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Reducing cooling requirement by using cladding for external walls ventilated at rear

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Abstract:
The choice of building components can significantly influence the energy performance of buildings. In cold climates building components determine the dimensions of transmission and ventilation heat loss and are crucial to thermal comfort. On the other hand, the amount of solar heat gain in hot climates depends on the building components as well. Transparent components have a higher influence and play a more important role for heating up buildings than non-transparent (opaque) components do. Therefore more research has been conducted on transparent building components until now. Research on claddings has been neglected, even though it could prove to have a substantial influence on energy savings with respect to cooling. Claddings for external walls ventilated at rear (opaque) are characterized in their thermal behavior primarily by the properties of thermal insulation material and the micro-climatic conditions in the air layer. In summer situations, the temperature differences between surface temperature, exterior and interior and also the air gap temperature cause stack-effects. Therefore, a higher air mass flow for the air gap is expected. As a result, it can be supposed that the heat from the exterior layered cladding is reduced by heat transportation of the airflow. This paper deals with experimental studies to investigate and calculate the volumetric air flow of claddings for external walls ventilated at rear and their influence on reducing the cooling requirement. For this purpose, different cladding surfaces have been investigated.

Keywords: *Reducing cooling requirement; energy efficiency; opaque building components; air flow; curtain wall*

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1. Introduction

In Northern Europe the focus of attention lies on winter heat protection instead of summer comfort. Since the introduction of the Energy Saving Regulation in Germany the summer situation has been gaining importance, particularly with regard to the cooling requirement of buildings. The German standards DIN V 18599 and EN ISO 13790 offer the possibility to calculate the energy use for space heating and cooling. In accordance with DIN V 18599, one of four factors calculating the heat sources is the solar heat gain Q_s. The solar heat gain Q_s (eq. 1) consists of two parts: the solar gain of transparent components $Q_{s,tr}$ and opaque components $Q_{s,op}$.

$$Q_S = \sum Q_{S,tr} + \sum Q_{S,op} \tag{1}$$

Within the scope of this study the solar heat gain of opaque components $Q_{s,op}$ has been investigated (Eq. 2).

$$Q_{S,op} = R_{se} \cdot U \cdot A \cdot \left(\alpha \cdot I_s - 250 \cdot \varepsilon\right) \tag{2}$$

(Eq. 2) includes the absorption coefficient α and the surface emissivity ε for the outside but does not differ between claddings for external walls ventilated at rear and solid walls with insulation to calculate the solar gains of non-transparent components. In the European Standard EN ISO 6946 the calculation of the heat transfer coefficient U is defined as (Eq. 3):

$$U = \frac{1}{R_T} = \frac{1}{R_{si} + \sum R_i + R_{se}} = \frac{1}{R_{si} + \sum \left(\frac{d_i}{\lambda_i}\right) + R_{se}} \tag{3}$$

The thermal resistance R depends on layer thickness d and their thermal conductivity λ. R_{si} and R_{se} are defined as heat transfer resistance for the exterior (se) and interior (si). Their values depend indirectly on convection and radiation at the surface of the wall and are simplified for vertical constructions with: $R_{se} = 0{,}04\,(\text{m}^2\,\text{K})/\text{W}$ (4) and $R_{si} = 0{,}13\,(\text{m}^2\,\text{K})/\text{W}$ (4)

In case of using claddings for external walls ventilated at rear, the European Standard EN ISO 6946 indicates that when calculating the heat transfer coefficient *U*, only component layers from the inside up until the air gap are considered and therefore the heat transfer resistance R_{se} for the outside is increased (Eq. 5):

$$R_{se} = R_{sí} = 0{,}13\,(\mathrm{m^2\,K})/\mathrm{W} \quad (5)$$

But by following this directive and using (Eq. 5) in (Eq. 2), the result would be deceptive since the solar heat gain for solid walls is actually higher than for claddings for external walls ventilated at rear. Therefore it is necessary to go into more detail and to focus on the physical phenomena of the air gap, and evaluate the heat transfer by convection and radiation. The heat transfer by convection and radiation into the air gap has been neglected and thus (Eq. 2) has to be revised.

2. Experimental set-up and laboratory investigation

The experiment set-up requirements create a surface temperature that approximates real situations; they reduce forced convection as much as possible and allow measurement of velocity of airflow, ambient air, air layer und surface temperature. Certainly some characteristics of the heat source and laboratory where the experiment set-up is being installed can produce undesirable effects. Heating up the floor may lead to a long-wave radiation and a convective heat transfer. Therefore, an aluminum reflective layer finishing to the floor reduces surface heating, long-wave radiation and convective heat flux.

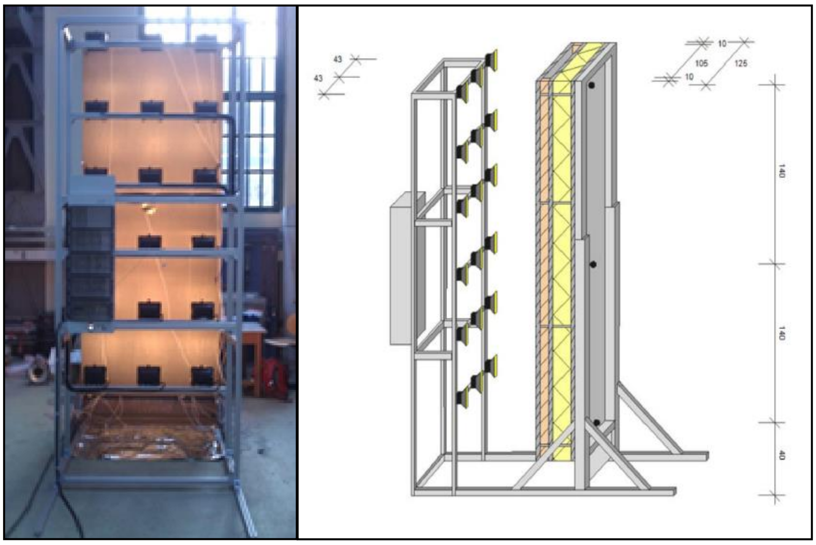

Fig. 1 Experiment set-up.

Fig. 1 illustrates the experiment set-up design. The dimensions of the test specimen are 125 × 310 cm². The curtain wall on the inside consists of different layers of fiber cement tile, thermal insulation, fiber cement tile, an air layer and a fiber cement tile positioned facing the heat source. The fiber cement tile arranged between the air layer and the thermal insulation will facilitate measurements. The experiment set-up is designed to allow a series of measurements of air velocity and temperature. For purposes of temperature measurement, 30 sensors (Pt100) are mounted on the curtain wall: 28 sensors at the surface inside the air layer and 2 at the surface outside of the construction. In order to conduct measurements, seven sensors with a hot-wire probe are mounted within the air layer. Since this paper deals with investigating the influence of the surface conditions, nine different variations of surface conditions are applied. The thickness of the air layer is 7.5 cm and remains the same for all investigations. In this test series in all cases, the curtain wall is exposed to the same light intensity. Three different colors for the surface of the fiber cement tile have been chosen: black, white and silver.

3. Evaluations, Results and Discussion

As described above, each test was carried out with the same boundary conditions. The color of the fiber cement tile has a major influence in terms of absorption, reflection and emission. With respect to the absorption coefficient for all colors used, the black surface reaches the highest temperatures with an outside surface temperature of about 67°C (Fig. 2). Consequently, the silver surface used for the outside obtains the lowest surface temperatures, with a temperature of about 44°C (Fig. 4).

	black	white	silver
1	6.2	10.5	28.4
2	10.7	14.0	28.3
3	7.3	11.5	23.4
4	12.1	14.3	31.1
5	9.7	12.0	30.8
6	11.9	15.5	26.9
7	5.6	11.8	20.1

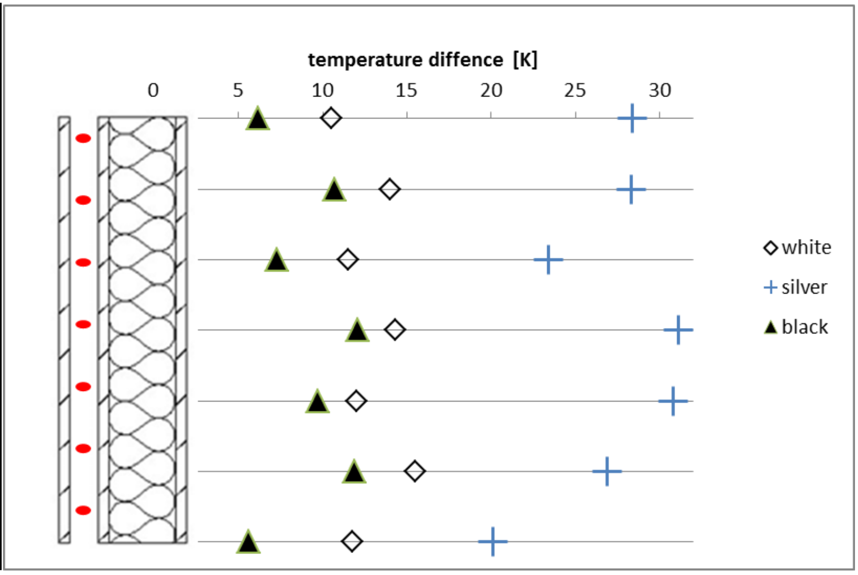

Fig. 2 Temperature difference in the air gap with a black surface outside (outside temperature 67°C).

	black	white	silver
1	6.0	5.7	14.3
2	7.7	7.6	15.6
3	5.0	4.8	13.3
4	9.2	6.6	18.1
5	5.9	6.5	15.4
6	7.8	5.4	16.9
7	3.6	6.1	9.5

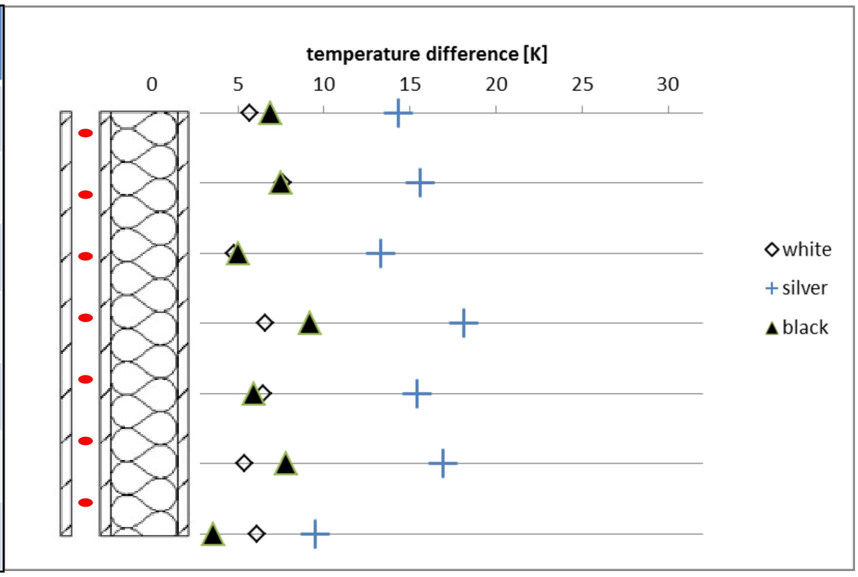

Fig. 3 Temperature difference in the air gap with a white surface outside (outside temperature 55°C).

	black	white	silver
1	3.2	5.5	7.1
2	2.9	5.0	5.7
3	1.5	4.0	5.3
4	6.3	8.0	9.9
5	4.7	3.0	9.9
6	6.7	7.0	8.3
7	4.4	6.1	4.9

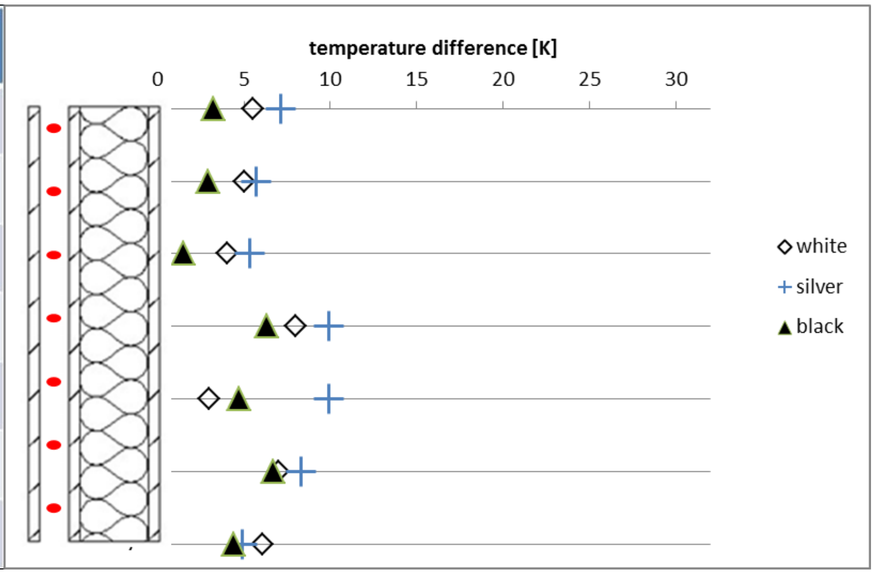

Fig. 4 Temperature difference in the air gap with a silver surface outside (outside temperature 47°C).

Similar to this result, white surfaces also prevent a heating of the surface. Figs. 2-4 display the temperature differences in the air layer. It is obvious that emission plays an additional role for the air layer temperature. The biggest temperature difference is found with a black outside surface and a silver surface on the inside (Fig. 2). If black and silver are switched it leads to the lowest temperature differences (Fig. 4). This phenomenon might be caused by the maximum temperature on the surface. Fig. 5 displays the volumetric flow in the air layer. In total the highest air flow is reached with the black surface outside, which is definitely caused by the highest surface temperature outside. A silver surface inside results in the smallest amount of volumetric air flow but also the highest temperature difference of the air layer, which indicates that radiation might play an important role for the heat transfer in claddings for external walls ventilated at rear.

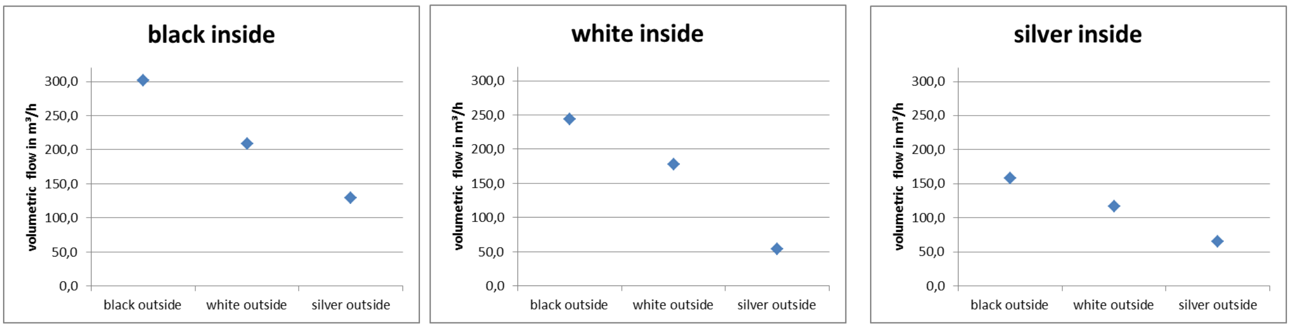

Fig. 5 Volumetric flow in the air layer: black inside left, white inside middle and silver inside

4. Conclusion

There is a high potential for reducing the solar heat gain by using claddings for external walls ventilated at rear. In general, the air layer offers the possibility for the heat to escape. The surface condition has a major influence on the outside surface temperature and also on temperature differences in the air layer. Black surfaces reach the highest surface temperature, silver the lowest. The combination of black on the outside and silver on the inside causes the air layer to reach the highest surface temperature outside and also the greatest temperature difference inside. A low surface temperature outside and the smallest temperature difference inside are obtained by the combination of silver on the outside and black on the inside.

As a result, two aspects might minimize solar heat gain: It is beneficial to obtain a low temperature by using white or silver surfaces on the outside of the curtain wall. For using black surfaces on the outside it would make sense to have a silver surface inside to obtain a high temperature difference in the air layer and therefore a low temperature at the surface of the insulation.

Finally, it must be noted that, more investigations are necessary. It is obvious that using claddings for external walls ventilated at rear have an influence of the heat transfer. Convection but also radiation plays an important role. The volumetric airflow of the air layer but also the radiation component depends on the respective surface conditions (absorption coefficient, emissivity, air velocity).

With regard to climate policy, resource conservation and environmental protection using claddings for external walls ventilated at rear offer a chance to reduce the cooling of buildings in particular for hot climates. As a consequence, the electricity requirements for cooling can be lowered and environmental impact can thereby be reduced.

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