Experimental data from an In-Situ measurement.

Content

1. Introduction

The reported measurements are made for the Joint Research Centre, Institute for Energy and Transport in ISPRA, Italy. The well controlled measurements concern a concrete wall exposed to indoor and ambient conditions, with and without solar radiation. A training exercise for the Summer School on *Dynamic Calculation Methods for Building Energy Performance Assessment* has been prepared using data from this measurement. Note that is an extended version of the (before2019) exercise.
The exercise is presented in In_Situ_ExerciseWall.PDF and comes with two DATA_Cserie*.TXT files, containing 4 temperature signals and 1 heatflux signal.

2. Description of the wall

The tested wall is obtained through adding extra insulation to a normal external wall at the laboratories of an insulation production plant in the south of Sweden. The test wall is a three layer wall with 150 mm Gas Concrete insulated on both sides with a 27 mm glass fibre board layer; see Figure 1 (next page).

The glass fibre board layers were treated in a grinding machine in order to obtain a constant thickness. The Gas Concrete is the normal construction in the laboratory, while the two insulation layers have been added to create this experimental set-up. The test wall is facing south-west. It is situated near one corner of the laboratory, where a small room is positioned, the ”*bunker*”, with a door that was closed during the measuring period.

This three layer test wall had some extra layers in order to get reliable measuring data:

- On the external side, it was covered by a thin, yellow cloth to protect the wall from rain. The cloth (type Gore-Tex) was open for vapour diffusion and was sprayed with extra silicon. See Figure 3.

- On the external side of the cloth, the wall had an air space and a sun shield of wood with an aluminium foil on the side facing the test wall. This shading device was only used at the first half of the measuring period. It was then removed, and the rain protecting cloth was not any more sheltered for solar radiation.

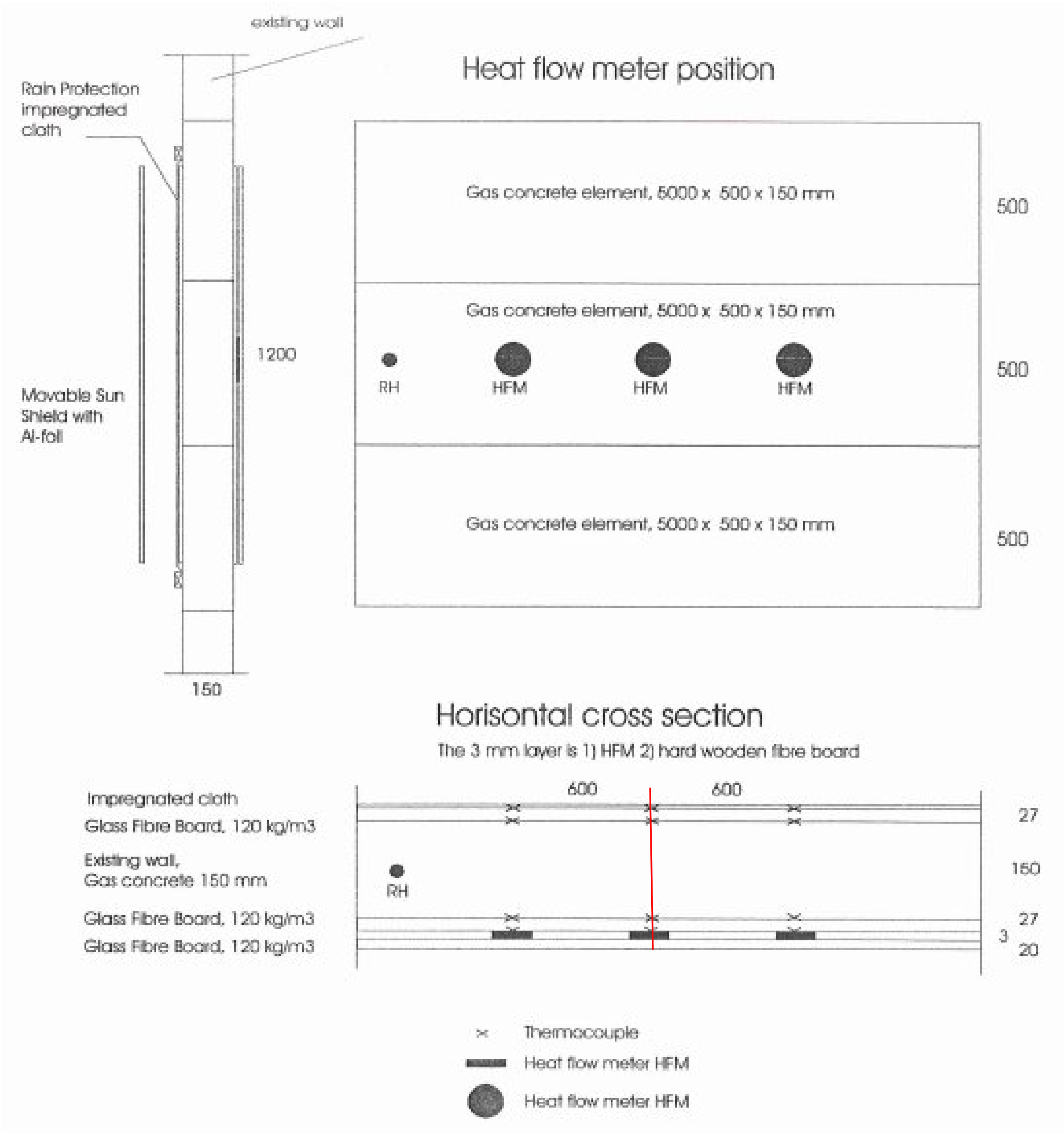

Fig 1. Cross view of the experimental set-up and sensors positions.

- On the internal side of the test wall, one layer of wood fibre board with round holes for the Heat Flow Meters was mounted. The thickness and the thermal conductivity of the wood fibre board were nearly equal to the thickness and the thermal conductivity of the Heat Flow Meters. On both sides of the wood termocouples are placed which leads to 4 termocouples in one (red) line from inside to outside. See fig 1.

- Finally, this inhomogeneous layer was covered by one more layer of glass fibre board. The board was used in order to obtain a one-dimensional heat flow and it was tightly fixed to avoid air spaces in the test wall. See also Figure 2.

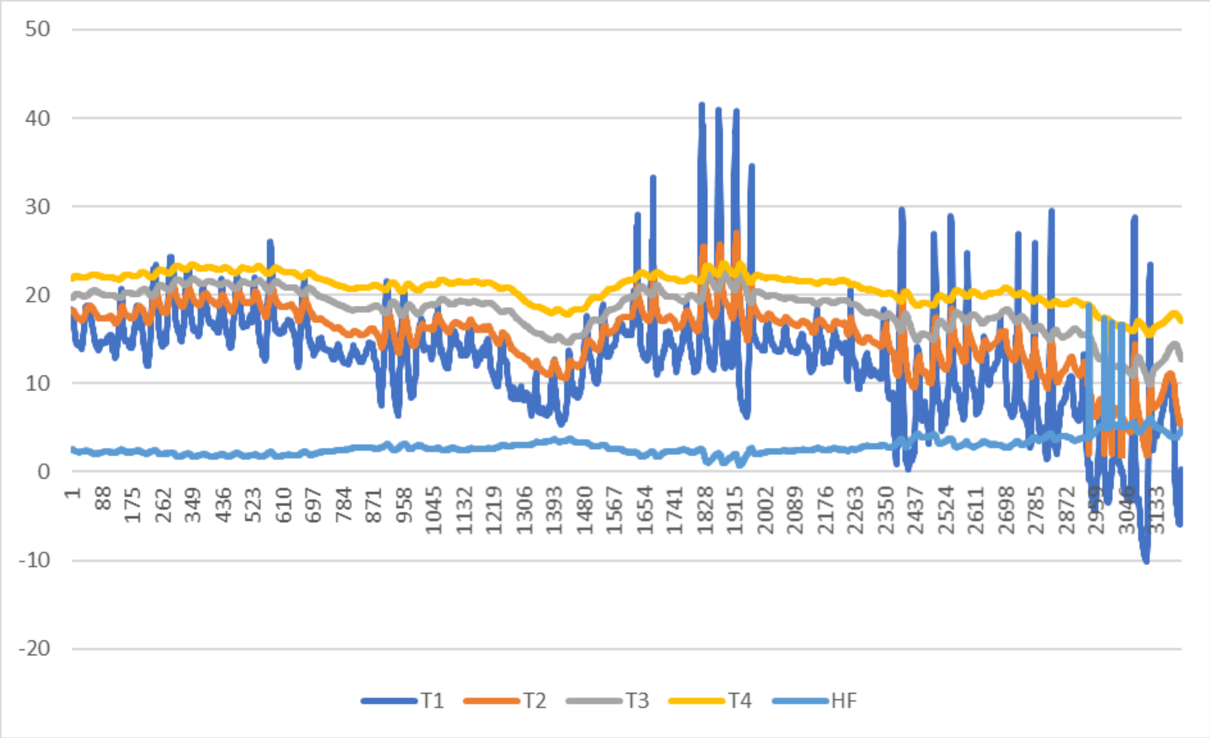

Figure 2. Measured data of both periods; with shading device and without.

The period without shading device starts at datapoint 1619 and hence the most external termocouple senses the impact of solar radiation on the cloth.

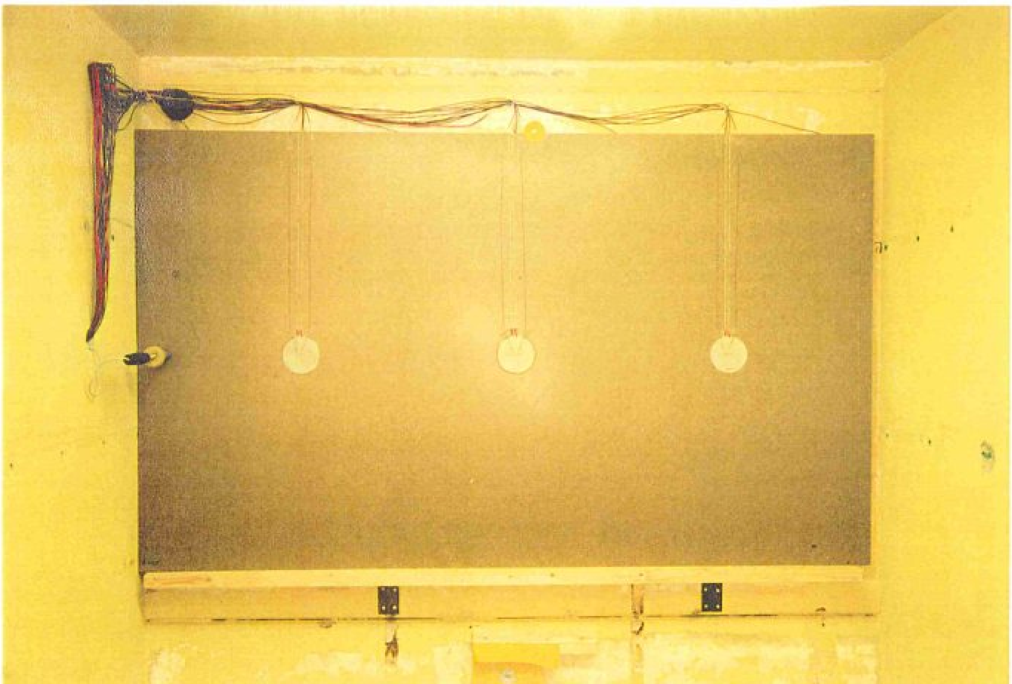

Fig 3a. Three heatflow meters mounted in a wooden board. On the left the humidity sensor.

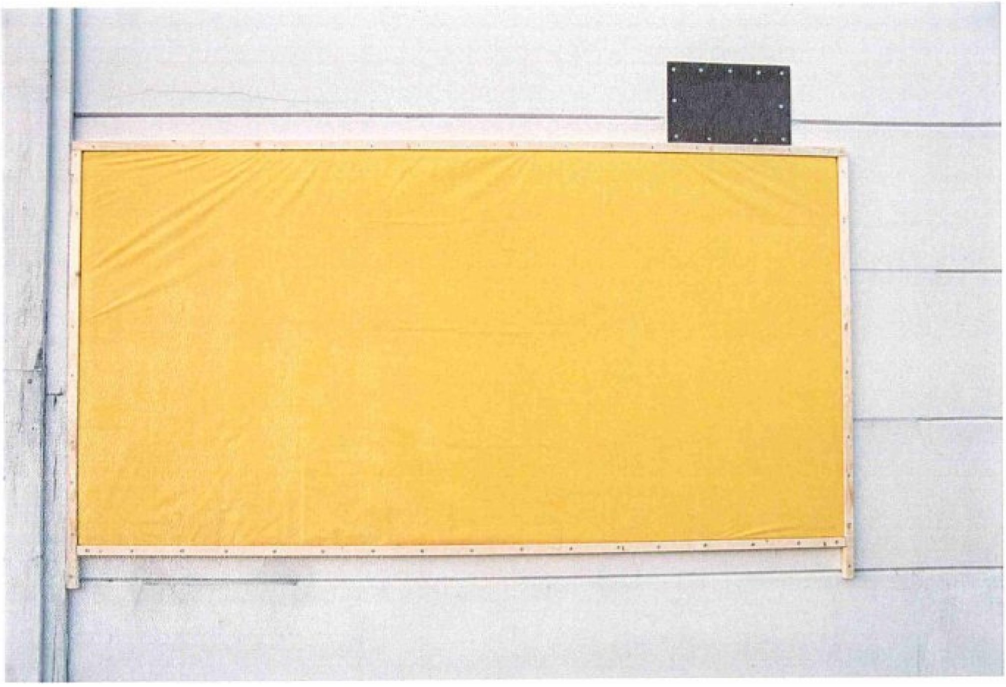

Fig 3b. The GoreTex cloth mounted on the exterior side of the concrete wall. The solar shading device is not yet in place.

The external climate is natural, the first period with a shading device and the second period with solar radiation on the exterior side of the wall. The temperature in the closed room was regulated with a heater and a fan, fooled to sensitivity of ± 1°C by an air tube, which forced a small part of the air stream from the heater directly to the on-off temperature sensor.

Note, that even if the indoor temperature was rather constant, the warm temperature of the three layer test wall varied a lot with the external temperature because of the internal extra layers.

3. Method to collect Data. Time schedule

All temperatures and heat flows were measured every five minutes, and a logger, CR 10 WP, calculated mean values every ½ hour. The ½-hour mean values were stored in a computer.

The measurements started September 1 (day 244) at 16.00 and ended November 7 (day 311) at 11.00. In total 15 (12 temperatures and 3 heat flows) times 3207 values were collected.

The solar shading device was removed October 5 at 09.00. This time relates to the observation 1619 of the 3207 measured observations in the original data files.

4. Thermocouples, Heat Flow Meters and Relative Humidity meter

The thermocouples were made of Copper-Constantan, 0.2 mm, taken from the same delivery and without any additional joints between the sensor and the Data Logger.

The three Heat Flow Meters are made by TNO, type TPD WS 31, with a diameter of 103 mm and a thickness of 3 mm.

The Relative Humidity meter was a Vaisala HMI 31. It was calibrated before the measurements and checked again afterwards. The deviation was then -1% at RH = 13% and +1% at RH = 95%.

5. Glass fibre boards - Thickness, Density, Organic content and Thermal conductivity

When the measurements were completed, three samples were taken, size 400 x 400 mm, from the internal and external glass fibre board. The centre of the samples coincides with the centre of the three heat flow meters.
Then 6 thermal conductivity measurements were made, see the table below. The thermal conductivity for each individual slabs is obtained from six measurements. They are measured two by two, and a mean value for these two slabs was obtained at every measuring occasion. Then the individual thermal conductivity was calculated. The measuring device was a Heat Flow Meter apparatus with horizontal heat flow and with the HFM placed between the two glass fibre boards.

Table 1: Experimental periods:

	Slab 1	Slab 2	Slab 3
Measurement 1	Internal	Internal	
Measurement 2	Internal		Internal
Measurement 3		Internal	Internal
Measurement 4	External	External	
Measurement 5	External		External
Measurement 6		External	External

The Heat Capacity C is calculated with the assumption that the specific heat capacity is 840 J/(kg,K) for glass and 1500 J/(kg,K) for the organic content. It is not measured, only calculated.

Table 2.: Results for material specifications:

	Internal boards	External boards	All boards
Thickness, mm	27.16 +- 0.04	27.06 +- 0.10	27.11 +- 0.09
Dry density, kg/m^3	114.8 +- 5.1	118.3 +- 4.4	116.6 +- 4.7
Organic content, weight-%	9.5	9.6	9.55 +- 0.05
Thermal conductivity, mW/(m,K)	31.23 +- 0.04	31.31 +- 0.26	31.27 +- 0.17
R-value, (m^2,K)/W	0.870 +- 0.001	0.864 +- 0.010	0.867 +- 0.007
C-value, kJ/(m^2,K)	2.81 +- 0.13	2.89 +- 0.10	2.85 +- 0.11

6. Gas Concrete - Density, Moisture content at the end of the measuring period

Three samples were taken by drilling round cores in the Gas Concrete when the measurements were completed. Three cylinders were obtained with a diameter of approximately 95 mm and a height of 150 mm. The cylinders were divided in three parts, external, middle and internal.

Table 3.: Results from moisture measurements:

	Internal	Middle	External	All
Dry density, kg/m^3	544 +- 7	552 +- 2	558 +- 4	552 +- 6
Moisture content, weight -%	3.67 +- 0.15	4.65 +- 0.47	5.09 +- 0.75	4.47 +- 0.78

The density is quite constant and the moisture content is higher at the external side than at the internal side. According to Ahlgren, "*Fuktfixering i porösa byggnadsmaterial*", the moisture contents relates to a Relative Humidity between 58 % and 92 %, see Figure 4.

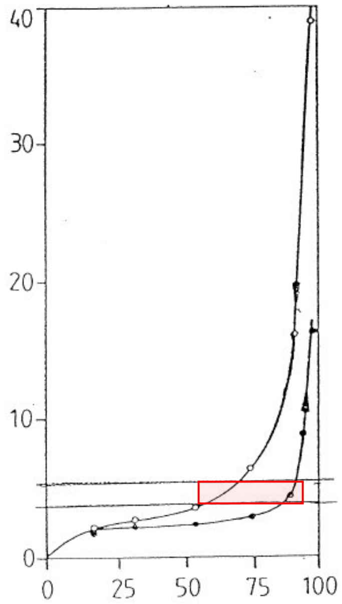

Figure 4. Moisture content in weight - % as a function of the relative humidity for Gas Concrete with a density of 500 kg/m³ according to Ahlgren.

7. Calibration of the heat flow meters

Calibration of the Heat Flow Meters was done in the same HFM Apparatus as the thermal conductivity was performed. The results are compared with a second apparatus that is calibrated several times a year. These constants are nearly identical with earlier calibrations.

The obtained constants for the three HFM were:

		New calibration	Old calibration
Left HFM	F1 - 31908	3807 W/(mV,m^2)	3804 W/(mV,m^2)
Middle HFM	F2 - 31937	4327 W/(mV,m^2)	4309 W/(mV,m^2)
Right HFM	F3 - 31936	4464 W/(mV,m^2)	4487 W/(mV,m^2)

8. Data: Relative Humidity

The Relative Humidity was measured in the Gas Concrete. A hole was drilled from the internal side to the centre of the Gas Concrete layer, and the meter was placed in the hole with its sensor in the middle of the Gas Concrete, 75 mm from both surfaces. The hole was then sealed.

The sensors are placed in the centre of the wall, but the sealing of the hole is placed approximately 25 mm to the internal side. Therefore, there is a 25 mm cylindrical cavity towards the internal side, starting from the centre. It is possible, that the readings relate to this volume rather than exact to the centre.

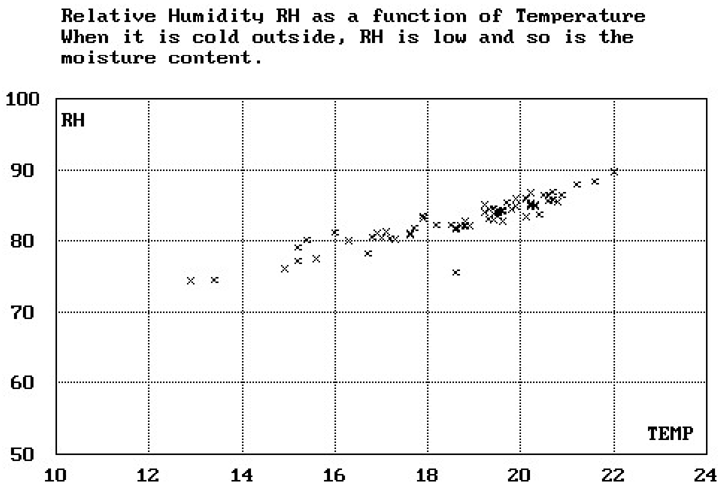

Figure 6. There is a clear relation between the manually measured temperature and RH.

Without doing any sophisticated analysis of the measured values in the table above, the following can be noticed: there is a clear relation between RH and temperature. A diagram is shown in Figure 6.

Some conclusions can be made from the figures. When the external temperature is high, there is vapour diffusion inwards, and the vapour content increases. When the external temperature is low, there is vapour diffusion outwards, and the vapour content decreases. Obviously, this mass transfer will also affect the heat flow to a certain extent. This is one effect which complicates thermal In-Situ measurements.

9. Summary

The test wall is a three layer wall with 150 mm Gas Concrete insulated on both sides with a 27 mm glass fibre board layer. The wall is facing south-west. The external climate is natural. During the first half of the measuring period, the wall was protected against solar radiation.

The measurements started September 1 and ended November 7. In total 15 x 3207 ½-hour mean values were stored, 12 temperatures and 3 heat flows at 3207 occasions.

The Relative Humidity and the temperature were measured manually in the centre of the Gas Concrete at 74 occasions during the measuring period.

When the measuring period was over, the thickness, density, organic content and thermal conductivity of the Glass fibre boards and the density and moisture content of the Gas Concrete were measured. The Heat Flow Meters were also calibrated.

Note:
These data have been analysed by several people (now >150) in the past. During training workshops, Summer Schools and identification competitions, different approaches and calculation tools have been presented and discussed and are made available (contact www.DYNASTEE.info) to interested people for study. In general, the estimation of the thermal capacitance of the concrete part has been proven a more complicated task.

Note 2:

To prepare the data as input for LORD, you have to place the header information between quotes, ‘xyz’. In order to do so you need to tell excel that a quote is considered to be text, thus in excel, type ''Tin1'

The result will be as given below in the created xyz.csv file

'Tin1'	'Tin2'	'Tex3'	'Tex4'	'HF'
15.90333	17.58033	19.78133	21.704	2.187016
16.453	17.66967	19.78767	21.70333	2.1908
16.60633	17.76833	19.79567	21.716	2.158826
17.92667	17.95567	19.797	21.724	2.218635
18.56333	18.15467	19.80333	21.72933	2.188064

Two xyz.CSV data files are available; without solar shading GFwallNotshaded (1589 records) and GFwallShaded (1617 records).

See also JRCMEAN2.xlsx from which these .CSV data files have been created.