

Toplotne izgube v tla pri stavbah glede na standard SIST EN ISO 13370 - poenostavljena metoda izračuna

Heat Losses to the Ground According to the SIST EN ISO 13370 Standard - a Simplified Calculation Method

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Toplotne izgube v tla imajo, še posebej pri velikih stavbah, velik vpliv na rabo energije za ogrevanje. V uporabi so različne metode za določitev teh izgub, vključno z metodo, ki jo predpisuje standard SIST EN ISO 13370. Ta metoda je razmeroma zahtevna. Zato smo oblikovali poenostavljeno metodo z utežnimi faktorji, ki jo predstavljamo v prispevku. Utežni faktorji so določeni za nepodkletene in podkletene stavbe z različnimi toplotnimi prehodnostmi konstrukcij, ki so v stiku s tlemi. Zmanjšano je bilo tudi število vplivnih parametrov, ki so uporabljeni v SIST EN ISO 13370. Uporaba poenostavljene metode je posebej primerna pri postopku načrtovanja toplotne zaščite stavb in določevanja specifičnih toplotnih izgub le-teh.

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(Ključne besede: zaščita toplotna, zaščita zgradb, prenos toplote, metode izračunavanja)

Heat losses from buildings through contact with the ground, especially in the case of large buildings, have a strong influence on energy demand. Various methods for calculating these heat losses are available, including one method that is defined by the SIST EN ISO 13370 standard. Due of the complexity of this method we have developed a method that is presented in this paper. Using our method we have calculated weighting factors for buildings with and without basements with a variety of thermal transmittances of structures in the contact between the building and the ground. Also the number of influential parameters used in SIST EN ISO 13370 is reduced. Our simplified method is particularly appropriate for use in the process of designing the thermal insulation of buildings and determining the specific heat losses from buildings.

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(Keywords: thermal insulation, building insulation, heat transfer, calculation methods)

0 UVOD

Izkušnje kažejo, da toplotno zaščito in njeno pravilno vgradnjo načrtujejo arhitekti v začetni fazi snovanja stavbe. Zato je odločitev arhitektov povezana z dolgoročnimi posledicami. Metode za določitev toplotnih lastnosti gradbenih konstrukcij, ki potrebujejo veliko vhodnih podatkov, so zahtevne in lahko vodijo k nepravilnostim. Kot zahtevno lahko ocenimo tudi metodo za izračun toplotnih tokov v tla, ki jo določa SIST EN ISO 13370. V tem prispevku je opisan razvoj poenostavljene metode, s katero določimo toplotni tok skozi gradbeno konstrukcijo, ki je v stiku s tlemi. Toplotni tok lahko normaliziramo glede na ogrevano prostornino ali površino ovoja stavbe in se tako prilagodimo različnim predpisom o toplotni zaščiti stavb. Ker je razvita metoda namenjena načrtovanju toplotne izolacije, smo uporabili izraze, ki določajo največji mesečni toplotni tok.

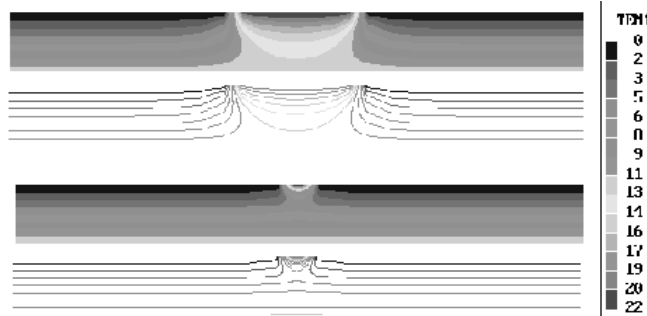
0 INTRODUCTION

Experience shows us that heat insulation and its appropriate installation is the responsibility of the architect in the early stages of a building's design. The decisions made by architect are, therefore, bound to long-term consequences. Methods for determining the thermal and technical properties of building structures, with their large amount of input data, are complicated, which leads to calculation inconsistencies. SIST EN ISO 13370 is one such method for determining heat losses through floors and walls. In this paper we develop a simple method for calculating heat losses to the ground, which can later be normalised to the volume or the surface of the building according to the different regulations of building's thermal insulation. As the simplified method is designed to be used for rating a building's thermal insulation, the expression for maximum monthly heat flow rate will be used.

1 DOLOČITEV TOPLOTNIH IZGUB V TLA - OPIS METOD

Raba energije za ogrevanje v sodobnih stavbah se zmanjšuje zaradi vse večjega spoznanja o omejenih zalogah fosilnih goriv, spoznanj o njihovih negativnih vplivih na okolje in tudi vse strožjih predpisov o toplotni zaščiti stavb. Toplotna zaščita stavb je lahko predpisana z dovoljenimi toplotnimi prehodnostmi gradbenih konstrukcij, specifičnimi toplotnimi izgubami poslopja ([2], [15] in [16]), ali letno rabo energije za ogrevanje ([3] do [5]). Zaradi manjših toplotnih prehodnosti zunanjih zidov, strehe in še posebej oken se je povečal relativni delež toplotnih izgub v tla. To je še posebej pomembno pri poslopih z veliko tlorisno površino, kakršno imajo trgovski centri in industrijski objekti.

Toplotni tok v tla lahko določimo na različne načine: analitično z reševanjem diferencialnih enačb neustaljenega prevoda toplote ([6] in [7]); s primernimi numeričnimi metodami in programskimi paketi ([8] in [9]); semiempiričnimi enačbami v obliki linijskih toplotnih prehodnosti ([10], [11] in [13]) ali z utežnimi faktorji ([2], [12] in [14]).



Sl. 1. Časovno ustaljene temperature tal pod ogrevano nepodkleteno stavbo, določene numerično z metodo nadzornih površin; zgoraj stavba s tlorisno površino 100x50 m, specifični toplotni tok skozi pod je 2,1 W/m²; spodaj stavba s tlorisno površino 10x10 m, specifični toplotni tok skozi pod je 7,3 W/m² [9]

Fig. 1. Steady state temperatures below the buildings on the ground – above for building with floor area 100 x 50 m, below for the building with floor area 10 x 10 m, specific heat flux to the ground is 2.1 W/m² in case of the larger and 7.3 W/m² in case of the smaller building [9]

V standardu SIST EN ISO 13370 je toplotni tok v tla določen s semiempiričnimi enačbami, ki vsebujejo različne parametre, kot so velikost in oblika poda, toplotne prehodnosti gradbenih konstrukcij, toplotne prevodnosti tal, povprečne mesečne temperature znotraj in zunaj stavbe itn., torej razmeroma veliko število različnih vhodnih podatkov. Z uporabo metode utežnih faktorjev lahko število vplivnih parametrov zmanjšamo. Toplotni tok v tla je tako določen z enačbo:

$$\Phi_G = F_G \cdot U_G \cdot A_G \cdot (\theta_i - \theta_{e,p}) \quad (1)$$

Utežni faktorji (F_G), ki so v uporabi, so ali nespremenljivi (npr. 0,5 [2]) oziroma nespremenljivi v

1 DETERMINATION OF THE HEAT FLUX TO THE GROUND – A DESCRIPTION OF COMMON METHODS

The energy used for heating in new buildings is being reduced as a result of better understanding of the limited quantities of fossil fuels, their negative influence on the environment and also because of the tighter regulations that apply to the heated buildings. The thermal insulation thickness can be determined by the permitted thermal transmittance, the specific building heat losses ([2], [15] and [16]) or the annual heat use ([3] to [5]). As a consequence of the lower thermal transmittances of external walls, roofs and especially windows, the relative amount of heat lost to the ground has increased. This point is particularly important for large-area buildings, such as modern shopping centres and industrial premises.

Heat flux to the ground can be determined using various methods: analytically by solving differential equations of non-stationary heat conduction ([6] and [7]); with appropriate numerical methods and program codes ([8] and [9]); semi-empirical equations in the form of linear thermal transmittance ([10], [11] and [13]); or weighting factors ([2], [12] and [14]).

In SIST EN ISO 13370 the heat flux is determined with semi-empirical equations that are dependent on many different factors, such as the size and shape of the building's floor, the thermal transmittances of the building's structures, the ground's thermal conductivity, the average monthly temperatures inside and outside building, etc., a relatively large number of different input data. With the introduction of weight factors, the amount of input data required is reduced. The heat flux to the ground is then determined by:

The weight factors (F_G) in use recently are either constant (for instance 0.5 [2]) or expressed as con-

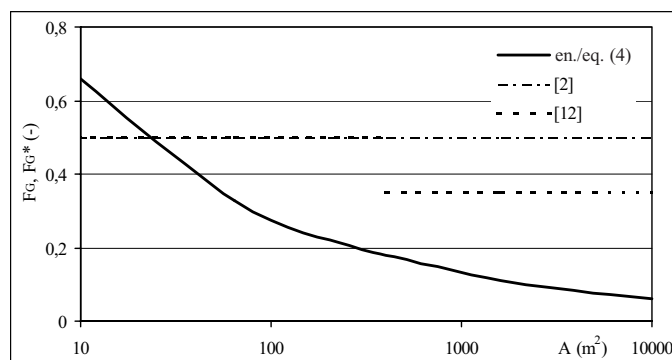
določenem območju parametrov [12]. Glede na standard SIST EN ISO 13370 utežne faktorje lahko določimo iz enačbe za največji mesečni toplotni tok:

$$\Phi_{\max} = L_s \cdot (\bar{\theta}_i - \bar{\theta}_e) + L_{pe} \cdot \hat{\theta}_e \cong F_G^* \cdot U_G \cdot A_G \cdot (\theta_i - \theta_{e,p}) \quad (2).$$

Vrednosti L_s in L_{pe} določata toplotne in geometrične (velikost, oblika in debelina) lastnosti gradbenih konstrukcij in toplotne lastnosti tal (toplotna prevodnost). Glede na izhodišča v SIST EN ISO 13370 pri izračunu ni treba upoštevati vpliva podtalnice. Vrednost L_s določa ustaljeno komponento toplotnega toka, vrednost L_{pe} pa periodično komponento toplotnega toka skozi gradbene konstrukcije v stiku s tlemi. Vrednost L_{pe} je vedno pozitivna, ker enačba (2) določa največji toplotni tok. Znak \cong v enačbi (2) ponazarja dovoljeno napako, ki je še sprejemljiva. Slika 2 prikazuje primerjavo med različnimi F_G , ki so v uporabi ([2] in [12]). Razvidno je, da so vrednosti utežnih faktorjev zelo različne pri majhnih in velikih stavbah. Fizikalna resnica je, da vrednost utežnega faktorja F_G^* ni nespremenljiva. Zato morajo biti utežni faktorji odvisni od različnih vplivnih parametrov.

starts for different variable ranges [12]. According to EN ISO 13370 the weight factor can be determined from the expression for the maximum monthly heat flux:

Functions L_s and L_{pe} determine the thermal and geometrical (size, shape and width) properties of the building structures and the ground heat properties (heat conduction). According to the assumptions in SIST EN ISO 13370, the effect of ground water is not taken into account. The function L_s determines the steady component of the heat flux, the function L_{pe} determines the periodic component of the heat flux. The L_{pe} value is always positive because equation (2) determines the maximum heat flux. The symbol \cong in equation (2) illustrates the error that is still acceptable for the simplified method. Figure 2 shows a comparison between the different F_G in common use ([2] and [12]). We can see that the values of these factors are very different for small buildings and large buildings. The value of weight factor (F_G^*) is not constant and must be determined for different influencing parameters.



Sl. 2. Vrednosti F_G in F_G^* v različnih virih oziroma metodah; vrednosti F_G^* so določene za $k_G=1,5$ W/mK, $U_F=0,4$ W/m²K, za nepodkleteno stavbo in s kvadratnim podom v kraju z $SD = 2985$ Kdan in $\theta_{e,p} = -18$ °C

Fig. 2. Values of F_G and F_G^* from different sources; values F_G^* determined for $k_G=1.5$ W/mK, $U_F=0.4$ W/m²K, building without basement and with square floor built in a place with $DD = 2985$ Kday and $\theta_{e,p} = -18$ °C.

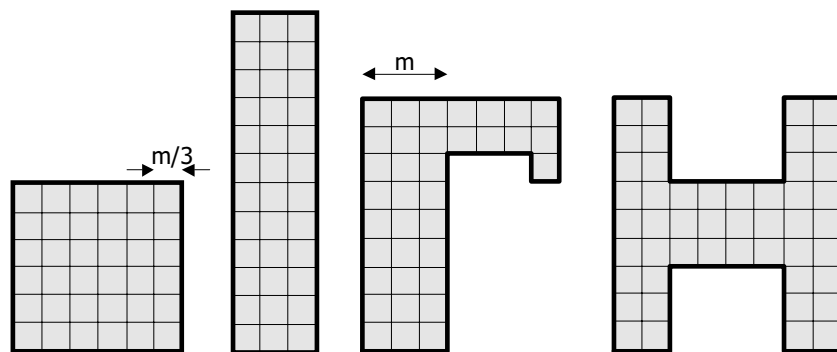
2 OSNOVE DOLOČITVE UTEŽNIH FAKTORJEV (F_G^*)

Pri oblikovanju funkcijsko odvisnih utežnih faktorjev F_G^* je treba izločiti čimveč vplivnih parametrov in vhodnih podatkov. V našem delu smo analizirali nepodkletene in podkletene stavbe. V primeru, da je stavba podkletena, sta toplotni prehodnosti poda in vkopanega zidu lahko enaki ali različni. Velikost in obliko poda stavbe popišemo s karakteristično izmero B' z izrazom:

$$B' = \frac{A_F}{0.5 \cdot P} \quad (3).$$

2 THE BASICS OF WEIGHT FACTOR (F_G^*) DETERMINATION

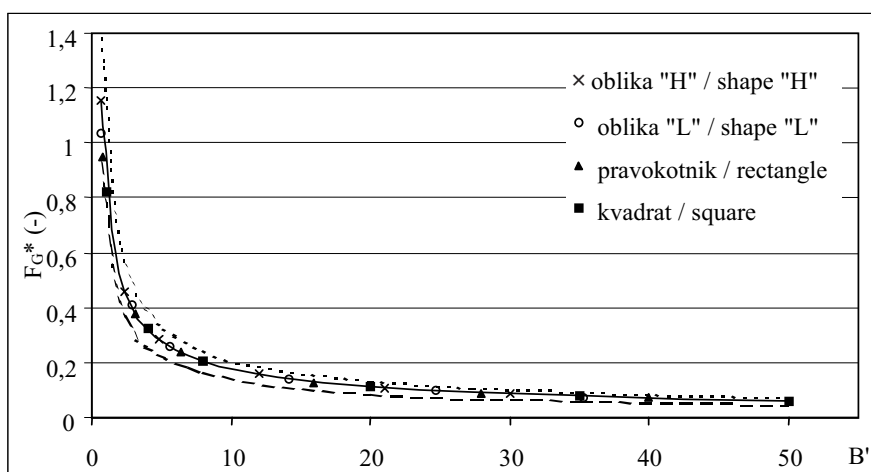
When designing a variables dependent weight factor F_G^* the influence of parameters had to be eliminated as much as possible. We focused on buildings without a basement or buildings with a basement. In the case of buildings with a basement the thermal transmittances of the floor and wall can either be the same or different. The size and shape of the building floor was substituted with the characteristic dimension B' :



Sl. 3. Analizirane oblike podov stavb
Fig. 3. Analysed shapes of building floors

Ta karakteristična izmera je uporabljena tudi v [1] in [12]. Obseg P je opredeljen v [1]. Slika 3 prikazuje analizirane oblike podov stavb z enotnim mrežnim korakom m . Utežni faktorji (F_G^*), določeni glede na SIST EN ISO 13370 z upoštevanjem izraza (2) za različne pode stavb, so prikazani na sliki 4. Izračuni so bili narejeni za m med 2 in 50 oziroma površino poda od 10 do 10000 m². Vrednosti utežnih faktorjev F_G^* so neodvisne od oblike in velikosti stavbe pri enaki karakteristični izmeri, zato pri oblikovanju poenostavljene metode ta parametra v celoti nadomestimo s karakteristično izmero stavbe B' .

This characteristic dimension is also used in [1] and [12]. The perimeter P is defined in [1]. Figure 3 shows the analysed shapes of building floors with a unified raster m . Weight factor (F_G^*) determined according to EN ISO 13370 by using equation (2) for differently shaped building floors are shown in Figure 4. In the calculations the raster m from 2 to 50 and floor areas from 10 to 10000 m² were taken into account. We can see that the characteristic dimension B' is appropriate to value the building's shape influence since the values of F_G^* are independent of the building shape with the same characteristic dimension B' .



Sl. 4. Utežni faktorji F_G^* so določeni za $k_G = 1,5 \text{ W/mK}$, $U_F = 0,4 \text{ W/m}^2\text{K}$, za nepodkleteno stavbo, zgrajeno v klimatskem območju z $SD = 2985 \text{ Kdan}$ in $\theta_{ep} = -18^\circ\text{C}$, črtkani črti pomenita mejo $\pm 20\%$

Fig. 4. Values F_G^* are determined for $k_G = 1.5 \text{ W/mK}$, $U_F = 0.4 \text{ W/m}^2\text{K}$, building without basement built in city (area) with $DD = 2985 \text{ Kday}$ and $\theta_{ep} = -18^\circ\text{C}$, dotted lines represent border $\pm 20\%$

Največji toplotni tok v tla je v SIST EN ISO 13370 določen s povprečno letno zunanjo temperaturo in letno periodično spremembo povprečnih mesečnih temperatur. V naši metodi smo želeli te temperature nadomestiti z zunanjo projektno temperaturo. Podatki o zunanjih projektnih temperaturah so namreč na voljo za veliko število krajev. Za analizo primernosti take zamenjave je bilo izbranih pet tipičnih krajev v različnih klimatskih območjih. Njihovi osnovni

The maximum heat flux through a building floor according to SIST EN ISO 13370 is defined with the average annual external temperature and the annual variation in the average monthly temperatures. In the simplified method the average annual temperatures and the variation in temperatures are replaced by an external project temperature. External project temperature data are available for a larger number of cities. Also, the determination of the specific heat losses of the building is easier. For the analysis, five

Preglednica 1. Meteorološki podatki izbranih krajev (območij)

Table 1. Meteorological data of selected cities (areas)

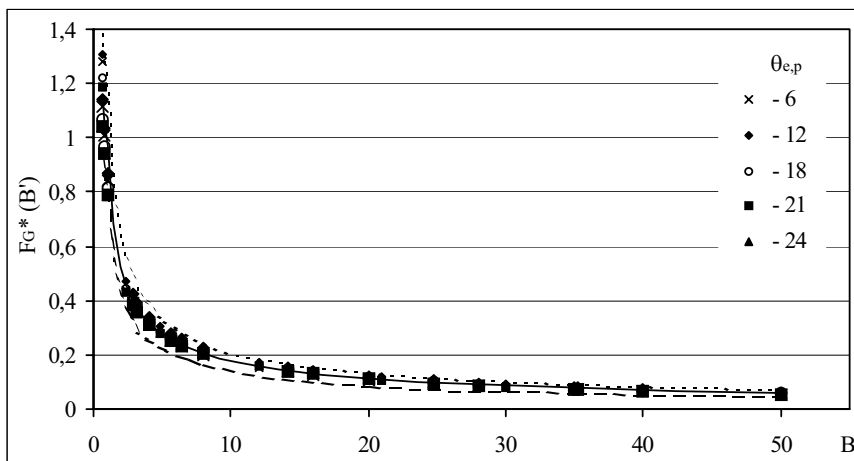
klimatsko področje climatic area	SD/DD (Kdan/Kday)	$\theta_{e,p}$ (°C)	$\bar{\theta}_e$ (°C)	$\hat{\theta}_e$ (°C)
mediteransko mediteranean	1874	-6	13,8	9,0
	2700	-12	10,8	9,5
celinsko continental	2985	-18	9,7	10,5
	3208	-21	9,2	11,0
alpsko alpine	3505	-24	8,2	11,0

meteorološki podatki so prikazani v preglednici 1.

Za vsak izbran kraj smo izračunali utežne faktorje F_G^* za široko območje karakteristične izmere B' . Rezultati s prikazom funkcijske odvisnosti so prikazani na sliki 5. Razvidno je, da so vrednosti F_G^* za dani primer znotraj območja -8% do +12%. Pri vseh preostalih analiziranih primerih pa je pričakovana nenatančnost med metodo po SIST EN ISO 13370 in razvito poenostavljeno metodo znotraj območja, ki ga predpisuje standard [13] za metode, ki temeljijo na "izračunu z uporabo kataloga". Iz tega izhaja, da je povprečne letne zunanje temperature in letne periodične spremembe povprečnih mesečnih temperatur mogoče nadomestiti z zunanjo projektno temperaturo določenega kraja.

typical cities in different climatic areas were chosen. Their basic meteorological data are shown in Table 1.

The values of weight factors (F_G^*) for each selected city and a wide range of characteristic dimension's B' were calculated. The results, together with a function curve, are shown in Figure 5. It is evident that all F_G^* values are within -8% and +12% limits. It was also observed that for all analysed combinations of the influencing parameters, the differences between the Φ_{max} calculated using EN ISO 13370 and our simplified method are smaller than expected uncertainly for manual calculations and "catalogue" methods according to reference [13]. Therefore, the average annual temperature and the variation in the average monthly temperatures can be replaced by project temperatures that are characteristic of a wide range of climatic conditions.



Sl. 5. Utežni faktorji F_G^* so določeni za $k_G=1,5$ W/mK, $U_F=0,4$ W/m²K, za nepodkleteno stavbo, $\theta_i=20$ °C, črtkani črti pomenita mejo ± 20 odstotkov

Fig. 5. Values F_G^* are determined for $k_G=1.5$ W/mK, $U_F=0.4$ W/m²K, building without basement, $\theta_i=20$ °C, dotted lines represent border $\pm 20\%$

Vrednosti (F_G^*) pa so odvisne tudi od drugih toplotnih in konstrukcijskih parametrov. Pri razvoju poenostavljene metode smo upoštevali, da so tla bodisi glinena ($k_G=1,5$ W/mK), peščena ($k_G=2$ W/mK) ali skalnata ($k_G=3,5$ W/mK). Predpostavili smo, da so stavbe enakomerno ogrevane na $\theta_i=20$ °C in da je debelina zunanjšega zidu na stiku s podom 0,35 m. Te vrednosti so bile izbrane kot najbolj

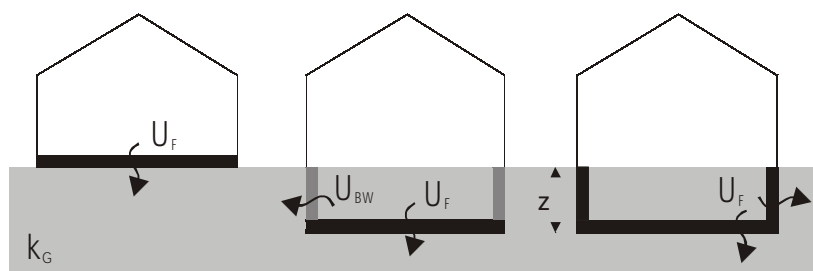
The values of the weight factors (F_G^*) also depend on other thermal and design parameters. When designing the simplified method we took into consideration that the ground can be clay ($k_G = 1.5$ W/m²K), sand ($k_G = 2.0$ W/m²K) or homogeneous rock ($k_G = 3.5$ W/m²K). The buildings are assumed to be uniformly heated to a constant temperature $\theta_i=20$ °C and have constructions in contact with the ground

pogoste, v praksi pričakovana odstopanja pa ne vplivajo bistveno na rezultat analize. Toplotne prehodnosti gradbenih konstrukcij v stiku s tlemi, ki smo jih analizirali, so bile 0,3; 0,4; 0,5 in 0,6 W/m²K. Te vrednosti so bile izbrane glede na predpis o toplotni zaščiti stavb in trdnostne lastnosti gradbene konstrukcije. Glede na lastnosti konstrukcije in globino podkletitve so stavbe razdeljene na tri kategorije, kakor je prikazano na sliki 6:

- nepodkletene stavbe,
- podkletene stavbe z različnima toplotnima prehodnostima poda in vkopanega zidu,
- podkletene stavbe z enakima toplotnima prehodnostima poda in vkopanega zidu.

that are 0.35 m wide. These values were chosen as the most representative, but in any case their influence on the results is negligible. The analysed thermal transmittances of the building structures were 0.3, 0.4, 0.5 and 0.6 W/m²K. When choosing these values, civil engineering technologies and common building thermal protection regulations were taken into consideration. According to the building's structural properties and the depth of the basement, buildings are divided into three categories, as shown in Figure 6:

- buildings without basement
- buildings with basement with different thermal transmittances of the basement floor and basement walls;
- buildings with basement with the same thermal transmittances of the basement floor and basement walls;



Sl. 6. Shematski prikaz analiziranih stavb. Na levi nepodkletena stavba, na sredini podkletena stavba z različnima toplotnima prehodnostima poda in vkopanega zidu, na desni podkletena stavba z enakima toplotnima prehodnostima poda in vkopanega zidu

Fig. 6. Schematic survey of the buildings analysed in this work; on the left is building without a basement; in the middle is a building with a basement with different thermal transmittances of the basement floor and basement wall; and on the right, a building with a basement with equal thermal transmittances of the basement floor and the basement wall

3 OBLIKOVANJE ENAČBE UTEŽNIH FAKTORJEV ($F_{G,F}^*$)

Enačbe utežnih faktorjev smo določili s statistično analizo 18720 analiziranih primerov. Enačbe za toplotni tok skozi tla (Φ_{\max}) in utežne faktorje ($F_{G,F}^*$) za različne tipe stavb so prikazane v nadaljevanju:

- za nepodkletene stavbe je največji toplotni tok v tla določen z izrazom :

$$\Phi_{\max} = F_{G,F}^* \cdot U_F \cdot A_F \cdot (\theta_i - \theta_{e,p}) \quad (4)$$

kjer $F_{G,F}^*$ določimo z izrazom:

$$F_{G,F}^* = a_F \cdot B'^{[-(2/3)]} \quad (5)$$

Utežni faktorji v odvisnosti od karakteristične izmere stavbe B' za izbrano nepodkleteno stavbo so prikazani na sliki 7. Vrednosti konstant a_F za analizirano polje spremenljivk so podane v preglednici 2.

- za podkletene stavbe z različnima toplotnima prehodnostima poda in vkopanega zidu je največji

3 DESIGNING OF WEIGHT FACTOR ($F_{G,F}^*$) EQUATIONS

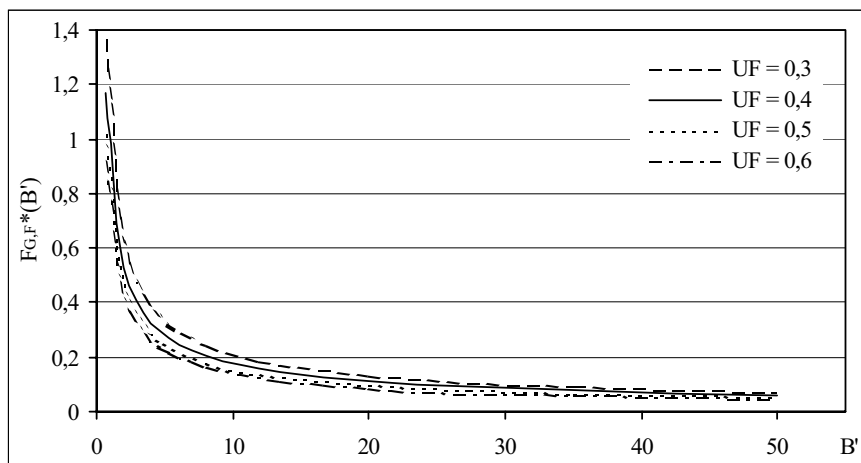
Weight factor equations were determined with a statistical analysis of 18720 analysed combinations. The equations for the heat flux to the ground (Φ_{\max}) and the weight factors ($F_{G,F}^*$) for different types of buildings are shown below:

- for buildings without a basement the maximum heat flux to the ground is determined by:

where $F_{G,F}^*$ can be calculated using equation:

Weight factors as a function of B' for the selected building without a basement are shown in Figure 7. The values of the constants a_F for the analysed range of variables are written in Table 2.

- for buildings with a basement with different thermal transmittances of the basement floor and the basement walls the heat flux is determined as the



Sl. 7. Vrednosti funkcije $F_{G,F}^*$ za nepodkletene stavbe; $k_G = 1,5 \text{ W/mK}$, $\theta_i = 20^\circ\text{C}$, $2 < B' < 50$, $-24 < \theta_{e,p} < -6^\circ\text{C}$
 Fig. 7. $F_{G,F}^*$ function curves for building without basement; $k_G = 1.5 \text{ W/mK}$, $\theta_i = 20^\circ\text{C}$, $2 < B' < 50$, $-24^\circ\text{C} < \theta_{e,p} < -6^\circ\text{C}$

Preglednica 2. Vrednosti konstante a_F
 Table 2. Values of constant a_F

U _F	0,3	0,4	0,5	0,6
k _G = 1,5	0,97	0,83	0,72	0,65
k _G = 2,0	1,15	1,00	0,89	0,80
k _G = 3,5	1,43	1,27	1,12	1,04

toplotni tok določen kot vsota specifičnih toplotnih tokov skozi pod in vkopani zid:

sum of specific heat fluxes through the basement floor and the basement walls:

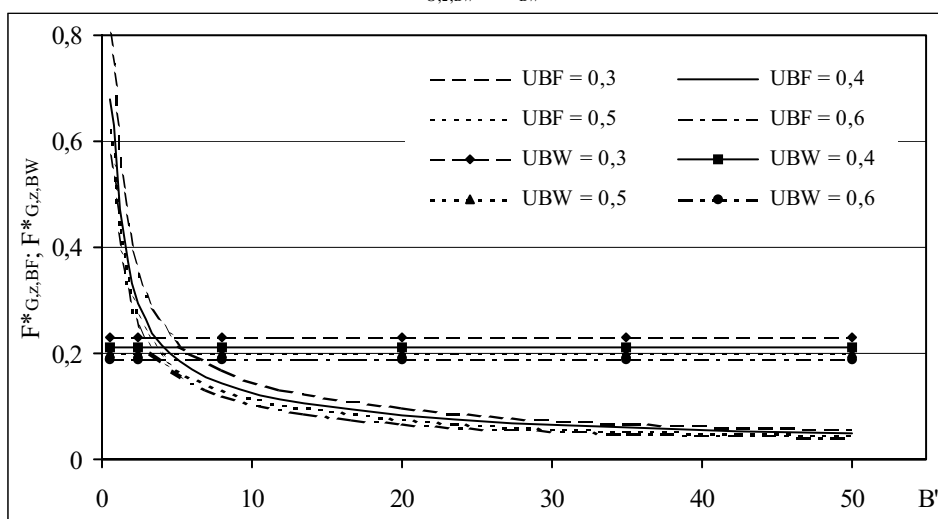
$$\Phi_{\max} = (F_{G,z,BF}^* \cdot U_F \cdot A_F + F_{G,z,BW}^* \cdot U_{BW} \cdot A_{BW}) \cdot (\theta_i - \theta_{e,p}) \quad (6)$$

kjer sta $F_{G,z,BF}^*$ in $F_{G,z,BW}^*$ določena z izrazoma:

where $F_{G,z,BF}^*$ and $F_{G,z,BW}^*$ can be calculated:

$$F_{G,z,BF}^* = a_{BF} \cdot B^{[-(\frac{3}{5})]} \quad (7)$$

$$F_{G,z,BW}^* = a_{BW} \quad (8)$$



Sl. 8. Vrednosti utežnih faktorjev $F_{G,z,BF}^*$ in $F_{G,z,BW}^*$ za podkleteno stavbo $z = 3 \text{ m}$, $k_G = 1,5 \text{ W/mK}$, $\theta_i = 20^\circ\text{C}$, $2 < B' < 50$, $-24 < \theta_{e,p} < -6^\circ\text{C}$
 Fig. 8. Values of $F_{G,z,BF}^*$ and $F_{G,z,BW}^*$ for a building with basement $z = 3 \text{ m}$, $k_G = 1.5 \text{ W/mK}$, $\theta_i = 20^\circ\text{C}$, $2 < B' < 50$, $-24^\circ\text{C} < \theta_{e,p} < -6^\circ\text{C}$

Slika 8 prikazuje vrednosti $F_{G,z,BF}^*$ in $F_{G,z,BW}^*$ kot funkciji B' za izbrane primere. Vrednosti konstant a_{BF} in a_{BW} so podane v preglednici 3.

Figure 8 shows the values of $F_{G,z,BF}^*$ and $F_{G,z,BW}^*$ as a function of B' for selected cases. The values of constants a_{BF} and a_{BW} are written in Table 3.

Preglednica 3. Vrednosti konstant a_{BF} in a_{BW}
Table 3. Values of constants a_{BF} and a_{BW}

U_F, U_{BW}		0,3		0,4		0,5		0,6	
$k_G = 1,5$	z (m)	a_{BF}	a_{BW}	a_{BF}	a_{BW}	a_{BF}	a_{BW}	a_{BF}	a_{BW}
	1,5	0,62	0,33	0,55	0,31	0,49	0,29	0,44	0,27
	3,0	0,60	0,23	0,53	0,21	0,47	0,20	0,42	0,19
	4,5	0,58	0,19	0,49	0,17	0,44	0,16	0,40	0,15
	6,0	0,55	0,17	0,48	0,15	0,43	0,13	0,39	0,12
$k_G = 2,0$	z (m)	a_{BF}	a_{BW}	a_{BF}	a_{BW}	a_{BF}	a_{BW}	a_{BF}	a_{BW}
	1,5	0,78	0,39	0,70	0,37	0,63	0,35	0,57	0,33
	3,0	0,75	0,28	0,68	0,26	0,61	0,24	0,55	0,22
	4,5	0,72	0,23	0,63	0,21	0,59	0,19	0,53	0,18
	6,0	0,70	0,20	0,62	0,18	0,58	0,16	0,52	0,15
$k_G = 3,5$	z (m)	a_{BF}	a_{BW}	a_{BF}	a_{BW}	a_{BF}	a_{BW}	a_{BF}	a_{BW}
	1,5	1,02	0,48	0,94	0,45	0,87	0,44	0,81	0,42
	3,0	0,99	0,33	0,92	0,31	0,85	0,30	0,79	0,29
	4,5	0,97	0,28	0,89	0,26	0,82	0,24	0,77	0,23
	6,0	0,95	0,24	0,88	0,22	0,81	0,21	0,76	0,20

- za podkletene stavbe z enakima toplotnima prehodnostima poda in vkopanega zidu je največji toplotni tok določen z enim utežnim faktorjem in vsoto površin poda in vkopanih zidov:

- for buildings with a basement with the same thermal transmittances of the basement floor and the basement walls the heat flux is determined with one weight factor and sum of the basement floor and the basement wall areas:

$$\Phi_{\max} = F_{G,z,B}^* \cdot U_F \cdot (A_F + A_{BW}) \cdot (\theta_i - \theta_{e,p}) \quad (10)$$

kjer je $F_{G,z,B}^*$ določen z izrazom:

where $F_{G,z,B}^*$ can be calculated:

$$F_{G,z,B}^* = (a_B + b_B \cdot B')^{-1} \quad (11)$$

Vrednosti konstant a_B in b_B so podane v preglednici 4.

The values of constants a_B and b_B are written in Table 4.

4 SKLEP

4 CONCLUSION

Prispevek predstavlja oblikovanje poenostavljene metode za določitev največjega toplotnega toka iz ogrevanih stavb v tla. Metoda je namenjena določevanju toplotne zaščite v fazi snovanja stavb in nadomešča neustaljen prenos toplote z ustaljenim. Zato je potrebno manj vhodnih podatkov. Analiziranih je bilo skupaj 18720 primerov.

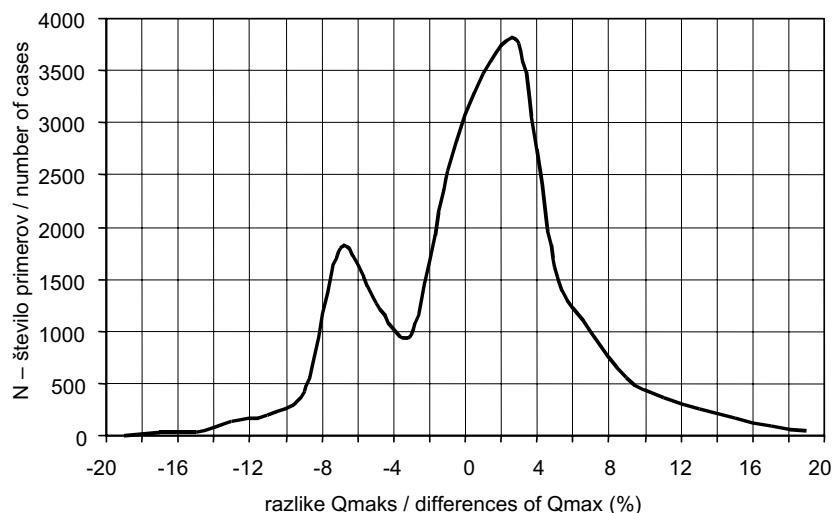
The paper presents a simplified method for determining maximum heat flux to the ground for heated buildings in contact with the ground. The method is intended for use in the design phase of building's thermal protection and substitutes non-stationary heat transfer calculations with stationary ones. As a result, less input data is needed. All together 18720 analysis were made.

Podrobna analiza pokaže, da se v nobenem od analiziranih primerov toplotni tok, določen po predlagani metodi utežnih faktorjev, in toplotni tok, določen po metodi, ki jo navaja SIST EN ISO 13370, ne razlikujeta več ko ± 20 odstotkov. Pri 93 odstotkih primerov je razlika manjša od $\pm 10\%$. Primerjavo izračunanih toplotnih tokov po obeh metodah za vse analizirane primere prikazuje slika 9.

The sensitivity analyses shows that none of the calculated heat fluxes using the weight factors are different from the heat flux determined according to EN ISO 13370 by more than $\pm 20\%$. For around 93% of the cases the differences are much smaller (within $\pm 10\%$). A comparison between the simplified calculation of Φ_{\max} and Φ_{\max} according to the EN ISO 13370 for all analysed cases is shown in Figure 9.

Preglednica 4. Vrednosti konstant a_B in b_B
 Table 4. Values of constants a_B in b_B

U_F		0,3		0,4		0,5		0,6	
$k_G = 1,5$	z (m)	a_B	b_B	a_B	b_B	a_B	b_B	a_B	b_B
	1,5	3,38	0,23	3,57	0,28	3,75	0,33	3,94	0,37
	3,0	4,21	0,20	4,56	0,24	4,90	0,29	5,24	0,33
	4,5	4,98	0,18	5,51	0,22	6,00	0,26	6,50	0,30
	6,0	5,71	0,17	6,41	0,21	7,05	0,25	7,68	0,28
$k_G = 2,0$	z (m)	a_B	b_B	a_B	b_B	a_B	b_B	a_B	b_B
	1,5	2,96	0,18	3,09	0,22	3,22	0,26	3,35	0,29
	3,0	3,67	0,16	3,92	0,20	4,17	0,23	4,42	0,26
	4,5	4,31	0,14	4,70	0,18	5,06	0,21	5,42	0,24
	6,0	4,91	0,13	5,43	0,17	5,90	0,20	6,38	0,22
$k_G = 3,5$	z (m)	a_B	b_B	a_B	b_B	a_B	b_B	a_B	b_B
	1,5	2,59	0,12	2,66	0,15	2,73	0,18	2,81	0,20
	3,0	3,16	0,11	3,30	0,13	3,44	0,15	3,58	0,17
	4,5	3,63	0,10	3,85	0,12	4,06	0,14	4,28	0,16
	6,0	4,05	0,09	4,35	0,11	4,64	0,13	4,92	0,15



Sl. 9. Razlike v toplotnih tokovih določenih z utežnimi faktorji in metodo SIST EN ISO 13370. Upoštevano je vseh 18720 analiziranih primerov

Fig. 9. Comparison between the differences between heat fluxes to the ground calculated by weight factors and the EN ISO 13370 standard. All 18720 observations are included

Vrednosti utežnih faktorjev (F_G^*) se lahko linearno interpolirajo znotraj analiziranega območja toplotnih prehodnosti poda (U_{BF}), vkopanih zidov (U_{BW}), toplotnih prevodnosti tal (k_G) in globine podkletitve (z). Kjer je to potrebno, se lahko upošteva tudi vpliv podtalnice, tako da pomnožimo utežni faktor (F_G^*) s faktorjem (G_W) iz SIST EN ISO 13370, dodatek H.

The values of the weight factor (F_G^*) can be within the analysed range of the basement floor (U_{BF}) and the basement wall (U_{BW}) thermal transmittances, the ground thermal conductivity k_G and the basement depth z linearly interpolated. In specific cases the effect of the ground water can be taken into account multiplying the weight factor (F_G^*) with factor G_W according to EN ISO 13370 annex H.

5 OZNAKE
5 NOMENCLATURE

površina poda v stiku s tlemi	A_F	m^2	floor area in contact with ground
površina vkopanega zidu v stiku s tlemi	A_{BW}	m^2	basement wall area in contact with the ground
površina gradbene konstrukcije v stiku s tlemi	A_G	m^2	building structure area in contact with the ground
karakteristična izmera poda	B'		characteristic dimension of building floor
stopinje dnevi/leto	DD	Kday/a	degree days/year
utežni faktor	F_G^*		weight factor
utežni faktor za nepodkletene stavbe	$F_{G.F}^*$		weight factor for buildings without basement
utežni faktor za pod podkletene stavbe	$F_{G.z.BF}^*$		weight factor for basement floor for buildings with basement
utežni faktor za vkopan zid podkletene stavbe	$F_{G.z.BW}^*$		weight factor for basement wall
utežni faktor za podkletene stavbe z enakima toplotnima prehodnostima poda in vkopanega zidu	$F_{G.z.B}^*$		weight factor for buildings with equal basement floor and wall thermal transmittances
specifične toplotne izgube v ustaljenem stanju	L_s	W/K	steady-state thermal coupling coefficient
zunanje periodične specifične toplotne izgube	L_{pe}	W/K	external periodic thermal coupling coefficient
zunanji obseg poda	P	m	perimeter of the building
toplotna prehodnost gradbene konstrukcije	U_G	W/m ² K	thermal transmittance of building structure
toplotna prehodnost poda stavbe	U_F	W/m ² K	thermal transmittance of building floor
toplotna prehodnost vkopanega zidu stavbe	U_{BW}	W/m ² K	thermal transmittance of basement wall
globina podkletitve	z	m	basement depth below ground level
konstante, potrebne za izračun utežnih faktorjev F_G^*	$a_F, a_B, b_B, a_{BF}, a_{BW}$		constants for the calculation of weight factors F_G^*
največji toplotni tok skozi gradbeno konstrukcijo v stiku s tlemi	Φ_{max}	W	maximum heat flux through building constructions in contact with the floor
notranja projektna temperatura	θ_i	°C	internal project temperature
zunanja projektna temperatura	$\theta_{e,p}$	°C	external project temperature
povprečna letna notranja temperatura	$\bar{\theta}_i$	°C	average annual internal temperature
povprečna letna zunanja temperatura	$\bar{\theta}_e$	°C	average annual external temperature
amplituda nihanja zunanje temperature	$\hat{\theta}_e$	°C	external temperature variation amplitude

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