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Influence of ambient air speed on convective heat transfer coefficient at natural convection regime

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Introduction

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The correct internal surface transport coefficients modelling in the complex models of the heat, air and moisture transport in a building concerns the local thermal balance of the air boundary layer near the internal surfaces.

The heat transfer between a solid wall and an air is defined by the temperature difference and the convective heat transfer coefficients.

The new experimental optical non-invasive method that does not influence the conditions in the boundary layer has been used in this work.

The combination of the experimental data and CFD numerical simulations were used to evaluate of the influence of ambient air speed on convective heat transfer coefficient.

Experiment

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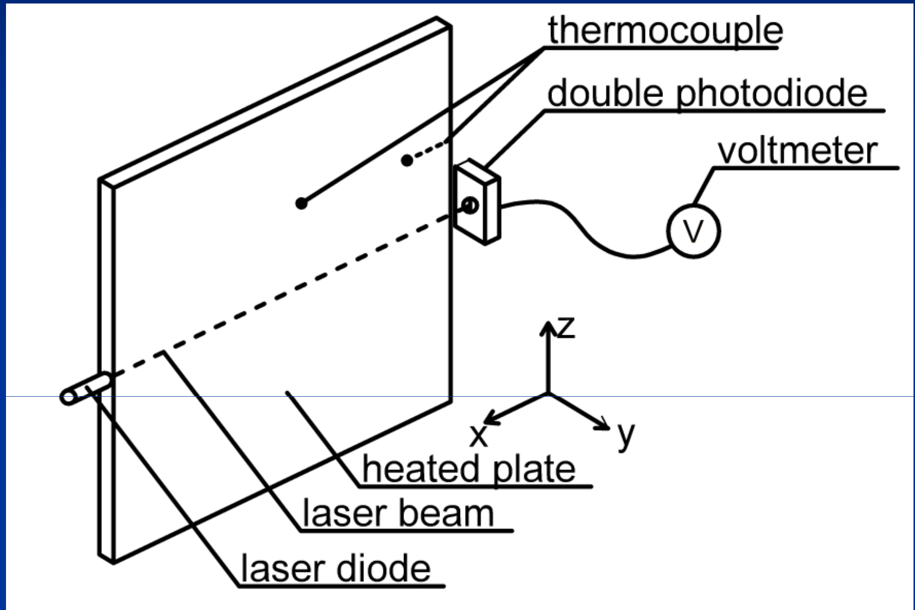
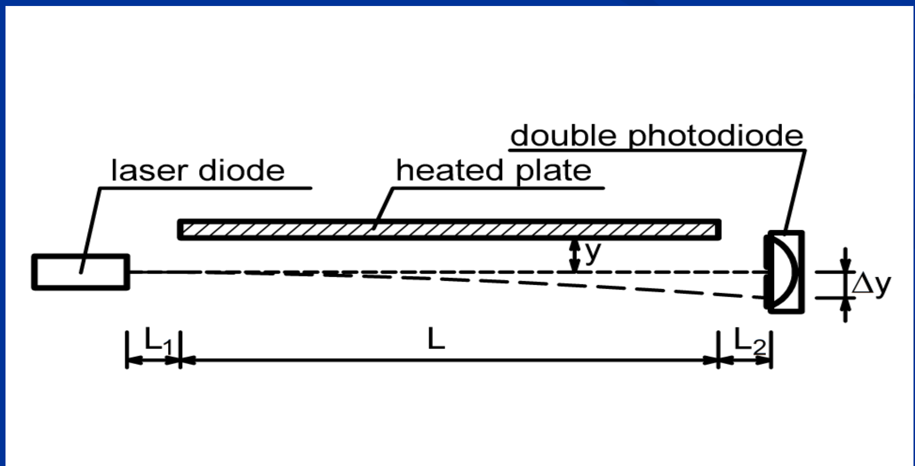
Scheme of the experiment





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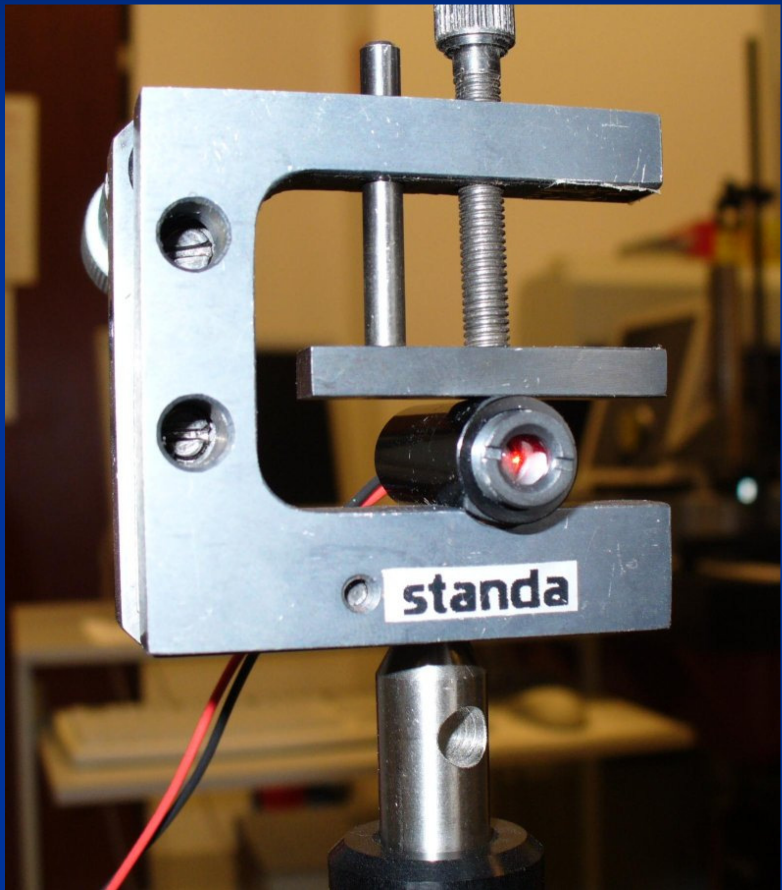
Experimental apparatus



Laser diode

10mW/650nm

Double photodiode

Experiment

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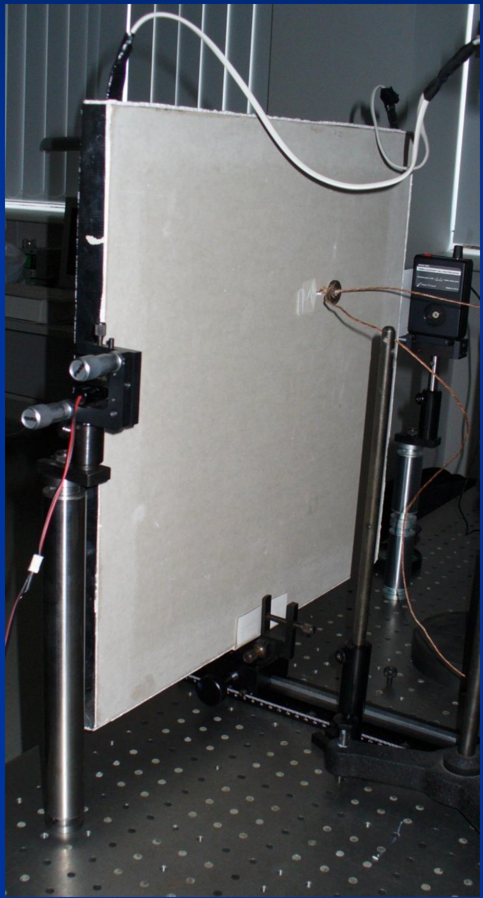
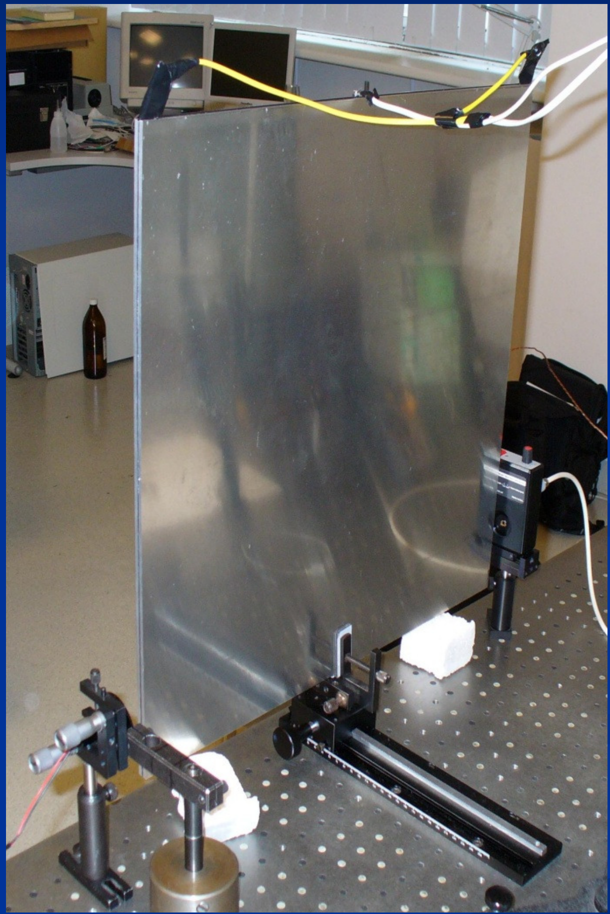
Exprimental apparatus



- gypsum board 12.5 mm
- heating foil max 197W/m^2
- gypsum board 12.5 mm



- aluminium plate 4 mm
- heating foil max 197W/m^2
- aluminium plate 4 mm

Numerical simulation

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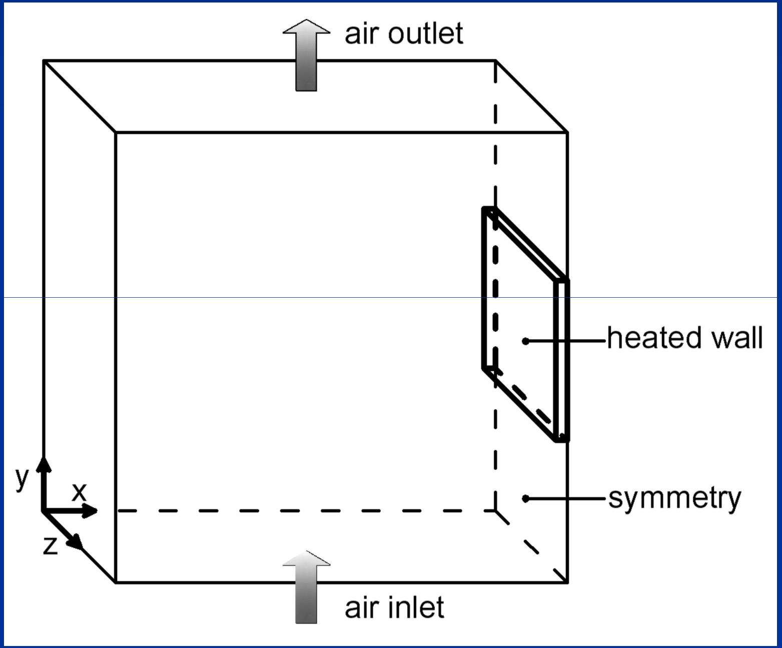
Simulation model



- OpenFoam CFD v.1.2 software package,

- laminar convective regime,

- Boussinesq approximation for natural convection,

-Structural grid with 1mm control volume thickness near wall,

-1.2mil. control volumes.

Results

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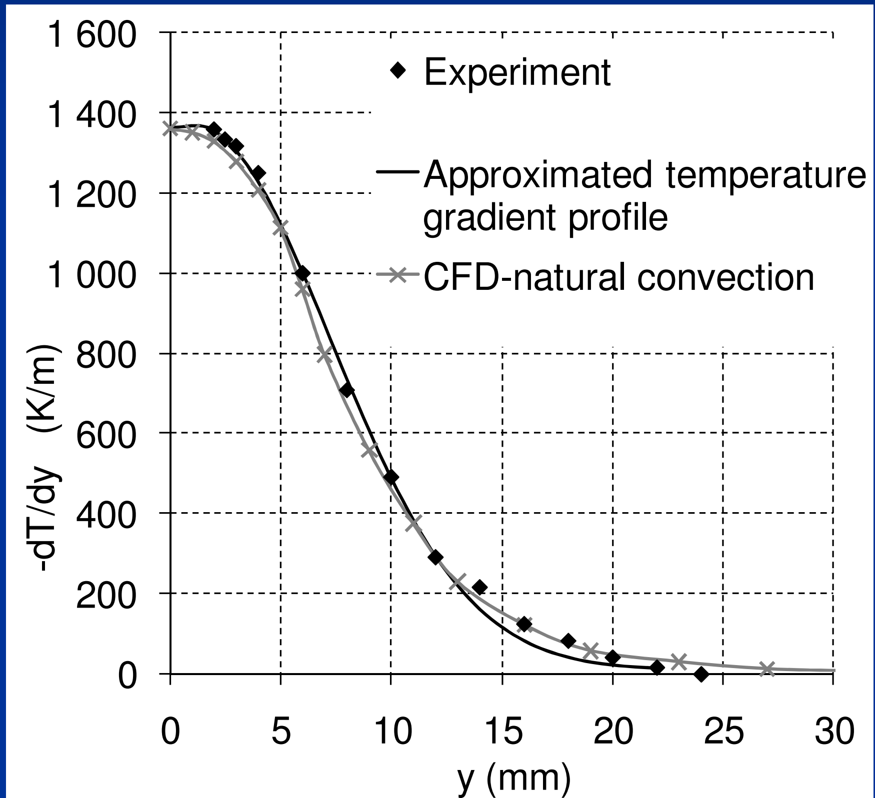
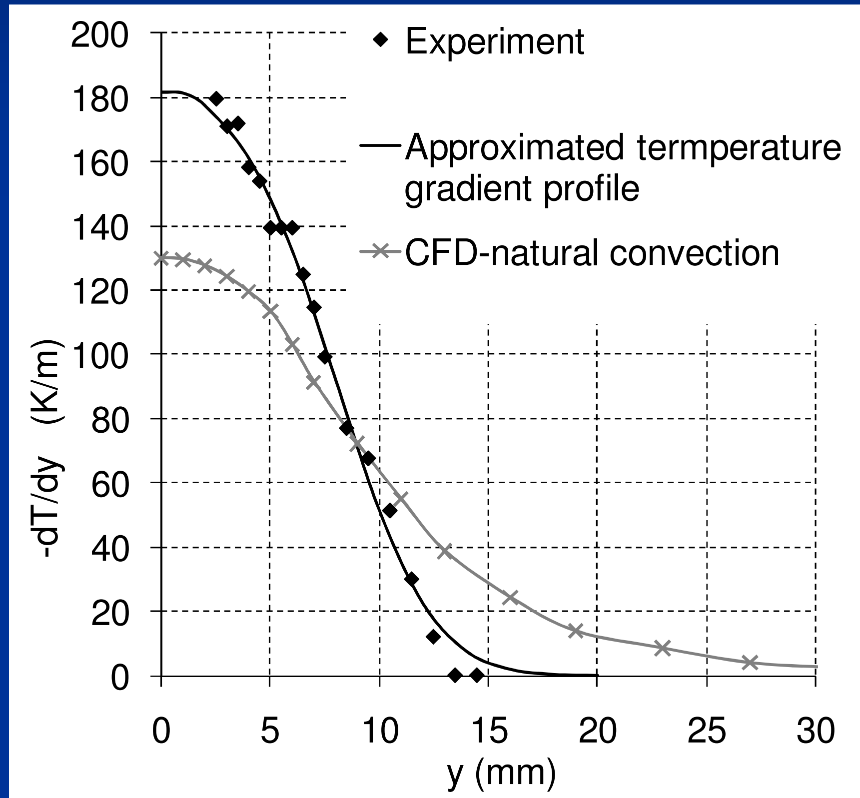
Measured temperature gradient profiles in comparison with CFD simulation of natural convection regime



ΔT = 12.2 K

z = 0.25 m

Gr = 3.105E7



ΔT = 1.5 K

z = 0.10 m

Gr=2.398E5

Results

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Approximation of the measured temperature gradient profile

Gauss regression

$$\frac{d\theta}{dy} = a + b \cdot e^{-\left(\frac{y-c}{d}\right)^2}$$

Temperature profile

$$\theta(y) = \int \frac{d\theta}{dy} dy = a \cdot y + \frac{1}{2}\pi^{\frac{1}{2}} \cdot d \cdot erf\left(\frac{y}{d} - \frac{c}{d}\right) \cdot b + C$$

Integration constant

$\theta(y=0) = \theta si$

$$C = \theta_{si} + \frac{1}{2} \cdot \pi^{\frac{1}{2}} \cdot d \cdot erf\left(-\frac{c}{d}\right) \cdot b$$

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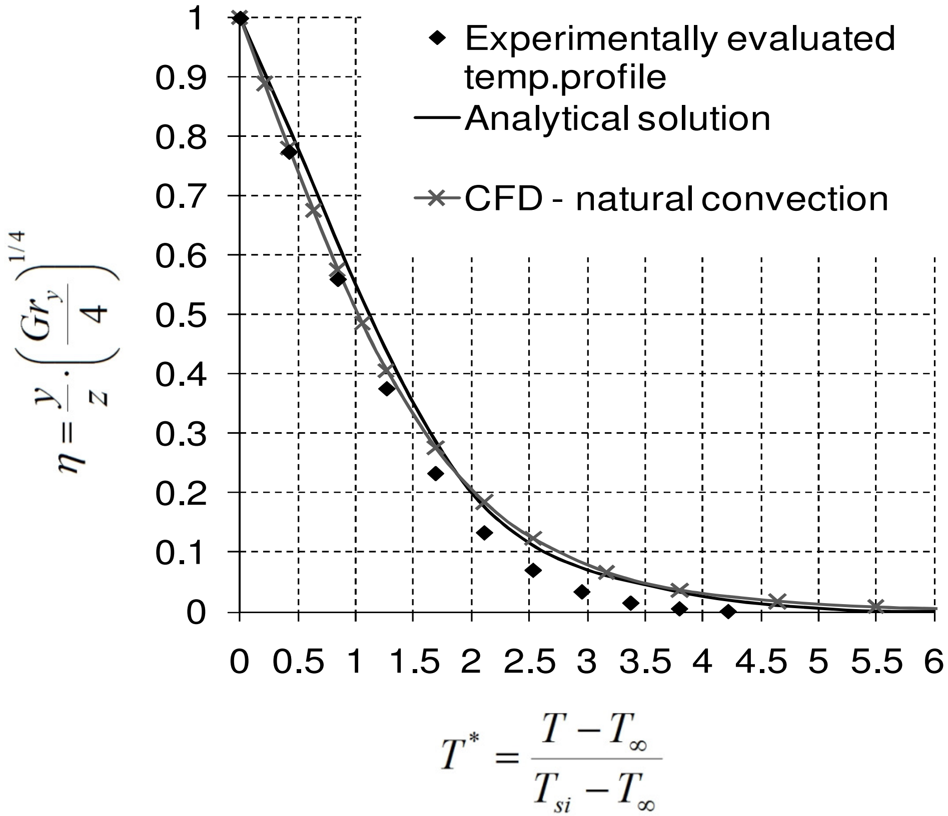
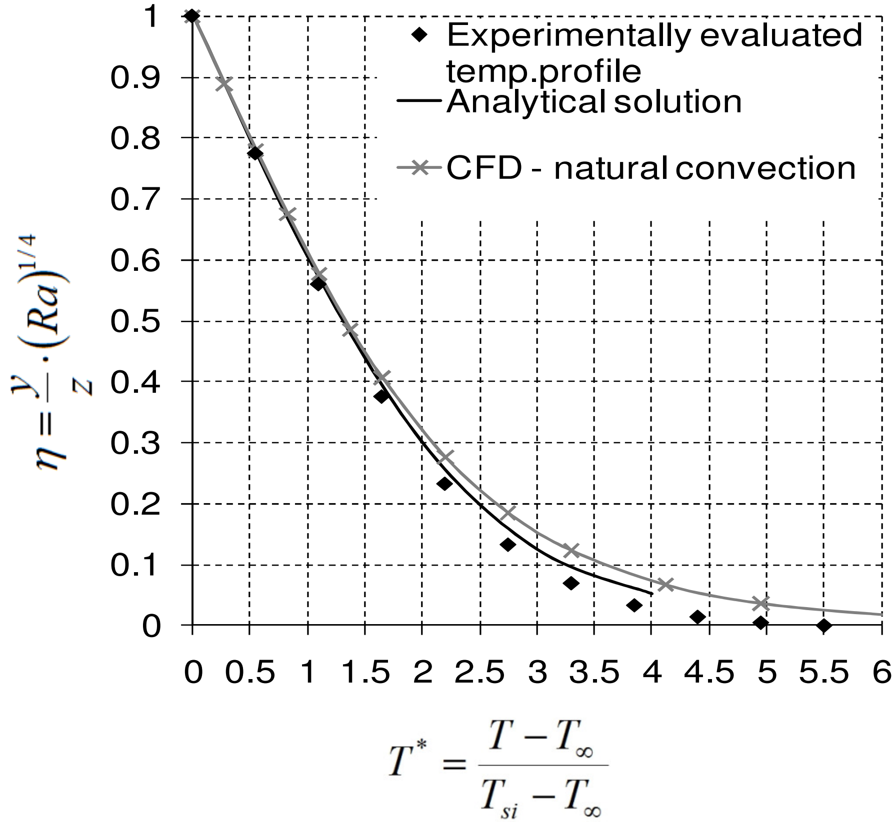
Dimensionless temperature profiles

$\Delta T = 12.2$ K, z = 0.25 m, Gr = 3.105E7

Ostrach´s approach



Bejan´s approach



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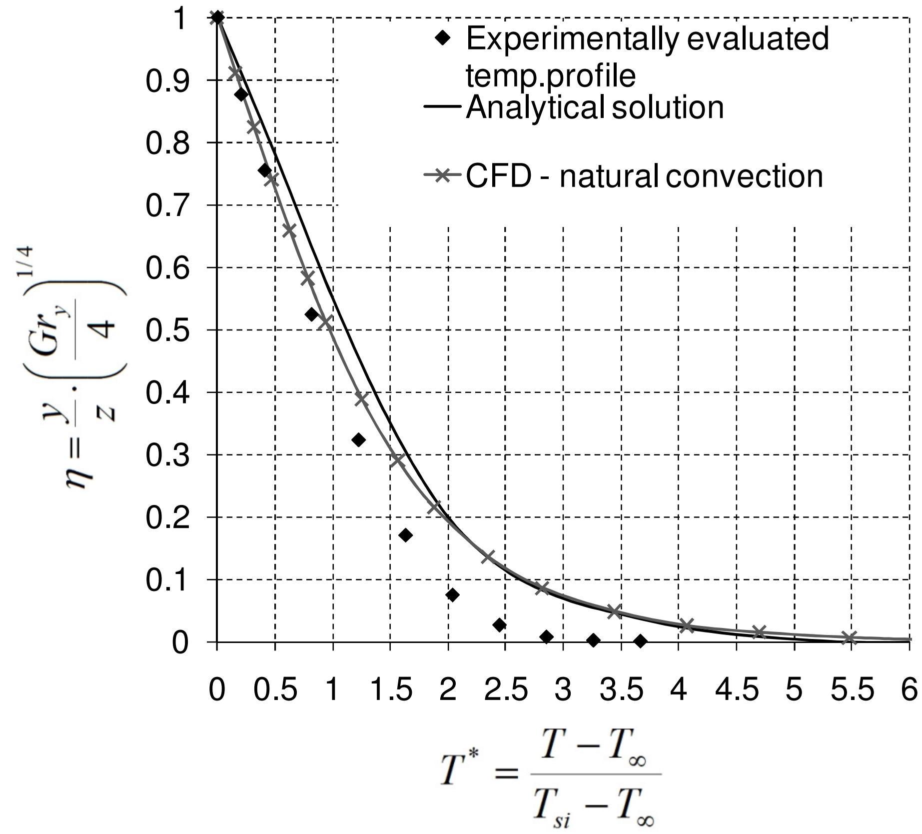
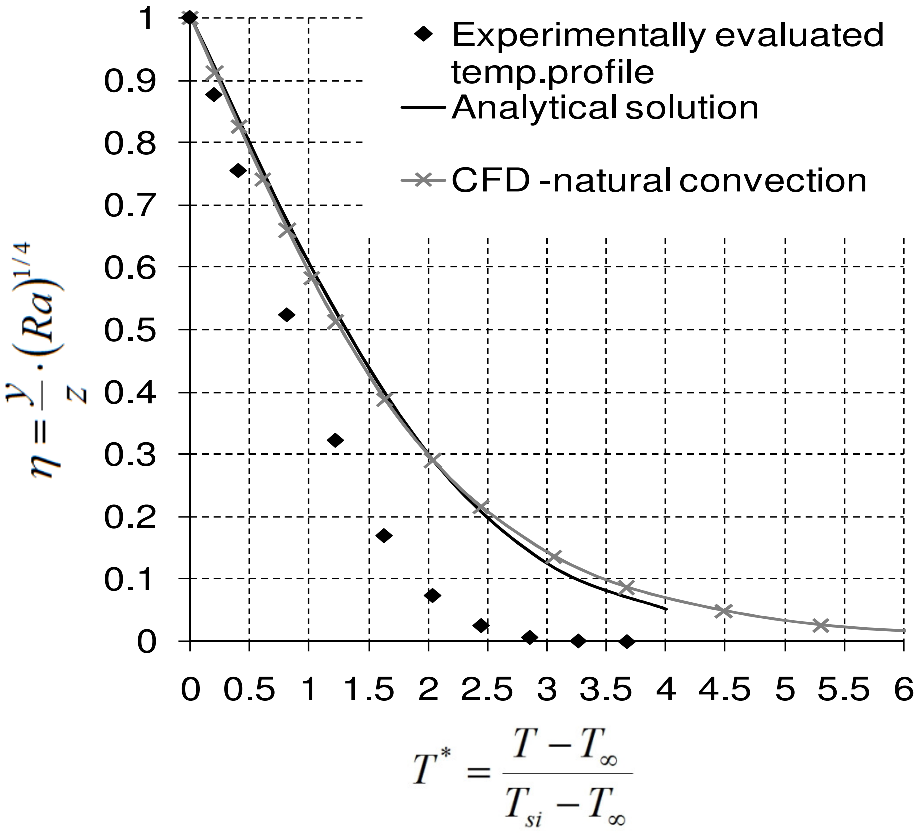
Dimensionless temperature profiles

$\Delta T = 1.5$ K, $z = 0.10$ m, Gr=2.398E5

Ostrach´s approach



Bejan´s approach



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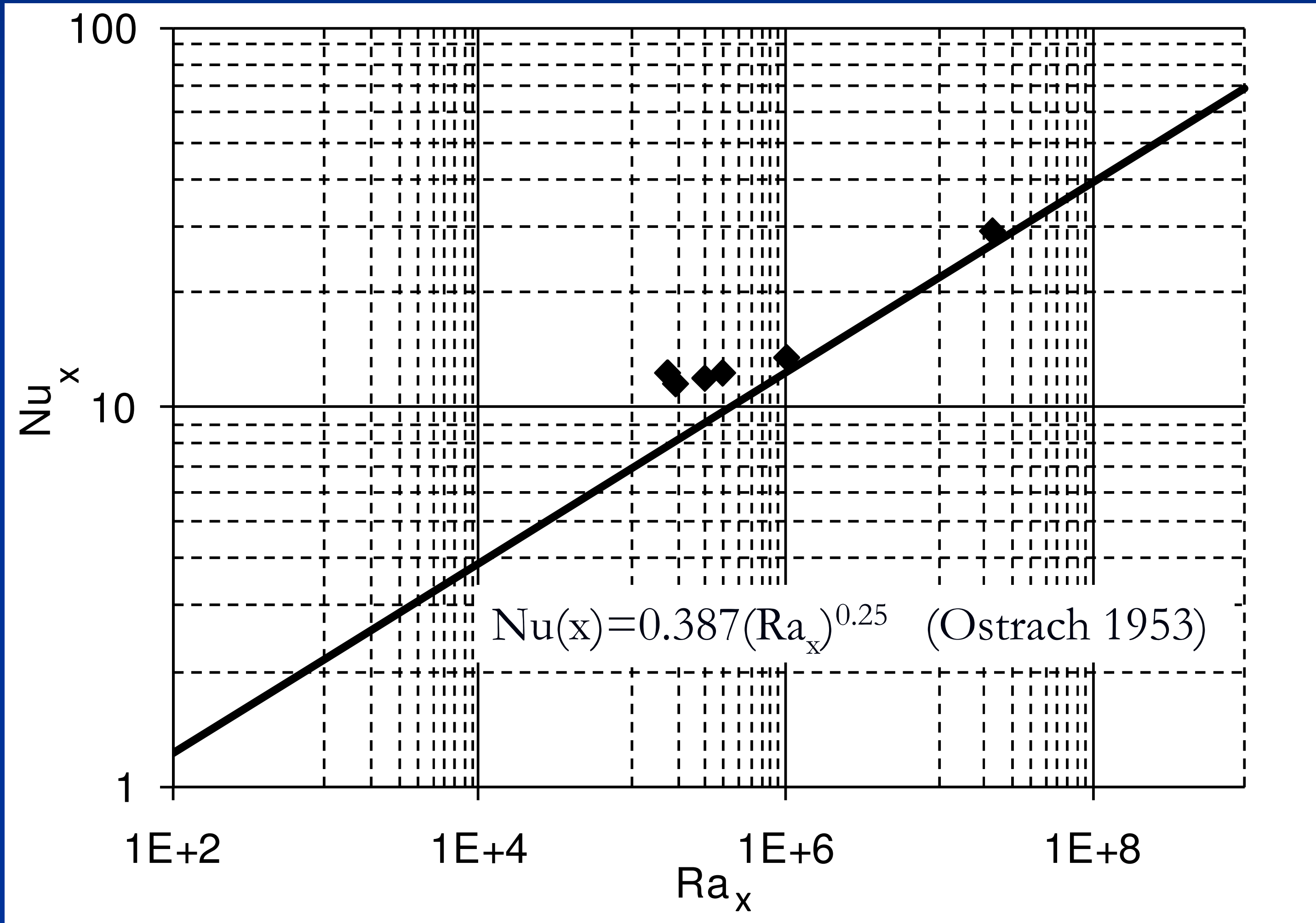
Local Nusselt number vs. Local Rayleigh number



Results

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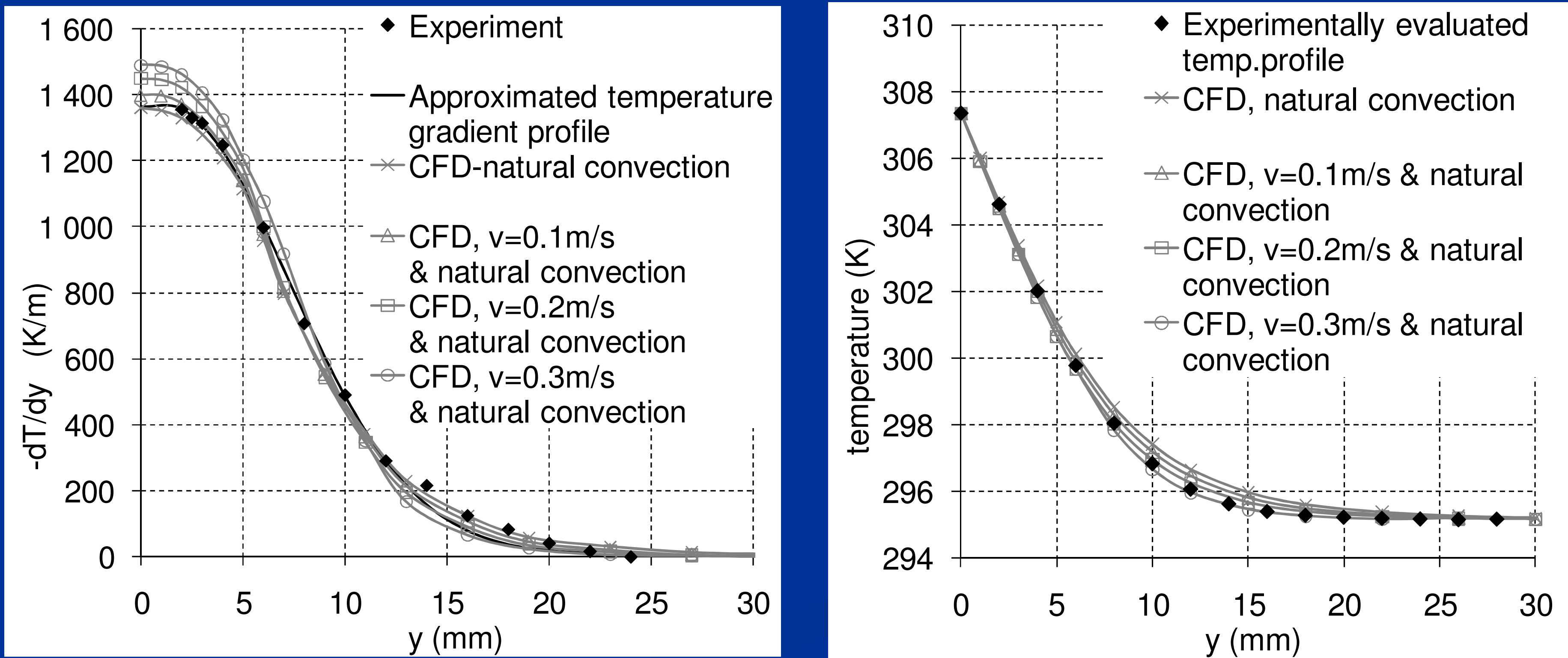
Approximation of temperature gradient and near wall temperature using initial air flow velocity

ΔT = 12.2 K, z = 0.25 m, Gr = 3.105E7



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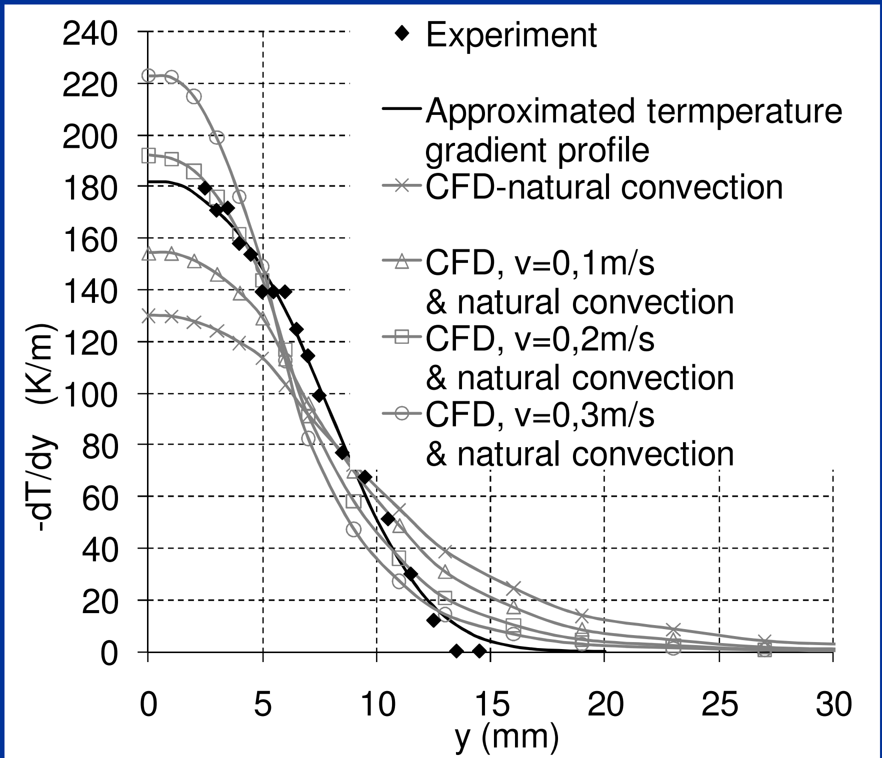
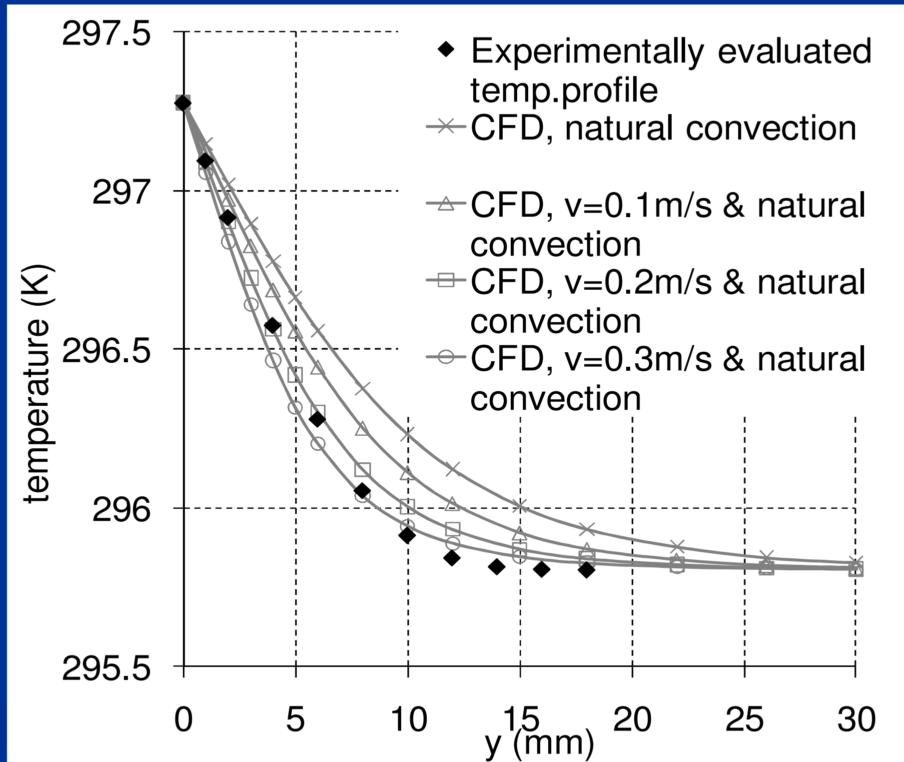
Approximation of temperature gradient and near wall temperature using initial air flow velocity

$\Delta T = 1.5$ K, $z = 0.10$ m, Gr=2.398E5





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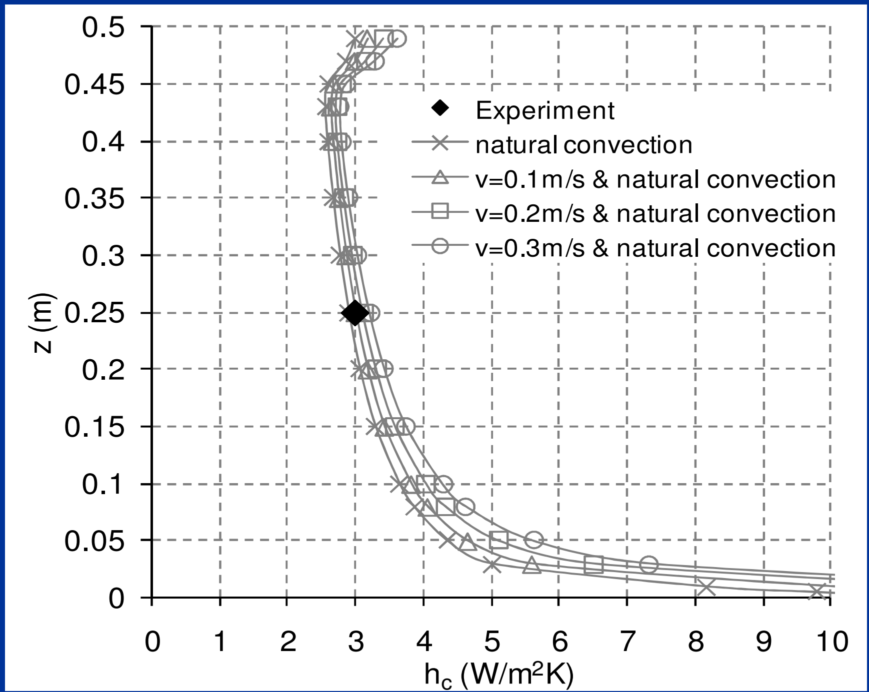
Calculated vertical profile of convective heat transfer coefficient



$\Delta T = 12.2$ K
z = 0.25 m
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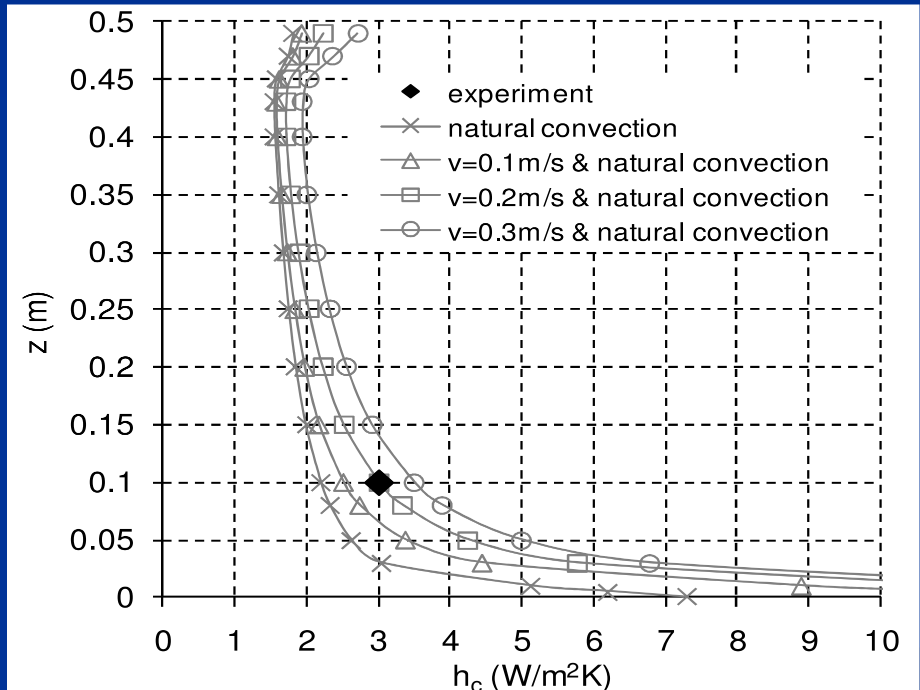

$\Delta T = 1.5$ K
z = 0.10 m
Gr=2.398E5

Conclusion

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- Experimental optical non-invasive method that does not influence the conditions in the boundary layer has been used.

- At the higher temperature difference conditions the better coincidence with the data of CFD modelling has been observed and on the contrary, at smaller temperature differences the experimental values differ noticeably.

- Influence of the ambient air velocity on the convective heat transfer coefficient at low temperature differences had shown as significant.

- Dominant influence of the ambient air speed on the local values of convective heat transfer coefficient was obtained mainly at the bottom part of the plate.

- The proposed approach of experimental/numerical analysis of the boundary layer has shown its usefulness and effectiveness for the study of the boundary layer even at the conditions at very low temperature contrast of only a few degrees.

Thanks for your attention …