# Experimental Investigations of a Full-Scale Louvre Element

**Methodology description and result presentation**

Academic report from Department of Civil and Architectural Engineering

2025

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# Data

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Summary: This report summarises the experimental investigations of a full-scale louvre element conducted in September 2024 in the laboratories of the Department of Civil and Architectural Engineering, Aarhus University. The report describes the existing laboratory facilities and the modifications done for the experiment. Further it describes the louvre element and the measurement equipment. At last, the results are given.
Keywords: Experiment; Louvre; Measurement; Ventilation

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# Contents

# 1.0 Facilities and test room

## 1.1/ Laboratory facilities

The measurement was conducted in the laboratories of the Department of Civil and Architectural Engineering at Navitas (Inge Lehmans Gade 10, 8000 Aarhus). The laboratories are located on the ground floor and consist of an anteroom to which three roughly equal sized rooms are connected (Figure 1).

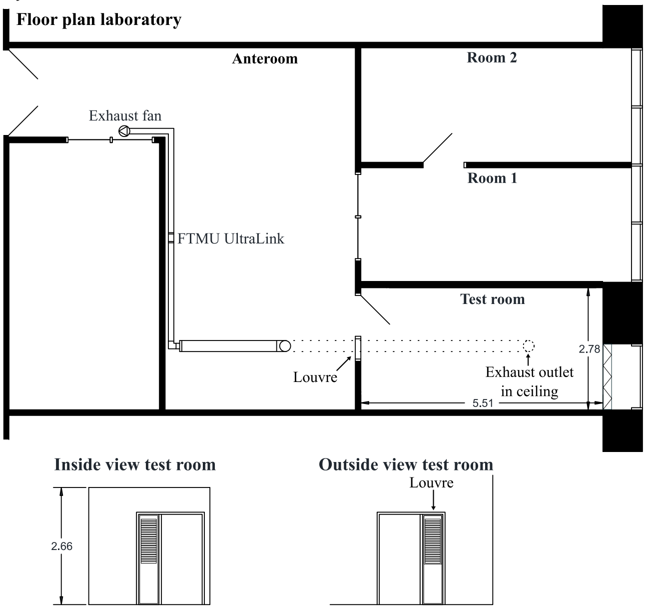


**Figure 1 Floor plan of laboratory area and, inside and outside view of test room.**

All rooms are located at the façade. Two rooms (Room 1 and Room 2) have a floor to ceiling fully glazed façade and are separated by a door to the anteroom. The test room used for the experiment has a 1.50 m x 1.10 m window and a suspended ceiling at 2.66 m height with one ventilation supply inlet and outlet exhaust (Figure 2). The total room height without suspended ceiling was 4.07 m. The room is separated to the anteroom by a wooden door with an adjacent glazed element (0.41 m x 2.00 m) (Figure 3). The radiator in the room was turned off and there was no supply during the experiment.

## 1.2/ Modifications

A plastic foil was installed just below the suspended ceiling to lower the room height and air tighten the room. The existing exhaust and supply openings were sealed, and a new exhaust opening was installed in the rear part of the room. The glazed element was replaced by a commercially available louvre element (0.40 m x 1.10 m) whereby the remaining open part was filled with a wooden plate with a whole inside for wiring.

**Figure 2 Window in test room (left) and ventilation original supply inlet (top right) and exhaust outlet (bottom right)**

**Figure 3 Outside view and inside view of test room door and glazed element before louvre installation.**

**Figure 4 Louvre element from outside (left) and inside (right)**

All joints of the room were taped from the inside. The door was sealed from the outside. The window was covered by a foil from the outside protecting from solar radiation. Additionally, the window cavity was filled with polystyrene.

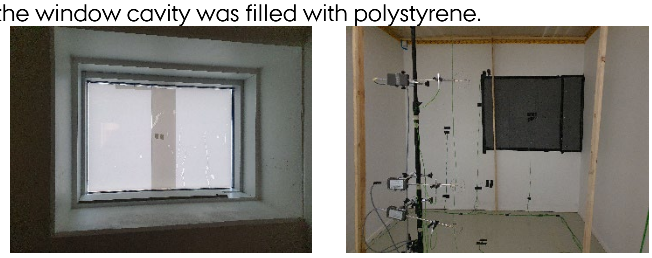

**Figure 5 Window with foil (left) and window with polystyrene (right).**

To create an exhaust flow in the room, the supply side of the existing balanced ventilation was rerouted and connected to a fan (Lindab CK 125 C1) which was controlled by a transformer. The routing inside the anteroom can be seen in Figure 1.

**Figure 6 Exhaust ventilation system.**

### 1.3/ Louvre element

The chosen louvre element was the “Rain Defence Louvres – RSH-5700” from Construction Specialties®. It has a depth of 0.129m and a blade pitch of 0.051m.It is rated with the highest possible water penetration class A up to 3.0 m/s wind velocity according to DS/EN 13030:2001 (2001). Further, it has an airflow coefficient $C_e$ (entry loss) and airflow coefficient $C_d$ (discharge loss) of 0.284 and 0.289 respectively which are both considered Class 3 according to DS/EN 13030:2001 (2001). It has additionally the possibility to have a burglary resistance class RC2.

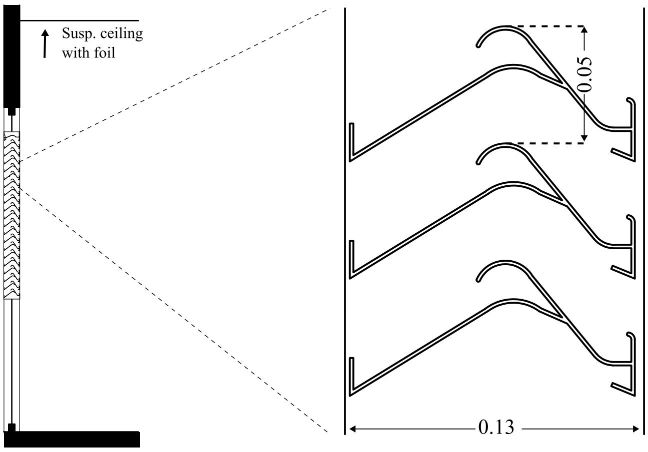


**Figure 7 Louvre installation in test room wall (left) and close up of three regular louvre elements (right).**

# 2.0 Measurement equipment

The air and surface temperature in anteroom and test room was measured by 52 thermocouples (type-k) (Figure 8). 19 thermocouples were installed on the walls. Four thermocouples were installed on Wall 2 and Wall 4. Three thermocouples were installed on Wall 1, the floor and the ceiling. Only two thermocouples were installed on Wall 3 as on the position of the lower thermocouple the beforementioned radiator was located. The air temperature in the anteroom and in front of the louvre (inlet temperature) was measured by one centrally placed thermocouple, respectively. Four thermocouples, one per temperature datalogger, were inserted into two JOFRA ETC Easy Temperature Calibrators which were set to 0 °C. Three thermocouples where mounted on the heat source closer to Wall 4.

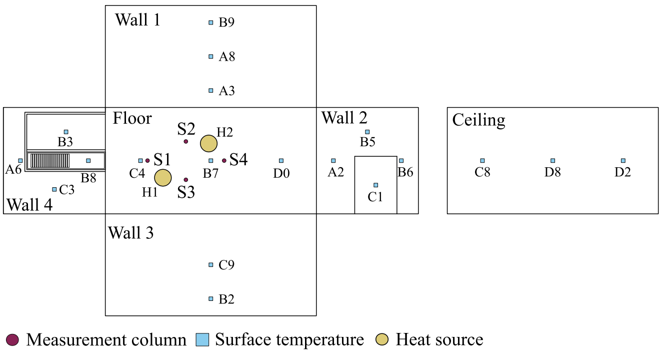


**Figure 8 Sensor location in test room.**

The air temperature in the test room was measured by 24 thermocouples mounted on four measurement columns (S1-S4). The installation heights was based on the recommendations of DS/EN ISO 7730:2006 (2006) for measuring physical quantities of an environment for sitting and standing persons. The heights can be seen in Figure 9.

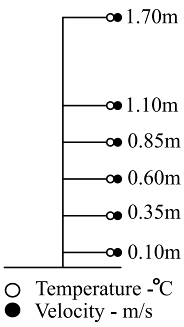


**Figure 9 Measurement column heights of thermocouples and velocity sensors.**

The velocity sensors were installed in the same location as the thermocouples. The location of the measurement columns is marked in Figure 8. Two are located on the centre line of the room and two 0.89cm from the wall, all within the occupied zone defined according to DS/EN 16798-3:2017 (2017). The two heat source each with 80W mimicked two sitting persons. The heat sources were removed for the cases without heat supply. The location can be seen in Figure 8. Two energy loggers (Energy Logger 4000) monitored the active power of the heat sources and the transformer. A Lindab FTMU UltraLink flow meter recorded the exhaust air temperature and the exhaust air flow.

Measuring range, accuracy and logging interval of the measuring quantities can be seen in Table 1.

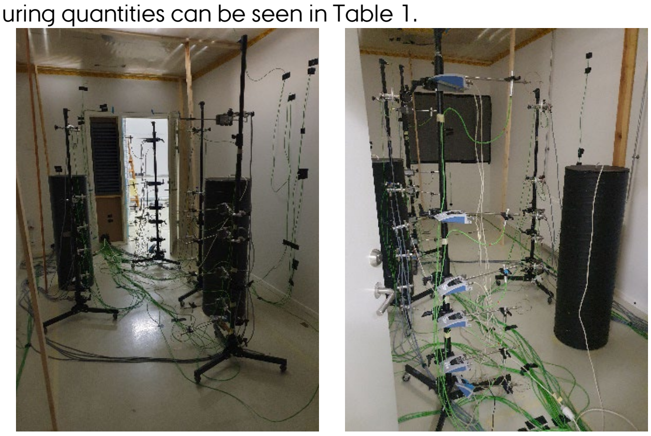

**Figure 10 Test room set up with heat source.**

## 2.1/ Calibration

The thermocouples were calibrated using the dry block probe of the Testo Thermator II. They were calibrated between 10 and 35°C with 2.5°C intervals. Each interval run for 5 min with the last 2 min as averaging period. The calibration curves can be found the Result_summary.xlsx. The velocity sensors were calibrated by the manufacturer.

**Table 1 Location, measuring range and accuracy and set logging interval of measuring equipment.**

| Location | Number | Equipment | Range | Accuracy | Logging interval |
|---|---|---|---|---|---|
| **Temperature** | | | | | |
| Test room surfaces<br>Heat source surface<br>Test room air<br>Inlet air<br>Anteroom air<br>Ice point reference | 52 | k-type thermocouples | 10 - 35 °C | ±0.1 °C<br>(after calibration) | - |
| | 3 | Squirrel datalogger with 16 thermo-couples each | | 0.05 % of reading + 0.025 % of range (at 25 °C) | 30 sec |
| | 1 | Squirrel datalogger with 4 thermocou-ples | | 0.05 % of reading + 0.025 % of range (at 25 °C) | 30 sec |
| Exhaust air | 1 | FTMU UltraLink (125 mm) | -10 – 50 °C | ±1°C | 30 sec |
| **Flow rate** | | | | | |
| Exhaust air | 1 | FTMU UltraLink (125 mm) | 0 - 184 l/s | 5 % or ± 1.25 l/s (be-tween 0.2 – 15.0 m/s) | 30 sec |
| **Velocity** | | | | | |
| Room air | 7 | Vivo Draught sensor | 0.05 - 5.0 m/s | ±2 % OR ±0.02 m/s | 1 min |
| | 12 | Comfort sense draught probes (54R10) | 0.05 - 10.0 m/s | ±2 % OR ±0.02 m/s | - |
| | 5 | Comfort sense draught probes (54T21) | 0.05 - 5.0 m/s | ±2 % OR ±0.02 m/s | - |
| | 2 | Comfort Sense data logger | | | 2.5 sec |
| Fan & heat sources | 1 | Energy-Logger 4000 | 0.1-3500 W | 1 % | 1 min |

# 3.0 Cases & experimental procedure

In total, six experimental test cases were investigated. Thereby, a combination of heat load presence and volume flow rate was test. The air flow rate ranged from 3 ACH to 7 ACH. Lower flow rate could not be measured as test runs indicated that velocities in the room fall below the measuring range of the velocity sensors. All measurement were run under steady-state conditions during the night when solar radiation was not present. For most case, stable conditions were reach after 10 hours. The mean and standard deviation was calculated when stability was reach for 1 hour. Every measurement was repeated at least four times.

**Table 2 Experimental test cases.**

| Name | ACH - $h^{-1}$ | Volume flow - $m^3/h$ | Heat source |
|---|---|---|---|
| WHS 3 | 3 | 121.4 | Yes |
| WHS 5 | 5 | 202.3 | Yes |
| WHS 7 | 7 | 283.2 | Yes |
| WOHS 3 | 3 | 121.4 | No |
| WOHS 5 | 5 | 202.3 | No |
| WOHS 7 | 7 | 283.2 | No |

**Table 3 Measurement Date and selected time period for averaging**

| Name | Date | Start | End |
|---|---|---|---|
| WHS 3 | 22.-23.09.2023 | 01:00:00 | 02:00:00 |
| WHS 5 | 21.-22.09.2023 | 02:30:00 | 03:30:00 |
| WHS 7 | 20.-21.09.2023 | 04:30:00 | 05:30:00 |
| WOHS 3 | 15.-16.09.2023 | 03:30:00 | 04:30:00 |
| WOHS 5 | 08.-09.09.2023 | 04:00:00 | 05:00:00 |
| WOHS 7 | 16.-17.09.2023 | 04:30:00 | 05:30:00 |

### 3.1/ Uncertainty

The uncertainty calculation of the temperature measurement included statistical error, calibration, ice point reference and linear regression for all thermocouples with datalogger. The uncertainty was calculated to be ±0.1 °C. With that, the measuring range and accuracy matched the recommended characteristic of measuring instruments for Class C (comfort) of DS/EN ISO 7726:2001 (2001).

In addition, there was an uncertainty related to the laboratory area. Due to the test room being connected to the outside and multiple rooms to the inside which could not be controlled, the temperature boundaries might differ between the repetitions of the same experimental test case. Moreover, due to the use of the building during the experiment the actual flow rate deviated from the targeted flow rate. The mean flow rate is given with the results.

# 4.0 Results

The results for the measurement columns for velocity and temperature versus the height are presented in the following subsections.

## 4.1/ Cases without heat source

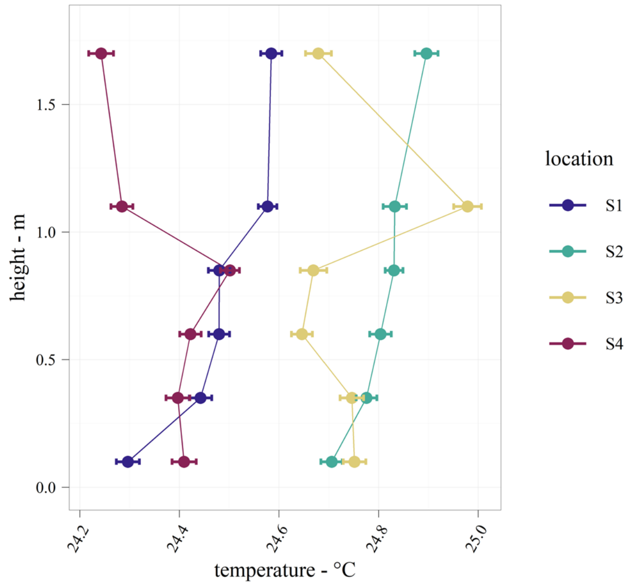


Figure 11 WOHS 3 ACH Temperature

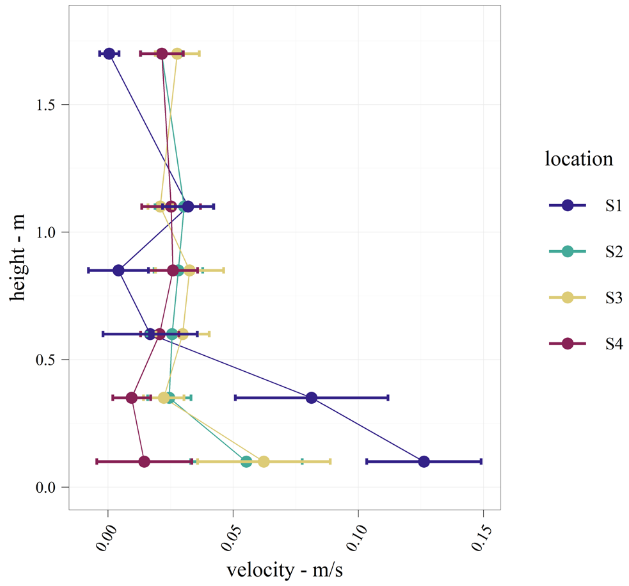


Figure 12 WOHS 3ACH Velocity

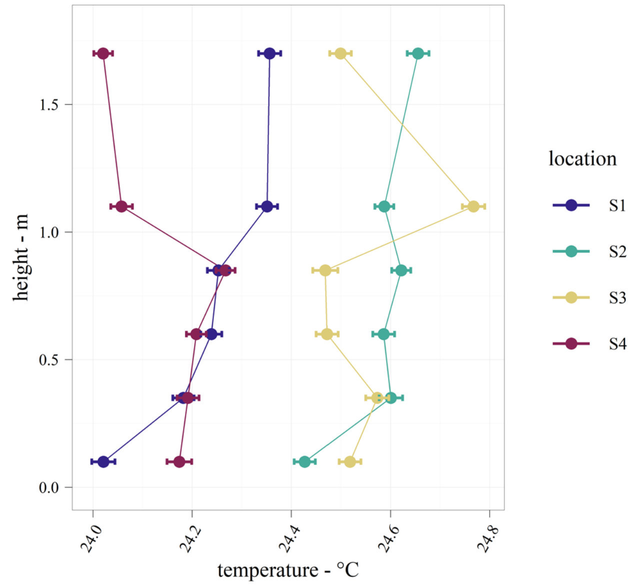


Figure 13 WOHS 5ACH Temperature

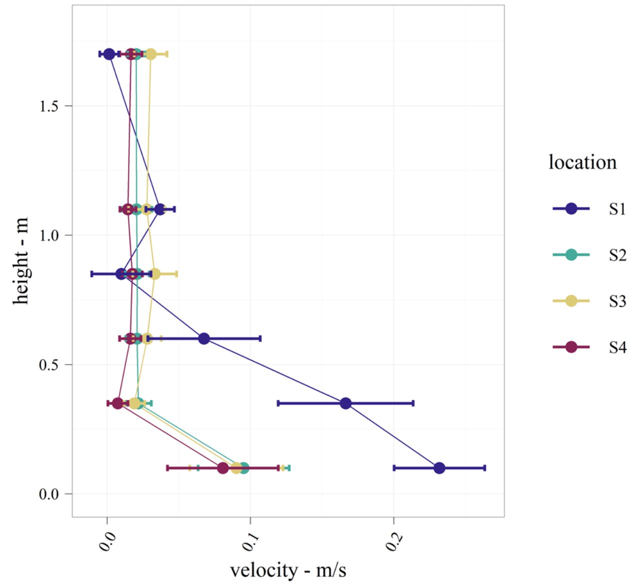


Figure 14 WOHS 5 ACH Velocity

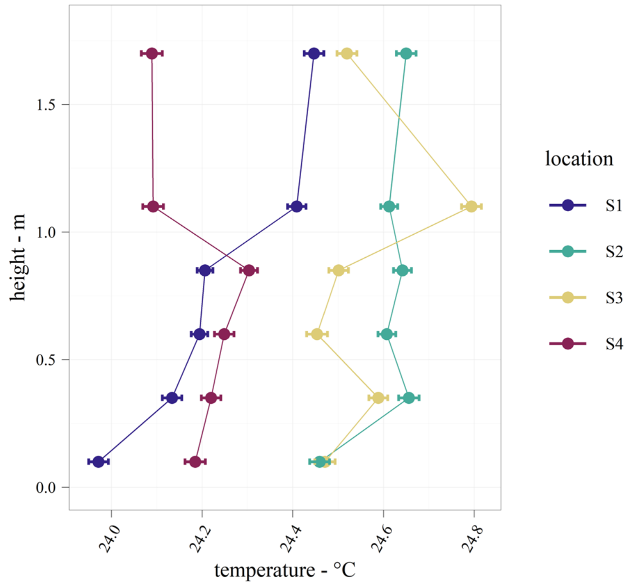


Figure 15 WOHS 7ACH Temperature

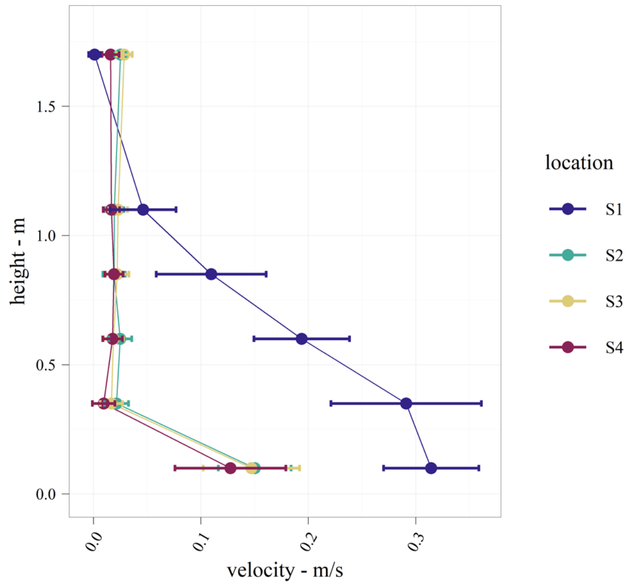


Figure 16 WOHS 7ACH Velocity

## 4.2/ Cases with heat source

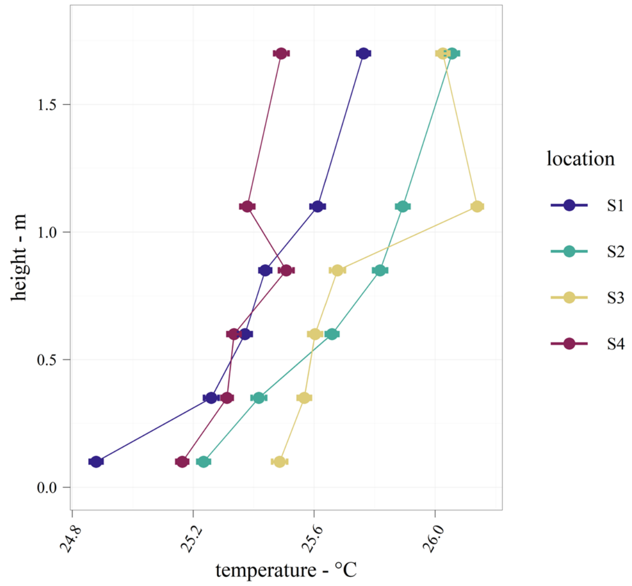


Figure 17 WHS 3 ACH Temperature

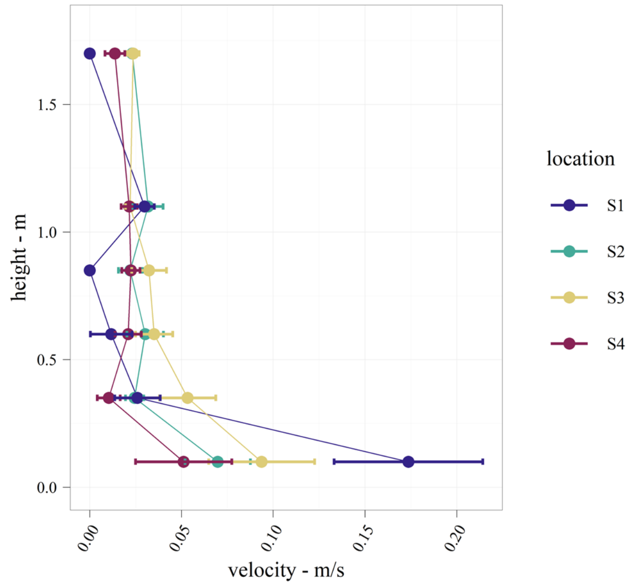


Figure 18 WHS 3ACH Velocity

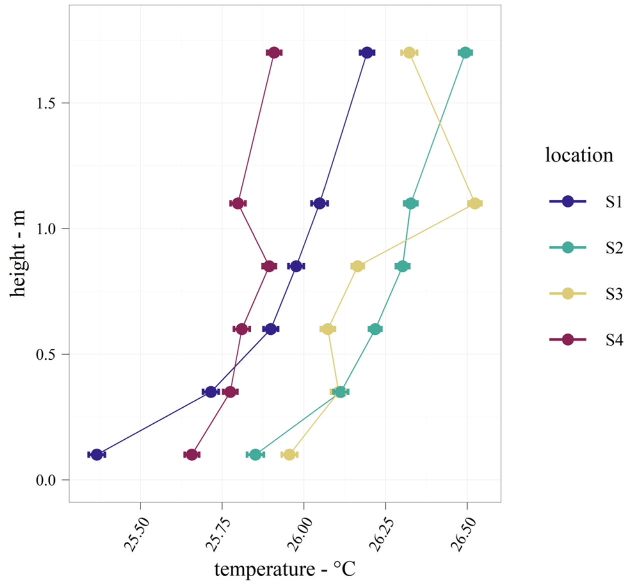


Figure 19 WHS 5ACH Temperature

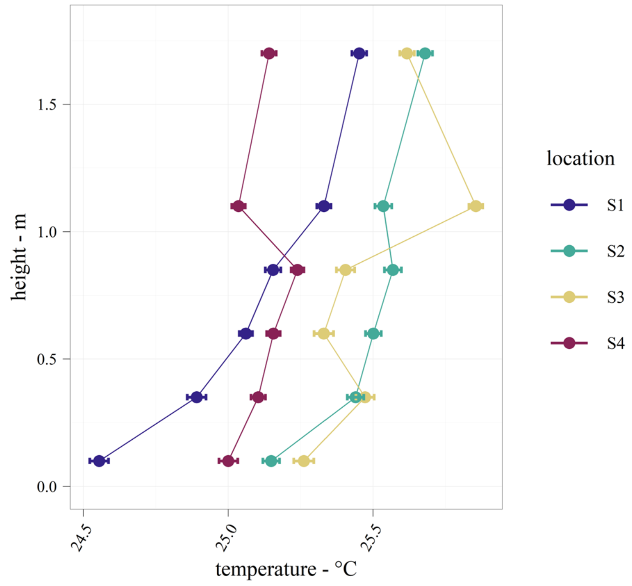


Figure 21 WHS 7ACH Temperature

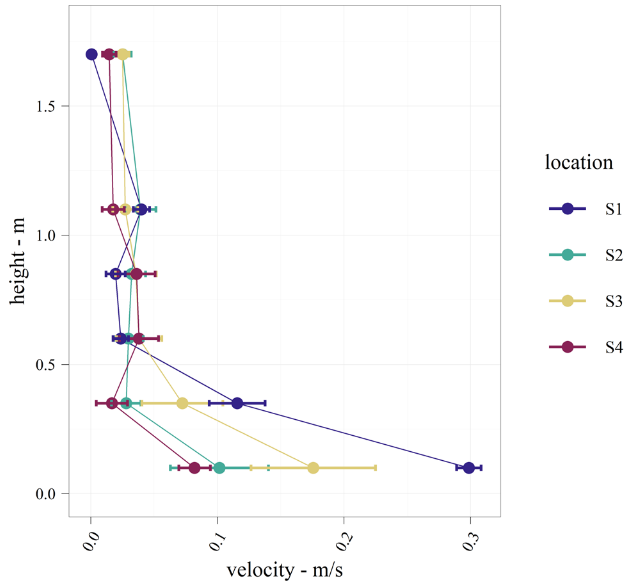


Figure 20 WHS 5ACH Velocity

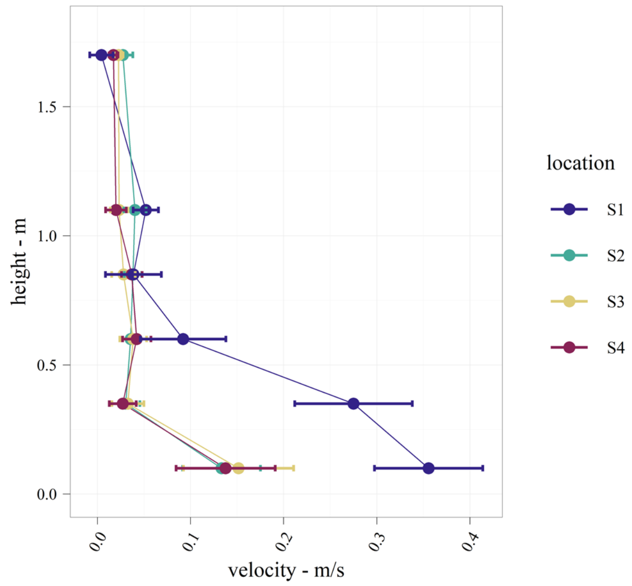


Figure 22 WHS 7ACH Velocity

# 5.0 Dataset

Raw data and detailed processed results of each measurement can be found here https://doi.org/10.5281/zenodo.14614814. The folder "Dataset" contains the following structure:

```
Dataset
¦  Result summary.xlsx
¦
+---WHS 3ACH
¦     WHS_3ACH_CS_velocity.csv
¦     WHS_3ACH_DL1_temperature.csv
¦     WHS_3ACH_DL2_temperature.csv
¦     WHS_3ACH_DL3_temperature.csv
¦     WHS_3ACH_DL4_temperature.csv
¦     WHS_3ACH_flow_meter.csv
¦     WHS_3ACH_VIVO_velocity.csv
¦
+---WHS 5ACH
¦     WHS_5ACH_CS_velocity.csv
¦     WHS_5ACH_DL1_temperature.csv
¦     WHS_5ACH_DL2_temperature.csv
¦     WHS_5ACH_DL3_temperature.csv
¦     WHS_5ACH_DL4_temperature.csv
¦     WHS_5ACH_flow_meter.csv
¦     WHS_5ACH_VIVO_velocity.csv
¦
+---WHS 7ACH
¦     WHS_7ACH_CS_velocity.csv
¦     WHS_7ACH_DL1_temperature.csv
¦     WHS_7ACH_DL2_temperature.csv
¦     WHS_7ACH_DL3_temperature.csv
¦     WHS_7ACH_DL4_temperature.csv
¦     WHS_7ACH_flow_meter.csv
¦     WHS_7ACH_VIVO_velocity.csv
¦
+---WOHS 3ACH
¦     WOHS_3ACH_CS_velocity.csv
¦     WOHS_3ACH_DL1_temperature.csv
¦     WOHS_3ACH_DL2_temperature.csv
¦     WOHS_3ACH_DL3_temperature.csv
¦     WOHS_3ACH_DL4_temperature.csv
¦     WOHS_3ACH_flow_meter.csv
¦     WOHS_3ACH_VIVO_velocity.csv
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+---WOHS 5ACH
¦     WOHS_5ACH_CS_velocity.csv
¦     WOHS_5ACH_DL1_temperature.csv
¦     WOHS_5ACH_DL2_temperature.csv
¦     WOHS_5ACH_DL3_temperature.csv
¦     WOHS_5ACH_DL4_temperature.csv
¦     WOHS_5ACH_flow_meter.csv
¦     WOHS_5ACH_VIVO_velocity.csv
¦
+---WOHS 7ACH
      WOHS_7ACH_CS_velocity.csv
      WOHS_7ACH_DL1_temperature.csv
      WOHS_7ACH_DL2_temperature.csv
      WOHS_7ACH_DL3_temperature.csv
      WOHS_7ACH_DL4_temperature.csv
      WOHS_7ACH_flow_meter.csv
      WOHS_7ACH_VIVO_velocity.csv
```

The result summary contains 8 sheets with the following information:

- Overview:
  - Measurement cases with target flow rate and heat source presence.
  - The date of the experiment and the time period in which the data was averaged for the processed results.
  - The allocation of the thermocouples to the datalogger.
  - The sensor location on the stands (temperature and velocity).
  - The sensor location on the surfaces (temperature)
  - The sensors used for the ice point references.
  - The sensors used in the anteroom.
  - The sensors used for the heat source.
  - Graphical representation of sensor location and room.
- Calibration curves:
  - Calibration curves for all thermocouples according to datalogger.
- WOHS/WHS:
  - Mean temperature according to sensor, datalogger, location, height.
  - Standard deviation according to sensor, datalogger, location, height.
  - Mean velocity according to sensor, datalogger, location, height.
  - Standard deviation according to sensor, datalogger, location, height.
  - Turbulence intensity.

  - u_u0: mean velocity at sensor/mean velocity in flow meter.
  - Mean temperature at flow meter.
  - Mean velocity at flow meter.
  - Mean flow rate at flow meter.

Files with the ending _temperature.csv contain the following:

- Column 1 (datetime): date and time in ISO8601 format (YYYY-MM-DDThh:mm:ssZ)
- Column 2 (sensorname): temperature at sensor in °C

Files with the ending _flow_meter contain the following:

- Column 1 (datetime): date and time in ISO8601 format (YYYY-MM-DDThh:mm:ssZ)
- Column 2 (velocity): velocity at flow meter in m/s
- Column 3 (exhaust_temperature): temperature at flow meter in °C
- Column 4 (flow_rate): flow rate at flow meter in $m^3/h$

Files with the ending _CS_velocity.csv (CS stands for the comfort sense sensors) contain the following:

- Column 1 (datetime): date and time in ISO8601 format (YYYY-MM-DDThh:mm:ssZ)
- Column 2-17 (sensorename): velocity at sensor in m/s

Files with the ending _VIVO_velocity.csv contain the following:

- Column 1 (datetime): date and time in ISO8601 format (YYYY-MM-DDThh:mm:ssZ)
- Column 2-7 (sensorename): velocity at sensor in m/s

Note that for the VIVO system each sensor logged their result individually which means measurements are not at the same time stamp. This leads to NA entries.

# 6.0 Acknowledgement

This research was funded by Independent Research Fund Denmark, grant number "0217-00018B". The authors gratefully acknowledge the Independent Research Fund Denmark for its financial support of the project "Climate Responsive Renovation" (DFF FTP1).

We extend our deepest gratitude to everyone involved, with special appreciation to Niels Uhre Christensen, whose ideas and invaluable assistance were instrumental in setting up the experiment. Furthermore, we would like to thank Jeppe Østberg and Jørgen Holm for assisting in preparing the laboratory.

# 7.0 Bibliography

DS/EN 13030:2001. (2001). Ventilation i bygninger - Armaturer - Prøvning af jalousiriste ved simuleret regn. Københaven: Dansk standard

DS/EN 16798-3:2017. (2017). Bygningers energieffektivitet – Del 3: Ventilation i bygninger – I bygninger ikke beregnet til beboelse – Ydeevnekrav til ventilationsanlæg og anlæg til konditionering af rum (Modul M5-1, M5-4). Københaven: Dansk standard

DS/EN ISO 7726:2001. (2001). Ergonomi i termisk miljø - Instrumenter til måling af fysiske størrelser. København: Dansk standard

DS/EN ISO 7730:2006. (2006). Ergonomi inden for termisk miljø - Analytisk bestemmelse of fortolkning af termisk komfort ved beregning af PMV- og PPD-indekser og lokale termiske komfortkriterier. København: Dansk Standard