Результати. *Було оцінено теплозахисні характеристики різноманітних конфігурацій стін із металевим каркасом.*

Наукова новизна. *Визначено шляхи підвищення теплозахисної ефективності металокаркасних стін.*

Практична значимість. *Результати роботи можуть бути використані при проектуванні нових енергоефективних будівель та споруд.*

Ключові слова: *стіна із металевим каркасом, коефіцієнт теплопередачі, теплова ізоляція, теплозахисна ефективність.*

ТЕПЛОЗАЩИТНАЯ ЭФФЕКТИВНОСТЬ СТЕН С МЕТАЛЛИЧЕСКИМ КАРКАСОМ

ПАНАСЮК И. В., КУЗНЕЦОВА Е. А.

Киевский национальный университет технологий и дизайна

Цель. *Определить конфигурации металлокаркасных стен с улучшенными теплотеплозащитными характеристиками.*

Методика. *Коэффициенты теплопередачи металлокаркасных стен были определены с помощью прикладной компьютерной программы для моделирования теплопередачи THERM 7.6.*

Результати. *Были оценены теплозащитные характеристики различных конфигураций стен с металлическим каркасом.*

Научная новизна. *Определены подходы для повышения теплозащитной эффективности металлокаркасных стен.*

Практическая ценность. *Результаты работы могут быть использованы при проектировании новых энергоэффективных зданий и сооружений.*

Ключевые слова: *стена с металлическим каркасом, коэффициент теплопередачи, теплоизоляция, теплозащитная єффективность.*