Final Empirical Test Case Specification

Test Case DSF100_e and DSF200_e IEA ECBCS Annex43/SHC Task 34 Validation of Building Energy Simulation Tools

Kalyanova, Olena; Heiselberg, Per

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O. Kalyanova
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by

O. Kalyanova
P. Heiselberg

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1. General information

1.1. Introduction

This document includes the empirical specification on the IEA task of evaluation building energy simulation computer programs for the Double Skin Facades (DSF) constructions. There are two approaches involved into this procedure, one is the comparative approach and another is the empirical one. In the comparative approach (**Ref. 1**) the outcomes of different software tools are compared, while in the empirical approach the modeling results are compared with the results of experimental test cases.

Figure 1. The "Cube", outdoor test facility at Aalborg University.

The DSF Test Facility Building at Aalborg University (the "Cube") is the prototype for the specified model and the place for conducting the empirical test-cases. Initially the DSF Test Facility Building is calibrated for air tightness and wind profile, further on these investigations will be followed with the heat transmission and time constants tests.

The empirical test cases cover three operational strategies of the DSF:

Case DSF100. All the openings are closed. There is no exchange of the zone air with the external or internal environment. The zone air temperature results from the conduction, convection and radiation heat exchange. The movement of the air in the DSF appears due to convective flows in the DSF. The test case is focused on assessment of the resulting cavity temperature in DSF and solar radiation transmitted through the DSF into zone.

Case DSF200. Openings are open to the outside. DSF function is to remove surplus solar heat gains by means of natural cooling. Temperature conditions and air flow conditions in the DSF are to be examined together with the magnitude of natural driving forces.

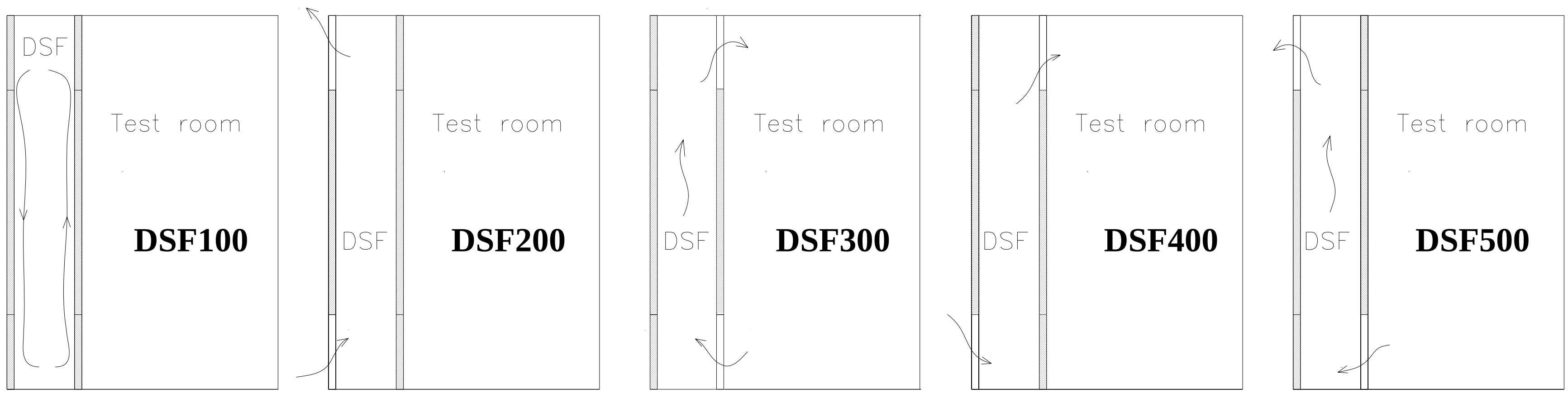


Figure 2. Test Cases. DSF100, DSF200, DSF300, DSF400, DSF500.

Case DSF100 - all openings are closed
Case DSF200 - openings are open to the outside
Case DSF300 - openings are open to the inside
Case DSF400 - bottom opening is open to the outside and the top opening is open to the inside (preheating mode)
Case DSF500 - top opening is open to the outside and the bottom opening is open to the inside (chimney/exhaust mode)

General test case	Empirical test case	Corresponding comparative test case	Solar shading		Driving force		Boundary conditions	Openings area
			Yes	No	Mechanical force	Combined natural forces	Internal=const External=floating	No control
DSF100	**DSF100_e**	**DSF100_2**		**X**			**X**	**All openings closed**
DSF200	**DSF200_e**	**DSF200_4**		**X**		**X**	**X**	**X**

Table 1. Summary table of modelling cases.

1.2. Test case DSF100_e objectives

The main interest in this test case is to ascertain the transmission of solar radiation into the room (zone 2), when there is no airflow between external and/or internal environment. Cooling system extracts the surplus heat from the zone and the cooling load to the zone 2 become the necessary parameter for estimation of the DSF influence. The heating system is installed to serve exactly the same needs as cooling – to keep constant temperature conditions in the room. The amount of heat supplied can be used as a criterion, similar to the cooling load.

Results of simulations will be compared with the experimental data from the outdoor test facility.

1.3. Test case DSF200_e objectives

The main objective of this test case is to test the building simulation software on its general ability to model the transmission of solar heat gains through the two layers of fenestration combined with naturally driven airflow through the DSF cavity. This time, the air movement exists only between the cavity and external, and the air temperatures in the cavity are mainly influenced by external environmental temperatures and solar radiation. The internal conditions remain constant; the Cooling/Heating system is introduced to the model to keep internal temperature in the zone 2 constant.

Results of simulations will be compared with the experimental data from the outdoor test facility.

1.4. Accompanying files for simulations

- Template for the output data
- Weather data files
- Data for ground temperature
- Temperature data for neighboring zones
- Spectral data for opaque and transparent surfaces
- Files with additional documentation (*Drawing of window frames.pdf*)

2. Weather data description

2.1. General

The weather data is prepared for simulations in xls-file format as it is easy to transform into any other format. For each empirical test case, there are provided two weather data files. For example for the test case DSF100_e:

wDSF100_e10.xls - provides average data for every 10 minutes. If the testing software tool is not able to perform calculation in this time interval, then 1-hour average data file can be used:

wDSF100_e60.xls - this data provides average data for every 1 hour, which is obtained by averaging 10 minutes-data.

It is assumed that parameters in the climate data are constant, for example:

from 00:00 until 00:10 – for 10 min average data
from 00:00 until 01:00 – for 1 hour average data.

Parameters in the weather data files:

- External air temperature, ^{o}C
- Global solar irradiation on horizontal surface
- Diffuse solar irradiation on horizontal surface
- The wind direction in the data sheet is given in degrees from the North, so East corresponds to 90 degrees.
- Wind speed, m/s, measured at 10 m above the ground
- Air relative humidity, %
- Atmospheric pressure, Pa

Weather data for the empirical test cases is following:

DSF100_e	19.10.2006 - 06.11.2006 (both days are included)
DSF200_e	01.10.2006 – 15.10.2006 (both days are included)

2.2. Time plots of available weather data for the test case DSF100_e

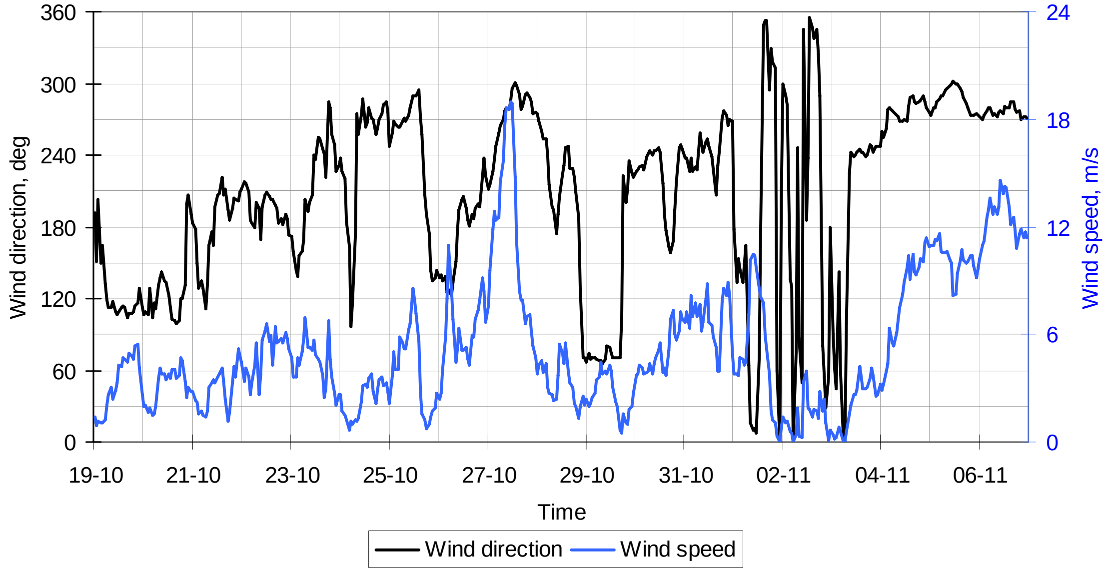


Figure 3. Wind direction and wind speed in weather data, test case DSF100_e.

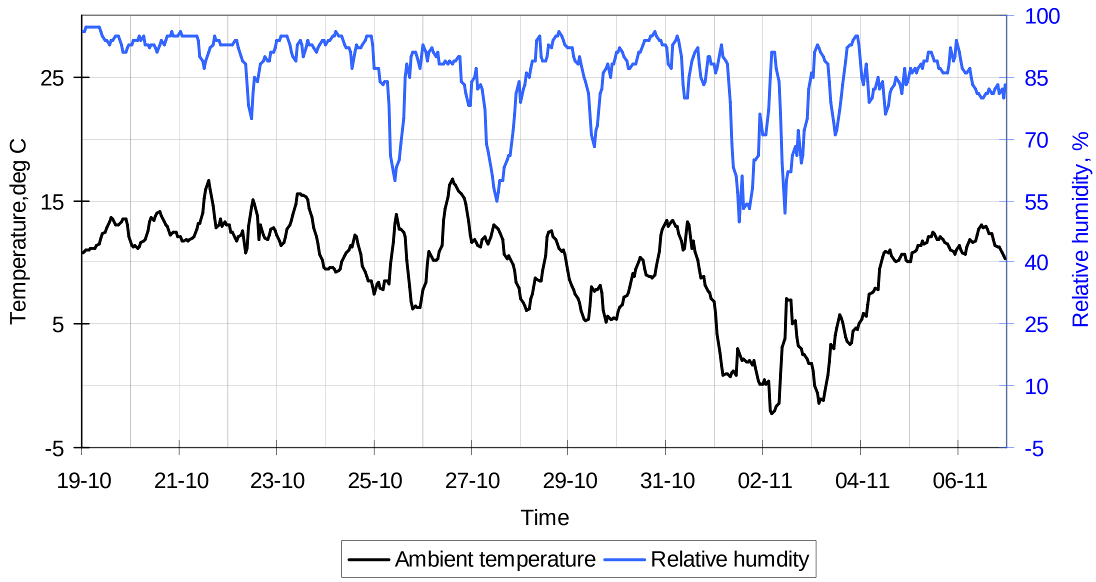


Figure 4. Air temperature and relative humidity in weather data, test case DSF100_e.

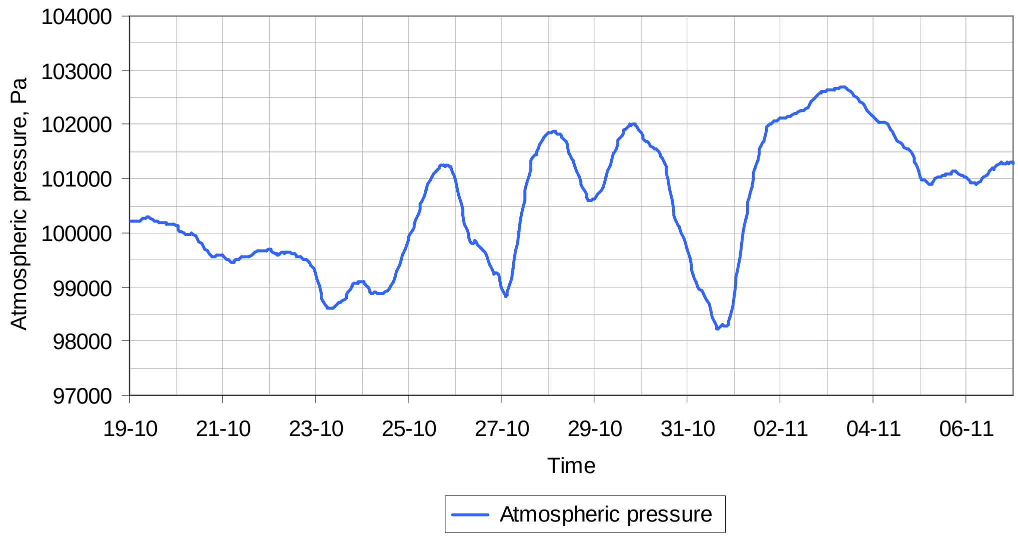


Figure 5. Atmospheric pressure in weather data, test case DSF100_e.

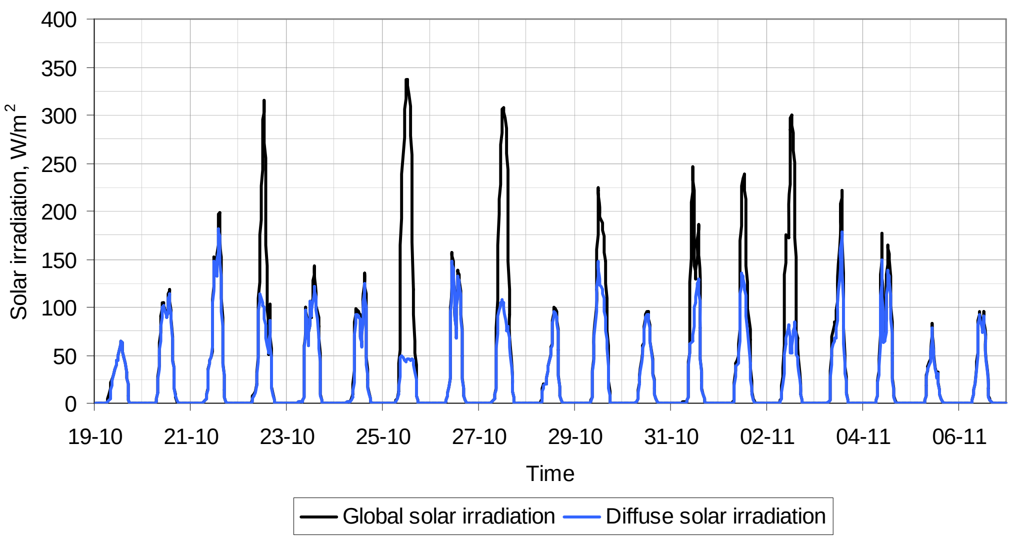


Figure 6. Global and diffuse solar irradiation on horizontal surface, test case DSF100_e.

2.3. Time plots of available weather data for the test case DSF200_e

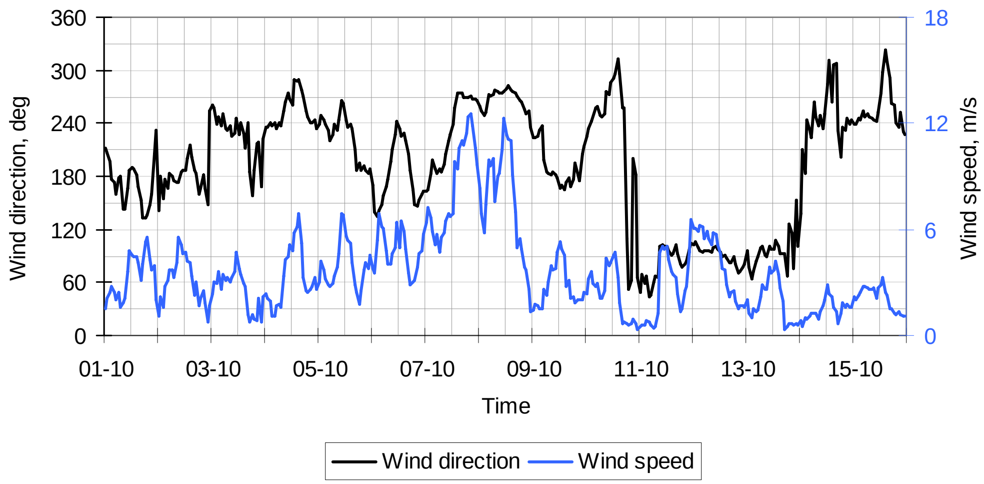


Figure 7. Wind direction and wind speed in weather data, test case DSF200_e.

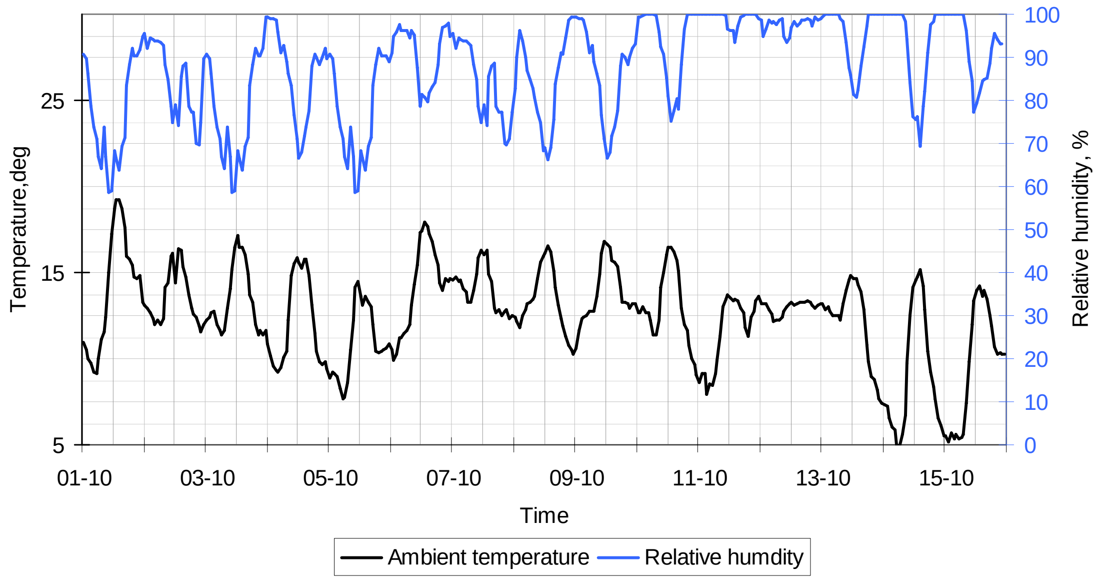


Figure 8. Air temperature and relative humidity in weather data, test case DSF200_e.

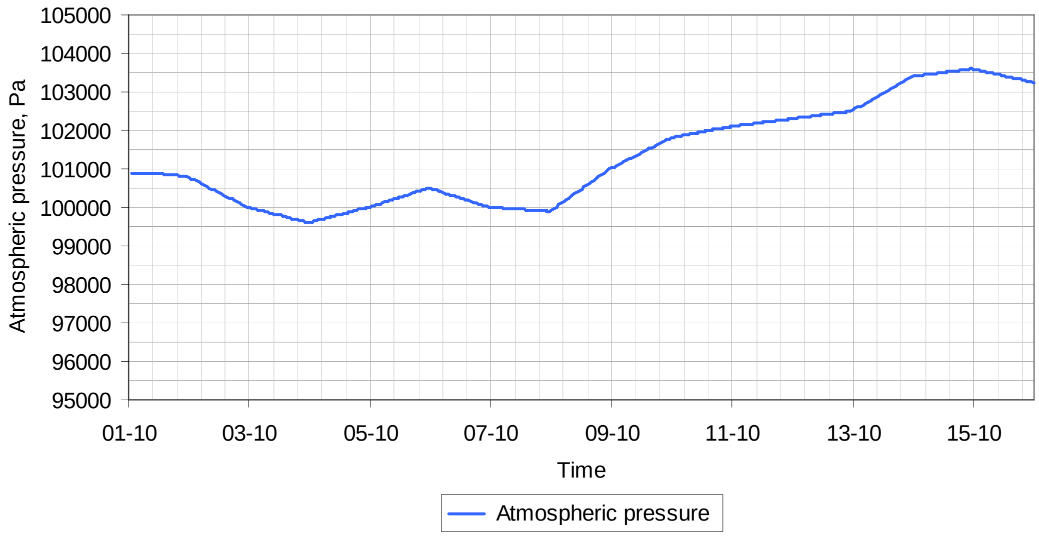


Figure 9. Atmospheric pressure in weather data, test case DSF200_e.

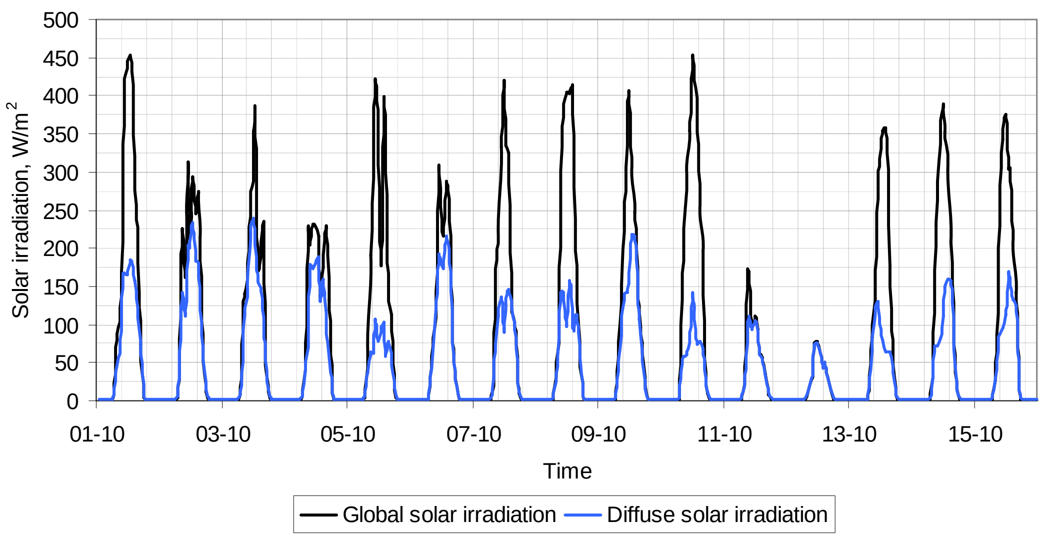


Figure 10. Global and diffuse solar irradiation on horizontal surface, test case DSF200_e.

2.4. Ground temperature

The ground temperature under the foundation was measured during the experiments and provided to the participants as an input parameter.

Ground temperature_DSF100_e10.xls - provides average data for every 10 minutes.
Ground temperature_DSF100_e60.xls - provides average data for every 1 hour.

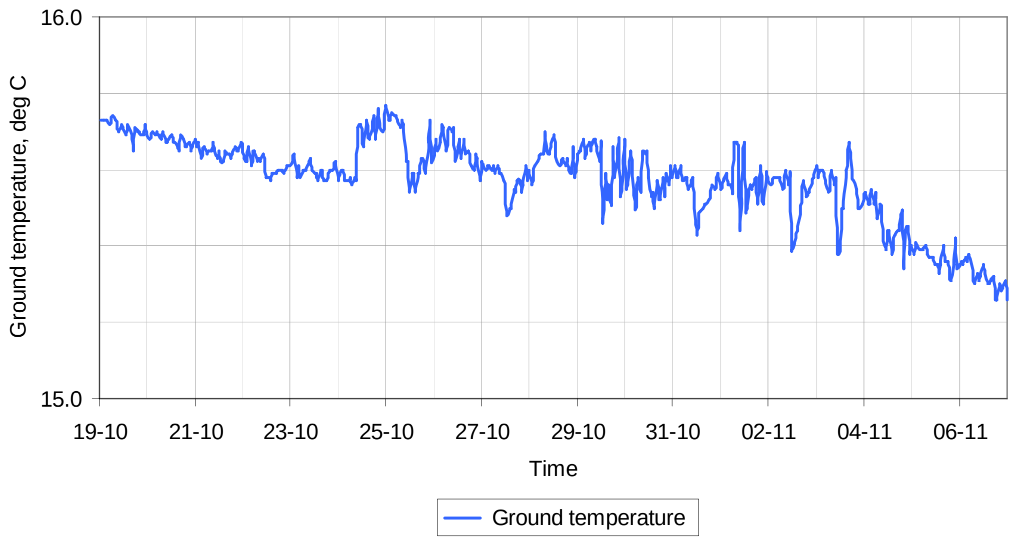


Figure 11. Ground temperature under foundation, test case DSF100_e

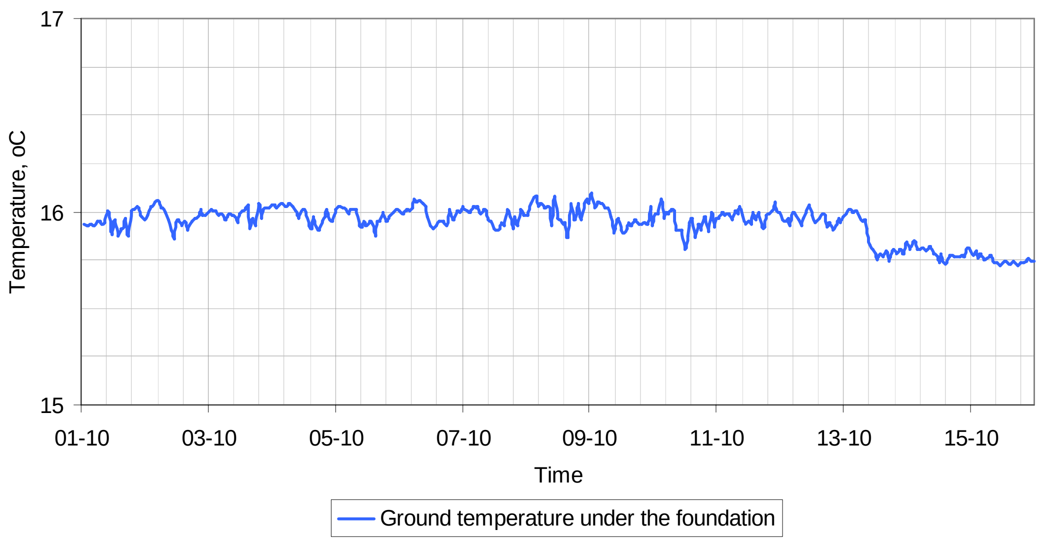


Figure 12. Ground temperature under foundation, test case DSF200_e

If the information about ground temperature can not be used in the software tool being tested, then use following values and note it in the report.

DSF100_e 15.6 °C
DSF200_e 16.0 °C

3. Rules for the modelling

3.1. Modelling methods

Various building simulation software includes different approaches and applications for modelling of the physical processes involved. Initially, it is desired that all case-models involve the same applications for the same parameters in every model and use the most detailed level of modelling allowed by simulation program being tested.

Cases specified for modelling involve interaction of various processes, thus modelling may require different combinations of software applications and their options. For this reason the requirements for the modelling are untied. Design of the model can be performed after the capability of the simulating software and user's decision, but as close as possible to the prescribed one in a physical and mathematical meaning and as close as possible to the specification and other cases modelled by the same task participant. The user is asked to notify whether and where differences exist. It is necessary to include the detailed documentation of changes into the report on modelling results in order to perform the overall comparison of the results.

3.2. Input parameters

In the specification for the test case modelling the input parameters are prescribed. These are to be used whether it is needed in the simulation software or to be used for approximate estimation of another parameter needed. When the specified parameter is found to be inapplicable for the modelling the user may disregard that and continue the modelling. The notification in modeler report is desirable.

3.3. Geometry parameters

In order to simplify the geometry input-parameters for all the building simulation software involved into the Annex 43, the interior volume of the zone 1 and 2 are specified. The definition of the zones and the geometrical details will be specified further in the document.

For zone 1 (DSF) the location of windows is specified in the following figures, the interior volume is counted from the glass-pane surfaces, which are not symmetrical to the center-line of the window frame. If it is not possible to specify the location of the glass-panes, please find a technique to keep the volume of zone 1, as close as possible to the prescribed one.

3.4. Simulation

When the simulation software allows the initialization process, then begin the simulation with the zone air conditions equal to the outdoor air conditions.
If the simulation software allows the iterative simulation of an initial time period until temperature or fluxes, or both stabilize at initial value, then use this option.
The duration of the simulations for all the cases has to be complete, correspondingly to the provided weather data. The outputs are prescribed in section 9.

3.5. Time convention

The standard local time is used (this is not the solar time!), specified in section 4. The full day duration is 0:00-24:00. The duration of the first hour, for instance, is from 0:00 until 1:00. There is no daylight saving time to be considered.

3.6. Schedule/occupants

There are no occupants in the zones and no weekend or holiday schedules for the systems. All simulated days are considered to be equal.

3.7. Modifications of prescribed values

Some software may require modifications of values prescribed in this specification to be able to run the simulation. These modifications are undesired, but still might be necessary. The user has to make sure that the new values are obtained on the mathematical and physical basis and that these steps are documented in the modellers report.

3.8. Units

The specification is completed in SI-units, if you require conversion of units use conversions of ASHRAE.

3.9. Shading by outdoor constructions

There are no outdoor constructions that shade the model.

4. Geography, site location

The modelling building is located close to the main campus of Aalborg University, Aalborg, Denmark. The following coordinates define the geographical location of the model:

Time zone	+1 hr MGT
Degrees of longitude	9°59'44.44"E
Degrees of latitude	57° 0'41.30"N
Altitude	19 m

Table 2. Geographical and site parameters for the model.

The orientation of the test facility is illustrated in Figure 14. Geometry

5. Model geometry

The model-building is subdivided into 2 zones one of the zones represents the indoor environment in the ordinary room behind the DSF, named zone 2. To be able to attain the output results, it is necessary to identify DSF as a separate zone, named zone 1. It has been suggested to prescribe the interior volume of the zones as the first priority, the wall thickness may vary as long as the physical processes are correct (the user may need to perform the recalculation of the wall-thickness together with thermal properties of the wall). Zones and numbering of walls are defined in the Figure 14.

However, the actual Test Facility Building contains two supplementary rooms attached behind the Northern façade of the zone 2 (Figure 13). These two rooms are not to be modelled, but different heat transmission processes through the Wall 3 are necessary to include into calculations. User shall build up the model with the Wall 3, divided into three parts: one part faces external environment, and two others face the supplementary rooms. Air temperature in the supplementary rooms is given for every 10 minutes and 1 hour time intervals. For example for the test case DSF100_e

conditions 3_3 DSF100_e10.xls - provides average data for every 10 minutes.
conditions 3_2 DSF100_e10.xls- provides average data for every 10 minutes.

conditions 3_3 DSF100_e 60.xls- provides average data for every 1 hour.
conditions 3_2 DSF100_e60.xls- provides average data for every 1 hour.

Wall 3.3 and Wall 3.2 face different zones, the depth of both of these zones is 3 m.

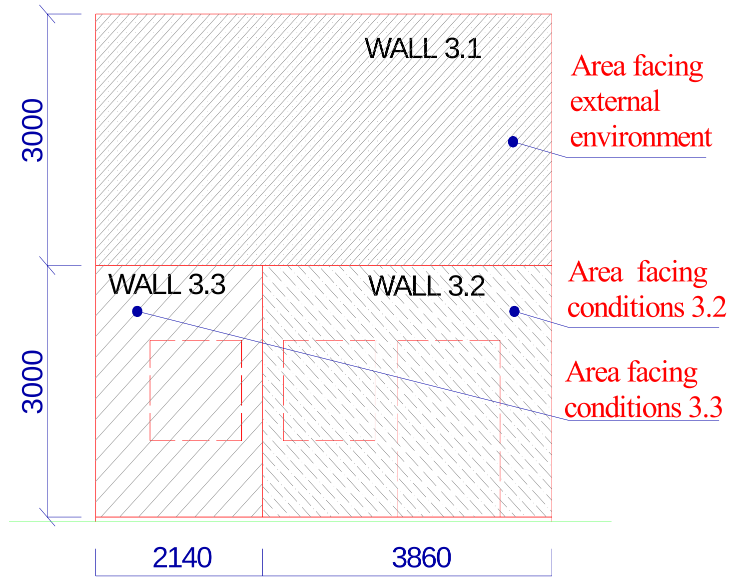


Figure 13. North Façade - left. Partitioning of the Wall 3 (view from the outside)-right.

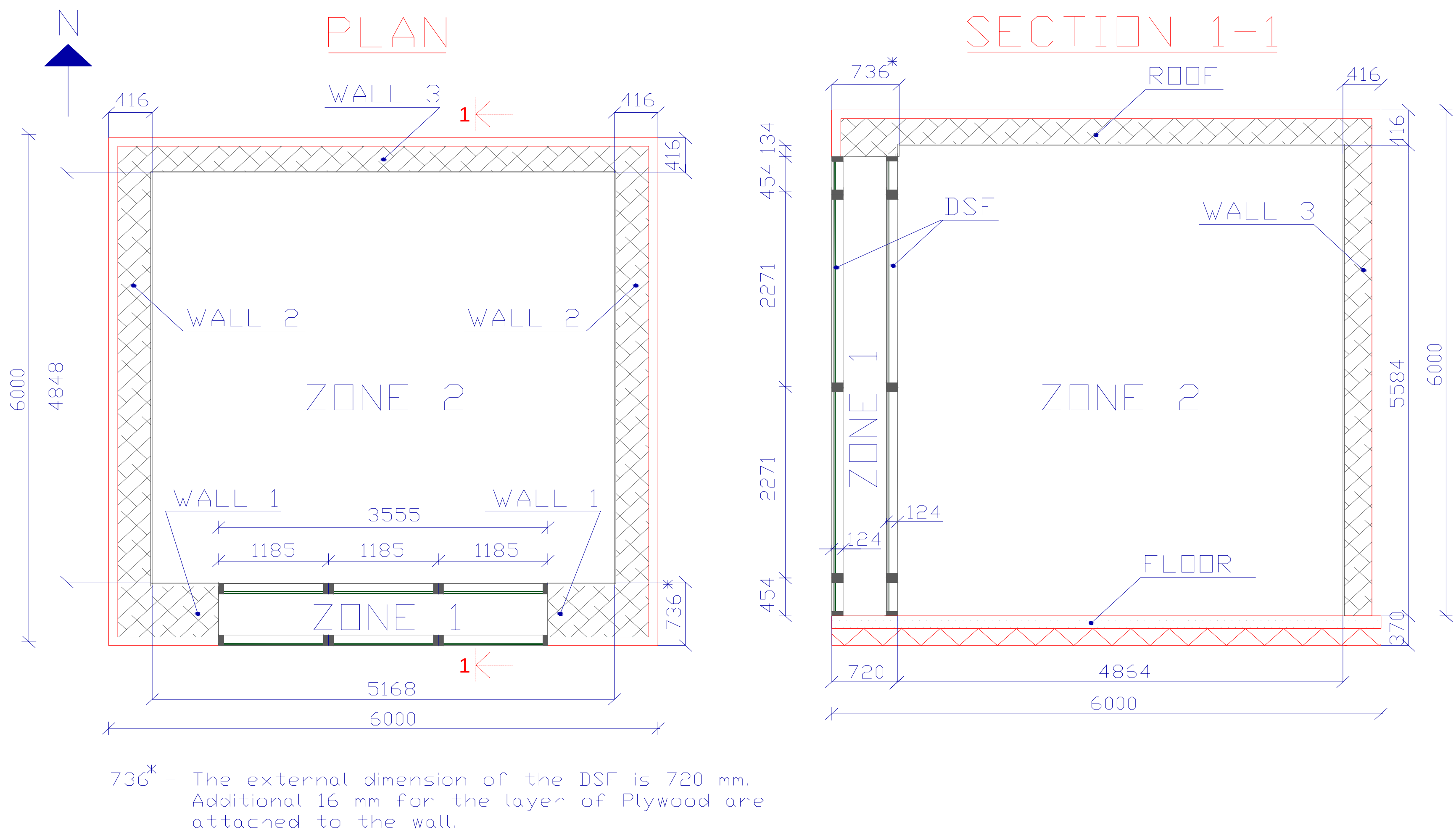


Figure 14. Detailed plan and section of the model.

The prescribed interior volumes are (these dimensions are also specified on the previous figures):

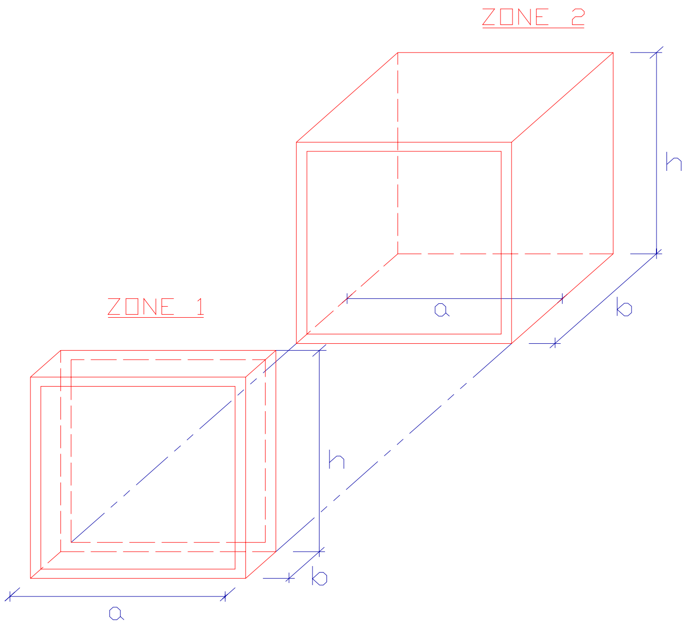


Figure 15. Internal dimensions .

Zone number	*a, mm*	*b, mm*	*h, mm*	*Volume*, m^3*
ZONE 1	3555	580	5450	11.24*
ZONE 2	5168	4959	5584	143.11*

**Volume of Zone 1 and Zone 2 is calculated to the glass surfaces of the windows and NOT to the window frame*

Table 3. Internal dimensions.

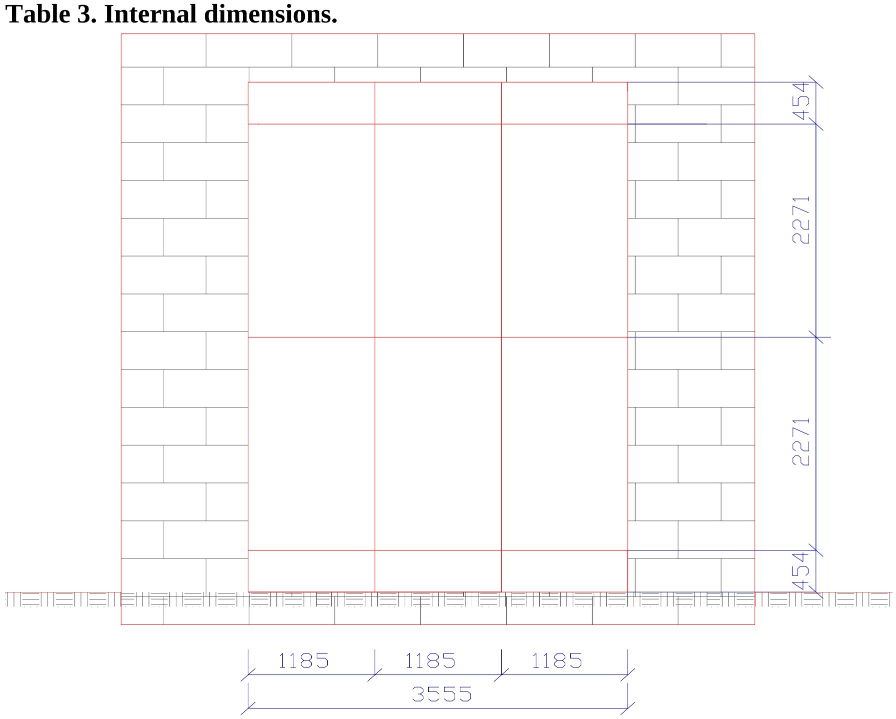


Figure 16. South facade. Dimensions of windows are inclusive frame.

Air temperature in the zone 2 is constant and uniform due to a ventilation system installed in the zone. Thus, in order to avoid temperature gradients, the air was mixed, heated up or cooled down by the system. The recirculation of the air in the zone took place with the air intake at the top of the zone, its' preconditioning in the ventilation system and the exhaust at the bottom of the zone. In order to keep the exhaust velocities as low as possible the air is supplied through the FIBERTEX fabric ke-low impulse channels (Figure 17). The air motion caused by ventilation system resulted in the air velocity of apx. 0.2 m/s. As a consequence of this solution, only a part of the floor surface is exposed to the direct solar radiation. Moreover, air of different temperature than the ambient temperature is supplied to the zone trough the fabric channels, which results in different floor surface temperature underneath of the fabric channels. Finally, the weight of the ventilation system, located in the zone 1 is apx.750 kg, which acts as a thermal mass.

Figure 17. Ventilation recirculation system.

It has been agreed that the modellers will themselves find a solution how to model the floor in the zone 2 and describe it in the report.

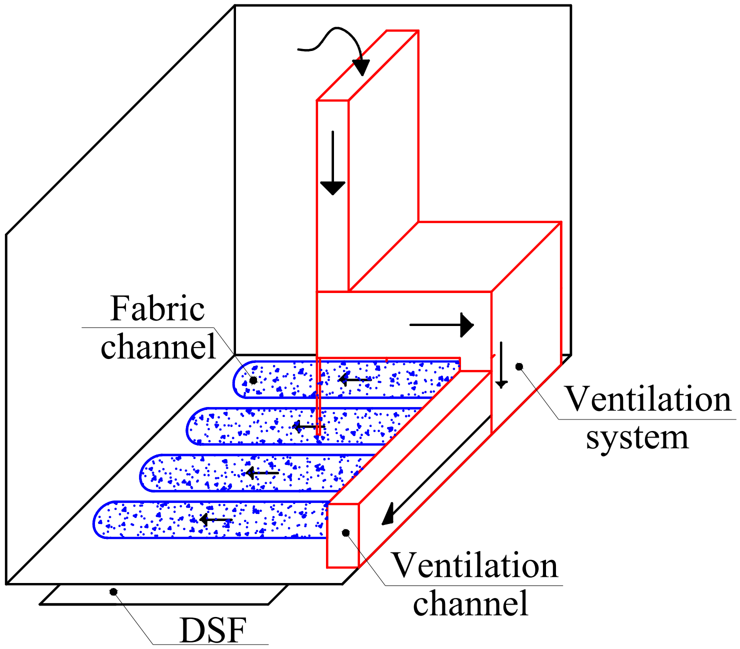


Figure 18. Schema of the ventilation recirculation system in zone 1.

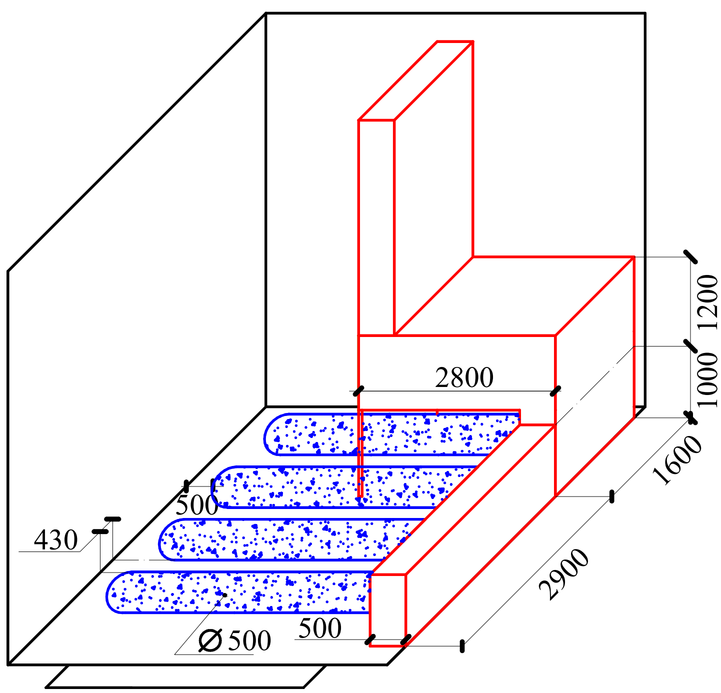


Figure 19. Dimensions of the ventilation system in the zone 1.

6. Windows geometry

It can be recognized six sections of windows V1-V6 (Figure 20), the top and bottom sections of windows are operable and modelled as partly open in the test case DSF200_e.

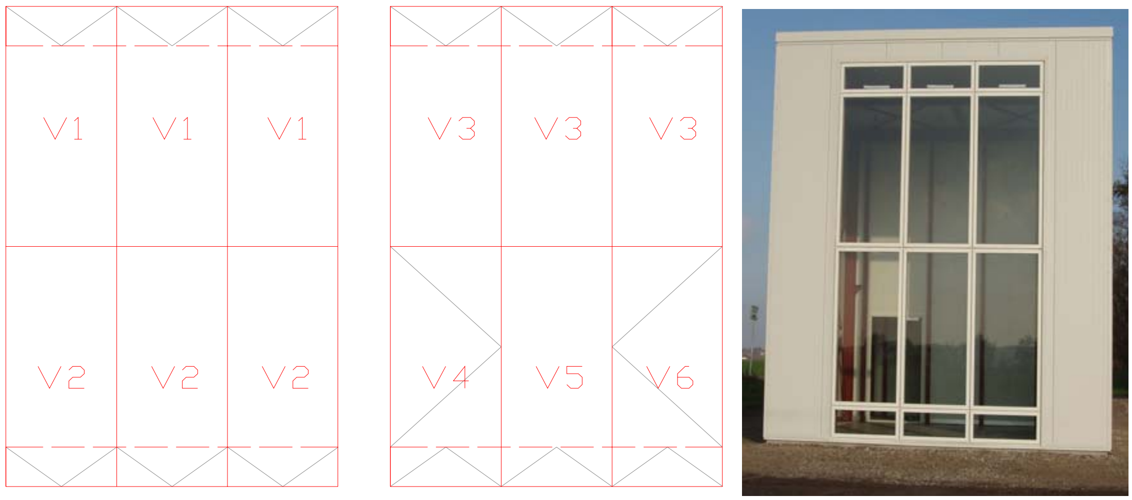


Figure 20. External window sections (left), Internal window section (center), photo of the DSF from the outside (right).

The windows facing external environment are named as external windows and windows facing internal environment - as the internal ones. The dimensions given in Figure 16 are valid both for the internal and external windows. User must pay attention that the window constructions in Figure 20 have different typology, see Table 11.

Dimensions of window sections V1-V6 with the frames are given on the Figure 21; the frame of 54 mm width encloses the glass panes.

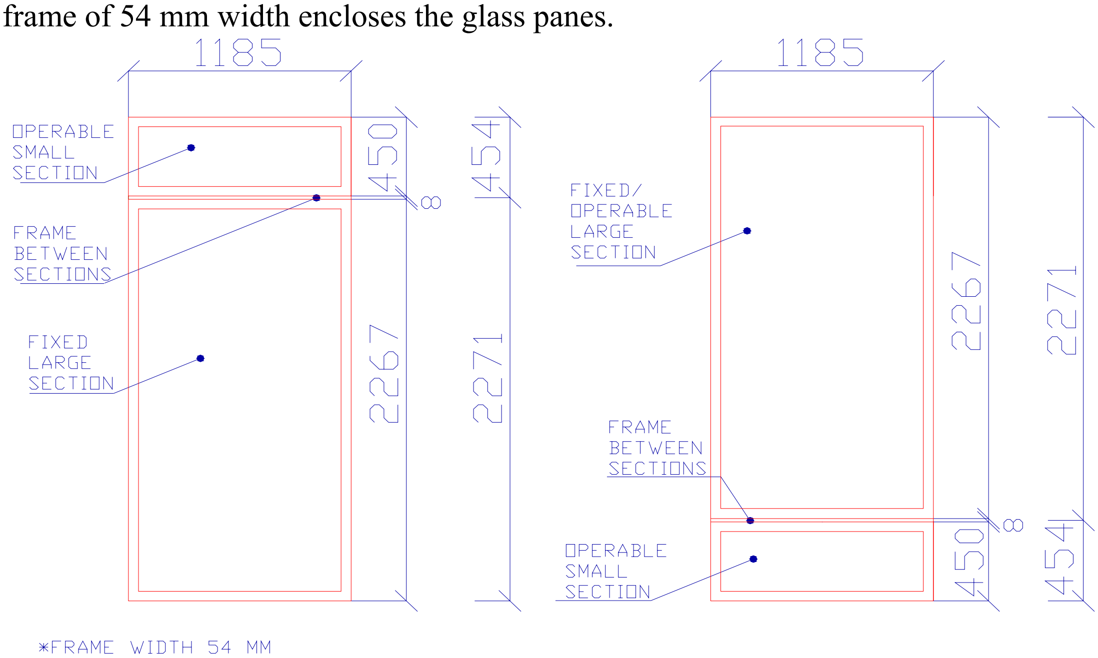


Figure 21. Dimensions of window sections with the operable top-opening (left) and bottom-opening (right).

The following table is combined as a summary for Figure 21:

Window section	*Total area of visible glazing of window (large and small section), m^2*	*Total frame area of window (large and small section), m^2*	*Total area of window (large and small section), m^2*
V1-V6	2.693	0.536	3.229

Table 4. Glazing and frame areas for the window sections.

Detailed dimensions of the windows, including distances between the glass panes, thickness of the glass and cavity-gap are depicted.

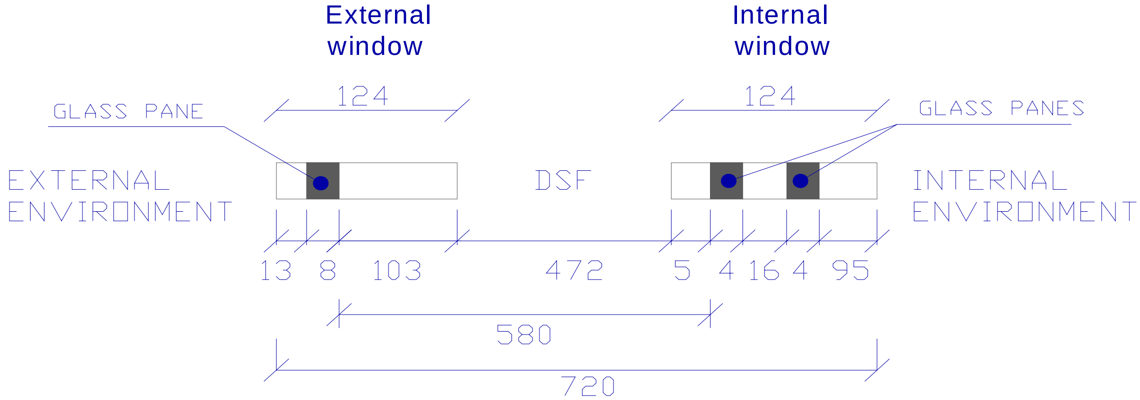


Figure 22. Distances between windows' surfaces in DSF (distances in mm).

As was explained before, the internal and external windows are of different type. The above figure demonstrates that the external window partitions consist of single 8mm-glazing, while the internal windows are double-glazed, filled with 90 %Argon.

In the file *Drawing of window frames.pdf* additional information about the window frames' construction is to be found if necessary. External part of window frame material is Aluminum and the material of the internal one is wood.

6.1. Opening degree

In the empirical test case DSF100_e all openings are closed.

In the empirical test case DSF200_e only the external top and bottom openings are open. The definition of free opening area as well as a drawing of top and bottom windows open is given below.

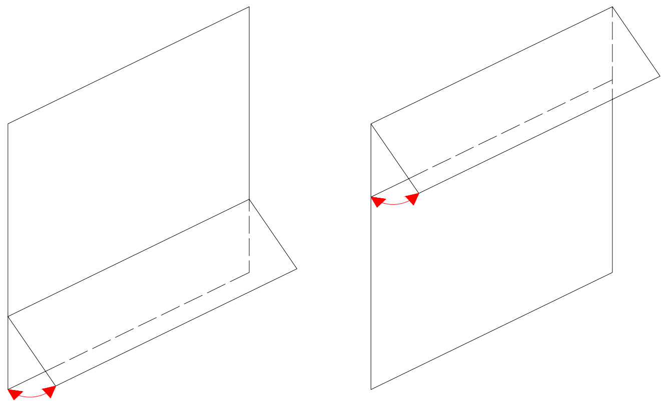


Figure 23. Direction of opening windows. Bottom window (left), top window (right).

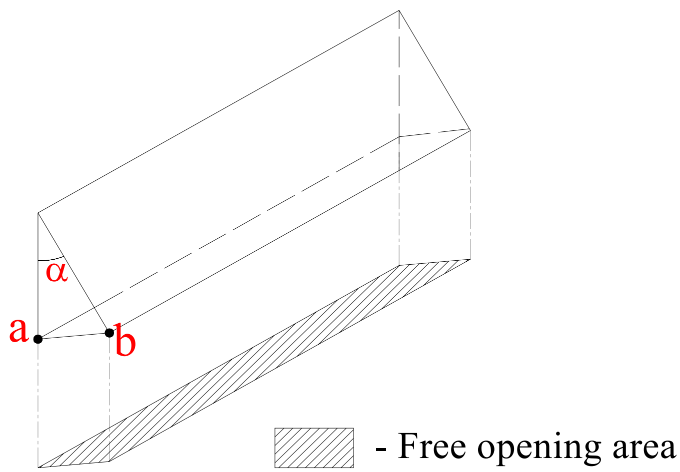


Figure 24. Free opening area.

Following is the free opening areas for the empirical test case DSF200_e.

	Top opening	Bottom opening
Free opening area *of one operable opening*, m^2	0.11	0.13
Distance 'ab', m	0.09	0.110
Angle α, deg	11.5	14

Table 5. Free opening area.

It is expected that this information must be enough to complete the geometrical modelling of the window partitions.

7. Physical properties of the constructions

All constructions in the building are very well insulated. Constructions are subdivided into groups, which are:

- Wall 1- the South façade wall, comprise of external and internal windows
- Wall 2- the East and West façade walls, consist of the same materials.
- Wall 3- facing the North is divided into the three zones, as defined in the chapter 5.Model geometry
- Roof
- Floor

This grouping of the constructions is also depicted in the Figure 14. The material properties are prescribed in the following tables.

The data is given in separate tables for each of previously defined construction. The physical properties of the constructions are prescribed; these are required to keep unchanged.

The first layer in the table always denotes layer facing the internal environment of the model.

7.1. Walls' properties

Wall 1:

Material layer number	*Material*	*Layer thickness, mm*	*Material density, kg/m^3*	*Thermal conductivity, W/mK*	*Specific heat capacity, J/kgK*	*Thermal resistance, m^2K/W*
1	Plywood	16	544	0.115	1213	0.139
2	Rockwool M39	620	32	0.039	711	15.897
3	Isowand Vario	100	142	0.025	500	4

Table 6. Wall 1. Material properties.

Wall 2:

Material layer number	*Material*	*Layer thickness, mm*	*Material density, kg/m^3*	*Thermal conductivity, W/mK*	*Specific heat capacity, J/kgK*	*Thermal resistance, m^2K/W*
1	Plywood	16	544	0.115	1213	0.139
2	Rockwool M39	300	32	0.039	711	7.692
3	Isowand Vario	100	142	0.025	500	4

Table 7. Wall 2. Material properties.

Wall 3:

Material layer number	*Material*	*Layer thickness, mm*	*Material density, kg/m³*	*Thermal conductivity, W/mK*	*Specific heat capacity, J/kgK*	*Thermal resistance, m²K/W*
1	Plywood	16	544	0.115	1213	0.139
2	Rockwool M39	300	32	0.039	711	7.692
3	Isowand Vario	100	142	0.025	500	4

Table 8. Wall 3. Material properties.

Roof:

Material layer number	*Material*	*Layer thickness, mm*	*Material density, kg/m³*	*Thermal conductivity, W/mK*	*Specific heat capacity, J/kgK*	*Thermal resistance, m²K/W*
1	Plywood	16	544	0.115	1213	0.139
2	Rockwool M39	300	32	0.039	711	7.692
3	Isowand Vario	100	142	0.025	500	4

Table 9. Roof. Material properties.

Floor:

According to the DS 418, the ground resistance to the heat transmission is 1.5 m^{2}K/W.

Material layer number	*Material*	*Layer thickness, mm*	*Material density, kg/m³*	*Thermal conductivity, W/mK*	*Specific heat capacity, J/kgK*	*Thermal resistance, m²K/W*
1	Reinforced concrete, levelled and smoothed	150	2400	1.800	1000	0.639
2	Expanded Polystyrene	220	17	0.045	750	4.889

Table 10. Floor. Material properties.

7.2. Windows' properties

Grouping of window partitions and their dimensions were specified in the geometry-part. The physical properties of the windows are prescribed for the same groups.

Window	*U-value of glazing W/m^2K*	*U-value of frame W/m^2K*
V1,V2- External window partition	5.67	3.63
V3-V6 Internal window partition*	1.12	3.63

** U-values are given for standard conditions, using external-internal surface film coefficients and NOT internal-internal surface film coefficients.*

Table 11. Windows. U-value.

7.3. Glazing

Windows V1-V6 consist of glazing, which has been tested and spectral properties are available for every sample. Samples are defined in the table:

Window	*Sample number*	
	Glass layer facing outside	*Glass layer facing inside*
External window sections V1, V2	Clear glass ***Sample 1***	
Internal window sections V3- V6, filled with Argon, 90 %	Clear glass ***Sample 2.1***	Glass with the coating attached to the front* surface. ***Sample 2.2***

**The definition of front and back is given below*

Table 12. Definition of samples for the glazing spectral data.

Front side always turned towards exterior, while back is turned towards the interior (zone 2).

The data from the spectral analyses for every sample is enclosed in file:
Glazing spectral data.xls

It includes following data in the wave length interval 250-2500 [nm]:

- Transmittance
- Reflectance (back and front)

The emissivity of the glass surfaces is following,

Window	*Sample*	*Front*	*Back*
External window sections V1, V2	Sample 1	0.84	
Internal window sections V3- V6, filled with Argon, 90 %	Sample 2.1	0.84	
	Sample 2.2	0.037	0.84

Table 13. Emissvity of glazing.

In case if the spectral data is inapplicable for the software tool, then the following data can be used:

Incident angle	External window pane			Internal window pane			
	Transmission of external window	Reflection of external window	g-value of external window	Transmission of internal window	Reflection of internal window FRONT	Reflection of internal window BACK	g-value of internal window
0	0.763	0.076	0.8	0.532	0.252	0.237	0.632
10	0.763	0.076		0.531	0.252	0.237	0.632
20	0.76	0.076		0.529	0.251	0.237	0.631
30	0.753	0.078		0.524	0.252	0.239	0.627
40	0.741	0.084		0.513	0.258	0.245	0.618
50	0.716	0.103		0.488	0.277	0.264	0.595
60	0.663	0.149		0.435	0.326	0.309	0.542
70	0.55	0.259		0.331	0.436	0.405	0.433
80	0.323	0.497		0.163	0.638	0.579	0.244
90	0	1		0	1	1	0

Table 14. Glazing properties according to spectral properties processed using WIS software.

7.4. Surface finishes

A carpet of known reflectance property was placed in front of the test facility in order to estimate solar radiation reflected from the ground. Spectral data of the carpet is given in the file:

Ground carpet spectral data.xls

If spectral data for ground reflectance can not be used by the software tool being tested then use ground reflectance 10%, this has to be documented in the report.

Ceiling and wall surface finishing in Zone 1 and in Zone 2 were tested as well and the spectral data can be found in the following files:

Surface finish_zone1_ zone2_spectral data.xls

If spectral data for surface reflectance can not be used by the software tool being tested then use surface reflectance, as following and note it I the report:

67% - for zone 2
65% - for zone 1

Properties of the floor surface in both of the zones and of the external surfaces can be assumed the same as for walls in zone 1.

Longwave emissivity	0.88
Surface roughness, mm	0.03

Table 15. Surface finish properties.

8. Other parameters and specifications

8.1. Infiltration

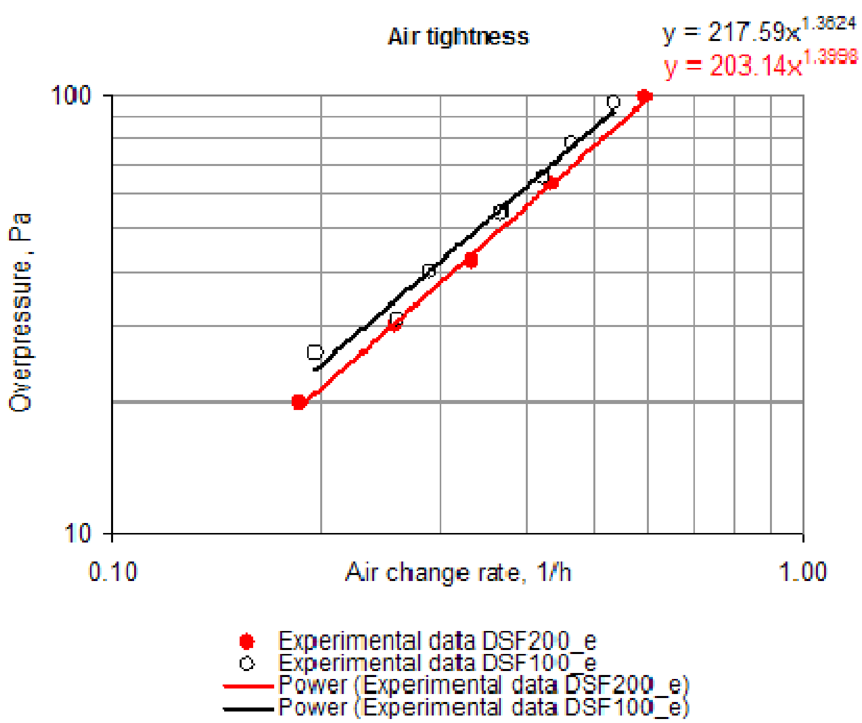
The overall tightness of the test facility measured with the blower door test in overpressure mode, with the assumption that the overpressure mode is equivalent to the underpressure mode.

Test case DSF100_e

The outer skin of the DSF kept closed during the blower door test. Results of the testing are given on the following figure and have to be included into the test case simulation (Figure 25. Overall air tightness characteristic of the "Cube" for the test case DSF100_e and DSF200_e.Figure 25).

Test case DSF200_e

The outer skin of the DSF kept open during the blower door test. Results of the testing are given on the following figure and have to be included into the test case simulation.



** Air change rate is calculated in correspondence with the dimensions of zone 2*

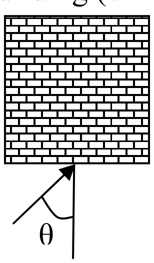
Figure 25. Overall air tightness characteristic of the "Cube" for the test case DSF100_e and DSF200_e.

8.2. Discharge coefficient

Each opening defined with two discharge coefficients. Discharge coefficient is set to 0.65 when opening is functioning as the supply opening. Another value of the discharge coefficient must be used if the air moves from inside towards the outside (opening is functioning as the exhaust opening), the discharge coefficient is set to 0.72.

8.3. Wind pressure coefficients

Wind pressure coefficients correspond to the wind velocity at the height of the roof of the building (6 m).



θ – wind angle

Location	*Wind angle*									
	0°	*45°*	**65°*	*90°*	*135°*	*180°*	*225°*	*270°*	**295°*	*315°*
Top openings	0.58	0.22	-0.2	-0.71	-0.5	-0.36	-0.5	-0.71	-0.2	0.22
Bottom openings	0.61	0.33	-0.06	-0.55	-0.5	-0.35	-0.5	-0.55	-0.06	0.33

***** *Interpolated data*

Table 16. Wind pressure coefficients [Ref. 2].

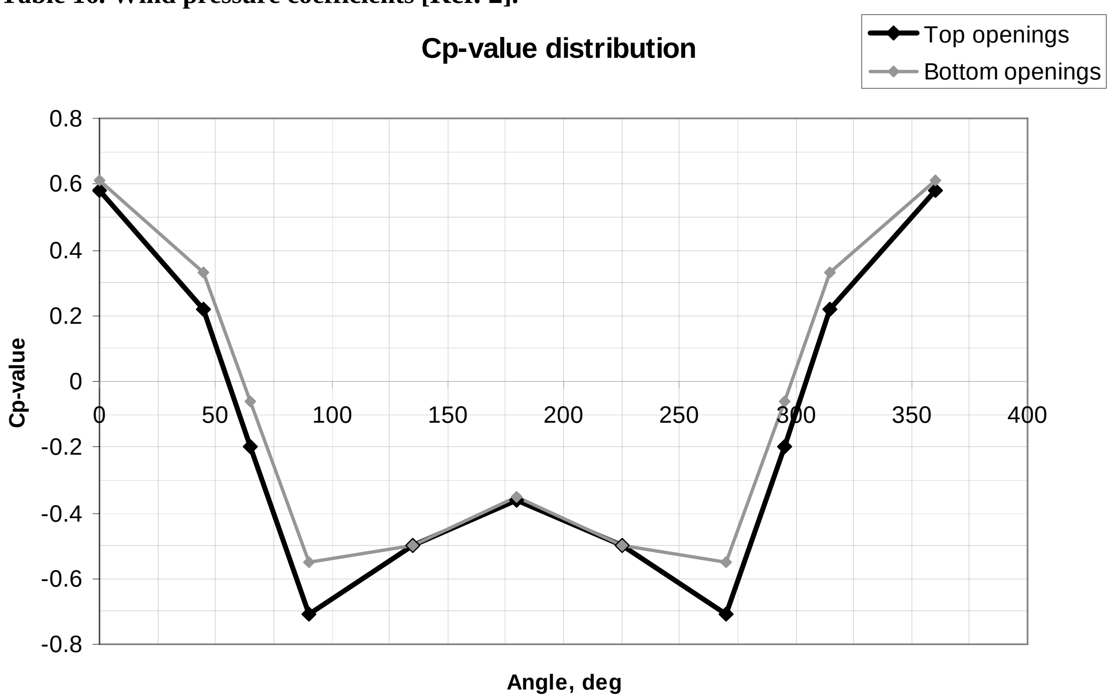


Figure 26. Distribution of wind pressure coefficients.

If the testing software tool does not allow manual definition of the wind pressure coefficients and values different from the above were used in the model, than the modeller report has to include detailed information about the values used.

8.4. Wind speed profile

Wind velocity profile is described by logarithmic low according to conducted measurements of horizontal velocity profile.

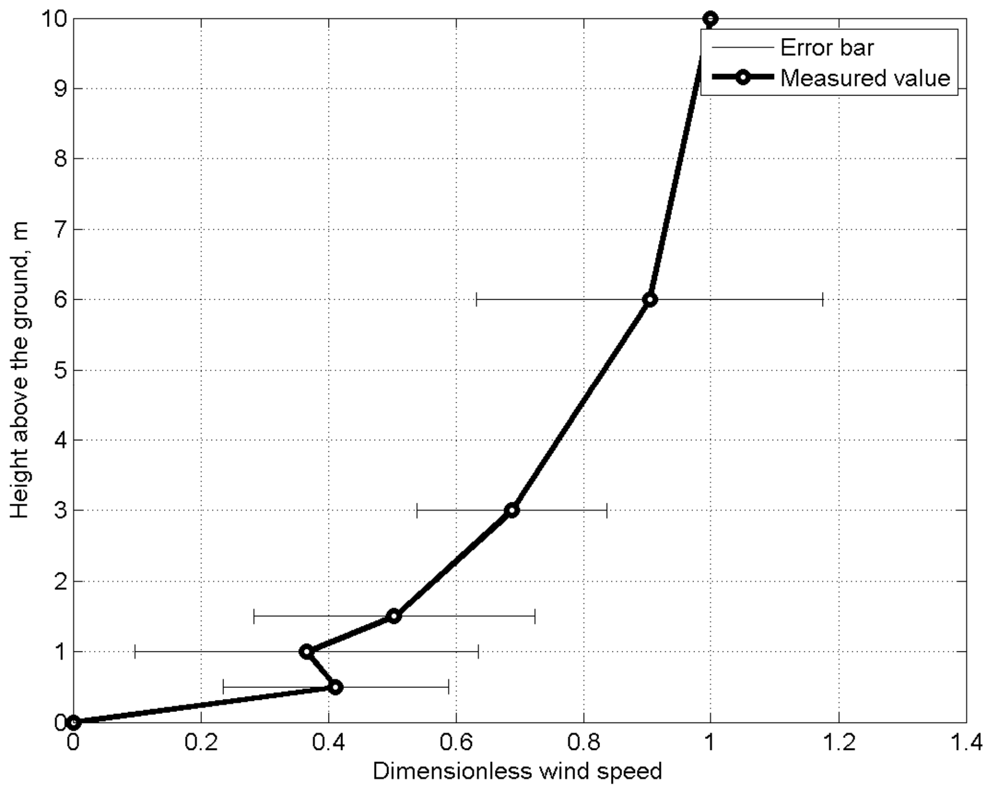


Figure 27. Dimensionless wind velocity profile at the measuring site.

General expression for the logarithmical wind velocity profile (**Ref. 3**)

$$V(h) = \frac{V_*}{K} \ln\left(\frac{h}{h_o}\right)$$

V(h) – wind speed at height h
h – height above the ground
V_* – friction velocity
K – von Karman's constant
h_o – roughness height

Constants for the wind velocity profile at the measuring site are defined for the wind velocity provided in the weather data files.

Von Karman's constant is approximately 0.4.
Roughness height is 0.31
Friction velocity is the transient parameter and can be calculated from the experimental data as following:

$$V(h_{10}) = \frac{V_*}{0.4} \ln\left(\frac{h_{10}}{0.31}\right)$$

$$V_* = \frac{V(h_{10}) \cdot 0.4}{\ln\left(\frac{h_{10}}{0.31}\right)}$$

$V(h_{10})$ – wind speed at height 10 m
0.4 – von Karman's constant
h_{10} – 10 m height above the ground
0.31 – roughness height

8.5. Thermal bridges

The calculation of heat transmission through thermal bridges has to be included into the test cases.

Values for the overall heat transmission from the zones are given based on measurement results from calibration study on the test facility (**Ref. 5**), these are compared against the heat losses calculated manually, using the U-values and dimensions of the constructions in the "Cube", see Figure 28.

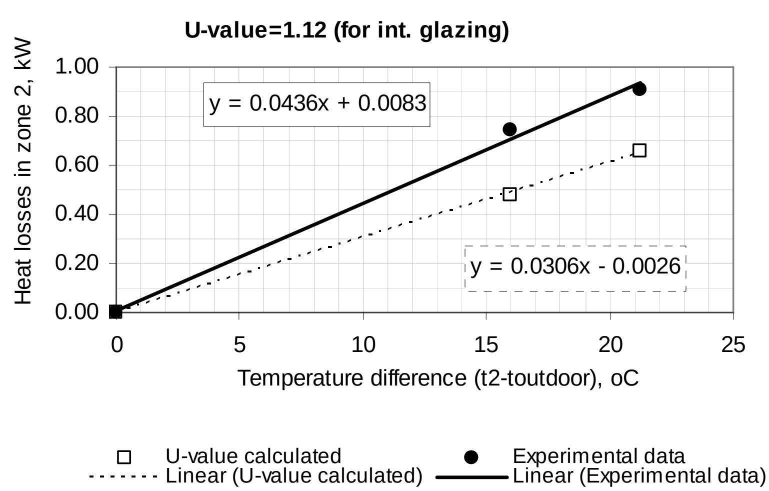


Figure 28. Heat transmission losses in the "Cube"

8.6. Driving force

In the test case DSF200_e thermal buoyancy is combined with the wind influence and has transient character.

8.7. Mixing in zone 2

Air in the zone 2 has been continuously mixed during the experiments.

8.8. Air temperature in zone 2

The air temperature in zone 2 is regarded to be uniform, with a fixed value of 21.8 ^{o}C. In order to keep this temperature constant a control of cooling/heating system has to be included, as explained below.

8.9. Systems in zone 2

The zone 2 is provided with a mechanical heating/cooling system to provide constant zone air temperature. The energy has to be delivered to the zone air only by means of convection. The controlling sensor has to be located in the same zone. The schedule of the systems has to be *always,* during the simulation. System efficiency set to 100%. Do not use Heat Recovery.

8.10. Operable openings control

There is no control of the openings. Area of the open openings is constant for the whole test case.

8.11. Distribution of solar radiation in a zone

Whether the software being tested allows the solar incidence to be distributed geometrically correct to surfaces (detailed analyses of the path of direct solar radiation through a building, thus calculating shadowing by constructions, etc.) then this option has to be used. When this is not possible, use the most accurate, physically correct option, able to handle solar radiation heat transmission. Approach for calculation of distribution of transmitted solar radiation to the surfaces has to be documented in the report.

8.12. Longwave radiation with external

If the software being tested allows the calculation of the longwave radiation exchange with the exterior, use this function, else note it in the report.

8.13. Longwave radiation with internal

If the software being tested allows the calculation of the longwave radiation exchange with the interior, use this function, and note in the report the approach that has been used.

8.14. Surface heat transfer coefficients

The computations of surface heat transfer coefficients for the empirical test cases are not prescribed. Every software tool should be able to present the best possible results of simulations.

It is required to notify the techniques for computations of surface heat transfer coefficients in the report.

8.15. Shading

No shading device defined for the empirical test cases.

8.16. Moisture transport

There is no moisture transport included into the simulations

9. Modeller report

This section includes the requirements to the contents and outline of the final modeller report, discussed and agreed on during the breakout session on March, 26 in Colorado. The earlier requirements mentioned in the text of the specification are also summarized.

Besides completing the modeller report participants are asked to fill in a questionnaire about the model and modelling approaches *for the test case DSF200_e*:

E_questionnaire_XXX.doc

XXX - name of the organization
E - corresponds to *Empirical* test cases

As a general requirement the user is asked to notify whether and where differences exist between test case specification and the model. This includes:

- Disregarded parameters in specification
- Modification of parameters in specification
- Application of parameters not included in specification

The level of detail in the modeller report must allow anyone, using the same simulation tool, to repeat the model described in the report and achieve the same results.

The scope of this subtask is to perform a validation of the building simulation software for buildings with the double skin façade. As explained in the literature review (**Ref. 4**), the physics of the double skin façade involves complex processes and therefore require detailed calculations of optics, flow regime, convection, natural air flow etc. Often, the building simulation software is not able to perform such detailed level of computations. When the detailed computations are not possible, then the simplified models used as an alternative, as a result it is not always possible to validate the advance physical processes and this is not the objective. The building simulations must be validated on their performance *together with their limitations.*

Although the validation of models for transmission of solar radiation, naturally driven flow, etc. is carried out by the other subtasks, the complexity of the DSF physics results in difficulties for some of the simplified natural air flow models to predict accurately the airflow in the DSF cavity. In fact, results of the comparative test cases from the few rounds of simulations have shown large disagreements in the modelling of air flow rate in the DSF cavity. Therefore the prediction and validation of the natural air flow in the DSF cavity have to be considered as a criterion and also as an objective for validation of building simulation tools for modelling DSF.

On account of importance of the air flow model used when modelling the test cases, participants are asked to include *detailed* description of the airflow model used.

Following is the summary of additionally requested information for the modeller report. However it requires less detailed description than the air flow model does. All modellers are asked to:

- Notify what is the solar model used for simulations
- Describe the main assumptions used for calculation of transmitted and distributed solar radiation to the surfaces in the model (area weighted distribution of solar radiation or distribution according to the view factors; are there any differences when calculate transmitted direct or transmitted diffuse solar radiation?)
- Report on modelling windows (Is the glazing and frame modelled separate?)
- Include into the report the parameters about the glazing optical properties used for the modelling, especially if ones have been calculated on the basis of IGDB number. This information must be attached to the report as a separate Excel-file
- Notify the principle for calculation of the glazing temperature
- Explain assumptions (if there are any) for modelling the cavity air temperature: is there any temperature gradient, how is the temperature gradient defined?
- Describe what are the heat transfer coefficients used in the model, what is the background for calculation of convection heat transfer
- Describe the how is the floor in the zone 2 is modelled

In the separate sections of the empirical test case specification the modellers are asked to report on several matters, depending on the design of their model compared to the specification. These requests are summarized below:

The user is asked to notify whether and where differences with the empirical test case specification exist. It is necessary to include the documentation of changes into the report.

The modifications to specification are undesired, but still might be necessary, must be included into the report.

When the parameter given in the specification is inapplicable for the modelling the user may disregard it and continue the modelling. The notification in modeller report is needed.

If the information about ground temperature, air temperature in the neighboring zones, spectral data can not be used in the software tool being tested, then note it in the report.

If the testing software tool does not allow manual definition of the wind pressure coefficients and values provided in the specification are different from the ones fixed within the code, then the modeller report has to include detailed information about the values used.

It is required to notify the techniques for computations of the surface heat transfer coefficients in the report.

It is requested to report on the glazing properties used/calculated in the model.

The report has to include the notation for the approach used for calculation of transmitted direct and diffuse solar radiation.

If the software being tested allows the calculation of the longwave radiation exchange with the exterior, use this function, else note it in the report.

If the software being tested allows the calculation of the longwave radiation exchange with the interior, use this function, and note in the report the approach that has been used.

10. Output results

One of the main requirements for the modelling procedure is consistency: user is asked to use the same applications for the same parameters in every model and use the most detailed level of modelling allowed by simulation program being tested. Besides, user is asked to follow carefully the test case specification definitions. However this is not always possible and modelling report has to include documentation of all discrepancies between model and test case specification. Moreover, report has to include documentation of main principles for calculation of essential processes and any other factors which user might find important.

The list of the output results is specified for every test case separately. It is expected that the output results are compared to the experimental results and/or between the task participants. However, the first simulation of the empirical test case is blind (participants will receive empirical results only when submitted their results of modelling).

The template file for the output results is delivered in a separate file for each test case. For example for test case DSF100_e:

Output results DSF100_e60.xls - file for the output results for the comparative test case DSF100_e with 1 hour average data.

10.1. Output parameters for the test case DSF100_2

N	*Output*	*Unit*	*Description*
1	Direct solar irradiation on the window surface	W/m^2	Mean hourly value
2	Diffuse solar irradiation on the window surface	W/m^2	Mean hourly value
3	Total solar irradiation on the window surface	W/m^2	Mean hourly value
4	Total solar radiation received on the external window glass surface	kW	Mean hourly value
5	Solar radiation transmitted from the outside into zone 1	kW	Mean hourly value
6	Solar radiation transmitted from zone1 into zone2 (first order of solar transmission)	kW	Mean hourly value
7	Power used for cooling/heating in the zone 2	kW	Mean hourly value (with the '+'sign for heating and '-'sign for cooling)
8	Hour ave glass pane, raged surface temperature of external window surface facing external	^oC	Mean hourly value
9	Hour averaged surface temperature of external window glass pane, surface facing zone1	^oC	Mean hourly values
10	Hour averaged surface temperature of internal window glass pane, surface facing zone1,	^oC	Mean hourly value
11	Hour averaged surface temperature of internal window glass pane, surface facing zone2	^oC	Mean hourly value
12	Hour averaged floor surface temperature in the zone 1	^oC	Mean hourly value
13	Hour averaged ceiling surface temperature in the zone 1	^oC	Mean hourly value
14	Hour averaged floor surface temperature in the zone 2	^oC	Mean hourly value
15	Hour averaged ceiling surface temperature in the zone 2	^oC	Mean hourly value
16	Hour averaged air volume weighted temperature in the zone 1	^oC	Mean hourly value
17	Solar altitude angle	deg	In the middle of the hourly interval

Table 17. Required output parameters for the test case DSF100_2.

Depending on the software tool used for modelling and its accuracy the minimum required outputs defined in the above table. Besides that, a modeller is asked to report on the additional outputs, if this is possible:

- Solar radiation absorbed in the opaque surfaces in zone 1 and zone 2 (mean hourly values)
- Convective/ radiative heat fluxes at the glass surfaces (mean hourly values)
- Anyone using CFD, please provide vector plots together with the data sheets
- Report the air temperature in zone 1, as an air temperature for each stacked sub-zone. This must be reported in a separate Excel-file of free format

10.2. Output parameters for the test case DSF200_e

N	*Output*	*Unit*	*Description*
1	Direct solar irradiation on the window surface	W/m^2	Mean hourly value
2	Diffuse solar irradiation on the window surface	W/m^2	Mean hourly value
3	Total solar irradiation on the window surface	W/m^2	Mean hourly value
4	Total solar radiation received on the external window glass surface	kW	Mean hourly value
5	Solar radiation transmitted from the outside into zone 1	kW	Mean hourly value
6	Solar radiation transmitted from zone 1 into zone2 (first order of solar transmission)	kW	Mean hourly value
7	Power used for cooling/heating in the zone 2	kW	Mean hourly value (with the '+'sign for heating and '-'sign for cooling)
8	Hour averaged surface temperature of external window glass pane, surface facing external	^oC	Mean hourly value
9	Hour averaged surface temperature of external window glass pane, surface facing zone1	^oC	Mean hourly value
10	Hour averaged surface temperature of internal window glass pane, surface facing zone1,	^oC	Mean hourly value
11	Hour averaged surface temperature of internal window glass pane, surface facing zone2	^oC	Mean hourly value
12	Hour averaged floor surface temperature in the zone 1	^oC	Mean hourly value
13	Hour averaged ceiling surface temperature in the zone 1	^oC	Mean hourly value
14	Hour averaged floor surface temperature in the zone 2	^oC	Mean hourly value
15	Hour averaged ceiling surface temperature in the zone 2	^oC	Mean hourly value
16	Hour averaged volume weighted air temperature in the zone 1	^oC	Mean hourly value
17	Mass flow rate in the zone 1	kg/h	Mean hourly value, including the sign convention: '+'sign for the upwards flow and '-'sign for the downwards flow

Table 18. Required output parameters for the test case DSF200_e

Depending on the software tool used for modelling and its accuracy the minimum required outputs defined in the above table. Besides that a modeller is asked to report on additional outputs, if this is possible:

- Solar radiation absorbed in the opaque surfaces in zone 1 and zone 2 (mean hourly values)
- Convective/ radiative heat fluxes at the glass surfaces (mean hourly values)
- Report the air temperature in zone 1, as an air temperature for each stacked sub-zone. This must be reported in a separate Excel-file of free format
- Anyone using CFD, please provide vector plots together with the data sheets

11. References

Ref. 1. Kalyanova O., Heiselberg P. (2005). Comparative Test Case Specification – Test Cases DSF100_2 and DSF400_3: Report for IEA ECBCS Annex 43/SHC Task 34 Validation of Building Energy Simulation Tools / Aalborg : Instituttet for Bygningsteknik, Aalborg Universitet.

Ref. 2. Straw M.P. (2000). Computation and Measurement of Wind Induced Ventilation: PhD thesis/ Nottingham University

Ref. 3. Allard F. (1998) Natural Ventilation in Buildings. A Design Handbook/James&James (Science Publishers) Ltd/ MPG Books Limited

Ref. 4. Poirazis H. (2006). "Double Skin Facades for Office Buildings - Literature Review Report" (9.86MB). Division of Energy and Building Design, Department of Construction and Architecture, Lund Institute of Technology, Lund University, Report EBD-R—04

Ref. 5 Kalyanova O. (2007). Experimental set-up and full-scale measurements in 'the Cube'. Aalborg:Aalborg University: Department of Civil Engineering. ISSN 1901-726X DCE Technical Report No.034.

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