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THERMODYNAMIC DESIGNING OF A SOLAR BLOCK OF FLATS WITH A TROMB'S WALL WITH VENTUCE HOLES

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Abstract. *The paper examines the effects of passive solar heating of an individual residential object, located in Niš, that occur by the use of a combined passive system consisting of a Tromb's wall with ventuce holes and windows for direct insolation. The diagrams are included that show the inner air temperatures of a thermally insulated residential object with A Tromb's wall made of brick and concrete, 20cm and 45cm thick, with ventuce openings.*

Key words: *Tromb's wall with ventuce holes, passive solar heating of residential objects*

INTRODUCTION

Depending on how solar energy reaches an object, there are two different manners in which an object can be heated by sunlight: direct and indirect. In direct solar heating, sunlight directly penetrates the room through a transparent screen (window), whilst in indirect solar heating the external elements of an object (Tromb's wall, water wall, active massive wall, etc.) receive and absorb sunlight and transmit it to the rooms that are to be heated.

Passive solar collection is made possible by an object with no additional devices that can collect sunlight and convert it into other forms of energy. In these systems the entire object serves as a solar collector.

Designing energy-efficient residential buildings includes the application of passive systems for solar heating [1-4].

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The paper presents the results of a study on thermodynamic behavior of buildings whose constructive elements (floor, walls, ceiling) have been insulated or not, in conditions when sunlight is collected through a Tromb's wall with ventuce openings and through windows (direct insolation). The object is not additionally heated [2 - 8].

SOLAR OBJECT WITH A TROMBS'S WALL WITH VENTUCE OPENINGS AND WINDOWS FOR DIRECT INSOLATION

An object with a Tromb's wall with ventuce openings and windows for direct insolation is given in Figure 1. The total surface of the object's base is 96 m^2 (8m×12m). The northern facade is 2.4m high and with an area of 28.80m^2. The southern facade is 3.60m high, with an surface (including openings) of 43.20m^2. The western and eastern facade are both of the same surface, $A_W = A_E = 24.00m^2$. The surface of the slanting roof of the object is 97.20 m^2.

A Tromb's wall is positioned on the southern facade and comprises a dual glass transparent screen (with a solar absorption coefficient of $\alpha_w = 0.80$, and a coefficient of glass transparent screen transmission of $\tau_w = 0.70$), ventuce openings, and solar roof-windows. The surface of the Tromb's wall is $A_{tw} = 22.00m^2$, and of solar windows $A_{sw} = 8,16m^2$. The distance between the wall and the transparent screen is b = 0.10 m. On winter days, air velocity through the channel is 10 [m/s] (the fan is switched on, air circulation is forced through the channel). External air velocity is 2.5 [m/s]. During winter nights, the ventuce openings are closed and thermally insulated with wooden covers. The insulation is $d_{ins} = 0.01m$ and $\lambda_{ins} = 0.210$ [W/mK] [2].

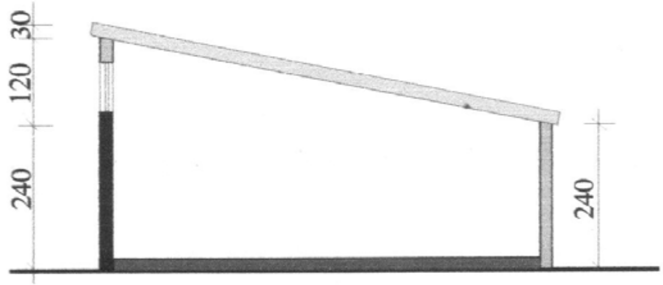

Fig 1. A solar object with a Tromb's wall and window for direct insolation: cross-section of the object

The structure of the construction parts of the insulated passive solar residential object is given in Table 1.

Table 1. Structure of construction parts of the insulated passive solar house

Structure of Constructions	d[m]	$\lambda \left[\frac{W}{m K}\right]$	$R = \frac{d}{\lambda}\left[\frac{m^2 K}{W}\right]$	$\rho \left[\frac{kg}{m^3}\right]$	$C \left[\frac{J}{kg K}\right]$
Construction of the insulated outer wall					
Solid brick	0,300	0,640	0,468	1600	920
Mineral wool	0,080	0,038	2,100	80	840
Façade brick	0,120	0,640	0,187	1600	920
Construction of the insulated floor on the ground					
Parquet	0,022	0,210	0,105	600	2090
Rabic cement substrate	0,050	1,160	0,043	2200	960
Ferro-concrete	0,150	1,160	0,129	2000	960
PVC foil	0,0004	0,190	0,002	1200	960
Vunizol	0,070	0,041	1,707	150	840
Rabic cement substrate	0,030	1,160	0,026	2000	960
Multi layered bitumen hydroinsulation	0,015	0,190	0,079	1100	1460
Ferro-concrete	0,100	1,160	0,086	2000	960
Ruffle gravel	0,150	0,810	0,519	1700	840
Construction of the insulated slanting roof					
Calcareous mortar	0,020	0,810	0,025	1600	1050
Ferro-concrete plate	0,140	2,04	0,069	2400	960
Steam barrier	0,005	0,190	0,260	1100	1460
Vunizol MP	0,100	0,038	2,631	60	840
Ventilated layer of air	0,020	100	0,000	1,180	1005
Tile	0,012	0,990	0,0121	1900	1460

STUDY RESULTS

The temperatures have been calculated for the rooms of the solar object with a brick and concrete (d = 20 cm and d = 45cm, a 24 - hour operiod, January 15 th) Tromb's wall with ventuce openings. The object was located in Nis (Serbia and Montenegro), (L = 43°), and ψ = 0°, ± 80°, thermally insulated, and contained a direct system and a Tromb's wall with ventuce openings for solar collection with no additional heating device (combined passive system, Figure 1.). The room temperature was calculated by using an original mathematics model [2].

Temperatures in a room of a thermally insulated object with a combined system

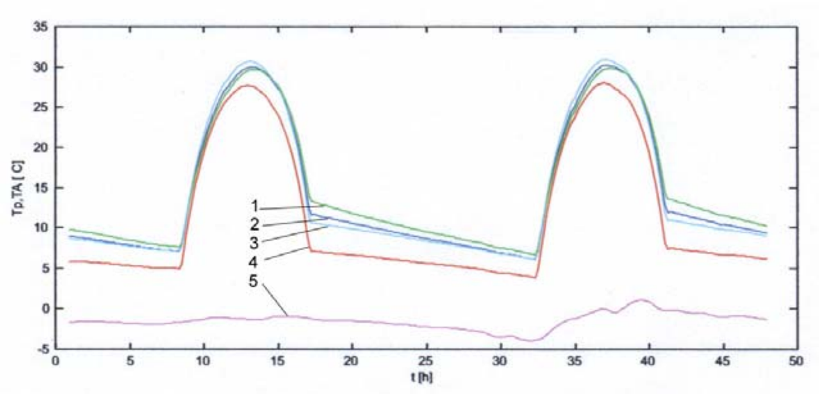

Fig. 2. Room temperatures for ψ = 0°: 1. room temperature for brick wall $d_{b.\ wall}$ = 20 cm; 2. room temperature for concrete wall $d_{c.\ wall}$ = 20 cm; 3. room temperature for brick wall $d_{b.\ wall}$ = 45 cm; 4. room temperature for concrete wall $d_{c.\ wall}$ = 45 cm; 5. ambient temperature

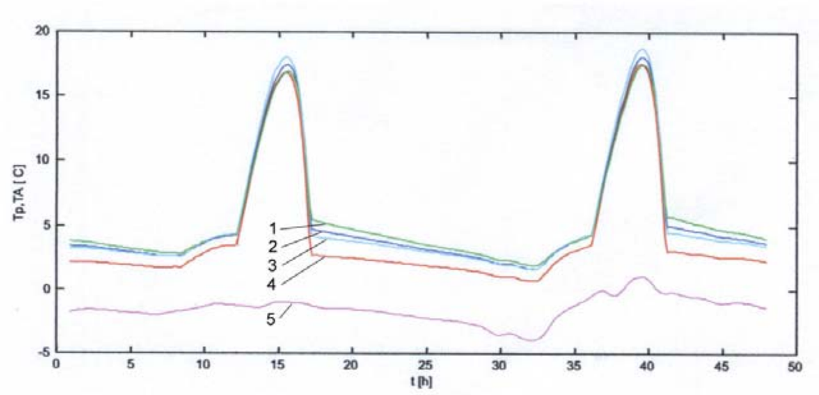

Fig.3. Room temperatures for ψ = + 80°: 1. room temperature for brick wall $d_{b.\ wall}$ = 20 cm; 2. room temperature for concrete wall $d_{c.\ wall}$ = 20 cm; 3. room temperature for brick wall $d_{b.\ wall}$ = 45 cm; 4. room temperature for concrete wall $d_{c.\ wall}$ = 45 cm; 5. ambient temperature

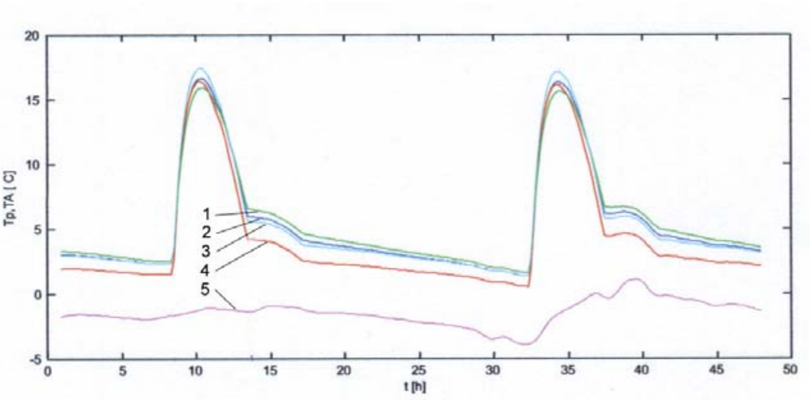

Fig. 4. Room temperatures for ψ = - 80°: 1. room temperature for brick wall $d_{b.\ wall}$ = 20 cm; 2. room temperature for concrete wall $d_{c.\ wall}$ = 20 cm; 3. room temperature for brick wall $d_{b.\ wall}$ = 45 cm; 4. room temperature for concrete wall $d_{c.\ wall}$ = 45 cm; 5. ambient temperature

The influence of the object's orientation upon the air temperature inside the room of the insulated object has been defined**,** by comparing the inner air temperatures of the room of the object with a Tromb's wall of southern orientation (ψ = 0°) with the air temperature in the room of the object with Tromb's wall of ψ = ± 80° orientation (over a time cycle of 24 hours). The obtained results are as follows:

1. In the object with a Tromb's wall of concrete (d = 20cm) and ψ = ± 80° orientation, the room's inner air temperatures are lower by 52% and 55.3% compared to the inner air temperatures in the object of southern orientation
2. The inner temperatures of the room of the object with a Tromb's wall of concrete (d = 45cm) and ψ = ± 80° orientation are lower by 49.5 % and 54.6 % compared to the temperatures in the room of the object of southern orientation.
3. When a Tromb's wall is of brick (d = 20 cm) and ψ = ± 80°orientation, the inner air temperatures are lower by 52.2 % and 54.4 % compared to the air temperatures in the room with a Tromb's wall oriented to the south.
4. If the room of the object contains a Tromb's wall of brick (d = 45cm) and ψ = ± 80° orientation, the inner air temperatures are lower by 49.5 % and 52.3 % compared to the calculated inner air temperature in the room oriented to the south.

On the basis of the obtained results it is evident that the best orientation of the object is to the south (the highest inner air temperatures of the room), followed by the east (ψ = + 80°) and west orientation (ψ = – 80°).

The best variant of the combined system above-considered (direct insolation plus Tromb's wall with ventuce openings) has been determined by comparing the calculated inner air temperatures of the room of the object containing different construction variants of a Tromb's wall with ventuce openings [2].

Table 2 shows the construction variants of a combined system.

Table 2. Construction variants of a Tromb's wall of brick and concrete of different thickness in a combined system (direct insolation plus Tromb's wall with ventuce openings)

Variant	Construction of Tromb's Wall with ventuce openings	Construction of Tromb's Wall with ventuce openings
1	Concrete 20 cm	Concrete 45 cm
2	Concrete 20 cm	Brick 20 cm
3	Concrete 45 cm	Brick 45 cm
4	Brick 20 cm	Brick 45 cm
5	Concrete 20 cm	Brick 45 cm
6	Brick 20 cm	Concrete 45 cm

Variant 1: In the object oriented $\psi = 0°$, the air temperatures in the room with a Tromb's wall of concrete (d = 45 cm) are lower by 7,5 % compared to the calculated inner temperatures of the room of the object with a Tromb's wall of concrete (d = 20 cm).

Variant 2: If the object is oriented $\psi = 0°$, the air temperatures in the room of the object with a Tromb's wall of brick (d = 20cm) are lower by 6% compared to the calculated inner temperatures of the room of the object with a Tromb's wall of concrete (d = 20cm).

Variant 3: For the object oriented $\psi = 0°$, the air temperatures in the room with a Tromb's wall of brick (d = 45cm) are lower by 21,4% compared to the calculated inner temperatures of the room of the object with a Tromb's wall of concrete (d = 45cm).

Variant 4: If the object is oriented to the south, the air temperatures in the room with a Tromb's wall of brick (d = 45cm) are lower by 22,6% compared to the calculated inner temperatures of the room with a Tromb's wall of brick (d = 20cm).

Variant 5: For the object oriented $\psi = 0°$, the air temperatures in the room with a Tromb's wall of brick (d = 45cm) are lower by 26,8% compared to the calculated inner temperatures of the room with a Tromb's wall of concrete (d = 20cm).

Variant 6: For the object oriented $\psi = 0°$, the air temperatures in the room with a Tromb's wall of concrete (d = 45cm) are lower by 1,6% compared to the calculated inner temperatures of the room with a Tromb's wall of brick (d = 20cm) [2].

DISCUSSION

During the day, the air temperature in the room of the south-oriented thermally insulated object exceeds the level of temperature anticipated by the project ($T_{room} = +22°C$) in all the construction variants of the Tromb's wall with ventuce openings (brick and concrete, d = 20cm and d = 45cm, respectfully). In the objects with all the remaining orientations ($\psi = \pm 80°$), the daily inner temperatures of the room do not exceed +22°C.

After the facade with a Tromb's wall has been exposed to the sun (the fan has been switched off, evening time), the room temperature suddenly decreases. The highest temperature, after the Tromb's wall' exposure to sunlight, is registered in the room with a Tromb's wall of concrete (d = 20cm). In the room with the south-oriented wall the temperature is +14,5°C.

In the case when concrete or brick are of the same thickness (d = 20cm or d = 45cm), both daily and night temperatures are lower in the rooms with a brick Tromb's wall with ventuce openings (Variants 2, 3).

If the temperatures of the room with a thinner brick and concrete Tromb's wall (d = 20 cm) are compared with the temperatures of the room with a thicker Tromb's wall (d = 45 cm), the result is higher temperatures in the room with a thinner Tromb's wall (Variants 1, 4, 5, 6).

Taking into account the above results, it is obvious that the highest inner temperatures (a 24-hour period) are registered in the room with a 20cm thick concrete Tromb's wall with ventuce openings.

For all the considered variants of a combined system (direct insolation and a Tromb's wall with ventuce openings) there has been calculated a portion of solar energy (PSE) in the heating of a thermally insulated object that is not additionally heated (a 24-hour period, January 15th). The PSE has been calculated for ψ = 0°, + 80° and − 80° orientations and for a temperature of +22°C anticipated by the project. The values of the PSE for a combined system are given in Table 3.

Table 3. PSE for a combined system:
direct insolation and a Tromb's wall with ventuce openings

Object orientation ψ [°]	Construction variants of the Tromb's wall with ventuce openings (insulated object)			
	Concrete d =20cm	Brick d =20 cm	Concrete d =45 cm	Brick d =45 cm
	PSE [%]	PSE [%]	PSE [%]	PSE [%]
0	70,37	67,48	66,98	55,33
+ 80	32,55	30,85	33,77	28,87
− 80	29,98	28,92	28,55	23,98

Table 3 shows that the highest PSE is reached in the insulated object of south orientation with a 20cm thick concrete Tromb's wall with ventuce openings.

CONCLUSION

On the basis of the abovementioned, the following conclusions can be drawn:

1. The positioning of the object in the direction east–west allows for a maximum solar collection through passive systems built in the south facade of the object.
2. The energy-independent residential object provides up to 70% of thermal energy for heating (in the system with a 20cm thick concrete Tromb's wall with ventuce openings, for instance). As the attained energy level does not fully meet the conditions of comfort, it is therefore necessary that the object be provided with additional heating.
3. By conducting the energy flow in the object itself (directing the available heat from the sun in north-oriented rooms of the object), a substantially higher percentage can be accomplished in the object's independence of energy.

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TERMODINAMIČKO PONAŠANJE SOLARNE STAMBENE ZGRADE SA TROMBOVIM ZIDOM SA VENTUSNIM OTVORIMA

Jasmina Radosavljević, Miroslav Lambić, Tomislav Pavlović

U radu su prikazani efekti pasivnog solarnog grejanja individualnog stambenog objekata, lociranog u Nišu, koji nastaju primenom kombinovanog pasivnog sistema koji se sastoji od Trombovog zida sa ventusnim otvorima i prozorima za direktan zahvat sunčevog zračenja. Prikazani su dijagrami unutrašnjih temperatura vazduha toplotno izolovanog stambenog objekta sa Trombovim zidom sa ventusnim otvorima od opeke i betona debljine 20 cm i 45 cm.

Ključne reči: *Trombov zid sa ventusnim otvorima, pasivno solarno grejanje zgrada.*