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Romanian Standards for Energy Performance in Buildings

Translation of the Romanian Standards for Energy Performance in Buildings

by Adina – Ana Mureșan

Forward and Acknowledgements

This work is a part of the Master of Science Thesis written during the mobility organized by the Erasmus + Programme for exchange students at Universite de Liege, in Belgium (*Université de Liège, Belgique*), which is in bilateral agreement with Technical University of Cluj-Napoca, in Romania (*Universitatea Tehnică din Cluj-Napoca, România*) available between 2014 – 2020. The audience of this technical report is civil engineers and specialists in building energy and it aims to inform about the content of the standards for building energy performance used in Romania. The report presents the essential information of the Romanian standards for building energy performance, such as the calculation of the global thermal insulation coefficient or the annual heating demand, along with some critical aspects regarding the efficiency of the standards and their alignment with the European requirements and regulations.

The original content of the standards is found in the official language Romanian and is published in the special law publication from Romania named *Monitorul Oficial al României*. The legislative body that approved the publication of the Romanian energy performance standards C107 – 2005, Mc001 – 2006, C107/6-02 and C107-02, along with their annexes and modifications is the Ministry of Transport, Constructions and Tourism (*Ministerul Transporturilor, Construcțiilor și Turismului*). The content of the standards was elaborated by the following Romanian institutions: The University of Architecture and Urban Planning "Ion Mincu" – Bucharest (*Universitatea de Arhitectură și Urbanism "Ion Mincu" – București*), The Institute for Research in Buildings and Building Economy – Bucharest (*Institutul de Cercetări în Construcții și Economia Construcțiilor INCERC – București*), The Associastion of the Building Service Engineers from Romania (*Asociația Inginerilor de Instalații din România – AIIR*) and The Technical University of Civil Engineering – Bucharest (*Universitatea Tehnică de Construcții – București*).

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Introduction

For the analysis of buildings energy performance, in Romania are used the standards C107 – 2005 and Mc001 – 2006. C107 – 2005 consists of 5 parts which are the following: C107/1: “Standard for calculation of the global thermal insulation coefficients of the residential buildings” [3], C107/2: “Standard for the calculation of the global thermal insulation coefficients of buildings with other functions than residential” [4], C107/3: “Standard for the calculation of the thermal performances of building elements” [5], C107/4: “Guide for the calculation of the thermal performances of residential buildings” [6] and C107/5: “Standard for the thermal analysis of building elements in contact with ground” [7]. Mc001 – 2006 consists of 3 parts: Mc001/1: “The building envelope” [11], Mc001/2: “The energy performances of the building services” [9] and Mc001/3: “The audit and energy performance certificate of the building.” [10] To establish the standard interior temperature, it is used the standard SR1907: “Heating plant. Design heat requirements computation for buildings. Computation specifications” [13] and for analyzing thermal bridges there is a thermal bridge catalogue available called ”Catalogue with specific thermal bridges in buildings – Annex to Decree no. 1590/24.08.2012”. [8]

Besides these standards mentioned above, there are also C107/6 – 2002: “The general standard for the calculation of the mass transfer (humidity) through the building elements” [1] and C107/7 – 2002: “Standard for designing the building envelope for thermal stability” [2] which also deal with the building sustainability design.

1. C107/1: “Standard for calculation of the global thermal insulation coefficients of the residential buildings” [3]

C107/1 [3] is applied for individual residential buildings (single family house, coupled houses, duplex) and residential buildings with apartments. It describes the calculation of the global thermal insulation coefficient (G) $[W/m^3 \cdot K]$, the standard global insulation coefficient (GN) $[W/m^3 \cdot K]$, the annual heating demand (Q) $[kWh/m^3 \cdot yr]$ and the standard annual heating demand (QN) $[kWh/m^3 \cdot yr]$.

1.1. The global thermal insulation coefficient

G expresses the total heat losses of residential buildings which may be due to thermal transfer through the building envelope, from ventilation in normal conditions and due to excess of air infiltrations through joints of joiners. G does not depend on the heat gain from solar radiations and on the heat gain due to the building’s activity. The global thermal insulation coefficient is calculated with the following formula:

$$G = \frac{\sum(L_j \cdot \tau_j)}{V} + 0.34 \cdot n \quad [W/m^3 \cdot K] \quad (1)$$

Where:

L: The thermal coupling coefficient calculated with the mathematical relation:

$$L = \frac{A}{R'_m} \quad [W/K] \quad (2)$$

$\boldsymbol{\tau}$: The correction factor of the exterior temperatures. $[-]$

V: The volume of the interior heated space. $[m^3]$

$\boldsymbol{R'_m}$: The corrected specific average thermal resistance of a building element. $[m^2 \cdot K/W]$

A: The area of the building element with the thermal resistance R'_m . $[m^2]$

n: The velocity of the natural ventilation of the building, respectively the number of air exchanges per hour. $[h^{-1}]$

The correction factor of the exterior temperatures is calculated with the following expression:

$$\tau = \frac{T_i - T_j}{T_i - T_e} \quad [-] \quad (3)$$

Where:

$\boldsymbol{T_e}$: The exterior standard temperature during the cold season of the year which is considered according to the map of climate zones of Romania. [℃] (See ref. [5])

$\boldsymbol{T_i}$: The standard interior temperature during winter (See ref. [13]). [°C] For the residential buildings, the value is considered the dominant temperature of the building.

$\boldsymbol{T_u}$: The temperature of the unheated spaces from the exterior of the building envelope calculated according to the thermal sheet. [°C] (See ref. [5])

$\boldsymbol{T_j}$: The temperature of the exterior enviroment (outside the envelope) which can be $T_j = T_e$ or $T_j = T_u$. [°C]

GN represents the maximum values accepted in a residential building and is established according to the number of levels and to the ratio between the total area of the building anvelope (A) and the volume of the heated space (V). The value of GN is taken from the C107 – 2011 annex with modified values (See ref. [12]). The degree of global thermal insulation of residential buildings must be: $G \leq GN$.

1.2. The annual heating demand

Q reflects the degree of thermal protection regarding energy consumption and it determined with the following formula:

$$Q = \frac{24}{1000} \cdot C \cdot N_{12}^{\theta_i} \cdot G - (Q_i + Q_s) \quad [kWh/m^3 \cdot yr] \quad (4)$$

Where:

C: The correction coefficient. $[-]$

The correction coefficient depends on the reduction of interior temperature during night time, the variation of exterior temperature in time and endowment of the heating system with devices that adjust the interior temperature. It is determined from the graph from Figure 1 according to the number of degree – days N_{12}^{20} specific to the geographical location of the building (See Figure 2).

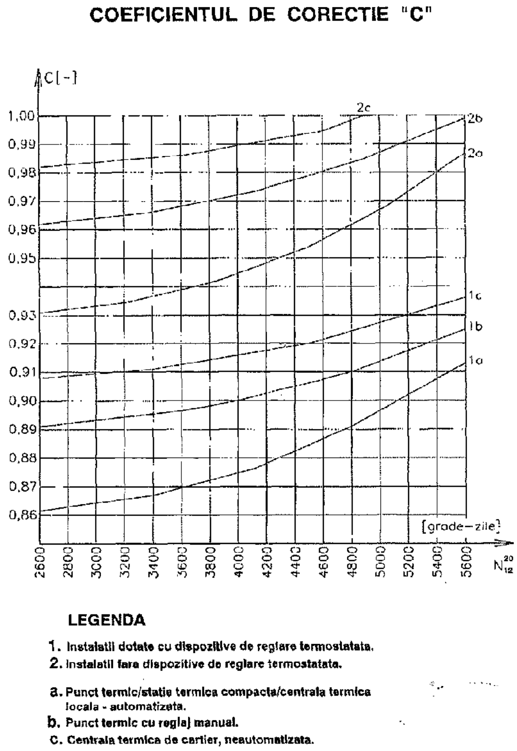


Figure 1 – The correction coefficient C. The graph represents the following:

1. Heating installation endowed with thermostat device.

2. Heating installation without thermostat device.

a. Automated thermal station or local central heating plant.

b. Thermal station with manual adjustment.

c. Non-automated district heating plant. [3]

$\boldsymbol{N_{12}^{\theta_i}}$: The annual number of degree – days of the city where the building is located calculated for the average interior temperature during heating period (θ_i) and for the daily average exterior temperature which sets the beginning and ending of heating ($\theta_{e0} = +12$°C). $[K \cdot days]$

The annual number of degree – days is calculated as follows:

$$N_{12}^{\theta_i} = N_{12}^{20} - (20 - \theta_i) \cdot D_{12} \quad [K \cdot days] \quad (5)$$

Where:

$\boldsymbol{N_{12}^{20}}$: The annual number of degree – days for the interior temperature $\theta_i = +20$°C and for the average exterior temperature which sets the beginning and ending of heating $\theta_{e0} = +12$°C. $[K \cdot days]$ The value is extracted from Table 7.1. of C107/1 (See ref. [3] and Figure 2).

$\boldsymbol{\theta_i}$: The average interior temperature. [°C]

$\boldsymbol{D_{12}}$: The standard heating period with respect to the exterior temperature which sets the beginning and ending of heating $\theta_{e0} = +12$°C. $[days]$ The value is taken from Table 7.1. of C107/1 (See ref. [3]) as seen in Figure 2.

NUMĂRUL ANUAL DE GRADE-ZILE DE CALCUL ŞI DURATA CONVENŢIONALĂ A PERIOADEI DE ÎNCĂLZIRE

Tabelul 7.1

Nr. crt.	Localitatea	θ_e °C	N_{12}^{20} K.zile	D_{12} zile	Nr. crt.	Localitatea	θ_e °C	N_{12}^{20} K.zile	D_{12} zile
1.	Adamclisi	10,8	3 120	193	41	Miercurea Ciuc	6,5	4 250	242
2.	Alba Iulia	8,9	3 460	210	42	Odorheiul Secuiesc	7,7	3 940	227
3.	Alexandria	10,7	3 150	189	43	Oradea	10,2	3 150	195
4.	Arad	10,4	3 020	192	44	Oravița	10,9	3 000	187
5.	Bacău	9,0	3 630	209	45	Păltiniș-Sibiu	4,5	5 170	266
6.	Baia Mare	9,5	3 350	201	46	Petroșani	7,6	3 960	227
7.	Bârlad	9,6	3 460	200	47	Piatra Neamț	8,7	3 560	198
8.	Bistrița	7,9	3 850	224	48	Pitești	9,7	3 420	199
9.	Blaj	8,9	3 530	210	49	Ploiești	10,1	3 390	196
10.	Botoșani	9,0	3 630	209	50	Poiana Stampei (Suceava)	4,0	5 290	284
11.	Brașov	7,5	4 030	227	51	Predeal	4,8	5 090	259
12.	Brăila	10,5	3 170	190	52	Râmnicu Sărat	10,6	3 170	190
13.	București	10,6	3 170	190	53	Râmnicu Vâlcea	10,3	3 120	194
14.	Buzău	10,7	3 150	189	54	Reșița	10,1	3 130	196
15.	Calafat	11,4	2 980	181	55	Roman	8,8	3 700	210
16.	Călărași	11,2	3 010	185	56	Satu Mare	9,4	3 370	201
17.	Câmpina	8,9	3 530	210	57	Sebeș	9,1	3 470	208
18.	Câmpulung Moldovenesc	6,5	4 270	242	58	SfântuGheorghe (Covasna)	7,0	4 140	235
19.	Câmpulung Muscel	7,9	3 820	224	59	Sibiu	8,5	3 660	215
20.	Caracal	10,9	3 100	187	60	Sighișoara	8,3	3 640	216
21.	Caransebeș	10,1	3 180	196	61	Sinaia(cota 1500)	3,6	5 650	325
22.	Cluj	8,3	3 730	218	62	Slatna	10,6	3 200	190
23.	Constanța	11,5	2 840	186	63	Slobozia	10,6	3 150	190
24.	Craiova	10,6	3 170	190	64	Suceava	7,5	4 080	230
25.	Curtea de Argeș	8,8	3 540	210	65	Sulina	11,3	3 000	190
26.	Deva	9,6	3 300	200	66	Târgoviște	10,1	3 390	196
27.	Dorohoi	8,4	3 850	217	67	Târgu Jiu	10,1	3 390	196
28.	Drăgașani	10,4	3 120	192	68	Târgu Mureș	8,8	3 540	210
29.	Făgăraș	7,7	3 930	227	69	Târgu Ocna	9,3	3 410	205
30.	Focșani	9,9	3 350	196	70	Târgu Secuiesc	6,8	4 370	237
31.	Galați	10,5	3 190	190	71	Tecuci	9,8	3 390	198
32.	Giurgiu	11,1	3 030	185	72	Timișoara	10,6	3 180	190
33.	Gura Honț(Arad)	9,8	3 290	198	73	Tulcea	11,0	3 070	191
34.	Grivița (Ialomița)	10,5	3 190	190	74	Turda	8,7	3 560	198
35.	Huși	9,7	3 420	199	75	Turnu Măgurele	11,2	3 010	185
36.	Iași	9,4	3 510	201	76	Turnu Severin	11,6	2 810	181
37.	Joseni	4,9	4 960	259	77	Urziceni	10,6	3 170	190
38.	Lugoj	10,4	3 100	192	78	Vaslui	9,3	3 570	205
39.	Mangalia	11,4	2 880	187	79	Vatra Dornei	5,3	4 580	257
40.	Medgidia	11,5	2 960	187	80	Zalău	9,5	3 300	201

Figure 2 – The annual number of degree days and the standard heating period for 80 towns from Romania. [3]

The average interior temperature is determined as follows:

$$\theta_i = \frac{\sum \theta_j \cdot V_{uj}}{\sum V_{uj}} \quad [°C] \quad (6)$$

Where:

$\boldsymbol{V_{uj}}$: The used volume of each room which is directly heated (which have heating devices). m^3

$\boldsymbol{\theta_j}$: The interior standard temperature of the room which is directly heated. [°C]

If the clear height of the rooms is the same, the average interior temperature can be calculated with the following formula:

$$\theta_i = \frac{\sum \theta_j \cdot A_{uj}}{\sum A_{uj}} \quad [°\mathrm{C}] \quad (7)$$

Where:

$\boldsymbol{A_{uj}}$: The used area of each room which is directly heated. $[m^2]$

G: The global thermal insulation coefficient calculated with formula (1).

$\boldsymbol{Q_i}$: The internal heat gains. $[kWh/m^3 \cdot yr]$

The internal heat gains come from people that inhabit the building, from the use of domestic hot water, from cooking using natural gas, from using the electricity for appliances, from artificial lighting, from mechanical ventilation, air conditioning etc. For residential buildings, the value of the internal heat gains is:

$$Q_i = 7\frac{kWh}{m^3 \cdot yr} \quad (8)$$

$\boldsymbol{Q_s}$: The solar heat gains. $[kWh/m^3 \cdot yr]$

The heat gains from solar radiation are done only through glazed areas: windows and exterior doors provided with windows. The solar heat gain is calculated with following mathematical expression:

$$Q_s = 0.40 \cdot \sum_{ij} I_{Gj} \cdot g_i \cdot \frac{A_{Fij}}{V} \quad [kWh/m^3 \cdot yr] \quad (9)$$

Where:

$\boldsymbol{I_{Gj}}$: The available global solar radiation with respect to the cardinal point j. $[kWh/m^2 \cdot yr]$

$\boldsymbol{g_i}$: The degree of absorption of solar energy through the windows I of the exterior joiners.

$\boldsymbol{A_{Fij}}$: The area of the exterior joiners provided with clear windows of type I and positioned with respect to the cardinal point j. $[m^2]$

V: The volume of the heated space (directly or indirectly heated). $[m^3]$

The available global solar radiation (direct or diffused) is determined as follows:

$$I_{Gj} = \frac{24}{1000} \cdot D_{12} \cdot I_{Tj} \quad [kWh/m^2 \cdot yr] \quad (10)$$

Where:

$\boldsymbol{D_{12}}$: The standard heating period with respect to the exterior temperature which sets the beginning and ending of heating $\theta_{e0} = +12°\mathrm{C}$. $[days]$ The value, given for 80 cities from Romania, is taken from Table 7.1. of C107/1 (See ref. [3] and Figure 2).

$\boldsymbol{I_{Tj}}$: The total intensity of the solar radiation which has values with respect to the cardinal point j and to the geographical location of the building. $[W/m^2]$ In Table 7.2. of C107/1 are given the average values of $\boldsymbol{I_{Tj}}$ for vertical plane and horizontal plane for 30 cities from Romania. If the city is not included in Table 7.2. (See ref. [3]), then the value is taken from the closest city listed in the table.

For initial design, it is accepted to take the average value of $\boldsymbol{I_{Gj}}$ on the Romanian territory as following:

- South: $I_{GS} = 420\, kWh/m^2 \cdot yr$
- South – East and South – West: $I_{GSE} = I_{GSW} = 340\, kWh/m^2 \cdot yr$
- East and West: $I_{GE} = I_{GW} = 210\, kWh/m^2 \cdot yr$
- North – East and North – West: $I_{GNE} = I_{GNW} = 120\, kWh/m^2 \cdot yr$
- North: $I_{GN} = 100\, kWh/m^2 \cdot yr$
- Horizontal surfaces: $I_{GO} = 360\, kWh/m^2 \cdot yr$

QN $[kWh/m^3 \cdot yr]$ represents the standard annual heating demand and it depends on whether the building was designed before or after January 1st, 2011 and on the A/V ratio. The standard value of the annual heating demand is extracted from the graph in Figure 3. The annual heating demand must fulfill the following condition: $Q \leq QN$.

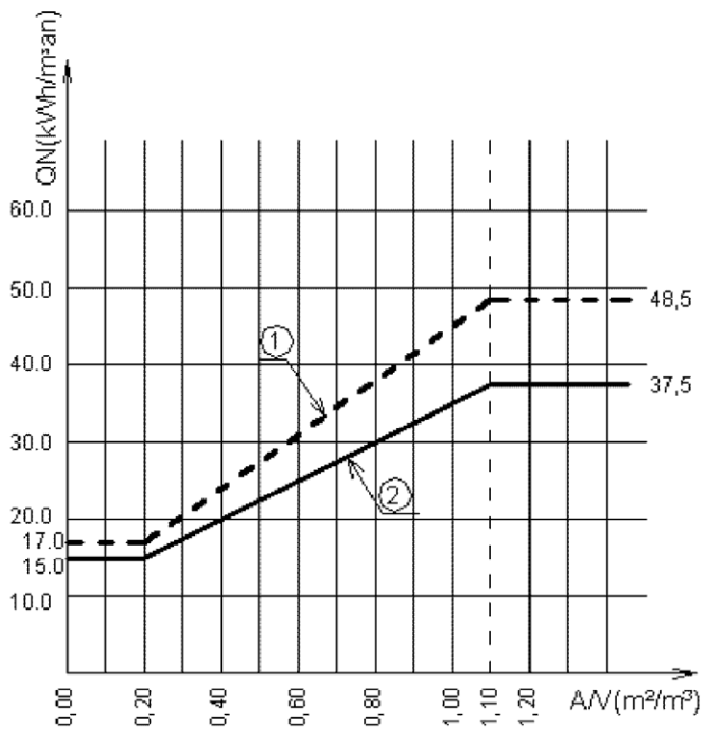


Figure 3 – The graphic representation of the standard annual heating demand from C107 – 2011, the modified annex [12]. *The legend of the graph:*

1. Residential buildings designed and contracted before January the 1st, 2011.

2. Residential buildings designed and contracted after January the 1st, 2011.

2. C107/2: “Standard for the calculation of the global thermal insulation coefficients of buildings with other functions than residential” [4]

The second part of C107 – 2005 divides the buildings with other functions than residential into 2 categories:

- **Category 1 buildings**, which are buildings with continuous occupation and buildings with discontinuous occupation with high thermal inertia
- **Category 2 buildings**, which are buildings with discontinuous occupation with low and moderate thermal inertia.

The function of the buildings with continuous occupation demands that the interior temperature should not go lower with more than 7°C below the normal service temperature between 12 am – 7 am (i.e. nursery schools, hostels, hospitals). In the buildings with discontinuous occupation it is aloud to have a deviation higher than 7°C from the normal service temperature for 10 hours/day, from which at least 5 hours are between 12 am – 7 am (i.e. schools, theatres, administrative buildings, restaurants, industrial buildings with 1 or 2 shifts etc.). CR107/2 [4] also describes the calculation of the effective global thermal insulation coefficient (G1) $[W/m^3 \cdot K]$ and of the global reference coefficient (G1ref) $[W/m^3 \cdot K]$.

2.1. The effective global thermal insulation coefficient

G1 indicates the level of energy performance during cold season of a building or a sector of building having distinct function. It represents the hourly heat losses by transfer through the building envelope, for 1°C temperature difference between the interior and exterior environment, with respect to the volume of the heated space. The mathematical expression of G1 is the following:

$$G_1 = \frac{1}{V} \cdot \left[\sum \frac{A_j \cdot \tau_j}{R'_{mj}} \right] \quad [W/m^3 \cdot K] \quad (11)$$

Where:

V: The volume of the heated space. $[m^3]$

$\boldsymbol{A_j}$: The area of the element j through which takes place the thermal transfer. $[m^2]$

$\boldsymbol{\tau_j}$: The temperature difference correction factor of the environments separated by the element j. $[-]$ It is calculated with relation (3).

$\boldsymbol{R'_{mj}}$: The corrected average thermal resistance of the element j. $[m^2 \cdot K/W]$

2.2. The global reference coefficient

G1ref is represented by formula (12). It is calculated to establish the thermal performance of the building according to the architectural plan and these performances must be ensured by the contractor and maintained for the whole life cycle of the building.

$$G_{1ref} = \frac{1}{V} \cdot \left[\frac{A_1}{a} + \frac{A_2}{b} + \frac{A_3}{c} + d \cdot P + \frac{A_4}{e} \right] \quad [W/m^3 \cdot K] \quad (12)$$

Where:

$\boldsymbol{A_1}$: The area of the opaque surfaces of the vertical walls, which have an angle greater than 60° with respect to the horizontal plane, in contact with the exterior or an unheated space, calculated by taking into consideration the dimensions in between the axes. $[m^2]$

$\boldsymbol{A_2}$: The area of the slabs from the last floor (horizontal or with an angle less than 60° with respect to the horizontal plane), in contact with the exterior or an unheated space, calculated by taking into consideration the dimensions in between the axes. $[m^2]$

$\boldsymbol{A_3}$: The area of the slabs from the inferior floors in contact with the exterior or an unheated space, calculated by taking into consideration the dimensions in between the axes. $[m^2]$

P: The exterior perimeter of the heated space of the building, in contact with the soil or buried. $[m]$

$\boldsymbol{A_4}$: The area of the glazed surfaces of the walls in contact with the exterior or an unheated space, calculated by taking into consideration the standard dimensions of the window hole. $[m^2]$

V: The volume of the heated space, calculated by taking into consideration the interior dimensions of the building. $[m^3]$

a, b, c, d, e: Control coefficients of the building elements mentioned above which have the values listed in Table 1 (See ref. [4]) and Table 2 (See ref. [4]) from C107/2 and which depend on the building category (category 1 or category 2), the function of building (other than residential) and the climatic zone defined in C107/3 [5].

The verification is as in the case of residential buildings: $G1 \leq G1ref$.

2.3. The thermal inertia of the buildings

The thermal inertia of the non-residential building is calculated in order to establish in which of the two categories the building fits in. The determination of the thermal inertia is done for the whole building if the developed area of the heated space is smaller than $200m^2$, otherwise it can be determined for sectors of the building. The thermal inertia is determined with expression (13).

$$\frac{\sum_j m_j \cdot A_j}{A_d} \quad [kg/m^2] \quad (13)$$

Where:

$\boldsymbol{m_j}$: The unitary mass of each building element j which contributes to its thermal inertia. $[kg/m^2]$

$\boldsymbol{A_j}$: The used area of each building element j calculated by taking into consideration the interior dimensions. $[m^2]$

$\boldsymbol{A_d}$**:** The developed area of the entire building or of a sector from a building. $[m^2]$

According to the obtained result, the thermal inertia of the building is established as follows:

- **Low thermal inertia**, if relation (13) has a value up to $149\ kg/m^2$.
- **Moderate thermal inertia**, if relation (13) has a value between $150 - 399\ kg/m^2$.
- **High thermal inertia**, if relation (13) has a value higher and equal to $400\ kg/m^2$.

3. CR107/3: "Standard for the calculation of the thermal performances of building elements"[5]

C107/3 [5] refers to the calculation of all building elements except the ones in contact with the soil. To be thermal efficient, the structure of the building element must fulfill the following conditions:

- The building element must have the minimum thermal resistance necessary to ensure the interior comfort, to limit the thermal transfer through the element and to save energy of the building.
- The condensation of water vapors must be avoided at the interior surface of the building element.
- The building element must be impermeable to water vapors in order to limit and even to stop the condensation inside its structure.
- The necessary thermal stability must be ensured into the building during winter and summer in order to limit the huge temperature differences of the interior air and on the interior surface of the building element.

3.1. The standard temperatures

The standard exterior temperature (T_e) is chosen from the climate zones during cold season of Romania. Romania is divided into 4 climate zones as following:

- Area I: -12°C.
- Area II: -15°C.
- Area III: -18°C.
- Area IV: -21°C.

Figure 4 shows how the climate zones are distributed over the territory of Romania:

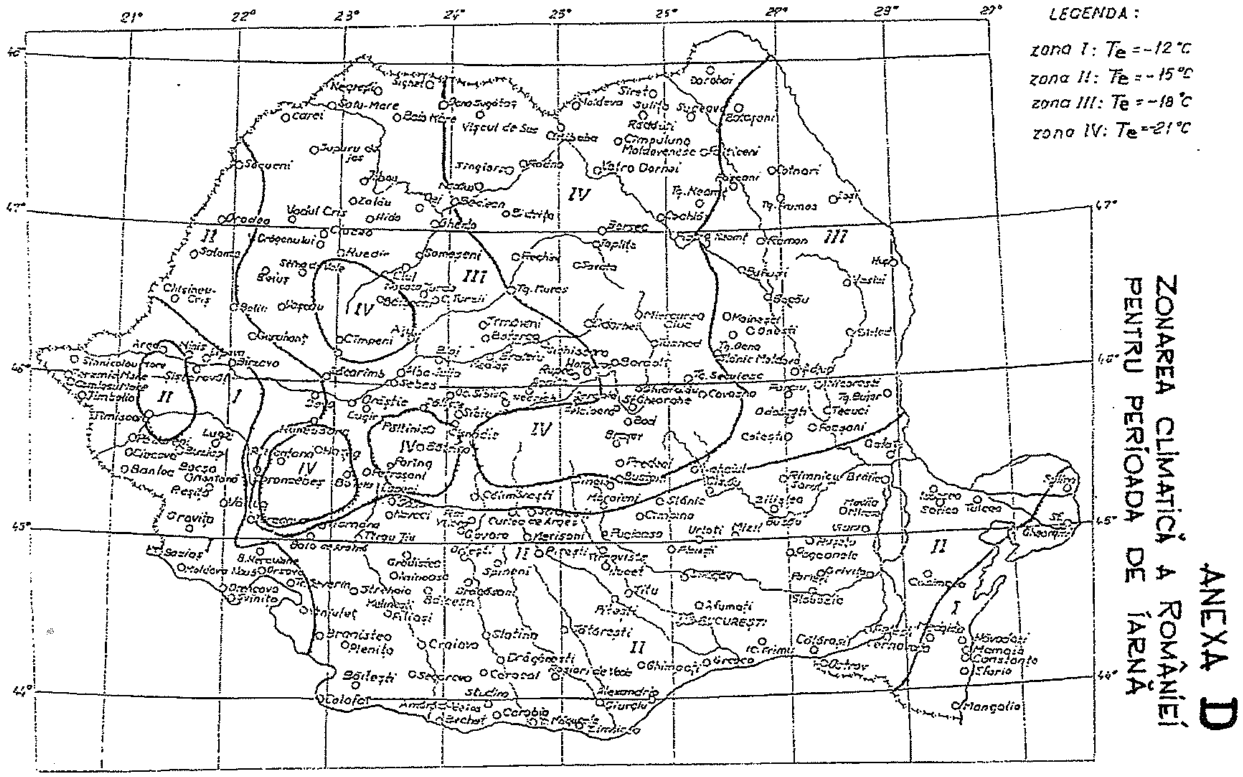


Figure 4 – The climate zones of Romania during winter. It is Annex D from C107/3 [5].

The standard interior temperatures of the heated room (T_i) are usually taken from standard SR1907: "Heating plant. Design heat requirements computation for buildings. Computation specifications" [13]. In case the heated rooms have different standard temperature, but there is one temperature which is dominant, then the dominant temperature is used in the calculations (i.e. for residential buildings is $T_i = +20$°C).

The interior temperatures of the unheated rooms (T_u) are determined based on a thermal sheet with respect to the standard interior temperatures of the adjacent rooms, to the areas of the building elements which form the boundary of the unheated space and to the thermal resistances of the building elements mentioned previously. It is mandatory to take into consideration the velocity of ventilation of the unheated space. The temperature T_u will also be determined for closed joints, attics, technical floors, balconies and loggias closed with exterior joiners.

The interior temperature for the unheated spaces is evaluated as follows:

$$T_u = \frac{\sum(T_j \cdot L_j) + 0.34 \cdot V \cdot \sum(n \cdot T_j)}{\sum L_j + 0.34 \cdot V \cdot \sum n} \quad [°\mathrm{C}] \quad (14)$$

Where:

$\boldsymbol{L_j}$: The thermal coupling coefficients of all the horizontal and vertical building elements which form the boundary of the unheated space from the adjacent environments: exterior air or heated rooms. $[W/K]$

$\boldsymbol{T_j}$: The standard temperatures of the adjacent environments: T_e or T_i. [°C]

V: The interior volume of the unheated space. $[m^3]$

n: The velocity of the natural ventilation of the unheated space, respectively the number of air exchanges. $[h^{-1}]$

3.2. The thermal resistance of the building elements

The thermal resistance of an homogeneous layer is calculated as follows:

$$R = \frac{d}{\lambda} \quad [m^2 \cdot K/W] \quad (15)$$

Where:

d: The thickness of the layer. $[m]$

$\boldsymbol{\lambda}$: The thermal conductivity of the material. $[W/m \cdot K]$

The thermal resistance of the superficial air layer (R_{Si} *and* R_{Se}) depends on the direction of the heat flow. The details are given in Table II (See ref. [5]) extracted from C107/3. Table II describes the direction of the heat flow through a specific building element and the values of the thermal resistance of the superficial air layer on the interior side (R_{Si}), respectively on the exterior side (R_{Se}) of a specific building element.

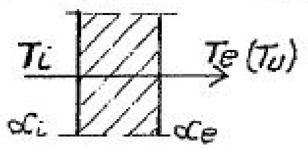
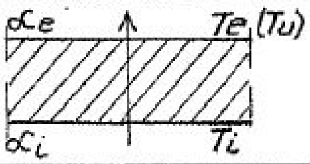
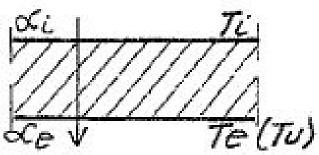
DIRECŢIA ŞI SENSUL FLUXULUI TERMIC	Elemente de construcţie în contact cu: • exteriorul • pasaje deschise (ganguri)		Elemente de construcţie în contact cu spaţii ventilate neîncălzite: • subsoluri şi pivniţe • poduri • balcoane şi logii închise • rosturi închise • alte încăperi neîncălzite	
	α_i/R_{si}	α_e/R_{se}	α_i/R_{si}	α_e/R_{se}
	8 / 0,125	24 / 0,042 *)	8 / 0,125	12 / 0,084
	8 / 0,125	24 / 0,042 *)	8 / 0,125	12 / 0,084
	6 / 0,167	24 / 0,042 *)	6 / 0,167	12 / 0,084

Figure 5 – Table II from C107/3 [5] *which describes the following: the direction of the heat flow through a specific building elements, the values of the thermal resistance of the superficial air layer*

if the element is in contact with the exterior or open passages and if the building element is in contact with unheated spaces (i.e. basements, attic, closed balcony)

The specific unidirectional thermal resistance of a building element composed of one or more layers of homogeneous materials, without thermal bridges, including some layers of unventilated air, perpendicular to the direction of the heat flow is calculated with the relation:

$$R = R_{Si} + \sum_{i} R_i + R_S \quad [m^2 \cdot K/W] \quad (16)$$

Where:

$\boldsymbol{R_{Si}}$**:** The thermal resistance of the superficial air layer on the interior surface of the building element. $[m^2 \cdot K/W]$

$\boldsymbol{R_i}$**:** The thermal resistance of the material layer i. $[m^2 \cdot K/W]$

$\boldsymbol{R_{Se}}$**:** The thermal resistance of the superficial air layer on the exterior surface of the building element. $[m^2 \cdot K/W]$

The unidirectional thermal transmittance has the following formula:

$$U = \frac{1}{R} \quad [W/m^2 \cdot K] \quad (17)$$

The final values of U and R are rounded by 3 decimals.

The specific thermal resistance of the building element must be corrected as below:

$$R' = r \cdot R \quad [m^2 \cdot K/W] \quad (18)$$

Where:

r: The reduction coefficient of the unidirectional thermal resistance. $[-]$ The coefficient is evaluated with the following formula:

$$r = \frac{1}{1 + \frac{R \cdot [\sum(\psi \cdot l) + \sum \chi]}{A}} \quad [-] \quad (19)$$

Where:

$\boldsymbol{\psi}$: The specific linear coefficient.

$\boldsymbol{\chi}$: The specific point coefficient.

A: The area of the building element.

The specific linear coefficient (ψ) and the specific point coefficient (χ) correct the unidirectional thermal resistance of the building element by taking into consideration the presence of the constructive thermal bridges and the real behavior of the heat flow in the non-homogeneous areas of the building element. The point thermal bridges resulted from the intersection between two linear thermal bridges are usually neglected. The specific coefficients $\boldsymbol{\psi}$ and $\boldsymbol{\chi}$ do not depend on the climate zones and they are determined automatically from the temperature field.

The average thermal resistance (R'_m) is determined in the following situations:

- For a room which has more types of surfaces on the same building element.
- For the same level of a building.
- For a whole sector from a building.

The thermal resistances of the glazed surfaces are usually given in Table V of C107/3, but most of the time they are taken from the producers' catalogues.

The building element must satisfy the following condition: $R' \geq R'_{nec}$.

Where:

$\boldsymbol{R'_{nec}}$: The necessary thermal resistance of the building element. $[m^2 \cdot K/W]$ The values for each building element are listed in the C107 – 2011, the annex with modifications (See ref. [12]).

3.3. The temperature at the interior surface of the building element

The temperature at the interior surface of the building element without thermal bridges or in the interior of the building element with thermal bridges is determined with the relation:

$$T_{Si} = T_i - \frac{\Delta T}{\alpha_i \cdot R} \quad [°\mathrm{C}] \quad (20)$$

Where:

$\boldsymbol{T_i}$: The standard interior temperature of the heated room. [°C]

$\boldsymbol{\Delta T}$: The temperature difference calculated as: $\Delta T = T_i - T_e$. [°C] If the building element is adjacent to unheated spaces, then it is calculated as: $\Delta T = T_i - T_u$.

$\boldsymbol{\alpha_i}$: The thermal transmittance of the interior superficial air layer. $[W/m^2 \cdot K]$

R: The thermal resistance of the building element. $[m^2 \cdot K/W]$

In the area of the thermal bridges, T_{Si} is determined from the temperature field using automatic calculations.

The temperature on the interior surface of the building element must be greater than the dew temperature: $T_{Si} \geq \theta_r$ [°C]. The dew temperature depends on the standard interior temperature T_i and on the relative interior humidity φ_i and its values are listed in the Annex B of C107/3 [5] as seen in Figure 6.

ANEXA B

TEMPERATURA PUNCTULUI DE ROUĂ (θ_r) PENTRU DIFERITE TEMPERATURI ŞI UMIDITĂŢI RELATIVE ALE AERULUI INTERIOR

— °C —

Umiditatea relativă a aerului φ_i %	Temperatura aerului interior, Ti, în °C					
	12	14	16	18	20	22
100	+ 12,0	+ 14,0	+ 16,0	+ 18,0	+ 20,0	+ 22,0
95	+ 11,2	+ 13,2	+ 15,2	+ 17,2	+ 19,2	+ 21,2
90	+ 10,4	+ 12,4	+ 14,3	+ 16,3	+ 18,3	+ 20,3
85	+ 9,6	+ 11,5	+ 13,5	+ 15,4	+ 17,4	+ 19,4
80	+ 8,7	+ 10,6	+ 12,5	+ 14,5	+ 16,5	+ 18,4
75	+ 7,7	+ 9,7	+ 11,6	+ 13,5	+ 15,4	+ 17,4
70	+ 6,7	+ 8,6	+ 10,5	+ 12,4	+ 14,4	+ 16,3
65	+ 5,7	+ 7,5	+ 9,4	+ 11,3	+ 13,2	+ 15,1
60	+ 4,5	+ 6,4	+ 8,2	+ 10,1	+ 12,0	+ 13,9
55	+ 3,2	+ 5,1	+ 7,0	+ 8,8	+ 10,7	+ 12,5
50	+ 1,9	+ 3,7	+ 5,6	+ 7,4	+ 9,3	+ 11,1
45	+ 0,4	+ 2,3	+ 4,1	+ 5,9	+ 7,7	+ 9,5
40	− 1,0	+ 0,6	+ 2,4	+ 4,2	+ 6,0	+ 7,8
35	− 2,6	− 1,1	+ 0,5	+ 2,3	+ 4,1	+ 5,9
30	− 4,5	− 2,9	− 1,3	+ 0,2	+ 1,9	+ 3,6
25	− 6,6	− 5,0	− 3,5	− 2,0	− 0,5	+ 1,1

Figure 6 – The dew temperature θ_r with respect to the standard interior temperature T_i and the relative interior humidity φ_i from Annex B of C107/3 [5].

4. C107/4 : “Guide for the calculation of the thermal performances of residential buildings”[6]

The 4th part of C107 – 2005 presents the following steps of calculations of the energy performance of a residential building:

1. ***Establish the geometric boundary of the building, as in the Figures 7 and 8.***

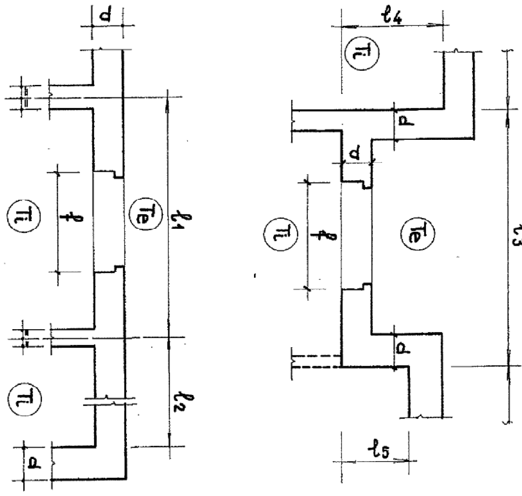


Figure 7 – Establishing the geometric boundary in plane (See ref. [5]*)*

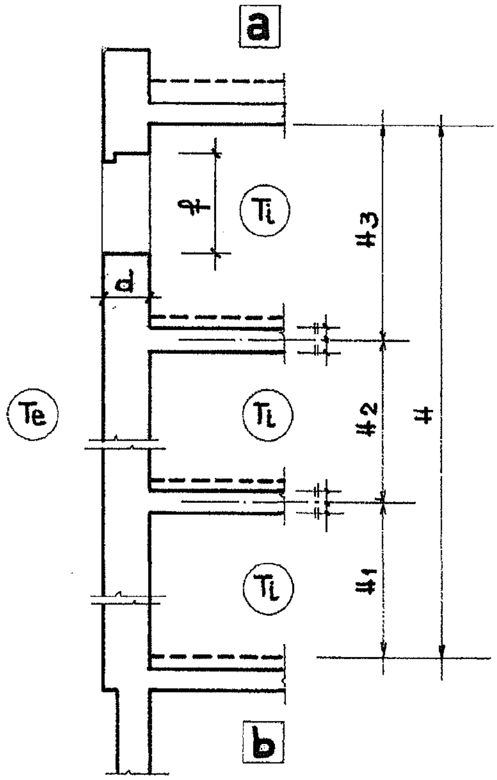


Figure 8 – Establishing the geometric boundary in elevation (See ref. [5]*)*

2. ***Calculation of the areas of the building elements*** (A_j)***.***

The areas that form the total area of the building envelope are the following:

- The area of the opaque surface of the walls.
- The area of the glazed surfaces: windows, windows of the exterior doors, curtain facades, skylights.
- The area of the slabs that form the terrace roof.
- The area of the slabs that are a part of the attic.
- The area of the slabs above the unheated basement.
- The area of the slabs in contact with the ground.
- The area of walls in contact with the ground.
- The area of walls and slabs which separate the heated volume of the building from unheated spaces or from sectors which have other function.

3. ***Calculation of the total area of the building anvelope and of the volume of the heated space.***

The volume of the heated space (V) contains the rooms heated directly, with heating devices, and the rooms heated indirectly, without heating devices, in which the heat transfers through the adjacent walls and which don't have a significant thermal insulation layer. In the volume of the heated space are not included the rooms have the temperature smaller than the average building temperature, the porch, the balconies, even though they are closed with joiners.

The area of the building envelope (A) represents the sum of all areas of the elements of the building envelope through which take place the heat losses.

$$A = \sum A_j \quad (21)$$

Where:

$\boldsymbol{A_j}$: The area of an element of the building envelope.

4. ***Determine the temperatures by thermal balance sheet. (See ref.** [5]**)***

See relation (14) in case of the interior temperatures for unheated spaces.

5. ***Determine the correction factors $(\boldsymbol{\tau_j})$. (See ref.** [3], [5]**)***

See relation (3).

6. ***Determine the average corrected thermal resistances $(\boldsymbol{R'_m})$. (See ref.** [5]**)***
7. ***Establish the number of air exchanges per hour $(\boldsymbol{n})$.***

This parameter is taken from Annex 1 of C107/1 [3] according to the sheltering class and permeability class of the building.

The sheltering classes of the building are the following:

- **Unsheltered buildings:** very tall buildings, buildings located in the suburbs and in markets.
- **Moderate sheltered buildings:** buildings located inside the city having at least 3 neighbor buildings.

- **Sheltered buildings:** buildings located in the city center, buildings located in forests.

  The permeability classes of the buildings are established as follows:

- **High permeability:** buildings with exterior joinery which is not sealed.
- **Moderate permeability:** buildings with exterior joinery which is sealed with packing.
- **Low permeability:** buildings with controlled mechanical ventilation and with exterior joinery which is provided with special sealing.

  The values of the air exchanges per hour are listed in Figure 9.

NUMĂRUL SCHIMBURILOR DE AER PE ORĂ - n - (h^{-1})
LA CLĂDIRI DE LOCUIT
(conform INCERC – București)

CATEGORIA CLĂDIRII		CLASA DE ADĂPOSTIRE	CLASA DE PERMEABILITATE		
			ridicată	medie	scăzută
Clădiri individuale (case unifamiliale, cuplate sau înșiruite ș.a.)		neadăpostite	1,5	0,8	0,5
		moderat adăpostite	1,1	0,6	0,5
		adăpostite	0,7	0,5	0,5
Clădiri cu mai multe apartamente, cămine, internate, ș.a.	dublă expunere	neadăpostite	1,2	0,7	0,5
		moderat adăpostite	0,9	0,6	0,5
		adăpostite	0,6	0,5	0,5
	simplă expunere	neadăpostite	1,0	0,6	0,5
		moderat adăpostite	0,7	0,5	0,5
		adăpostite	0,5	0,5	0,5

Figure 9 – The values of the air exchanges per hour which are according to the sheltering classes of the buildings (unsheltered, moderate sheltered, sheltered, to the permeability class (high, moderate, low), to the building category (single family house, multi-family house) and type of exposure (double, simple). [3]

8. ***Calculate in the table the expression*** $\sum \frac{A_j}{R'_m} \cdot \tau_j$.

   The table is represented in Figure 10 and its role is to simplify the calculations.

Nr. crt.	ELEMENTUL DE CONSTRUCȚIE		A	R'_m	τ	$A \cdot \tau/R'_m$
			m^2	m^2K/W	-	W/K
1	Pereți exteriori					
2	Planșee	peste subsol				
3		terasă				
4		pod	-			
5		sub bowindouri				
6	Pereți rost	deschis				
7		închis				
8	Tâmplărie exterioară	curentă				
9		cu obloane exterioare				
10	Pereți subsol încălzit	exteriori peste CTS				
11		exteriori sub CTS				
12		interiori (la subsol parțial)				
13	Placa	pe sol				
14		inferioară (subsol încălzit)				
TOTAL			ΣA	-	-	$\Sigma A \cdot \tau/R'_m$

Figure 10 – Table taken from File d of C107/4 [6].

9. ***Determine the global thermal insulation coefficient G.***

   For residential buildings, see relation (1). For non-residential buildings, see relation (11).

10. ***Determine the ratio A/V and the standard global thermal insulation coefficient GN.***

    The values are found in the modified annex of C107 – 2005 from 2011 (See ref. [12]).

5. C107/5 : "Standard for the thermal analysis of building elements in contact with ground"[7]

The last part of C107 – 2005 deals with characteristic cases of building elements in contact with soil which are the following (Figures 11 – 15):

- Slab on the ground
- Partially buried heated basement
- Overlapped heated basements
- Completely buried heated underground space
- Partially buried unheated basement.

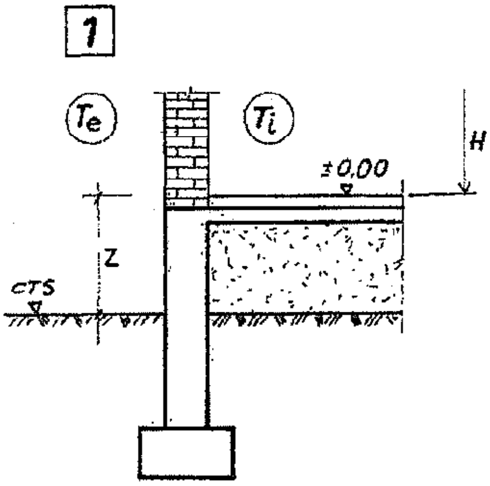


Figure 11 – Slab on the ground as represented by C107/5 [7].

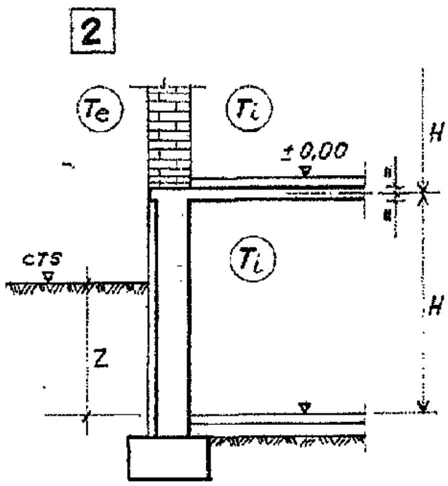


Figure 12 – Partially buried heated basement as represented by C107/5 [7].

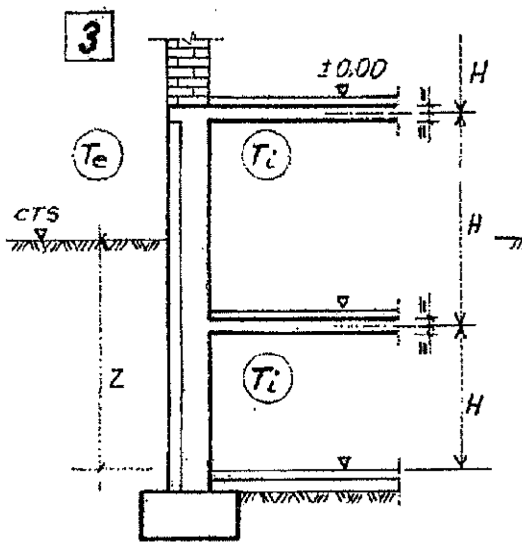


Figure 13 – Overlapped heated basements as represented by C107/5 [7].

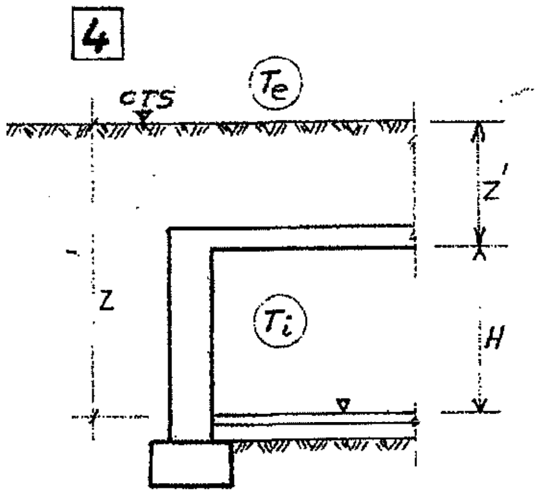


Figure 14 – Completely buried heated underground space as seen in C107/5 [7].

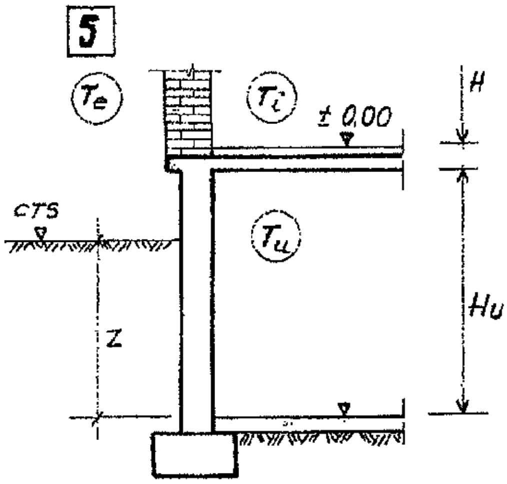


Figure 15 – Partially buried unheated basement as seen in C107/5 [7].

C107/5 [7] takes into consideration the temperature variations between the systematic ground level (SGL) and the invariable layer level (ILL). This standard temperature variation is represented in Figure 16 and is different with respect the climate zones from Romania. In the graph $\boldsymbol{T_p}$ represents the temperature of the soil at the invariable layer level which is also according to each climate zone. $\boldsymbol{T_p}$ [°C] is measured at the depth of 7 meters from the systematic ground level and this temperature is constant the entire year.

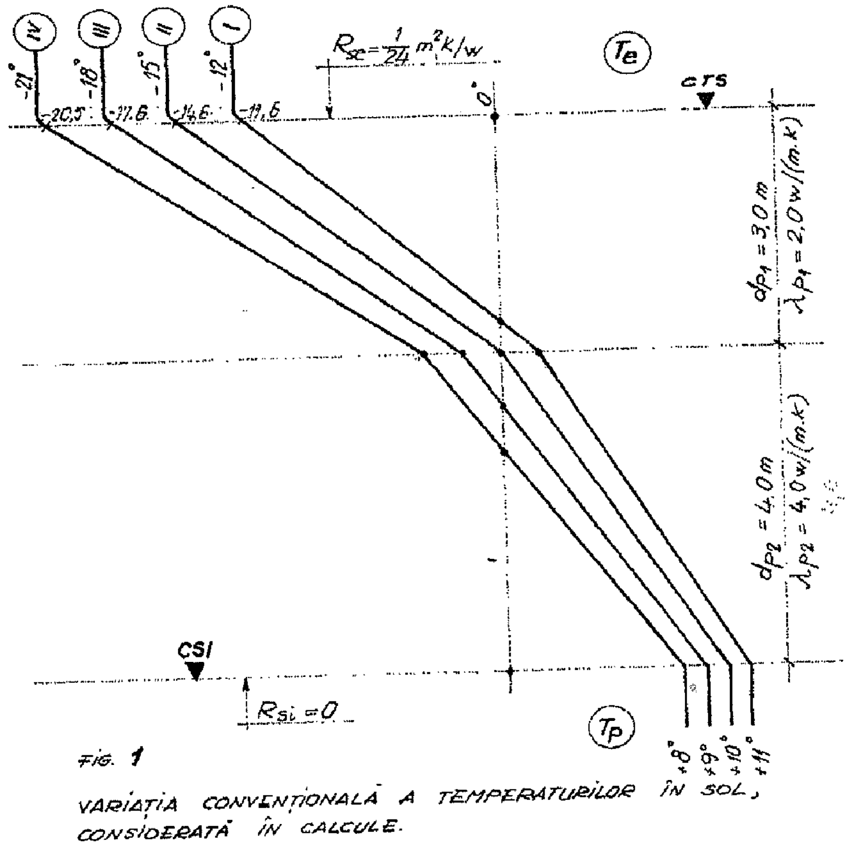


Figure 16 – The standard temperature variations between the systematic ground level and the invariable layer level from C107/5 [7].

In the thermal analysis of the building elements in contact with the ground it is important to take into consideration the ground water table (GWT). The influence of the GWT depends on the depth at which the GWT is located and on whether if the GWT is mobile or stationary. There are three cases to be taken into consideration in the problem of the GWT:

1. ***If the GWT is stationary and the maximum hydrostatic level (MHL) is located at more than 5 meters from the systematic ground level (SGL).***

   In this case the presence of the GWT can be ignored in the calculations.
2. ***If the GWT is stationary and the MHL is located at less than 5 meters from the SGL.***

   Here the following modifications that have to be done:

- The ground temperature (T_p) is considered at MHL and not at 7 meters from the SGL. The MHL must be located lower from the inferior surface of the basement.
- The specific unidirectional thermal resistances will be calculated by taking into consideration the layers in between the upper level of the finished floor and the MHL (instead of SGL).
- The thermal conductivity of the ground will have the unique value $\lambda_p = 2\, W/m \cdot K$ on the entire depth in between SGL and MHL.

3. ***If the GWT is mobile and the velocity of the underground water is significant.***

In the case of a mobile GWT with a significant velocity of the underground water appears a supplementary heat flow. The heat flow is as big as the velocity of the underground water if the depth at which the GWT is located is small and the thickness of the slab's thermal insulation layer is reduced. If the depth and the velocity of the GWT are known, then it can be calculated an over unit multiplication factor (G_w) which will reduce the corrected thermal resistance (R') or will increase the corrected thermal transmittance (U'). The method of calculating this multiplication factor is presented in Annex F of C107/5.

C107/5 [7] also presents the thermal characteristics of the soils. The thermal conductivity of the soils varies mostly between $0.6 - 3.5\, W/m \cdot K$. The factors that influence the thermal characteristics of the soils are the following:

1. ***The apparent density of the soil in dry state***

The apparent density of the soil in dry state is influenced by its porosity. The thermal conductivity is high, if the porosity is small and the apparent density is high. In case the pores of the soil are big and they are connected to each other, the thermal conductivity can be higher because of the convection phenomenon that may occur.

2. ***The humidity of the soil***

If the humidity increases, the thermal conductivity will increase too.

3. ***The mineral content and the size of the soil grains***

Usually sands have the thermal conductivity higher than clays and lower than rocks.

4. ***The behavior of the soil in case of freezing***

Frozen soils have higher thermal conductivities than the soil in normal state. At some frozen rocks, the thermal conductivity depends also on its amorphous or crystalline nature and on the direction of the heat flow with respect the cleavage planes.

6. Mc001/1 : "The building envelope" [11]. The interior comfort of the buildings

Mc001/1 [11] has similar content with C107 – 2005, but with upgraded information as following:

- The definition and the ranking of the elements of the building envelope and of the energy performance parameters associated to them.
- Specific exterior climate parameters for the application of the methodology.
- Elements regarding the architectural and constructive design of the building, in general and detailed, which influence the performances of the building regarding heating, natural ventilation, solar radiation and natural lighting.
- Functions of the buildings and their influence on their energy performance.
- The calculation of the parameters of thermal and energy performance and air permeability of the building envelope.
- The calculation of the parameters of the elements of building envelope in contact with ground.
- Performance requirements and thermal, energy and air permeability performance levels of the building envelope and its elements.
- The evaluation of the passive solar systems and of the solar radiation protection systems on the energy performance of the building.
- Conditions for the interior climate and natural lighting for the thermal and visual comfort of buildings.
- Special rules for applying the methodology on existent buildings which will be thermal rehabilitated.

Among the information mentioned in the first part of Mc001 – 2006, in this section will be given more attention on the conditions for thermal and visual comfort in buildings. The conditions for the interior climate and natural lighting are mentioned in Chapter 13 of Mc001/1.

6.1. The main interior environment parameters

The main parameters that influence the interior comfort in the buildings are the following:

1. ***The temperature of the air***

The temperature of the air represents the temperature measured by the dry thermometer at a certain height depending on the function of the room.

2. ***The average radiation temperature***

This is the temperature of the walls of a virtual room in which the temperature of the walls is uniformly distributed and the radiation exchanges between the virtual room and the indweller are equal to the heat exchanges through radiation in the real room.

3. ***The asymmetry of the radiation temperature***

Is the difference of the plane radiation temperature on two opposite sides of a small element. The plane radiation temperature is the uniformly distributed temperature of a room in which the radiation on one of the sides of a small plane element is similar to the real irregular environment.

4. ***The interior temperature***

Represents the arithmetic average between the air temperature and the average radiation temperature from the center of the room or occupied space.

5. ***The standard temperature***

It is the interior temperature established by using an adjusting system during normal heating regime. The standard temperature depends on the function of the room.

6. ***The absolute humidity and the relative humidity***

The absolute humidity represent the amount of water vapors contained in the air and which is expressed by the following parameters:

- **The partial pressure of the water vapors**, which is the pressure made by the water vapors, contained in a mixture of humid air, if these water vapors would occupy the same volume filled by the humid air at the same temperature.
- **Humidity ratio**, which is the ratio between the mass of water vapors contained in a sample of humid air and the mass of dry air from the same sample.

The absolute humidity is evaluated with the following formula:

$$W_g = 0.61298 \cdot \frac{p_a}{p - p_a} \quad [-] \quad (22)$$

Where:

$\boldsymbol{W_g}$: The humidity ratio. $[-]$

$\boldsymbol{p_a}$: The partial pressure of the water vapors. $[Pa]$

p: The total pressure of the atmosphere. $[Pa]$

The relative humidity represents the amount of water vapors from the air with respect to the maximum quantity that can be contained at a certain temperature. It is evaluated with the following relationship:

$$\varphi = \frac{p_a}{p_{a,sat}} \cdot 100 \quad [\%] \quad (23)$$

Where:

$\boldsymbol{\varphi}$: The relative humidity of the air. [%]

$\boldsymbol{p_a}$: The partial pressure of the water vapors. $[Pa]$

$\boldsymbol{p_{a,sat}}$: The saturated pressure of the water vapors. $[Pa]$

7. ***The velocity of air***

The velocity of air is defined by the constant module and direction. When the interior environment is analyzed, from the vector of air velocity is taken into consideration the constant module which will be used in the evaluation of the thermal comfort and local discomfort produced by the air flow.

6.2. The thermal comfort parameters

The thermal sensation felt by the indweller is represented by the thermal sensation of his body and it is influenced by:

- The environment parameters (i.e. the temperature of the air, the average radiation temperature, humidity and the velocity of air).
- The clothes that the indweller wears.
- The activity he has in that certain environment.

The thermal sensation of the human body is subjective and it is defined by two parameters:

1. **The average predictable vote index (PMV)**

In Romanian, in the standard, this index is named "Votul mediu previzibil (PMV)". PMV is the average opinion of an important group of people which expresses its vote regarding the thermal sensation with respect to the environment. This opinion is illustrated by a 7 level scale as follows:

- Very hot: +3
- Hot: +2
- Warm: +1
- Neutral: 0
- Chilly: -1
- Cold: -2
- Very cold: -3

PMV index is determined from the equation of thermal balance of the human body based on the following data:

- The parameters of the environment (i.e. the temperature of air, the average radiation temperature, the relative velocity of air, the partial pressure of water vapors).
- Human activity (i.e. generating metabolic energy).
- The thermal resistance of the clothes.

PMV can also be determined using values listed in tables based on:

- The level of activity.
- The thermal resistance of the clothes.
- The relative velocity of the air.
- The operation temperature.

The operation temperature represents the uniformly distributed temperature of a black radiant room where an indweller exchanges the same amount of heat through radiation and convection as in an irregular real environment. The operation temperature is evaluated with the following formula:

$$\theta_o = A \cdot \theta_a + (1 - A) \cdot \overline{\theta_r} \quad [°C] \quad (24)$$

Where:

$\boldsymbol{\theta_o}$**:** The operation temperature. [°C]

$\boldsymbol{\theta_a}$**:** The temperature of the air. [°C]

$\overline{\boldsymbol{\theta_r}}$**:** The average radiation temperature. [°C]

A: Correction factor which depends on the velocity of air (v_a), as following:

- If $v_a < 0.2\, m/s$, then $A = 0.5$
- If $0.2 \leq v_a \leq 0.6\ [m/s]$, then $A = 0.6$
- If $0.7 \leq v_a \leq 1\ [m/s]$, then $A = 0.7$

2. **The predictable percentage of dissatisfied index (PPD)**

In the standard, this index is translated in Romanian as “Procentul previzibil de nemulțumiți (PPD)” . PPD represents the percentage of people who might experience the sensation of very cold or very hot in the surrounding environment. This index gives information on the thermal discomfort of indwellers.

The interior environment which is suitable for the indweller’s comfort is described by the following range of values for the PMV and PPD indexes:

$$PPD < 10\%$$

$$-0.5 < PMV < +0.5$$

6.3. The general and detailed architectural and constructive concept of buildings which influence the interior comfort

The quality of the interior air depends on the quality of the exterior air which enters the building and on the contamination agents of the interior air. If none of these factors have an influence in taking a decision, the standard limits of natural ventilation are considered hygienic. This standard of natural ventilation is given with respect to:

- The number of indwellers occupying the room at the same time.
- The volume of interior air.
- The different polluting products produced by different industrial chemical substances, building materials or other different odors.

In order to ensure the standards of hygiene in the multi family residential buildings, the following rules must be respected:

- On December 21st must be ensured at least 1 ½ hours of daylight for at least 1 room, for 2 rooms apartments, and for at least 2 rooms, for 3 or 4 rooms apartments.
- In a residential district are aloud maximum 5% of the apartments to be shadowy.

Respecting the above standards of hygiene is very important because of the difference between the theoretical and real daylight length. Not respecting the standards of hygiene in buildings can lead to Sick Building Syndrome which gives the indwellers the following symptoms due to discomfort:

- Fatigue.
- Lack of concentration.
- Teary eyes.
- Breathing difficulties.
- Chills.
- Rheumatism.

7. Mc001/2: "The energy performances of the building services" [9]. Mechanical ventilation and air conditioning

Mc001/2 [9] offers detailed evaluation of the energy performance of the following building services:

- Heating installations.
- Mechanical ventilation and air conditioning.
- Installations for producing and distribution of domestic hot water.
- Installations for artificial lighting.

The second part of Mc001 – 2006 also offers alternative methods for the evaluation of the energy performances of the building services. This section will only refer to the energy performance of the mechanical ventilation and air conditioning in buildings and this aspect is presented in Chapter 2 of Mc001/2 [9]. Chapter 2 presents the following parameters for the evaluation of the energy performance of the mechanical ventilation and air conditioning:

- The calculation of the interior temperature during summer, the verification of the interior comfort and the necessity of air conditioning.
- The calculation of the energy demand for cooling the buildings – the monthly method.
- The calculation of the energy demand for cooling the buildings – the hourly method.
- The calculation of the air flow for natural and mechanical ventilation.
- The calculation of the energy consumption for the ventilation of the buildings.
- The calculation of the annual energy demand for centralized and decentralized air conditioning systems.

The ventilation is the process in which fresh air is brought inside the building, while the waste (i.e. humidity, gas, dust, vapors) air is eliminated. Depending on the energy used to put the air in motion, the ventilation can be:

- **Natural:** occurs because of the difference of pressure (due to difference of temperature or wind) between the interior and exterior of building.
- **Mechanical:** produced by mechanical systems such as fans.
- **Hybrid:** the mechanical system is turned on when the difference in pressure is not sufficient for the natural ventilation.

The air conditioning is the process in which in the room is ensured a prescribed interior temperature, especially during hot season when cooling is necessary. Often the air conditioning system is coupled with the ventilation system such that the interior temperature of the room is adjusted and the room is ventilated at the same time. The air conditioning system can be:

- With control on the interior humidity.

- With partial control on the interior humidity.
- With no control on the interior humidity.

7.1. Calculation of the interior temperature during summer season. Verification of the interior comfort. The necessity of air conditioning.

The interior temperature during summer season is determined in order to avoid the overheating of the building. Based on the results it is established whether it is necessary or not an air conditioning system to ensure the thermal comfort of the indwellers during hot season.

The calculation of the interior temperature during summer has the following hypothesis:

- The room is a closed space bounded by the building elements.
- The temperature of the air is uniformly distributed on the entire volume of the room.
- The surfaces of the building elements are isothermal.
- The thermal characteristics of the building elements are constant.
- The heat flow from every building element is one dimensional.
- The superficial air layers of the building elements are bounded by isothermal surfaces.
- The average radiation temperature is calculated as weighted average of superficial temperatures for every interior building element.
- The distribution of the solar radiation on surface doesn’t depend on time.
- The spatial distribution of the radiation part of heat due to interior sources is uniform.
- The heat exchange coefficients through convection and radiation (long wave length) for each interior surface are taken separately.
- The dimensions of every building element are considered or considered on the interior side for every element that forms the boundary of the room.
- The effects of the thermal bridges on the thermal transfer are neglected.

The main steps in the calculation of the interior temperature during summer are the following:

- Establish the calculation conditions with respect the climate zone and the geographical location of the building.
- Establish the room in which is studied the interior temperature.
- Establish the building elements that bound the room: surfaces, orientation, boundary conditions.
- The calculation of the thermal parameters (with permanent and dynamic regime) and of optical parameters for opaque and glazed elements.

- Define the ventilation scenario.
- Calculation of the heat gains from interior sources.
- The evaluation of the maximum, moderate and minimum daily operating temperature of the studied room based on the equations of thermal balance.
- Based on the values of the operating temperatures established at the previous step, the standard interior temperature during summer of a room without air conditioning system is determined. This temperature determines the overheating of the building and the necessity of air conditioning.

The method of calculation is based on the analogy with an electric circuit in order to model the heat transfer that takes place in the interior and exterior of the building. Figure 15 shows the analogy scheme. Based on the scheme from Figure 15, the building elements that bound the studied room are classified according to the thermal inertia and transparence as follows:

- Light opaque exterior elements.
- Heavy opaque exterior elements.
- Transparent elements: windows, skylights, glazed doors.

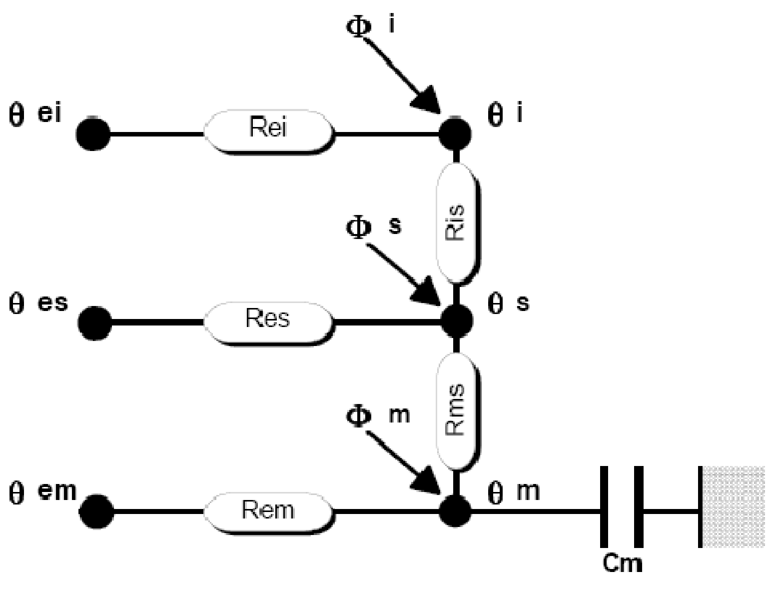


Figure 17 – The electric circuit analogy of the heat transfer through the building elements. (See ref. [9])

In Figure 17, the parameters described are the following:

$\boldsymbol{\theta_i}$**:** The interior temperature of the air. [°C]

$\boldsymbol{\theta_e}$: The exterior temperature of the air. [°C]

$\boldsymbol{\theta_{es}}, \boldsymbol{\theta_{em}}$: The equivalent temperature of the exterior air for the light, respectively heavy exterior building elements. [°C]

$\boldsymbol{\theta_s}$: The average between the temperature of air and average radiation temperature weighted by the thermal transfer coefficients through convection and radiation. [°C]

$\boldsymbol{\theta_m}$**:** Inertial temperature. [°C]

$\boldsymbol{R_{ei}}$**:** The thermal resistance corresponding to ventilation. $[K/W]$

$\boldsymbol{R_{es}}, \boldsymbol{R_{em}}$: The thermal resistance of the light, respectively heavy exterior elements. $[K/W]$

$\boldsymbol{R_{is}}, \boldsymbol{R_{ms}}$: The thermal resistance corresponding to the heat exchange between the interior surfaces of the building elements and the interior air. $[K/W]$

$\boldsymbol{C_m}$: The average daily thermal capacity of the building elements of the room. $[J/K]$

$\boldsymbol{\phi_i}$: The heat flow from the air node $\boldsymbol{\theta_i}$ which is produced by interior heat sources, direct solar radiation or convective heat gains from the ventilated interior air of glazed surfaces.

$\boldsymbol{\phi_s}$: The heat flow from the air node $\boldsymbol{\theta_s}$ which is produced by interior heat sources or direct solar radiation.

$\boldsymbol{\phi_m}$: The heat flow from the inertial node $\boldsymbol{\theta_m}$ which is produced by interior heat sources or direct solar radiation.

The thermal balance equations are written for every node in the scheme from Figure 15 and they are obtained step by step by integration with respect the time. The time interval for the integration is 1 hour. The process of calculation is iterative and the steps are repeated until the convergence condition for the interior temperature is fulfilled. The convergence of the iteration is reached when the difference of the temperature $\boldsymbol{\theta_m}$ at 12 am for two successive iterations is less than 0.01°C .

The standard interior temperature of a room without air conditioning system during summer season is considered to be the maximum value of the average of the operating temperatures for 3 consecutive hours and is evaluated with the following formula:

$$t_{ic} = max_{h=1,24}\left[\sum_{h}\frac{\theta_o(h) + \theta_o(h+1) + \theta_o(h+2)}{3}\right] - D \quad [°C] \quad (25)$$

Where:

$\boldsymbol{\theta_o}$: The operating temperature calculated using the relation (24). [°C]

D: Coefficient which takes into consideration the influence of the building's thermal inertia. This coefficient is calculated with the following relation:

$$D = 0.75 \cdot E \cdot \left(1 - \left[\frac{1 + 4.76 \cdot 10^{-4} \cdot C^2 \cdot (1 - B_1)^2}{1 + 4.76 \cdot 10^{-4} \cdot C^2}\right]^{1/2}\right) \quad (26)$$

Where:

E: The temperature difference between the standard daily average and monthly average. [°C]

$$B_1 = \frac{1}{(1 + R_{ms} \cdot H)} \quad (27)$$

$$C = \frac{0.278 \cdot C_{ms}}{H} \quad (28)$$

C: Time constant of the studied volume (room).

$\boldsymbol{C_{ms}}$: Standard thermal capacity which describes the damping of the temperature during summer for 12 days.

H: The average heat losses through walls and ventilation.

The standard interior temperature must be calculated with 0.1°C precision by rounding the obtained value to the closest value.

7.2. Calculation of the energy demand for cooling the buildings and of the energy consumption of the air conditioning systems

7.2.1. The monthly method

The energy demand for cooling is calculated based on the thermal balance of the entire building or of a sector from the building. These values are input data for the energy balance of the air conditioning system. The monthly method for determining the energy demand for cooling has the following steps:

- The definition of the geometric boundary of all the cooled and not cooled spaces.
- Divide the building into different areas.
- The calculation of the energy demand for cooling for each period and area of the building and also of the period of the cooling season.
- The combination of the results obtained in different periods and for areas having the same air conditioning system and the calculation of the energy consumption for cooling taking into consideration the dissipated energy.

The energy balance of the building contains the following parameters:

- The heat transfer through transmission between the cooled space and exterior environment due to temperature differences.
- The heat transfer for heating/cooling of ventilated air introduced mechanically or naturally due to temperature differences between the cooled space and introduced air.
- Interior heat sources, included the ones that absorb the heat.
- The sources of solar heat, direct (i.e. solar radiation that comes through windows) or indirect (solar radiation absorbed by the building’s opaque enclosure elements)

- The heat absorbed or released by the mass of building.
- The energy demand to cool the building or a sector from it. The air conditioning system extracts the heat to lower interior temperature under a maximum prescribed level.

For each area of the building, the energy demand for cooling for every month is evaluated with the following formula:

$$Q_R = Q_{surse,R} - \eta_R \cdot Q_{Tr,R}, \qquad if\ Q_R > 0 \quad (29)$$

Where:

$\boldsymbol{Q_R}$: The energy demand for cooling the building. $[MJ]$

$\boldsymbol{Q_{Tr,R}}$: The total energy transferred between the building and the exterior environment in case of cooling building. $[MJ]$

$\boldsymbol{Q_{surse,R}}$: The total energy given by the heat sources in case of cooling the building. $[MJ]$

$\boldsymbol{\eta_R}$: The use factor of heat losses in case of cooling.

The total heat transfer between the building and the adjacent environment which is not cooled for each area and for each period is:

$$Q_{Tr,R} = Q_T + Q_V \quad [MJ] \quad (30)$$

Where:

$\boldsymbol{Q_T}$: The heat transferred by transmission. $[MJ]$

$\boldsymbol{Q_V}$: The heat transferred through ventilated air. $[MJ]$

$\boldsymbol{Q_{Tr,R}}$ may have a negative value and this means that the heat is taken out from the building or may have positive value meaning that the heat enters the building.

The total heat from the interior sources is evaluated as follows:

$$Q_{surse,R} = Q_{int} + Q_s \quad [MJ] \quad (31)$$

Where:

Q_{int}: The heat which comes from internal sources. $[MJ]$

Q_s: The heat which comes from solar radiation. $[MJ]$

The heating and air conditioning systems are also sources of internal heat gains, sometimes they are negative (i.e. they absorb the heat). Because the heat that comes from these sources depends on the energy demand of the building, the calculation must be done in two steps:

- The calculation of the energy demand of the building without these sources.
- The calculation is done including the above sources of energy.

The relations presented above are general mathematical relations. The monthly method is a quasi-stationary method. The time period used by this method is 1 month.

The effect of the building's thermal inertia in case of an interrupted cooling or of the shut down of the air conditioning system is taken into consideration by introducing an adjustment to the interior temperature or a correction to the cooling demand calculated for the case the air conditioning system is functioning continuously. The use of the factor $\boldsymbol{\eta_R}$ takes into consideration the fact that only a part of the heat transmitted by ventilation and transmission lowers the cooling demand. The energy balance doesn't take into consideration the unused part of the heat transfer which is considered to be overbalanced by not respecting perfectly the prescribed interior temperature.

The monthly calculations give accurate results over the year, but the results obtained on the starting month and on the ending month of the cooling period may have relatively important errors.

7.2.2. The hourly method

The hourly method is similar to the simplified monthly method, but there are certain differences here:

- The hourly method allows the input of hourly functioning scenarios regarding the prescribed temperatures, the type of ventilation, the interior heat sources, the use of shadowing devices etc.
- The results obtained are more accurate than in the monthly method because the modeling is closer to real physical phenomena and the using regime.

The hourly method is preferable for buildings with high thermal inertia, high functioning interruptions and other special situations. The hourly method is based on an analogical thermal electric model which uses the Resistance – Capacity (RC) scheme. This is a dynamic method which models the thermal resistances and capacities and also the heat flows produced by the internal sources. It is also a simplified method because it combines the thermal transfer resistance with the thermal capacity of the building into one pair called "resistance – capacity". The model's purpose is the following:

- To represent in a simple manner the heat transfer phenomena in a building and mathematical expressions easy to turn into an algorithm.
- To realize a high level of accuracy, especially for rooms in which the dynamic thermal behavior has a significant impact.

For the calculation it is used an iteration having 1 hour step. In Figure 18 it is described the model for the hourly method.

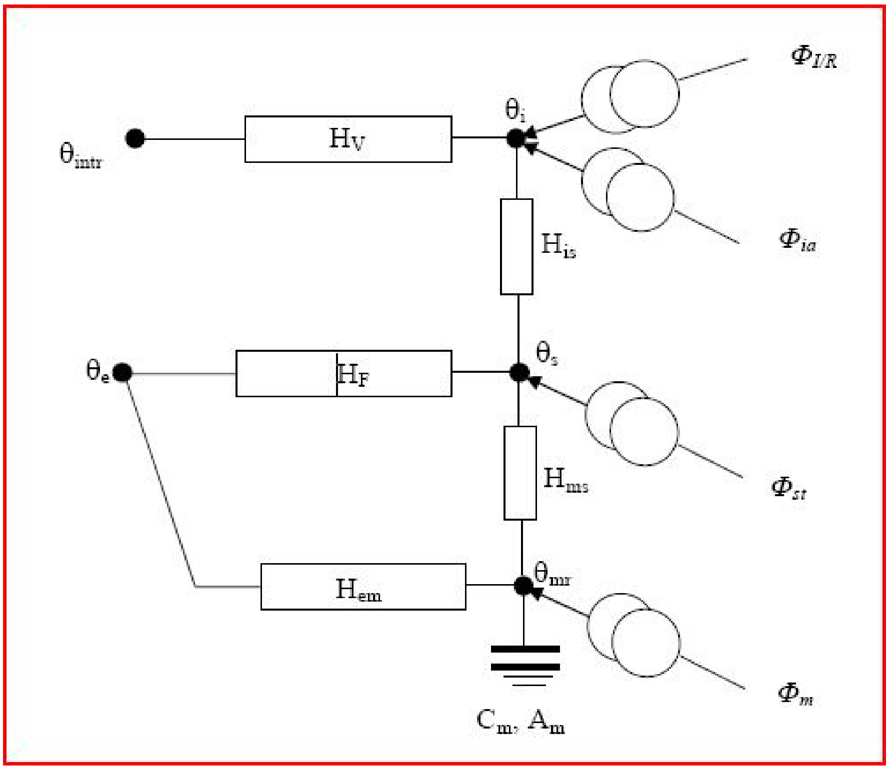


Figure 18 – The "Resistance – Capacity" model for the hourly method as seen in ref. [9]

The analogical model is composed of 5 nodes connected by 5 conductance and a capacity. From the thermal point of view, the nodes are described as following:

- The temperature of the interior air: θ_i
- The temperature of the exterior air: θ_e
- The temperature of the inserted air for ventilation: θ_{intr}
- The average radiation temperature: θ_{mr}
- The temperature θ_s described as an average between the temperature of the interior air θ_i and the average radiation temperature θ_{mr}.

The thermal transfer from the analogical model in Figure 16 is described in the following manner:

- **The heat transfer due to ventilation:** connection between node θ_i and node θ_{intr} through the thermal transfer coefficient for ventilation H_V.
- **The heat transfer through transmission:**

1. ***Heat transfer through window***, described by zero thermal inertia and the conductance H_F. It takes place between the node θ_e and node θ_s.
2. ***Heat transfer through massive elements***, it has a total conductance H_{op} and is described by two components:

   - The transfer through node θ_e and node θ_{mr} through the conductance H_{em}.

- The transfer through node θ_s and node θ_{mr} through the conductance H_{ms}.

The thermal mass which describes the inertia of massive elements is represented by the unique capacity C_m which is placed in node θ_{mr} in between H_{ms} and H_{em}.

The effect of the interior heat sources is represented by dividing equally the heat flow coming from solar radiation and form the interior activity on the 3 temperature nodes: θ_i, θ_s and θ_{mr}. In between node θ_i and θ_s there is a coupling conductance H_{is}.

The model presented above makes the difference between the interior temperature and the average temperature of the interior surfaces (the average radiation temperature). By this mean the representation of the interior thermal comfort is improved and the accuracy of representing the heat exchange through radiation is increased. This is also due to the possibility of taking into consideration the convection and radiation part for the lighting, solar gains or any other heat gains from interior sources. The standard interior temperature is the temperature of the interior air, because most of the adjusting and controlling devices are sensible to this value.

The energy demand for heating/cooling is calculated as the energy which has to be added/subtracted at every hour from the node that represents the interior temperature (θ_i) to maintain the prescribed interior temperature. The total energy demand for a certain period results from adding the hourly values.

7.3. The calculation of the air flow for natural and mechanical ventilation

The air flows can be calculated for the whole building or only for sectors. The building can be separated into sectors if each sector is connected to its own ventilation system or if the sectors are considered independent from the air transfer point of view (i.e. there is no air transfer between the sectors). The method of calculation of the air flow described in Section 6.2. of the Mc001/2 [9] is not for the evaluation of the necessary air flow to ensure the quality of the interior environment, for the evacuation of smoke in case of fire and also for the air permeability of the buildings.

The calculation of the air flow is based on the dry air mass balance from the building or sector which is considered. This mass balance is mandatory for heating systems with hot air and air conditioning systems because of the high differences between the density of the air introduced into the system and the interior air. For simplification it is aloud the volume balance, but only in certain situations.

The calculation of the air flow which passes through the building envelope is done in the following steps:

- Establish the mathematical relationships for the air flows for a reference interior pressure.

- The calculation of the reference interior pressure based on the mass balance of the air, for the air flows which enter and exit the building.
- The calculation of the air flows for the established reference pressure.

The air flows that enter the building are considered positive, while the air flows that exit the building are considered negative.

The building's interior is divided as follows:

- Into different sectors independent from the air transfer point of view (i.e. there is no air transfer between the neighbor sectors).
- If it is necessary, each sector can be connected to a common space (i.e. lobby, the stair case)

Figure 19 describes how the building is divided into sectors in order to evaluate the air flows.

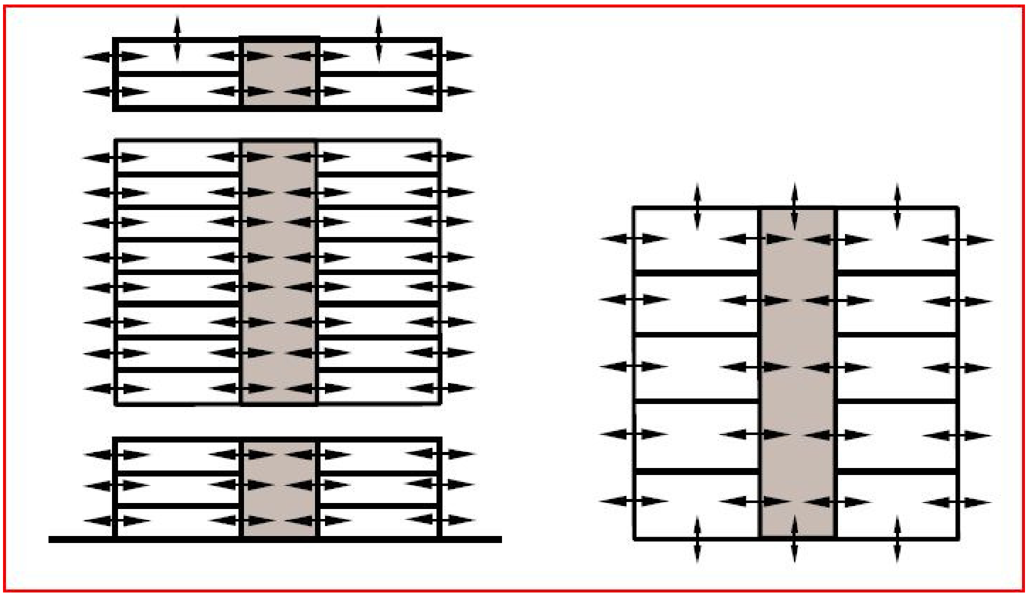


Figure 19 – The division of the interior of the building for the calculation of the air flows as seen in ref. [9]

The evaluation of the air flow has the following steps:

- The calculation of the mechanical ventilation.
- The calculation of the passive pipes for small residential and non-residential buildings.
- The calculation of the infiltrations and of the exit of air flow.
- The air flows for combustion in residential and non-residential buildings in case it is necessary.
- The calculation of the supplementary air flows that come from the opened windows.
- The calculation of the total air flow.

7.4. The calculation of the energy consumption for the ventilation of the buildings

In the calculation of the energy consumption for the ventilation of the buildings, the first thing that is taken into consideration in Mc001/2 [9] standard are the heat losses through the pipes of the ventilation system. Regarding the heat losses through pipes are 3 different situations:

1. **The heat losses through the pipes which are inside the ventilated room or sector.** These heat losses must be taken into consideration only when the difference between the temperature of the transported air and the temperature of the ventilated room or sectors is significant. They can be neglected when the system doesn't ensure the air conditioning of the space, only the simple ventilation.
2. **The heat losses through the pipes which are outside the ventilated room or sector.**
3. **The heat losses through the transport pipes.**

The second step is to analyze the energy consumption of parts of the ventilation system:

- The fans.
- The heat exchangers (the heat recoveries)
- The latent and sensible heat recoveries. Here are analyzed the problems related to freezing of the water from the installations and the control of defrosting.
- The mixing chambers. In this part of the ventilation system, the recycled air from the ventilated room is mixed with the exterior fresh air in order to recover the energy. These mixing chambers are endowed with valves that adjust the flow of the exterior air and of the recycled air.

Special attention is given to the isothermal humidification of the air during winter season. During winter season when the air is dry, the exterior air which enters the system must have its humidity increased until a prescribed value. This process is done by injecting saturated steam into the air flow and the thermal dynamic evolution of the air in the humidification chamber is quasi-isothermal.

7.5. The calculation of the annual energy demand for centralized and decentralized air conditioning systems

The calculation of the annual energy demand for air conditioning system is "degree – days" type. The factors that are taken into consideration in this situation are the following:

- The energy consumption due to latent heat charges.
- The existence of important charges due to high flows of fresh air.

- The endowment of the air conditioning systems with heat recoveries: sensible or sensible and latent.
- The thermal inertia of the building elements.
- The large variety of air conditioning installations and cooling sources used in buildings (i.e. “only air” centralized systems, systems with “air – water” terminal devices, chillers with mechanical compression, chillers with absorption, reversible chillers – heat pumps etc.)

The calculation method of the energy consumption is the monthly method. The degree – day calculation is done with the following formula:

$$NGZ = \frac{N \cdot (\theta_{aem} - \theta_b)}{1 - e^{-K \cdot (\theta_{aem} - \theta_b)}} \quad [degree - days] \quad (32)$$

Where:

N: The number of days of the considered month. $[days]$

$\boldsymbol{\theta_{aem}}$: The average monthly temperature of the exterior air for the considered month. [°C]

$\boldsymbol{\theta_b}$: The basic temperature evaluated according to the type of air conditioning system. [°C]

K: Constant which usually has the value 0.71.

The energy consumption for cooling and dehumidification is evaluated based on the number of degree – days and on the value of the chiller’s performance coefficient in the following manner:

$$Q_{chiller} = \frac{Q_r}{COP} \quad [kWh] \quad (33)$$

$$Q_r = 24 \cdot m \cdot c_p \cdot NGZ \quad [kWh] \quad (34)$$

Where:

$\boldsymbol{Q_{chiller}}$: The energy demand of the cooling source of the air conditioning system. $[kWh]$

$\boldsymbol{Q_r}$: The energy demand for cooling and dehumidification. $[kWh]$

COP: The chiller’s performance coefficient (in Romanian “coeficient de performanță al chiller-ului”) $[-]$

m: The mass air flow inserted in the air conditioning system. $[kg/s]$

$\boldsymbol{c_p}$**:** The specific heat of the air. $[kJ/kg$°C]

The energy consumption for the ventilation of air is based on the specific consumption of electrical energy. The specific consumption of electrical energy is determined for each room or group of rooms having the same function. The specific consumption of electricity for a building or a sector of building which uses air conditioning system results by calculating the average of the specific consumption of each room of group of rooms with respect the area of the floor. The total consumption of electricity for inserting the air into the air conditioning system is obtained by multiplying the specific consumption with the total area of the air conditioned rooms as following:

$$Q_{Vt} = Q_V \cdot S \quad [kWh/yr] \quad (35)$$

Where:

$\boldsymbol{Q_V}$: The specific consumption of electricity of the engines of fans from the air conditioning system. $[kWh/m^2 \cdot yr]$

S: The total area of the air conditioned rooms. $[m^2]$

The specific consumption of the engines of the fans from the air conditioning system is calculated with the formula below:

$$Q_V = \frac{P_V \cdot N_h}{1000} \quad [kWh/m^2 \cdot yr] \quad (36)$$

Where:

$\boldsymbol{N_h}$: The number of functioning hours at normal capacity $[hrs/yr]$. This value is taken according to the functioning data of the fan from Annex II.2.K of Mc001/2 (See ref. [9]).

$\boldsymbol{P_V}$: The specific power for the functioning of fans. $[W/m^2]$ It is calculated with the following formula:

$$P_V = \frac{\Delta p \cdot V'}{\eta_v \cdot 3600} \quad [W/m^2] \quad (37)$$

Where:

$\boldsymbol{\Delta p}$: The pressure losses from the system $[Pa]$. Its value is the average between two exchanges of the dust filter.

$\boldsymbol{V'}$**:** Specific volume air flow with respect to the area of the room. $[m^3/m^2, h]$

$\boldsymbol{\eta_v}$: The efficiency of the ventilation for the entire system.

If there are no available data regarding the pressure loss and the efficiency of ventilation, the specific power is evaluated with the following relation:

$$P_V = P_{sp} \cdot V' \quad [W/m^2] \quad (38)$$

Where:

$\boldsymbol{P_{sp}}$**:** The specific power of a fan. $[W/m^2/hr]$. It is evaluated as follows:

$$P_{sp} = \frac{\Delta p}{\eta} \quad [W/m^2/hr] \quad (39)$$

Where:

$\boldsymbol{\eta}$: The efficiency of the fan.

The recommended values of the specific power of the fans of the entire air conditioning system are given in Annex II.2.L of Mc001/2 (See ref. [9]) with respect to the type of installation, the function of the room and the energy efficiency of the installations. The number of functioning hours at normal capacity is equaled to an energy equivalent value such that for the number of functioning hours at partial capacity it must be taken into consideration the ratio between the specific power at low capacity and the specific power at normal capacity to obtain an equivalent value. If there are no available data regarding the functioning of the air conditioning system at low capacity and its energy efficiency, it is recommended to use the values from Annex II.2.K from Mc001/2 (See ref. [9]).

8. Mc001/3: “The audit and energy performance certificate of the building.” [10]

The last part of Mc001 – 2006 describes to the audit and energy performance certificate, which is done for residential buildings and buildings with other functions than residential. The audit is not applied for the following types of buildings:

- Historical buildings and monuments protected by law
- Temples, churches
- Temporary buildings used up to 2 years from industrial areas, workshops and non-residential buildings from the agricultural field which have low energy demand.
- Non-residential buildings which are used less than 4 months per year.
- Independent buildings having the surface less than $50\ m^2$.
- Buildings with special functions.

Mc001/3 [10] provides the following information:

- The evaluation of the energy performance of the buildings.
- Indexes for the economical efficiency of the technical solutions for thermal rehabilitation/upgrade of the existent buildings.
- Establish the technical solutions to increase the energy performance of the building and installations.
- The energy grading of buildings
- Templates for energy audit and energy certificate of buildings.

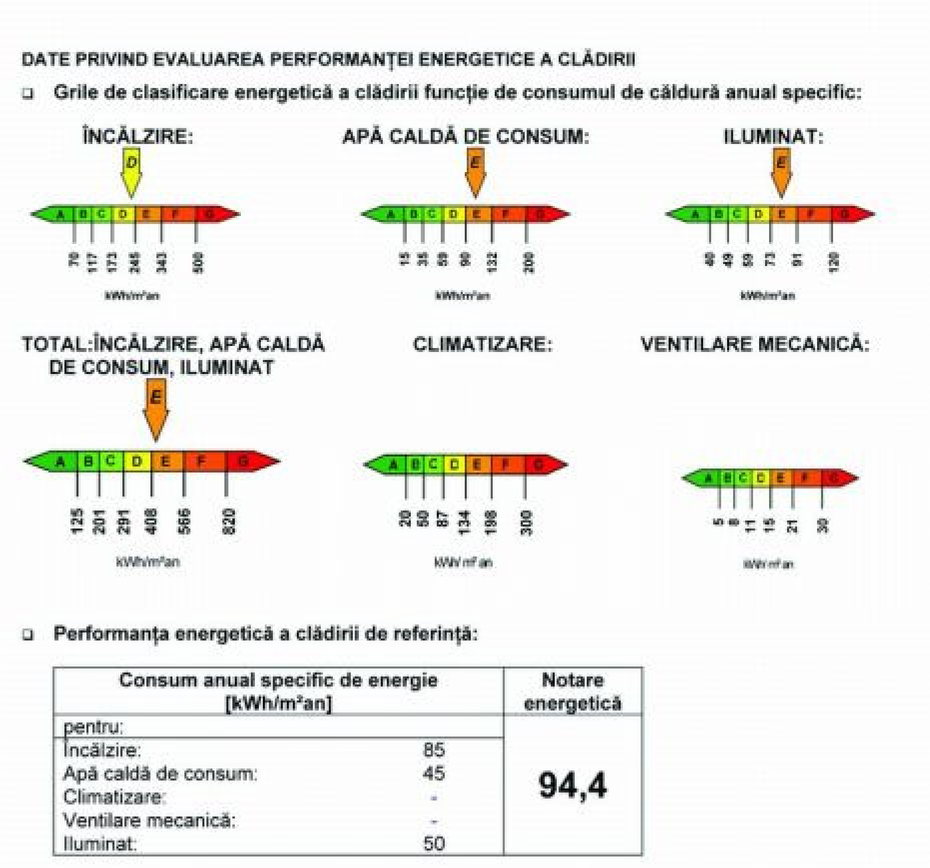
The energy audit of the building is done in 3 steps which are:

1. The evaluation of the energy performance of the building in normal conditions based on its real characteristics.
2. Identify the solution for upgrading the building.
3. The analysis of its economical efficiency and write the energy report.

The energy performance certificate is established in 5 steps as follows:

1. The evaluation of energy performance of the building in normal conditions based on its real characteristics.
2. Definition of the reference building attached to real building and its evaluation of energy performance.
3. Establish the energy class of the building.
4. Give the building an energy performance score.
5. Write the energy performance certificate.

In Figure 20 is the chart for energy performance in buildings for heating, domestic hot water, lighting, air conditioning, ventilation and for all the building services combined together.



DATE PRIVIND EVALUAREA PERFORMANȚEI ENERGETICE A CLĂDIRII

- Grile de clasificare energetică a clădirii funcție de consumul de căldură anual specific:

- Performanța energetică a clădirii de referință:

Consum anual specific de energie [kWh/m²an]		Notare energetică
pentru:		94,4
Încălzire:	85	
Apă caldă de consum:	45	
Climatizare:	-	
Ventilare mecanică:	-	
Iluminat:	50	

Figure 20 – The data about the evaluation of the energy performance of buildings as seen in Mc001/3 – 2006 [9]

9. C107/6-2002: "The general standard for the calculation of the mass transfer (humidity) through the building elements." [1]

C107/6 [1] is a special standard which contains methods for calculation of the water vapors diffusion in the building elements in order to choose the optimal solution to ensure normal relative humidity of the building elements during the life cycle of the building. According to these calculations, it is established whether is necessary or not to apply a layer of vapor barrier on the building element. In the building envelope, the heat transfer is followed by water vapor diffusion.

The calculation method presented in the standard C107/6 [1] is a simplified one and is based on the following hypothesis:

1. The thermal transfer takes place in a steady regime and is unidirectional.
2. All the thermal and physical properties of the materials are independent from temperature and humidity.
3. The air flow inside the building element or from the indoor environment to outdoor environment through the building element is not taken into consideration.
4. The superficial air layer from the building elements is taken into consideration as stated in the standard C107/3 [5].

In order to satisfy the requirements for hygiene and interior comfort in the building and to ensure the performance of the exterior and interior building elements, they should satisfy the following technical and performance conditions:

- **The increase of mass relative humidity of the materials from the building envelope's structure due to water vapors condensation:**

$$\Delta W \leq \Delta W_{adm} \ [\%] \quad (40)$$

Where:

$\boldsymbol{\Delta W}$: The increase of the building envelope's relative humidity at the end of the condensation period evaluated with the following expression:

$$\Delta W = \frac{100 \cdot m_w}{\rho \cdot d_w} \ [\%] \quad (41)$$

In expression (41) we have the following parameters:

$\boldsymbol{\rho}$: The apparent density of the material which became moist due to condensation. $[kg/m^3]$

$\boldsymbol{d_w}$: The thickness of the material which has water intake due to condensation. $[m]$

$\boldsymbol{m_w}$: The quantity of water vapors which may condensate inside the building element, during the cold season. $[kg/m^2]$. This quantity is calculated for 2 cases:

1. If the condensation area has finite thickness

$$m_w = 3600 \cdot \left(\frac{p_i - p_{sc1}}{R_v'} - \frac{p_{sc2} - p_{es}}{R_v''}\right) \cdot N_w \ \ [kg/m^2] \quad (42)$$

Where:

$\boldsymbol{N_w}$: The condensation time according to the climate zone. $[hours]$

$\boldsymbol{p_i}$**:** The partial pressure of the water vapors corresponding to the indoor temperature T_i and to the relative indoor humidity φ_i. $[Pa]$

$\boldsymbol{p_{es}}$: The partial pressure of the water vapors corresponding to the outdoor temperature during condensation period T_{es} and to the relative outdoor humidity φ_e. $[Pa]$

$\boldsymbol{p_{sc1}}$: The uncorrected saturation pressure of the water vapors corresponding to the temperature of the warm surface of the condensation area. $[Pa]$

$\boldsymbol{p_{sc2}}$: The uncorrected saturation pressure of the water vapors corresponding to the temperature of the cold surface of the condensation area. $[Pa]$

$\boldsymbol{R'_v}$: The vapor permeability resistance of the parts of the building element between the interior surface and the warm surface of the condensation area. $[m/s]$

$\boldsymbol{R''_v}$**:** The vapor permeability resistance of the parts of the building element between the cold surface of the condensation area and the exterior surface. $[m/s]$

2. ***If the condensation area is reduced to a surface***

$$m_w = 3600 \cdot \left(\frac{p_i - p_{sc}}{R'_v} - \frac{p_{sc} - p_{es}}{R''_v}\right) \cdot N_w \quad [kg/m^2] \quad (43)$$

Where:

$\boldsymbol{p_{sc}}$: The uncorrected saturation pressure of the water vapors corresponding to the temperature of the condensation surface. $[Pa]$

$\boldsymbol{R'_v}$: The vapor permeability resistance of the parts of the building element between the interior surface and the condensation surface. $[m/s]$

$\boldsymbol{R''_v}$**:** The vapor permeability resistance of the parts of the building element between the condensation surface and the exterior surface. $[m/s]$

- **Avoid the progressive accumulation of water inside the building envelope every year due to condensation phenomenon.**

$$m_w \leq m_v \quad [kg/m^2] \quad (44)$$

Where:

$\boldsymbol{m_w}$: The quantity of water vapors which may condensate inside the building element, during the cold season. $[kg/m^2]$.

$\boldsymbol{m_v}$: The quantity of water which may evaporate inside the building element during the warm season. $[kg/m^2]$ It is calculated with the following steps:

a. The building element is represented graphically by taking into consideration the vapor permeability resistance of the component layers.

b. The temperature variation inside the building element T_k is calculated according to the outdoor temperature T_{es}, which is the outdoor temperature during condensation period according to the climate zone.
c. The uncorrected saturation pressures of water vapors p_k inside each layer of the building element are determined according to the temperature T_k and using the values from Table B1 of Annex B (See ref. [1]). The variation curve of these pressures is represented after.
d. On the pressure variation curve, it is determined the point p_i (the indoor partial pressure of water vapors), corresponding to the indoor temperature T_i and to the indoor relative humidity φ_i, and the point p_{es} (the outdoor partial pressure of water vapors during condensation period), corresponding to the outdoor temperature T_{es} and to the outdoor relative humidity during condensation period φ_{es}, which is considered to be 70%.
e. The points p_i and p_{es} are united with the intersection point of the pressure variation curve with the plane that crosses the condensation zone axis, respectively the plane of the condensation surface.
f. The quantity of water which may evaporate inside the building element during the warm season is calculated in 2 cases as follows:

- ***If the evaporation area has finite thickness***

$$m_v = 3600 \cdot \left(\frac{p_{sc} - p_i}{R_v'} - \frac{p_{sc} - p_{es}}{R_v''}\right) \cdot N_v \quad [kg/m^2] \quad (45)$$

Where:

$\boldsymbol{N_v}$: The evaporation time. $[hours]$ It is calculated with the relationship:

$$N_v = 8760 - N_w \quad [hours] \quad (46)$$

In relation (46) $\boldsymbol{N_w}$ is the condensation time according to the climate zone. $[hours]$

$\boldsymbol{p_i}$**:** The partial pressure of the water vapors corresponding to the indoor temperature T_i and to the relative indoor humidity φ_i. $[Pa]$

$\boldsymbol{p_{es}}$: The partial pressure of the water vapors corresponding to the outdoor temperature during condensation period T_{es} and to the relative outdoor humidity φ_e. $[Pa]$

$\boldsymbol{p_{sc}}$: The uncorrected saturation pressure of the water vapors corresponding to the temperature from the plane that passes through the axis of the condensation zone. $[Pa]$

$\boldsymbol{R_v'}$: The vapor permeability resistance of the parts of the building element between the interior surface and the plane that passes through the axis of the condensation zone. $[m/s]$

$\boldsymbol{R_v''}$**:** The vapor permeability resistance of the parts of the building element between the plane that passes through the axis of the condensation zone and the exterior surface. $[m/s]$

- ***If the condensation area is reduced to a surface***

$$m_w = 3600 \cdot \left(\frac{p_{sc} - p_i}{R'_v} - \frac{p_{sc} - p_{es}}{R''_v}\right) \cdot N_v \quad [kg/m^2] \quad (47)$$

Where:

$\boldsymbol{p_{sc}}$: The uncorrected saturation pressure of the water vapors corresponding to the temperature of the condensation surface. $[Pa]$

$\boldsymbol{R'_v}$: The vapor permeability resistance of the parts of the building element between the interior surface and the condensation surface. $[m/s]$

$\boldsymbol{R''_v}$**:** The vapor permeability resistance of the parts of the building element between the condensation surface and the exterior surface. $[m/s]$

10. C107/7-2002: “Standard for designing the building envelope for thermal stability.” [2]

The standard C107/7 [2] contains prescriptions regarding the design of the opaque elements of the building envelope and of the separation elements in the buildings for thermal stability taking into account their thermal inertia and the thermal stability of the rooms. The thermal stability represents an important criterion for the sustainable design of the building and its purpose is to ensure interior thermal comfort during summer and winter. The thermal stability during summer and winter is evaluated in the room which has the most unfavorable direction and which is considered by the designer as a reference room inside the building. In case the building has more functions, the thermal stability is evaluated for each reference room from each sector having a different function.

According to the limitations imposed by the thermal stability, buildings are classified into 3 groups as following:

- If the rooms or building sectors are not endowed or do not need ventilation and air conditioning systems:

1. **Group “a”:** hospitals, hotels having at least 3 stars.
2. **Group “b”:** residential buildings, hotels having less than 2 stars, hostels, asylums, student residences, schools, nursery schools, administrative and office buildings, theatres, museums, clubs, restaurants, cafeterias, bars, bakeries, terminals for train stations, airports, bus stations, sports facilities.
3. **Group “c”:** buildings with temporary occupancy (vacation houses, social buildings belonging to companies), temporary buildings.

- If the rooms or the building sectors are endowed or need ventilation and air conditioning systems:

1. **Group “a”:** rooms or building sectors in which the working performance is not affected by a temperature difference up to 3°C.
2. **Group “b”:** rooms or building sectors in which the working performance is not affected by a temperature difference up to 5°C.
3. **Group “c”:** rooms or building sectors in which the working performance is not affected by a temperature difference greater than 6°C.

The thermal stability of the rooms or of the building sector is expressed by the amplitude of the indoor temperature oscillation and has different values according to the group in which the room or the building sector is classified. The values are expressed in the table from Figure 21. These are the maximum allowed values for the amplitude of the indoor temperature oscillation in order to ensure the performance level of the building.

Tabelul nr. 3

Amplitudinea de oscilatie a temperaturii aerului interior ,A_{Ti}, pe timp de:	Grupa de cladiri		
	“a”	“b”	“c”
• iarna	1,0	1,0	-
• vara	3,0	5,0	-

Figure 21 – The values of the amplitude of indoor temperature oscillation during winter, respectively summer for each group [2].

In the calculation of the thermal stability of the building, the following parameters are analyzed:

- The damping coefficient of the amplitude of the outdoor temperature oscillation (ν_T).
- The dephasing coefficient of the outdoor temperature oscillation (ε).
- The thermal stability coefficient of the boundary element (C_i)

The damping coefficient of the amplitude of the outdoor temperature oscillation (ν_T) is calculated according to the interior structure of the building element and the dephasing coefficient of the outdoor temperature oscillation (ε) is calculated for the summer season, also according to the structure of the building element. In case of ν_T and ε, there are different formulae for the homogeneous building element, for multi-layered building elements without air layers and for multi-layered building elements having air layers.

The thermal stability coefficient of the boundary element is calculated with the following formula:

$$C_i = \frac{R}{R_{Si} + \frac{M}{B_i}} \quad [-] \quad (48)$$

Where:

$\boldsymbol{R}$: The specific unidirectional thermal resistance of the opaque building element calculated according to C107/3 (See ref. [5]). $[m^2 \cdot K/W]$

$\boldsymbol{R_{Si}}$: The thermal resistance of the superficial air layer at the interior side of the building element according to C107/3 (See ref. [5]). $[m^2 \cdot K/W]$

$\boldsymbol{B_i}$: The coefficient of thermal assimilation through the interior surface of the boundary element. $[W/m^2 \cdot K]$ There are different formulae to evaluate this coefficient according to the number of layers of the building element included in the area with large temperature oscillations.

$\boldsymbol{M}$: The coefficient of non-even heat released by the heating installation system. Its values depends on the type of heating installation with which the building is endowed and they are listed in the table from Figure 22.

Tabelul nr.8

Tipul sistemului de incalzire	Coeficient de neuniformitate a cedarii de caldura M
Incalzire centrala:	
– cu apa calda cu functionare neintrerupta;	0,1
– cu apa calda cu intrerupere 6 ore / zi;	1,5
Incalzire cu centrala termostatata;	0,1
Incalzire cu abur sau cu radiatoare:	
– cu intrerupere 6 ore/zi;	0,8
– cu intrerupere 12 ore/zi;	1,4
– cu intrerupere 18 ore/zi;	2,2
Incalzire cu sobe de teracota la 1 foc /zi (24 ore):	
– la grosimea peretilor sobei de 1/2 caramida;	0,9
– la grosimea peretilor sobei de 1/4 caramida.	1,4

Figure 22 – The values of the coefficient of non-even heat released by the heating installation system. The types of the heating installation system presented in the table are: central heating system, central heating system endowed with thermostat, heating with steam or radiators, heating with terracotta stove. Besides the heating installation system is also the functioning schedule expressed in number of hours per day. [2]

In order to satisfy the performance level, the thermal stability coefficient of the building element must have the minimum values as listed in Figure 23. The values are established for the cold season.

Tabelul nr. 6

Nr. crt.	Element de inchidere	Valorile coeficientului C_i, recomandate pentru grupa de cladiri:		
		"a"	"b"	"c"
1	Pereti exteriori (exclusiv suprafetele vitrate, inclusiv peretii adiacenti rosturilor deschise)	6	5	-
2	Pereti interiori care separa spatii cu temperaturi diferite*) (inclusiv peretii adiacenti rosturilor inchise)	3	2	-
3	Planseu terasa	7	6	-
4	Planseu de pod sau planseu terasa cu strat de aer ventilat	4	3	-
5	Planseu care delimiteaza cladirea la partea infe-rioara, de exterior (la bowindouri, ganguri, etc.)	8	7	-
6	Planseu care separa spatii interioare cu temperaturi diferite*)	3	2	-
7	Placi pe sol	7	6	-

*) Numai in cazul in care peretii interiori sau planseele interioare separa spatii inchise cu temperaturi de exploatare care difera intre ele cu mai mult de 10^0K.

Figure 23 – The minimum recommended values of the thermal stability coefficient of the building elements for the cold season, according to the building/room group. The boundary elements listed in the table are: exterior walls (without the glazed surfaces and the walls adjacent to the open joints), interior walls which separate spaces having different temperatures (including the walls adjacent to closed joints), terrace roof floor, attic floor or terrace roof floor having a layer of ventilated air, floor which separates the building from the exterior environment at the inferior side (passages), floor that separates interior spaces with different temperatures, floors on the ground.

[2]

Conclusion

Unlike C107 – 2005, with the modified annex from 2011 which brings upgraded values for minimum thermal resistances required in building elements, new values for QN and other parameters used to establish G1ref and GN, Mc001 – 2006 is more detailed and seems closer to today's standards of energy performance. The standard C107 – 2005 concentrates only on the energy performance of residential and non-residential buildings in case of heating, the mechanical ventilation, air conditioning, domestic hot water or artificial lighting not being included. Also, in C107 – 2005 there are very few mentions about the interior climate of the building. The Mc001 – 2006, even though it seems closer to today's standards of energy performance, there aren't so many details regarding the interior comfort of the building. Some of the calculation methods which are described in the standard lead to results with errors, an example being monthly method for energy demand in cooling of the building [9, Chapter II.2, Section 2.4, p. 18]. Some of the formulae, such as the number of degree – days for the evaluation of the energy demand for the air conditioning systems [9, Chapter II.2, Section 2.8.4.1, p. 72], seem to be unclear. Probably the error comes from editing the standard. Also there is quite few information regarding the energy certification of the new buildings, this aspect being focused mostly on existing buildings.

The standards C107/6 [1] and C107/7 [2] were both released in year 2002 and since then there is no knowledge of them being upgraded in order to be close to the current standards for energy performance and building sustainability. In C107/6 [1] some of the formulae presented there seem to have mistakes in the notation of the indexes of the parameters [1, Chapter 5, Section 5.5, pp. 12–13], which might lead to the confusion of the designer who wants to use the standard. Maybe this mistake comes from the editing of the standard. In C107/7 [2] there is a mistake in naming the unit of measurement for temperature Kelvin as "degree Kelvin" (See Figure 23). The units of measurements for temperature which have the notation "degree" are "degree Celsius" and "degree Fahrenheit". The mistake is also probably from editing the standard. Also in C107/7 [2] there are no performance levels during warm season in case of the thermal stability coefficient (C_i), respectively for cold season for the dephasing coefficient of the outdoor temperature oscillation (ε).

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