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Description of Benchmark Cases for Window and Shading Performance Calculation

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Introduction

In the following document so-called benchmark cases for glazing and shading device configurations are described. Spectral input data for these cases are provided. Benchmark testing is used to establish a certain performance of a system. For calculations of window and facade properties this might serve several intentions:

- physical correctness of calculations
- speed / practicality of calculations
- correct use of calculations by the user
- correct implementation of algorithms in a computer program

The first item refers to physically correct algorithms, boundary conditions and input data. It is not within the scope of this network project nor is it the intention to compare benchmark cases calculated with monitored and tested values of real systems. However, the benchmark cases can be used to compare different algorithms, e.g. EN standards with other extended algorithms. This is probably the central use of the benchmark cases in this project. The cases as such, however, allow no decision which methodology gives the better approximation to physics and to the real use in buildings.

The second item is probably not a very important one. However, benchmark cases can be used in order to check e.g. whether a raytracing routine for shading devices on nowadays computers can be used with a program like WIS. Also, it can be checked, whether sufficient input data from experimental measurements are available or possible (practical to measure?).

The third item is a central use of the cases outside this project: The benchmarking should provide users of a calculation program with confidence into the correctness of his or her results. However, benchmark cases can be used in order to help a user of the tool to use it, to identify possible misunderstandings and to correctly transform a real problem into a calculation case. The most obvious problems users might have with window calculation programs may be input errors or missing input, just leaving some default values. Interchanging of interior and exterior sides, coated and uncoated faces are possible problems. In order to provide confidence for a wide range of practical applications, benchmark cases as a total set of configurations shall represent all typical cases encountered in practice to some extent, emphasizing however in each single case some special feature or complexity of the calculation.

Coming to the fourth item, it is probably not the main intention to check the correctness of implementations of calculation algorithms. Certainly when using an incorrectly working tool also benchmark cases are likely to produce wrong answers and can give some hints with respect to the problems encountered. On the other hand, good results for benchmark cases can not guarantee that the tool is working as it should. Therefore correct performance of a tool has to be investigated by other techniques as well.

The following cases are a suggestion from the Windat group which hopefully prove to be used widely in future.

1 Description of benchmark cases

The following configurations have been defined in a common action of the members of the Windat working group WP3 subgroub SG1 Benchmark calculation in order to have a limited number of glazing and shading configurations, which have different properties in order to cover the range of typical glazings and shading devices used.

For these configurations a number of spectral input data are needed. These data have been collected and are distributed in a Excel worksheet called **>>windat-wp3-ise-benchmark_input.xls<<.**

The following glass input data sets are distributed:

Glass	Acronym	description	Source *)
#1	Clear B2	3.90mm Float glass	TC10
#2	LowE	5.93mm low-e coated glass normal emittance 0.08	TC10
#3	Solar	5.93mm solar control glass normal emittance 0.033	TC10
#4	Abs	3.87mm absorbing glass	TC10
#5	Soft4	4.00mm low-e silver-based coated glass, normal emittance 0.03	EMPA
#6	Soft6	6.00mm low-e silver-based coated glass, normal emittance 0.03	EMPA
#7	Hard4	4.00 mm low-e pyroliticly coated glass, normal emittance 0.16	EMPA

#8	Clear6	6.0 mm Float Glass	UniSevilla
#9	Clear4 (#9)	4.0 mm Float Glass	IEA T27
#10	Clear8	8.0 mm Float Glass	IEA T27
#11	Low-E Soft	4.0 mm low-e coated glass normal emittance 0.08	IEA T27
#12	Solar Green	6.0mm Greenish solar control glass normal emittance 0.89	IEA T27
#13	Solar Soft	4.0mm low-e coated solar control normal emittance 0.03	ALTSET
#14	PVB	Internal transmittance of PVB film	UniSevilla

*) TC10: Jean Roucourt
EMPA: Thomas Nussbaumer
UniSevilla: Jose Molina
IEA T27: Dick van Dijk
ALTSET: Werner Platzer

1.1 Glazings

Some of these glazings have very similar properties. It makes little sense to use all of them for a benchmark comparison. Also it has been taken into account that some of these glazings have been used already in simulations for double-envelope facades. A side-effect of the benchmark calculations should be to have certifying information for the double-envelope exercise on the glazing details.

Thus a certain selection of glazing configurations are proposed for these calculations. The glass configurations are listed starting with outside and last inside.

- DGU float
  4.00 mm Clear4 (#9)
  12 mm Air
  4.00 mm Clear4 (#9)
- DGU heat mirror (coating pos. 3)
  4.00 mm Clear4 (#9)
  12mm Argon
  6.00 mm LowE Soft (#11)
- DGU solar control 1(coating pos. 2)
  5.93 mm Solar (#3)

15mm 40%Argon+60%Krypton
4.00 mm Clear4 (#9)

- DGU solar control 2(coating pos. 2)
  4.00 mm Solar Soft (#13)
  15mm 40%Argon+60%Krypton
  4.00 mm Clear4 (#9)
- DGU absorbing
  3.87mm Abs (#4)
  12mm Air
  3.87mm Abs (#4)
- TGU low U (coating pos. 3 and 5)
  4.00 mm Clear4 (#9)
  12mm Krypton
  4.00 mm LowE Soft (#11)
  12mm Krypton
  4.00 mm LowE Soft (#11)
- TGU exterior low-e (coatings pos 1, 3 and 5)
  4.00mm Hard4 (#7)
  12mm 90% Krypton, 10% Air
  5.93 mm Solar (#3)
  12mm 90% Krypton, 10% Air
  5.93 mm Solar (#3)
- TGU interior low-e (coatings pos 2,4,6)
  5.93 mm Solar (#3)
  12mm 90% Krypton, 10% Air
  5.93 mm Solar (#3)
  12mm 90% Krypton, 10% Air
  4.00mm Hard4 (#7)
- DGU Compound
  4.0 mm Clear4 (#9)
  0.8 mm PVB (#14)
  4.0 mm Clear4 (#9)
  15mm Argon
  6.0mm LowE Soft (#11)

  NB: Pay attention to the fact that the reflection changes at the interface Clear glass to PVB

These 9 glazing unit cases are called GLAZU1 to GLAZU9.

DGU	double glazed unit
TGU	triple glazed unit

1.2 Shading devices

The definition of the shading systems is based on real systems which have been selected within IEA Task 27 Subtask A for a case study on calculation of shading systems. The optical spectral data are also provided for the lamellae. It has to be noted however, that within the Task27 other optical data for the glazings in combination with the shading devices have been used. Within IEA experimental data for solar calorimetric testing could be given for certain input angle and tilt angle combinations. However, in our case this is not necessary. In order to minimize the amount of input data we use the glazings defined above in combination with the shading devices.Therefore there may be slightly different result values. However, the general overall behaviour of the shading devices should be similar.

1.2.1 Exterior blind system (SHADE1)

An exterior blind system has been investigated. The lamellae is a dark (brown) lamellae (Warema, C80A6, Colour W7329) of the following shape:

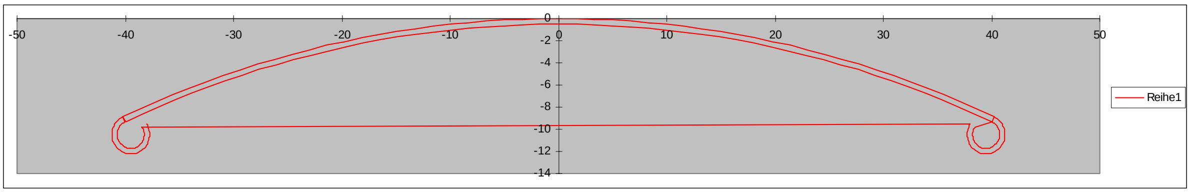

Figure 1: Sketch of single lamella sheet tilted horizontal (ignore single red line)
NB: The dimensions are given in Millimeter (mm)

The lamella and the system have the following specifications:

Sheet thickness	0.5	mm
lamella width	80	mm
lamella length	1000	mm
curvature radius	95	mm
lamellae distance vertical	72	mm
Pivot	center of lamella	
distance of pivot to exterior glazing	70	mm
side fixation	none	
top mounting	vented	
bottom mounting	vented	

Optical properties upper surface	Visual	Solar
Total reflectance ρ_{nh} (8°)	0.107	0.128
Diffuse reflectance ρ_{dh} (8°)	0.065	0.084
Optical properties lower surface		

Total reflectance ρ_{nh} (8°)	0.107	0.128
Diffuse reflectance ρ_{dh} (8°)	0.065	0.084

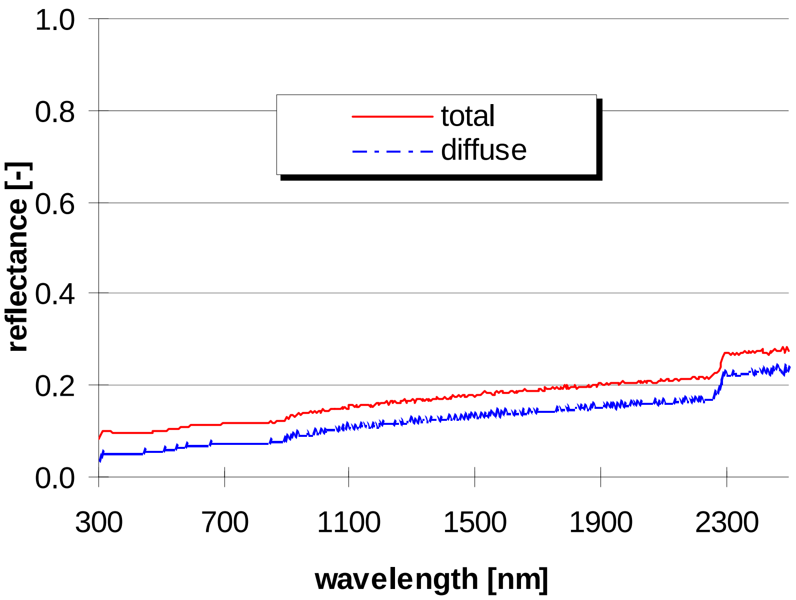

Figure 2: Spectral reflectance curves for brown lamella

1.2.2 Interior blind system (SHADE 2)

An interior blind system is being decribed in the next paragraph. The system consists of light grey lamellae (Warema Jal-1.25.01, Colour 3050) of the following shape:

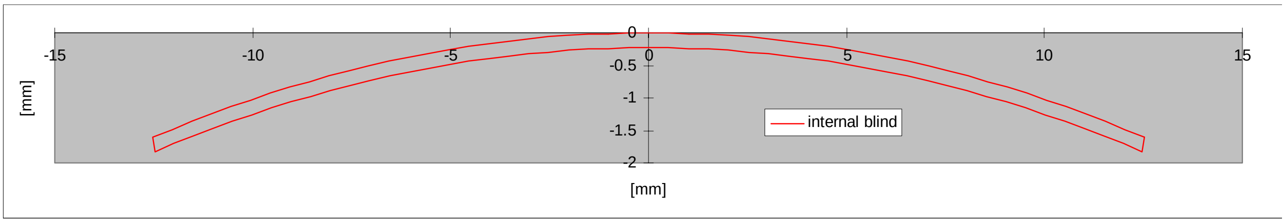

Figure 3: Sketch of single lamella sheet tilted horizontal (ignore single red line)
NB: The dimensions are given in Millimeter (mm)

The lamella and the system have the following specifications:

Sheet thickness	0.23	mm
lamella width	25	mm

lamella length	1000	mm
curvature radius	50	mm
lamellae distance vertical	22	mm
Pivot	center of lamella	
distance of pivot to interior glazing	40	mm
side fixation	none (open)	
top mounting	flush to ceiling	
bottom mounting	vented	

Optical properties upper surface	Visual	Solar
Total reflectance ρ_{nh} (8°)	0.528	0.465
Diffuse reflectance ρ_{dh} (8°)	0.504	0.444
Optical properties lower surface		
Total reflectance ρ_{nh} (8°)	0.528	0.465
Diffuse reflectance ρ_{dh} (8°)	0.504	0.444

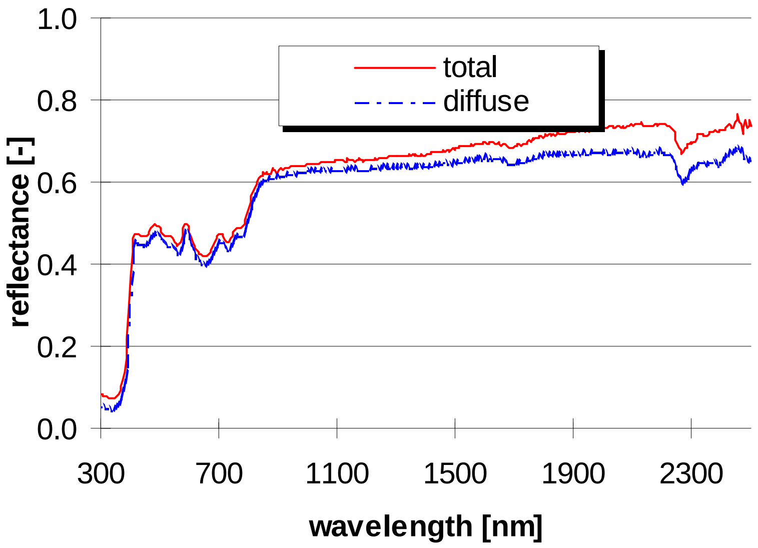

Figure 4: Spectral reflectance curves of light grey lamellae

1.2.3 Internal blind system (SHADE 3)

1.2.3.1 Description

Glazing	thickness [mm]	layer
DGU metallic blinds		
	4.00 mm	Clear4 (#9) (outside)
	22 mm	gap with aluminum type lamellae gas filling air
	4.00mm	Hard (#7) (inside)

Lamellae are in between the two glass panes. The vertical distance between the pivot points is about 12mm on the average. The lamellae projected width (there is a slight curvature) is 14mm. Thus there is an overlap when the lamellae are completely closed (position D, see below). There is a slight curvature of the blinds, but the radius is not known.

1.2.4 Internal textile roller blind system (SHADE 4)

In the data work book spectral data for a textile roller blind material to be used as internal system is given. It should be calculated in combination with different glazings (GLAZU2 and GLAZU3). The air gap between roller blind and glass should be 25mm and naturally ventilated (top and bottom opening aperture 25 mm width).

1.2.5 Optical properties and tilt angles

The blinds of the described shading systems are rotatable. The tilt may be adjusted according to sun position and view angle requirements. Within the project at least two tilt angles should be tested. The following figures shows schematically these two positions.

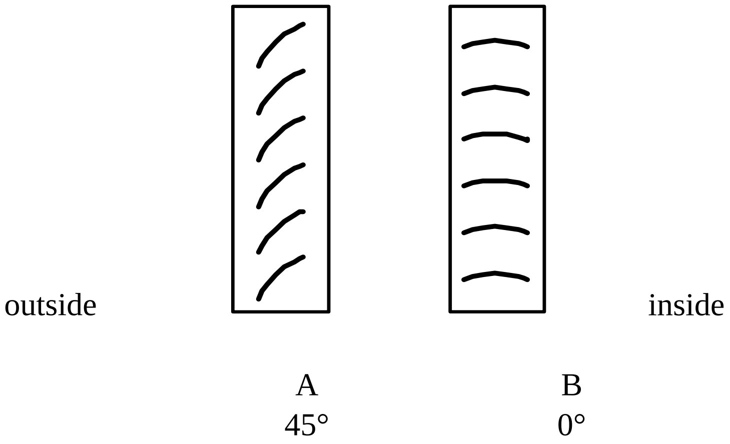

Figure 5 Tilt positions for shading systems
(solar radiation from the left hand side)

1.3 Double envelope facade

The benchmark cases for double envelope facades are more complex and include glazings, shading devices, the goemetry (height, width of gaps) and the ventilation conditions (natural, mechanical, on/off, inlet/outlet) of the double envelope.

These benchmark cases in a draft version have been developed and discussed by Ismo Heimonen and Henk de Bleecker in a separate document.

Some of the benchmark cases are identical to the glazings used there.

2 Calculation procedures and boundary conditions

For glazing calculations the obvious standards are EN410 and EN673 to be used. However for shading devices the situation is different. prEN 13363-1 is probably not sufficient to calculate the properties of solar shading devices. Other draft standards as FDIS ISO 15099 can be used, but also other techniques like ray tracing combined with heat transfer calculations (up to computational fluid dynamics CFD) can be used. It is not clear which simplifications are allowed and which conditions should be investigated in order to characterize shading systems in a sufficient way useful in practice. One approach of an advanced approach is decribed in [1], some differences of results using different algorithms for glazings with integrated shading are decribed and analysed in [2]. Of course, for double envelope facades the need for adequate calculation methods and algorithms is even more pronounced, and standards do not exist for these cases.

As different algorithms and implementations will be probably used in connection with the benchmark testing, it is advisable to define boundary conditions to make different calculations comparable. It is not always possible, but the following conditions are suggested to be used in all cases (e.g. some programs calculate internally heat transfer coefficients which cannot be fixed then):

Temperatures (air and radiative)
- Winter: inside Ti=20°C, outside Te=0°C
- Summer: inside Ti=25°C, outside Te=30°C

Heat transfer coefficients:

- Winter	inside $h_{c,i}$=3.6 W/m^{2}K, $h_{r,i}$=4.4*ε_i/0.837	(=> h_i=8 W/m^{2}K)
	outside $h_{c,e}$=19 W/m^{2}K, $h_{r,e}$=4.0*ε_i/0.837	(=> h_e=23 W/m^{2}K)
- Summer	inside $h_{c,i}$=2.5 W/m^{2}K, $h_{r,i}$=4.4*ε_i/0.837	(=> h_i=6.9 W/m^{2}K)
	outside $h_{c,e}$=8 W/m^{2}K, $h_{r,e}$=4.0*ε_i/0.837	(=> h_e=12 W/m^{2}K)

Irradiation:

- level	Summer 500 W/m2, Winter 300 W/m2
- spectrum	solar (global AM1) according to EN 410 table 2
	visual (D65) according to EN 410 table 1
– incidence angles	0° (normal), plus 45° and 60° altitude (where relevant)

Wind:
outside wind speed at the window surface V_s (free stream) can be calculated from the convective heat transfer coefficients according. to FDIS ISO 15099:

$$h_{c,e}=4.7 + 7.6\ V_s$$

so for example the average winter wind speed would be around 1.9 m/s.

The conditions given do not exactly match the conditions by FDIS ISO 15099, however, they are chosen in such a way that the winter case goes completely parallel with the standard heat transfer coefficients given by the EN standards (EN 410 for g-value, EN 673 for U-value) for vertical windows with h_i=8 W/m^{2}K and h_e=23 W/m^{2}K for ordinary glass with effective emissivity (observe: not normal emissivity!). Thus the calculations for the winter case are comparable with calculations according to the standards as they are given now. A discussion, which heat transfer coefficients are correct, as might arouse when comparing literature and the standards of CEN, ISO and ASHRAE should be avoided. It is important that the benchmark cases are defined unanimously and comparable.

For convenience and uniform evaluation, a spreadsheet is distributed for inputting the calculated results. The name of this spreadsheet is

>>windat-wp3-ise-benchmark_results_XXXX.xls<<.

This spreadsheet should be filled with results and sent back to the WP-leader with XXXX=name of participant before the next meeting in order to allow an evaluation of the incoming data.

3 Conclusion

Data and conditions for benchmark cases were presented as a suggestion to the Windat group. After the necessary discussions individuals could start with their calculations using their favourite algorithms. One item to clarify is the question whether the properties for a complete window or only for the central glazing part should be identified. In the first case a frame and edge seal has to be defined. It is suggested to leave that to a later exercise, as this would lead to a benchmark testing of frame heat transfer calculation tools like Therm, Kobru and others.

[1] T. Kuhn, Ch. Bühler, W.J. Platzer, Evaluation of overheating protection with sun-shading systems, Solar Energy 69, Nos. 1-6, pp. 59-74 (2000)

[2] J.L.J. Rosenfeld, W.J. Platzer, H. van Dijk, A. Maccari, Modelling the optical and Thermal Properties of Complex Glazings: Overview of Recent Developments, Solar Energy 69, No. 1-6, pp. 1-13 (2000)