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Comparative measurements of energy efficiency on different walls, including PMMA foam covered concrete wall

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ABSTRACT

Different types of walls have very different efficiency for the use of solar energy. To evaluate different types of walls, comparative measurements of this walls under identical conditions must be done.

A test object containing four identical cells with one changeable wall was prepared. A system for the measurements and control of thermal processes maintains constant temperatures in the cells and the main measured quantity is energy consumption of each cell. The PMMA foam covered concrete wall was compared to bare concrete wall, thermally insulated wall and black painted concrete wall, covered by glass.

Further measurements on different types of TIM and in different climatic conditions are planned.

INTRODUCTION

Climatic conditions in Slovenija, north-west part of Yugoslavia vary substantially with location. For the part near the Adriatic coast and in the mountains there is no doubt, that the use of solar energy is efficient. The plain country in the middle with the most of the population has a lot of foggy days from the late autumn to the early spring. In such conditions it is often doubtful which passive or active solar elements are effective.

One of the ways to answer this dilemma are adequate measurements. The ideal measurements should be made on a number of real objects, but such measurements are much too expensive.

MEASURING SYSTEM

A test object containing four test cells with changeable test walls was constructed for the measurements of energy gains and losses of different walls. The basic idea was to make comparative measurements on different walls under equal conditions, influenced by as few external changeable factors as possible.

The test object can be turned in any direction or moved to other location by normal means of transportation.

Test object is made of a specially prepared transport container, 7.35 m long, 2.21 m high and 2.43 m wide. The walls are thermally insulated. A smaller part is designed for measuring equipment.

The mobile solar test object contains four cells 1 m wide, 1.2 m high and 1.2 m deep (all inner measures). The walls are made of 7.5 cm concrete and on the outer side thermally insulated by 20 cm glass wool. The heat flows through these walls are thus reduced to minimum, so the only "active" wall in the cell is the test wall.

The test cells were designed to represent real conditions. This model represents a room in a middle of a multistory, multiflat buildings. Under the prediction, that all the surrounding rooms are identical, the energy flows only through the outer wall. In this way the influence of external factors on the investigation is reduced to a minimum.

Each cell, as described, corresponds to a room of 2 x 2.4 x 2.4 m, reduced to the half size. The wall thickness was not changed, but for the wall mass we had to take only one half of the real wall, as the other half interacts with the adjoining room. All the material properties - absorptivity, emissivity, transparency, heat conductivity, specific heat, density etc. remained unchanged.

Energy balance depends on absorbed and conducted energy and accumulation. They are all reduced by four as they change linearly with the wall surface. Only the volume of the air in the cell is reduced by 8. But the mass of air is 1.7 kg and the mass of walls approx. 1100 kg, so the effect of this is very small.

The accuracy of our presumptions was verified and proved through the simulations by two computer programmes - DEROB and KAMRA. (1),(2),

The cells are heated so that temperatures don't fall under 20 °C. Data acquisition system measures surface and air temperatures inside the cells, outdoor temperatures and solar energy (global, diffuse and on the south vertical surface), energy used for cell heating and heat flows through various walls.

CALIBRATION OF THE SYSTEM

First control measurements with four cells were performed to check the uniformity of test cells and performances of measuring system. The four test cells were supposed to be identical and thus they should respond identically to the climatic changes. For the first control, all four cells were equipped by identical test walls made of 12 cm concrete. After a week of temperature stabilization the measurements were started. The comparison of temperatures and heat flows pointed out that the responses of the cells to the climatic changes differ very little, so it was concluded, that the differences between cell would not affect results.

MEASUREMENTS ON PMMA FOAM

For the second in the series of measurements we changed the existing walls, to make the comparative measurements on some interesting wall types. The basis, however, were the existing concrete walls.

Test wall on the first cell remained unchanged and served as the reference wall. On the second cell 10 cm thermal insulation layer was added. The wall on the third cell was painted black and covered by glass, as a very simple Trombe-Michel wall. The wall on the fourth cell was also painted black, over it came transparent thermal insulation (16 mm polymetil-metacrilat foam) covered by glass. The PMMA foam was a test sample of a local producer covered ob both sides by protective foil.

The results of the measurements from March, 26 to April 6, 1989 are presented here. Fig. 1. shows the climatic conditions -

outdoor temperatures and solar irradiation during this period. The first five days were extremely sunny with daily temperatures up to 28 ^{o}C and night temperatures down to 5 ^{o}C. The peak of solar irradiation reached nearly 800 W/m^2. Next five days were more or less cloudy with smaller air temperature variations.

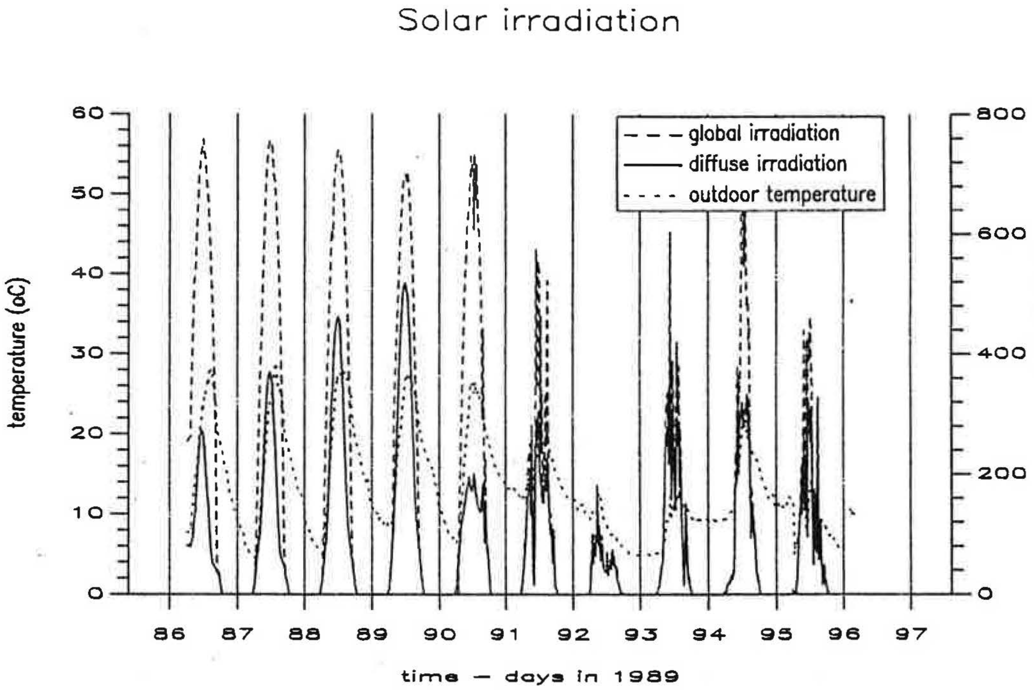

Fig 1. Outdoor temperatures and solar irradiation from March, 26 to April, 6 1989.

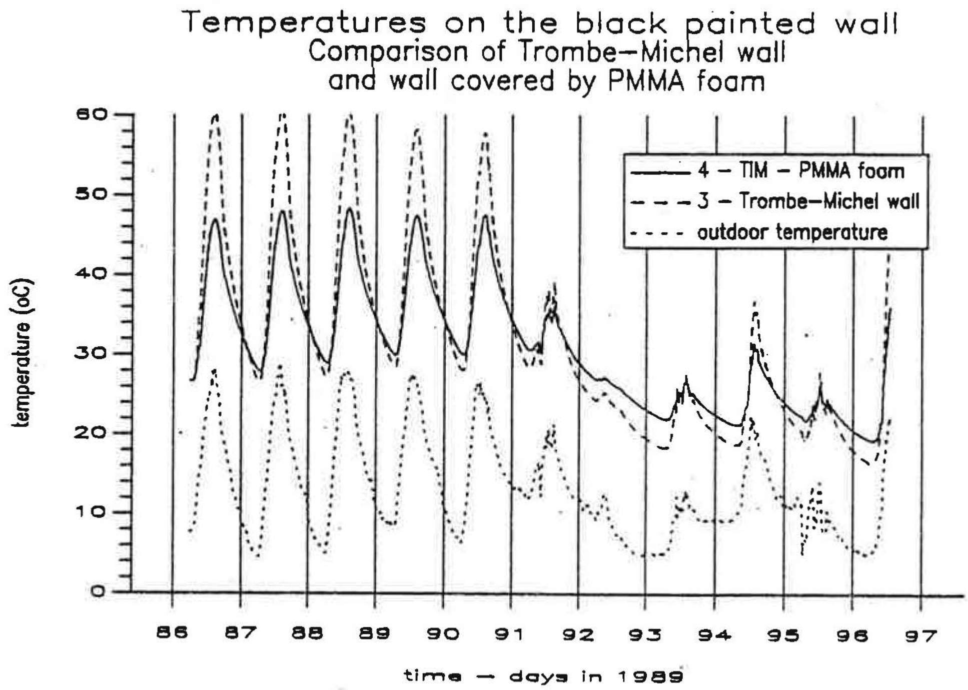

Fig. 2 Temperatures of the black painted wall under the glass or PMMA foam.

Fig. 2 shows the temperatures of the black painted wall under the glass or PMMA foam. The temperatures on the Trombe-Michel wall raised up to 60 °C, while the temperatures under the PMMA foam were up to 48 °C. During the colder, cloudy period, the temperatures under the PMMA foam were higher than the ones under glass.

Fig. 3 shows surface temperatures of the inner walls of all four cells. The highest temperatures were achieved in the cell with Trombe-Michel wall. No auxiliary heating was needed in this cell and the cell with PMMA foam. In the last 3 days auxiliary heating was turned on in the cells with concrete wall and thermal insulation. Here it is seen, that the sun has no influence on the cell with opaque thermal insulation.

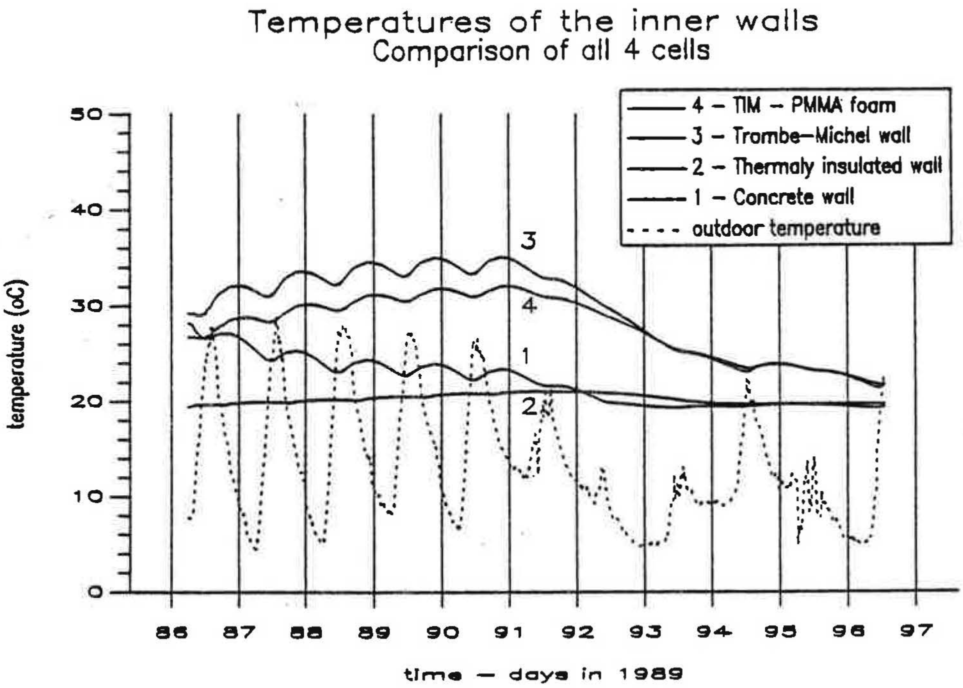

Fig. 3 Surface temperatures of the inner walls of all four cells.

CONCLUSION

The results shown in this paper are the results of the first series of measurements. On the basis of these measurements it can be said, that the wall with transparent thermal insulation used in our tests is less efficient for the solar gains in the time of high spring or autumn. The same walls should be tested in high winter. The measurements on the system continue.

REFERENCES

(1) DEROB EMPA-Version 2.0, Benutzeranleitung, EMPA Duebendorf, November 1982

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