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by

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Table of Contents

Foreword

The aim of this technical report is to provide a description and access to temperature and air velocity measurements performed on a full-scale wall element in both steady-state and dynamic conditions, that has been used to indicate internal convection.

Abstract

Internal convection of insulation materials is a phenomenon that occurs when a construction element is subjected to a temperature difference on either side of the element, as the temperature difference inside the insulation will facilitate an onset of air movement due to thermal buoyancy. This dataset represents the results of 11 unique experiments conducted at Aalborg University at the Department of the Built Environment, where a full-scale wall element insulated with loose-fill wood fiber insulation is investigated for internal convection. A large guarded hotbox is used to control the boundary conditions of either side of the wall element, to imitate a construction element subjected to external and internal boundary conditions, similar to a wall in a house. This dataset can be used to benchmark other insulation materials investigated at similar boundary conditions.

The dataset is structured into steady-state experiments and dynamic experiments, where a total of 7 unique cases are conducted in steady-state conditions, and 4 unique cases are conducted in dynamic conditions. The dataset for the steady-state experiments is structured by the temperature difference that the full-scale wall element is exposed to, from the cold and hot side, while the dynamic experiments are structured by the amplitude of the temperature variation, along with if an artificial sun is used or not.

The results for the internal convection of the loose-fill wood fiber insulation show similar results as other studies that have conducted experiments on other insulation materials.

For more information regarding the experimental setup, see [1].

Keywords

Internal convection, laboratory experiment, heat transfer, building physics, full-scale, wall element

Specifications table

Subject	Heat transfer, building physics, laboratory experiment
Specific subject area	Observing effects of internal convection in loose-fill wood fiber insulation by assessing the temperature profiles
Type of data	Text files
How the data was acquired	The data has been acquired by subjecting a full-scale wall element of 4.8 x 4.8 m to a hot and a cold environment on either side of the wall, using a guarded hotbox. The temperature is measured using type K thermocouples, that has been calibrated to a precision of $\pm$0.15 °C and logged using a Fluke Helios Plus 2287A datalogger.
Data format	Treated
Description of the data collection	The data set is generated from experimental tests on a full-scale wall element with loose-fill wood fiber insulation, and includes both steady-state and dynamic cases with varying boundary conditions. A total of 11 unique experiments are performed, 7 in steady-state and 4 in dynamic conditions. The data consists data of internal temperature sensors to determine the temperature profiles for the supposed 1D heat transfer in the wall element.
Data source location	Institution: Aalborg University, Department of the Built Environment City/Town/Region: Aalborg Country: Denmark
Data accessibility	Repository name: Zenodo.org Data identification of the dataset: 10.5281/zenodo.8204755 Direct URL to dataset: https://zenodo.org/record/8204755

Value of the data

- Internal convection can occur, under the right conditions, in insulation layers of both horizontal and vertical construction elements. It causes additional heat losses in the construction element and is therefore important to understand in depth.
- This dataset consists of a total of 11 cases, with different boundary conditions, and is a substantial contribution to the current body of experimental data available investigating internal convection.
- This dataset is suited for, but is not limited to, benchmarking with other insulation materials to assess their individual performance with similar boundary conditions.

Objective

This dataset was generated while observing the effects of internal convection and its effect on the thermal performance of a full-scale wall element with loose-fill wood fiber insulation. Other experiments have been conducted for other types of insulation, but not commonly on full-scale wall elements using the specific type of insulation used in this series of experiments. Also, the number of experiments and variation of boundary conditions is not commonly seen in the literature, providing additional value to this dataset for purposes such as benchmarking other insulation materials under similar boundary conditions. With a combined number of 75 internal temperature sensors, the resolution of the internal temperature profile is higher compared to similar studies. Furthermore, an additional 60 sensors measure surface and air temperature, to fulfill the temperature profile throughout the insulation and to the air and both sides of the construction element.

Data description

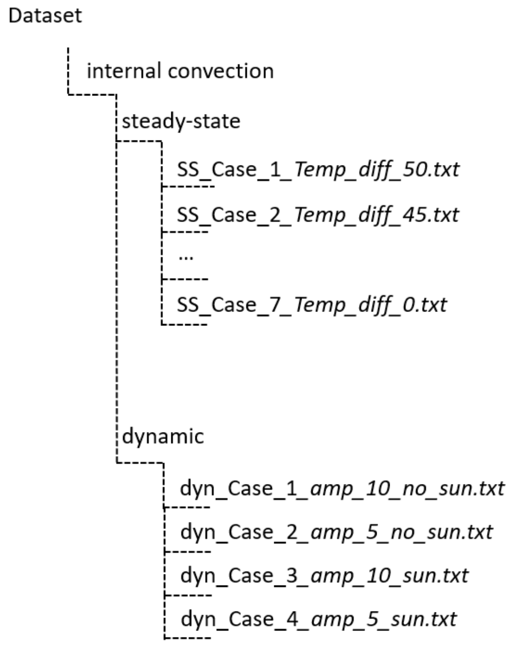
The dataset consists of sensors for internal and external temperature sensors. The internal temperature sensors refer to sensors inside the insulation layer of the wall element, while the external refers to surface temperature sensors and air temperature sensors on both the hot and cold side of the wall element.

A total of 135 temperature sensors of type K thermocouples are used to measure temperature profiles at 15 different points. This data is used to visualize and observe the effect of internal convection in insulation layers.

Dataset

The dataset consists of a single main folder, followed by two subfolders: one including the steady-state experiments and one including the dynamic experiments. Both subfolders include text files for each experiment with different boundary conditions, such as the temperature difference between the temperature in the hotbox and the temperature in the cold box, for the steady-state experiments. Each file contains the last three hours of measured data from the sensors, with a temporal resolution of 60 seconds. The data from the sensors ´can be used to construct the temperature profiles throughout the construction element for each of the 15 points.

The naming convention for the sensors and their placement is described in the following section.



Experimental design, materials, and methods

The data has been acquired for different temperature sensors in a full-scale wall element, where a large guarded hotbox has been used to condition the wall element to a cold and warm environment on either side of the wall element, to simulate outdoor and indoor conditions of a real building.

The wall element under investigation can be seen in **Figure 1**, where the measurement points for the thermocouples are shown. As shown in **Figure 1**, the wall element is partitioned into different modules.

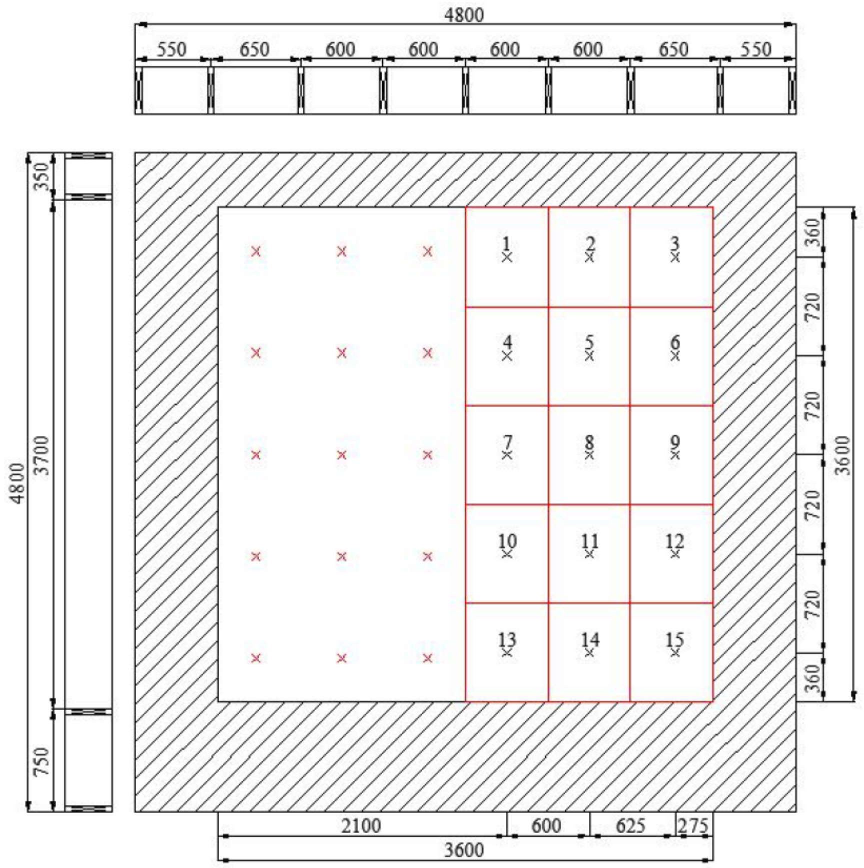


Figure 1. Location of thermocouples on wall element. The black crosses are the placements, and the red crosses represent symmetry points, and the hatched area indicates the edge of the hotbox. All measurements are in millimeters.

For each point on the wall (denoted by numbers in **Figure 1**), a total of 9 temperature points in the cross section of the wall is measured. This includes both internally in the insulation material and externally (air and surface temperatures).

For each case, a total of 135 sensors is used to measure the temperature profiles of 15 different points, with a total of 9 temperature measurements for each temperature profile. The thermocouples are calibrated to have an accuracy of ± 0.15 °C. For each measurement point, the sensor placement is denoted with a letter (**a** to **i**), to indicate the spatial position starting from the air temperature measurement on the hot side, see **Figure 2**. The measurement point is a welded measurement tip of a type K thermocouple, fastened on a fishing line with glue and shrinking tape.

The thickness of the wooden plate on the hot side is 12 mm, and the thickness of the wooden plate on the cold side is 22 mm.

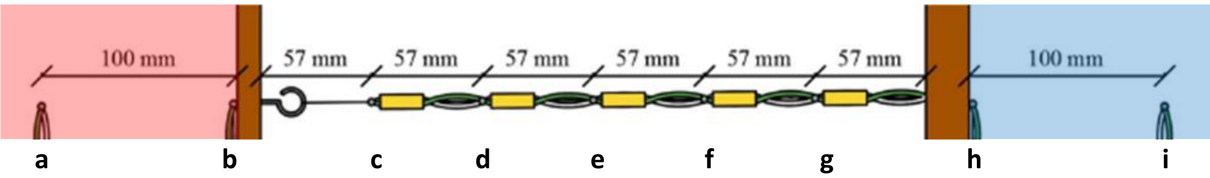


Figure 2. Spatial sensor placement location for each measurement point.

As an example, the sensor placed in measurement point 4, on the surface on the hot side, is named 4_b in the dataset. The spatial position (defined as the distance from the surface on the hot side of the construction element), is shown in **Table 1**.

Table 1. Spatial position of sensor placements (**a** to **i**) rounded to three decimals. *Defined as from the distance from the surface on the hot side.

Point	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**
Distance* [m]	-0.1	0	0.069	0.125	0.182	0.239	0.296	0.374	0.474

For each case, a text file is available with sensor data for each sensor. The first column is the elapsed time, with a temperature measurement every 60 seconds. It is structured with points in ascending order, with alphabetical order, meaning that it starts with point 1, with sensor **a** to **i**, then repeating with point 2 etc.

All 135 sensors are available for the steady-state cases, whereas only the inner most column, shown in **Figure *1***, is available for dynamic cases.

The steady-state cases are performed, such that either side of the wall element is subjected to static boundary conditions until steady-state has been reached. This is defined as when the average temperature of a sensor for a three-hour period deviate by less than 1% from the average temperature for the prior three hours.

A total of 7 unique steady-state experiments are conducted, see **Table 2**.

Table 2. Overview of design temperatures pertaining the steady-state cases. *Control case to investigate heat losses in guarded hotbox.

Case	Indoor temperature [°C]	Outdoor temperature [°C]	Temperature difference [°C]
1	30	-20	50
2	20	-25	45
3	20	-20	40
4	20	-15	35
5	20	-10	30
6	20	0	20
7*	20	20	0

Similarly, the dynamic cases are performed until they reach quasi steady-state, meaning that the measured temperature in the i^{th} hour of the day deviates by less than 5 % to the i^{th} hour of the day 24 hours before.

A total of 4 dynamic experiments are conducted, see **Table 3**.

Table 3. Overview of relevant parameters pertaining dynamic cases.

Case	Indoor temperature [°C]	Outdoor conditions		
		Mean temperature [°C]	Amplitude [°C]	Irradiance [W m^{-2}]
1	20	-10	10	0
2	20	-10	5	0
3	20	-10	10	628
4	20	-10	5	628

Additional information regarding the experimental setup, can be found in [1].

References

[1] Veit M, Johra H. (2022). Experimental Investigations of a Full-Scale Wall Element in a Large Guarded Hot Box Setup: Methodology Description. doi: 10.54337/aau488363266

Appendix A: Sample code to visualize results of case 1

The following is a showcase of visualization of the data from case 1, with a temperature difference of 50 °C, using Python.

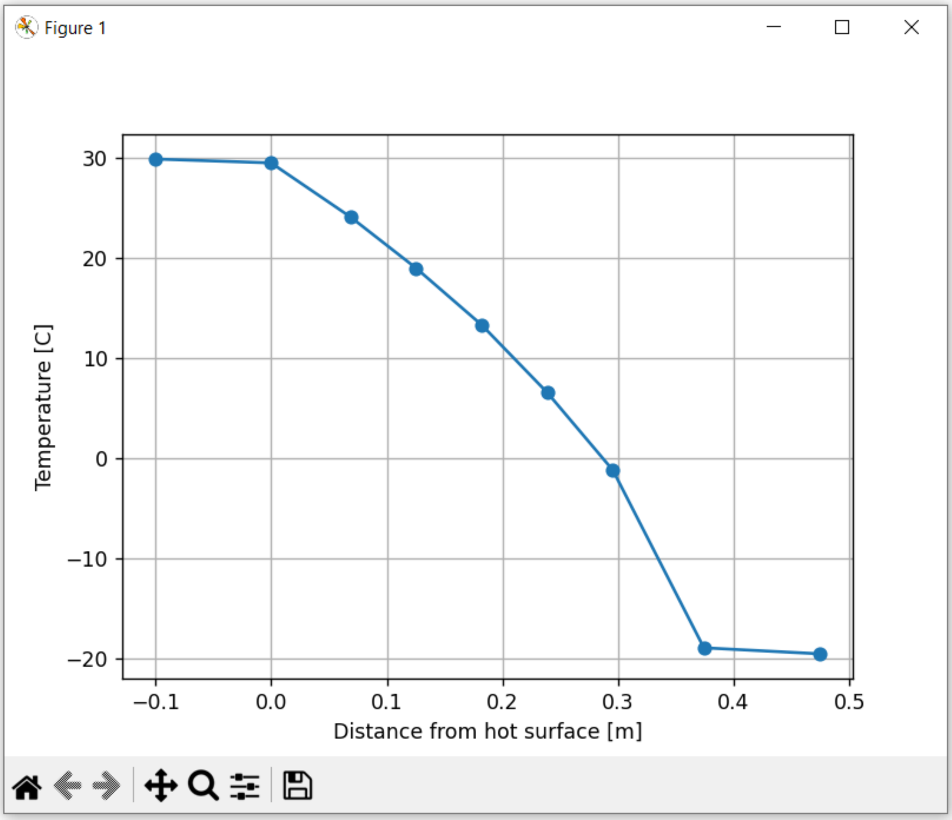
```
 # Packages
import os
import pandas as pd
import matplotlib.pyplot as plt

# Read data
path = os.getcwd() + "\SS_case_1_Temp_diff_50.txt"
df = pd.read_csv(path,sep='\t')

# Define the data to be investigated
point_1 = df.iloc[:,1:10].mean()

# Spatial location of points relative to hot surface
x = [-0.1, 0, 0.069, 0.125, 0.182, 0.239, 0.296, 0.374, 0.474]

# Plot data
plt.plot(x, point_1,'-o')
plt.grid()
plt.ylabel('Temperature [C]')
plt.xlabel('Distance from hot surface [m]')
plt.show()
```



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