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Passive solar systems enhanced efficiency

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Abstract. This article discusses the efficiency of passive solar systems auxiliary integrated into buildings and focuses on trombe wall. The first paragraph deals with measurement methods applicable for passive systems. Following chapter describes the elimination and correction of result uncertainities. The main part focuses on measurement and evaluation of trombe wall. The real passive solar system is integrated into model family house. The optimisation process and improvements are explained as the main result of this research.

Key words

passive solar system, trombe wall, heat penetration, emisivity.

1. Introduction

Energy consumption decreases are significant way for carbon footprint reduction and pollution gas emission cuts. Every technical field of human activity slowly changes traditional methods and conventional thinking. Also power engineering and electrical power engineering can significantly contribute to this effort [2].

Technical attempts tend to higher efficiency of every element in the power engineering chain. More efficient turbines work with better cycles, high efficient transmission and distribution lines are built and renewable energy sources became significant part in the power sources mix. The energy savings are not limited only to the production – distribution side, but also to the consumer side. Low consumption appliances became common on the market. Also buildings itself can very significantly contribute to the energy savings effort. Low energy and passive houses became the standard for new buildings. Passive solar systems slowly find their places in the market and design process. Correct installation and usage of these systems can increase the user comfort and internal environment with minimal purchase costs and with interesting energy savings [2, 3].

The main task is to choose optimal design and structure of the system and as ideal operational regime as possible. This article focuses on measurements and evaluation of trombe wall installed in model family house.

2. Model Object with Passive Solar System

Trombe wall presented on Fig. 1 is built up to 2,5 m from brickwork Porotherm 44 P+D 440 mm and between 2,5 m and 5 m consists from burnt bricks 300 mm.

The wall is stuked inside with 2 mm fine plaster and double painted with standard white interior paint Primalex.

Outer side is rough casted with external plastering and double painted with black toned standard exterior paint Primalex.

Mat black metal construction bears 5 mm glass tables sealed with insulation rubber Armaflex.

The functional air gap (100 mm) is fastened with PUR panels with additional ventilation flaps.

Fig. 1. Model family house with trombe wall.

3. Measurement Methods and Conditions

The paper was supported by SGS-2018-023.

All the measurements were executed between 23.9.2017 and 30.4.2018. To avoid effect of building preheating, the measurement interval was placed into the long period of consecutive days, rather than into a random set of favourable days [1, 3].

The measurements were practiced at 4 points in the interior rooms and at 8 points of the trombe wall. Fig 2 shows sensors layout inside the trombe wall while Fig. 3 presents measurement locations in the interior rooms.

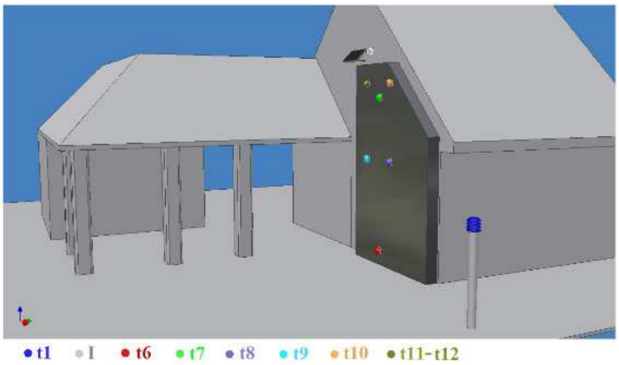

Fig. 2. Sensors layout inside the trombe wall.

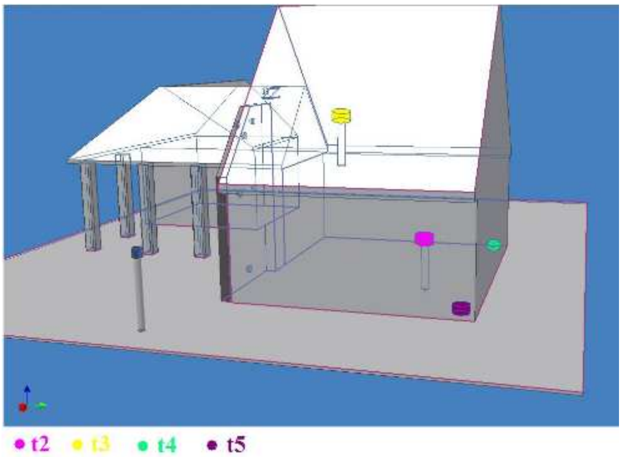

Fig. 3. Sensors layout in interior rooms.

Infrared cameras Flir T335 and Fluke TiX640 were used to visualize the temperature lay outs on the trombe wall. Extensive emissivity range of used structural materials involved proper and accurate interpretation of recorded thermograms as evident on Fig. 4 [1].

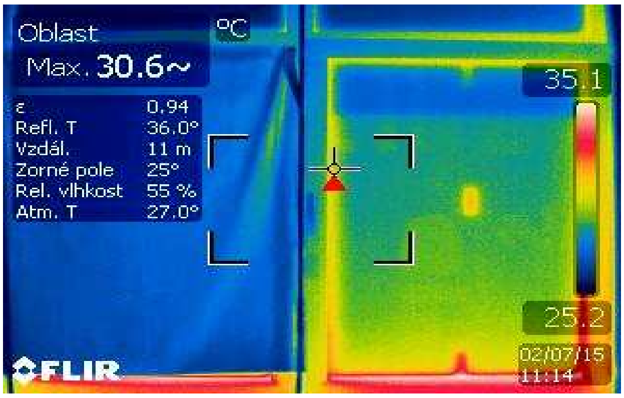

Fig. 4. Sample thermogram of the trombe wall exterior side.

Firstly, influence of IR radiation on the sensors had to be detected and compensated. Fig. 5 represents the IR compensation with reflective foil covering entire surface of the trombe wall.

Fig. 5. Sensors calibration with reflective foil on trombe wall.

Fig 6. visualizes temperature measurements on sensors. Temperature t_{11} represents the temperature of the plain sensor while t_{12} shows temperature of the sensor shielded in aluminium tube. The difference curve t_{11}-t_{12} can be used for the compensation during real measurements.

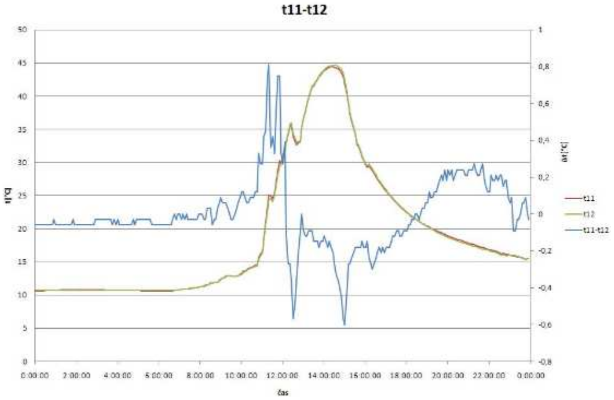

Fig. 6. Temperature measurement on sensors.

Total thermal gains (1) can be used either for technical or for economical calculations.

$$Q = \alpha \cdot S \cdot (t_W - t_{IN}) + \beta \cdot \left(\frac{T_W}{100}\right)^4 + \gamma \cdot S \cdot (t_W - t_{IN}) \quad (1)$$

Temperatures t_w and t_{in} mean the wall and interior temperature, S presents the active area of the trombe wall, T_W poses external source of IR radiation incidenting the wall and α, β, γ are coefficients of heat conversion via convection, conduction and radiation [1].

These gains must be regulated with flap cooling system to maintain the level of interior comfort. Fig. 7 shows daily energy gains during sample winter season correlated to solar radiation incidenting the trombe wall while Fig. 8 focuses in detail on sample winter day.

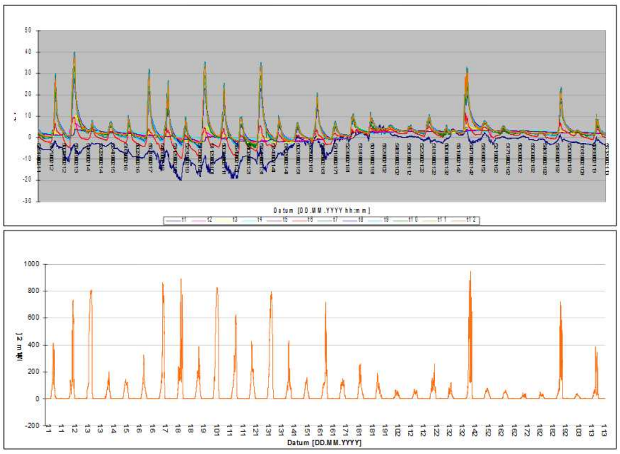

Fig. 7. Energy gain (sample winter season).

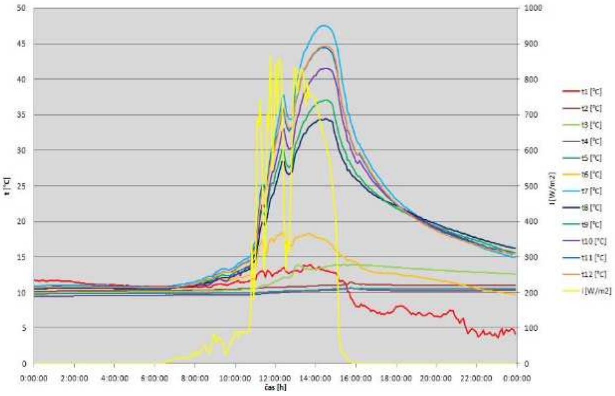

Fig. 8. Energy gain (sample winter day).

Energy gains are used for heating or tempering of the interior during winter season when interior flaps regulate the air circulation [4].

To avoid overheating during summer season these flaps are usually closed, while external flaps enable ventilation and cooling of the air gap between the wall and external glazing. Fig. 9 presents daily energy gains during sample summer season correlated to solar radiation analogically to Fig.7.

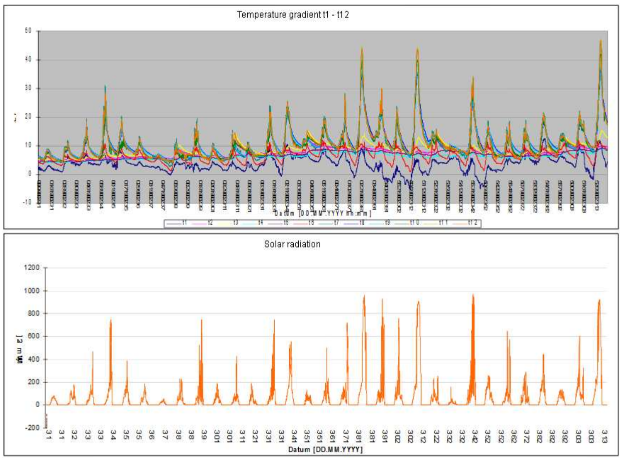

Fig. 9. Energy gain (sample summer season)

Fig. 10 summarizes temperature difference for sample winter day while Fig. 11 shows the same situation for sample summer day. Absolute values between the charts are evident and require above described proceedings.

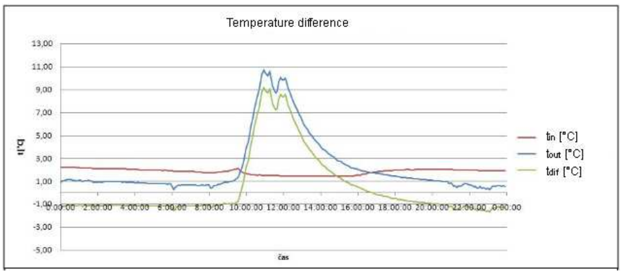

Fig. 10. Temperature difference (sample winter day).

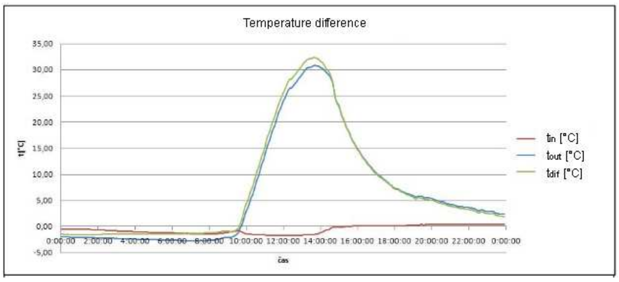

Fig. 11. Temperature difference (sample summer day).

4. Technical Features Optimisation

Heavy temperature oscillations demonstrated on Fig. 7 and Fig. 9 during winter (cold) and summer (hot) seasons tend to project of the trombe wall optimisation.

Trombe wall is except the energy source also significant design element. Possible way to affect the efficiency of the system is the surface emissivity. The influence on the heat penetration is evident in (1). The emissivity depends not just on the material itself, but also on surface trimming and colour. It is obvious that bright colours decrease the heat penetration. Although these colours can be interesting from design point of view are not usually acceptable from energy reasons [3, 4].

Particular technical and auxiliary components offer better opportunity for optimization, what is discussed in next paragraphs.

Above all the ventilation system can be improved and equipped with autonomous control system. Low purchase and operating costs predetermined important criteria of the project. Fig. 12 presents basic control system configuration.

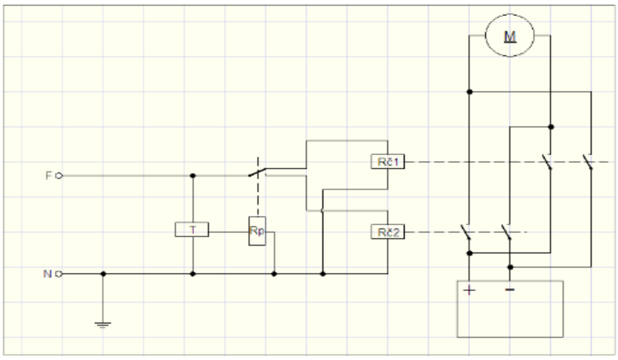

Fig. 12. Flap control system configuration.

Enforced air circulation can offer additional efficiency increments. The idea is trivial. Instead of free air flow, special electric ventilators are installed instead passive flaps.

Advantage is the possible regulation of air amount, speed and time switching. These benefits are redeemed with some energy consumption and lower circumstantiality. Additional air conduits (red branch) must be insulated against thermal looses. This could be provided by mineral wool or similar materials. Fig. 13 shows ventilators application on tested trombe wall.

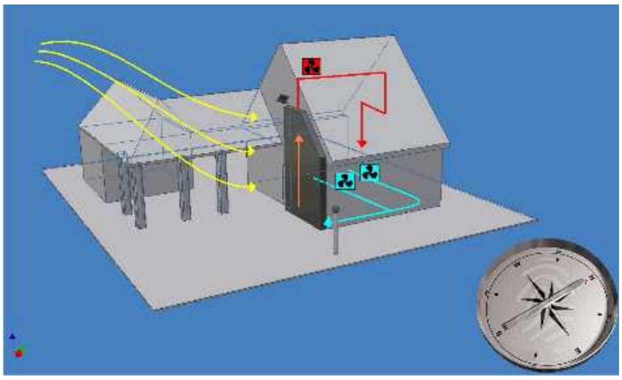

Fig. 13. Application of enforced air circulation.

Ventilatosr switching is executed with simple thermostat. First design requires sensors in living space of the house and in the middle part of the trombe wall. Ventilators are switched at predefined temperature difference. When the wall temperature exceeds the interior temperature about 8 °C, ventilators start to cool the wall and to heat the interior. The process is interrupted when the temperature difference drops below 4 °C.

More complex solution consists from sensors installed in both floors, in the wall and in the air conduits. Temperature differences are the same as in first case, but the air flow is more variable. Air routing can be between separate parts of the wall and between particular areas of the interior.

Ventilator parameters (Decor 100 CZ IPX4):

- flow: $95m^3$/min
- power: 13 W
- max. temperature: 45 °C
- rpm: 2500 rpm

Thermostat parameters (EuroTemp Solar 83):

- max. temperature: 110 °C
- min. temperature: -40 °C
- load: 16 A

Trombe wall is usually used for object tempering rather than object heating. It means that the system must be able of autonomous operation. Table 1 summarizes energy disposable for the designed control system during the year. This energy is covered by autonomous 12 W PV system installed on the building as demonstrated on Fig. 14.

Table I. – Control System Energy (12 W PV panel)

Month	**9**	**10**	**11**	**12**	**1**	**2**	**3**
E (Wh/day)	33	27	11	8	12	20	30

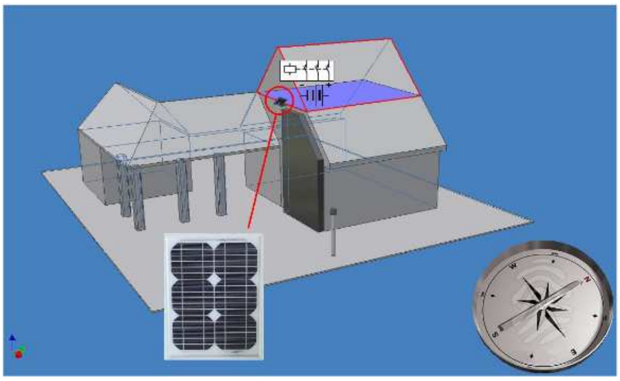

Fig. 14. Design of autonomous energy system.

System energy consumption:

• relays	3 x 3,0 W	9,0 W
• flap servomotors	2 x 3,6 W	7,2 W
• ventilators	5 x 13,0 W	65,0 W
• thermostat	1 x 0,1 W	0,1 W
total power		**81,3 W**

Purposed energy system consists from small photovoltaic panel (12 W) and 900 Wh accumulator that is capable to power the system for limited time. To increase the time and to guarantee all day operation, 200 W PV panel is necessary. That increases purchasing costs. Functional schema (variant 1) is presented on Fig. 15.

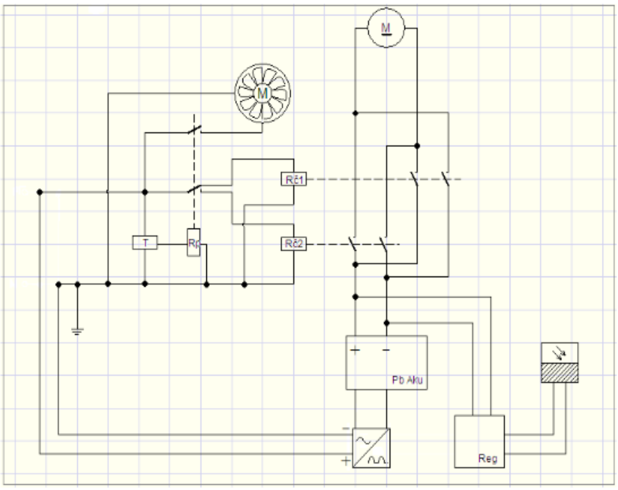

Fig. 15. Design of autonomous energy system (variant 1).

Another option is application of energy economic ventilators.

DC ventilator CoolMaster has nominal power 0,96 W. Entire energy consumption is decreased from 81,3 Wh to 26,7 Wh. 12 W PV panel can be powerful enough to power this variant. This solution (variant 2) is illustrated on Fig. 16.

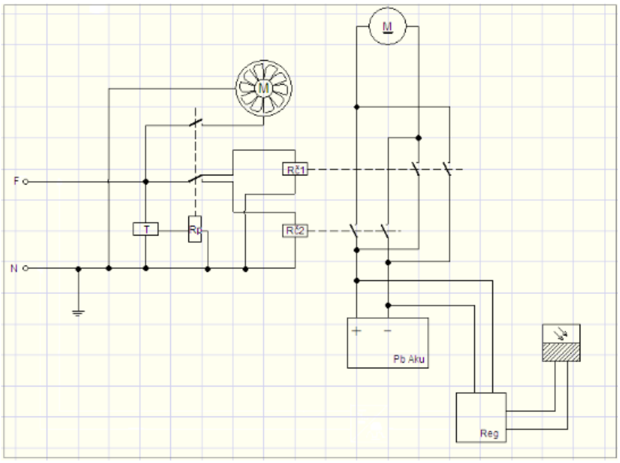

Fig. 16. Design of autonomous energy system (variant 2).

Functionality of proposed system (variant 1) was verified with similar measurements presented on Fig. 7, Fig, 9 and in detail view on Fig 8. The results are demonstrated on Fig. 17.

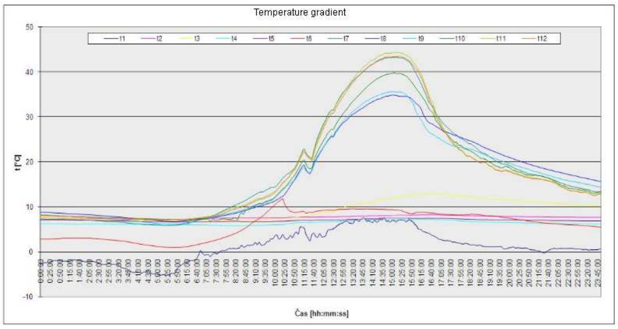

Fig. 17. Autonomous energy system (variant 1).

5. Results and Conclusions

Trombe wall can serve as autonomous energy source for bulding tempering. Beside that, the system increases thermal comfort inside the building.

Design improvement often decreases the energy efficiency. The best way to increase the operation and efficiency is application of enforced air circulation.

2 systems of enforced air circulation systems were discussed and measured. Except different energy consumption, both variants increase the efficiency in the same way.

The efficiency improvement in real conditions can be expected from 14 to 28 % depending on the season.

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References

[1] M. Kreidl, “Mereni teploty”, BEN, Praha, 2005.
[2] J. Cihelka, “Solarni tepelna technika”, T. Malina, Praha, 1994.
[3] M. Hanova. “Trombe wall for familly house heating assessment, Master thesis”, ZCU, Pilsen, 2009.
[4] T. Langhammer, „Passive solar systems optimization, Master thesis”, ZCU, Pilsen, 2011.