EDSL Tas 9.3.0 Compliance with BS EN 13791:2012

1. Heat Conduction Test

Four test cases were modelled. In each case the modelled geometry was a box 1m x 1m x 1m which was preconditioned to 20°C. All faces of the box were exposed to the outside air. The external air temperature increases from the preconditioning setpoint of 20°C to 30°C on the first hour of the simulation and remains at 30°C thereafter.

Section 6.3 of the standard specifies 8 W/(m^{2}K) for the external surface convective heat transfer coefficient, with no external longwave heat transfer. In the Tas model the external surface emissivities were set to zero and the wind speed was set to a constant 1 m/s, to give the required heat transfer coefficient (4 + 4*windspeed). The convective heat transfer coefficient of all internal surfaces was set to 2.5, with no internal longwave heat transfer. The emissivities of all internal surfaces were set to zero.

The four test cases had different construction details, set up in accordance with table 6 of the standard, but were otherwise identical. Details are given below in screenshots from Tas.

Opaque construction for test 1:

Layer	M-Code	Width (mm)	Conductivity (W/m·°C)	Density (kg/m³)	Specific Heat (J/kg·°C)
Inner	Layer 1A	200.0	1.2	2000.0	1000.0

Opaque construction for test 2:

Layer	M-Code	Width (mm)	Conductivity (W/m·°C)	Density (kg/m³)	Specific Heat (J/kg·°C)
Inner	Layer 2A	100.0	0.04	50.0	1000.0

Opaque construction for test 3:

Layer	M-Code	Width (mm)	Conductivity (W/m·°C)	Density (kg/m³)	Specific Heat (J/kg·°C)
Inner	Layer 3A	5.0	0.14	800.0	1500.0
2	Layer 3B	100.0	0.04	50.0	1000.0
3	Layer 3C	200.0	1.2	2000.0	1000.0

Opaque construction for test 4:

Layer	M-Code	Width (mm)	Conductivity (W/m·°C)	Density (kg/m³)	Specific Heat (J/kg·°C)
Inner	Layer 4A	200.0	1.2	2000.0	1000.0
2	Layer 4B	100.0	0.04	50.0	1000.0
3	Layer 4C	5.0	0.14	800.0	1500.0

Results

To comply, results should be within 0.5°C of the target values.

	Time	2 h	6 h	12 h	24 h	120 h
Target	Test 1	20.04	21.26	23.48	26.37	30.00
	Test 2	25.09	29.63	30.00	30.00	30.00
	Test 3	20.00	20.26	21.67	24.90	29.95
	Test 4	20.00	20.06	20.25	20.63	23.17
Tas Results	Test 1	20.09	21.34	23.48	26.36	29.97
	Test 2	24.91	29.38	29.97	30.00	30.00
	Test 3	20.00	20.31	21.70	24.85	29.94
	Test 4	20.00	20.07	20.25	20.63	23.17
Difference	Test 1	0.05	0.08	0.00	0.01	0.03
	Test 2	0.18	0.25	0.03	0.00	0.00
	Test 3	0.00	0.05	0.03	0.05	0.01
	Test 4	0.00	0.01	0.00	0.00	0.00

2. Long Wave Radiation Test

Four test cases were modelled. In each case a steady state calculation was carried out on a different geometry (see section 8.2.3 of the standard for details). In each case one wall, exposed to the external air (at a constant 30°C) absorbed a continuous 100W/m^2. The other walls were exposed to a constant 20°C. The emissivity of all internal surfaces was 0.9.

Results

The internal air temperature results from the steady state calculation are shown below. To comply, results should be within 0.5°C of the target values.

	Test 1	Test 2	Test 3	Test 4
Target	34.40	30.40	38.50	25.50
Tas Results	34.13	30.21	38.28	25.57
Difference	0.27	0.19	0.22	0.07

3. Sunlit Factor Test

Six test cases were modelled. In each case the sunlit factor was measured on a vertical surface. The geometry of each test case was set up in accordance with section 8.2.4 of the standard.

All results were taken from day 172 and at latitude 52°N.

Results

To comply, results should be within 0.05 of the target values.

	Time	7.5	8.5	9.5	10.5	11.5
Target	Test 1	0.66	0.38	0.19	0.26	0.32
	Test 2	0.34	0.62	0.88	1.00	1.00
	Test 3	0.00	0.00	0.07	0.26	0.32
	Test 4	1.00	1.00	1.00	0.97	0.86
	Test 5	0.95	0.81	0.58	0.07	0.00
	Test 6	0.00	0.00	0.33	1.00	1.00
Tas Results	Test 1	0.64	0.36	0.18	0.26	0.32
	Test 2	0.36	0.64	0.88	1.00	1.00
	Test 3	0.00	0.00	0.05	0.26	0.32
	Test 4	1.00	1.00	1.00	0.98	0.85
	Test 5	0.94	0.80	0.58	0.07	0.00
	Test 6	0.00	0.00	0.35	1.00	1.00
Difference	Test 1	0.02	0.02	0.01	0.00	0.00
	Test 2	0.02	0.02	0.00	0.00	0.00
	Test 3	0.00	0.00	0.02	0.00	0.00
	Test 4	0.00	0.00	0.00	0.01	0.01
	Test 5	0.01	0.01	0.00	0.00	0.00
	Test 6	0.00	0.00	0.02	0.00	0.00

4. Operative Temperature Test

Eighteen test cases were modelled. In each case one day, July 15th (day 196), was repeatedly simulated in a cycle until a steady result was reached. For each case the maximum, minimum and average operative temperatures for the day were compared to the target values from the standard.

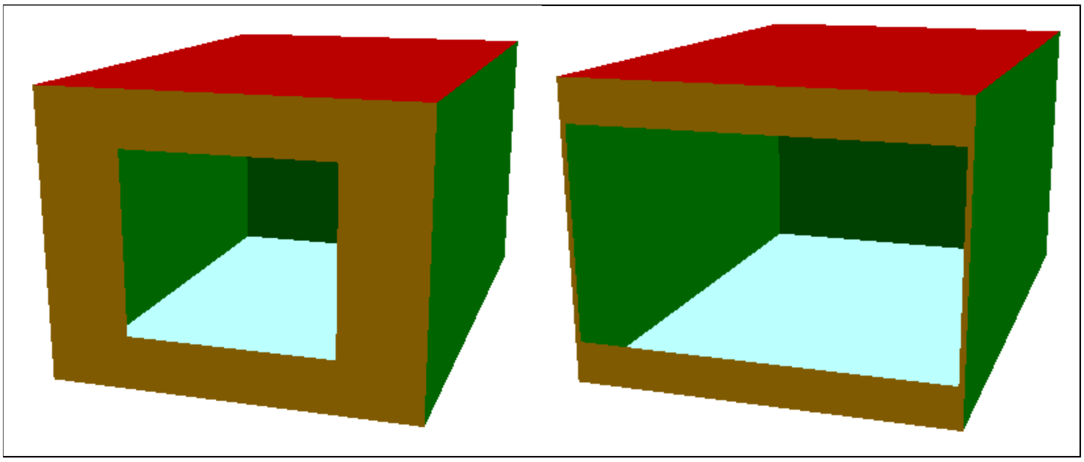
The operative temperature was calculated as the mean value of the room's dry bulb temperature and the mean radiant temperature of the room.

Input Data

Room Geometry

Two different geometries were used as a basis for the tests.

Geometry A: 3.5m^2 west-facing window. Latitude 40°N.
Geometry B: 7m^2 west-facing window. Latitude 52°N.



Left: Geometry A as seen in the Tas 3D modeller.
Right: Geometry B as seen in the Tas 3D modeller.

Element	Geometry A area (m^2)	Geometry B area (m^2)
External Wall	6.58	3.08
Glazing	3.50	7.00
Partition wall (left)	15.40	15.40
Partition wall (right)	15.40	15.40
Partition wall (back)	10.08	10.08
Floor	19.80	19.80
Ceiling	19.80	19.80

The volume of each geometry was 55.44m^3.

Construction Details

Opaque constructions were set up in accordance with table 14 of the standard. Details are given below in screenshots from Tas.

Type no. 1 (external wall)

Layer	M-Code	Width (mm)	Conductivity (W/m·°C)	Density (kg/m³)	Specific Heat (J/kg·°C)
Inner	Ext Wall Internal Plastering	15.0	0.7	1400.0	850.0
2	Ext Wall Masonry	175.0	0.79	1600.0	850.0
3	Ext Wall Insulation	60.0	0.04	30.0	850.0
4	Ext Wall Outer Layer	115.0	0.99	1800.0	850.0

Type no.2 (internal wall)

Layer	M-Code	Width (mm)	Conductivity (W/m·°C)	Density (kg/m³)	Specific Heat (J/kg·°C)
Inner	Int Wall Gypsum Plaster	12.0	0.21	900.0	850.0
2	Int Wall Mineral Wool	100.0	0.04	30.0	850.0
3	Int Wall Gypsum Plaster	12.0	0.21	900.0	850.0

Type no. 3 (ceiling / floor)

Layer	M-Code	Width (mm)	Conductivity (W/m·°C)	Density (kg/m³)	Specific Heat (J/kg·°C)
Inner	Type 3 Concrete	180.0	2.1	2400.0	850.0
2	Type 3 Insulation	40.0	0.04	50.0	850.0
3	Type 3 Concrete Floor	60.0	1.4	2000.0	850.0
4	Type 3 Covering	4.0	0.23	1500.0	1500.0

Note: order of layers is underside to topside.

Type no. 4 (ceiling / floor)

Layer	M-Code	Width (mm)	Conductivity (W/m·°C)	Density (kg/m³)	Specific Heat (J/kg·°C)
Inner	Type 4 Acoustic Board	20.0	0.06	400.0	840.0
2	Type 4 Mineral Wool	100.0	0.04	50.0	850.0
3	Type 4 Concrete	180.0	2.1	2400.0	850.0
4	Type 4 Insulation	40.0	0.04	50.0	850.0
5	Type 4 Concrete Floor	60.0	1.4	2000.0	850.0
6	Type 4 Covering	4.0	0.23	1500.0	1500.0

Note: order of layers is underside to topside.

Type no. 5 (roof)

Layer	M-Code	Width (mm)	Conductivity (W/m·°C)	Density (kg/m³)	Specific Heat (J/kg·°C)
Inner	Roof Concrete	200.0	2.1	2400.0	850.0
2	Roof Insulation	80.0	0.04	50.0	850.0
3	Roof External Layer	4.0	0.23	1500.0	1300.0

The glazing construction was set up in accordance with table 15 of the standard.

Component	Solar transmittance	Solar reflectance	Solar absorptance
Glass Pane	0.84	0.08	0.08
Shade	0.2	0.5	0.3

The solar parameters were considered to be independent of the solar angle.

Three different arrangements of constructions were considered:

Test no.	External wall	Internal adiabatic wall	Adiabatic ceiling	Adiabatic floor	Roof
1	1	2	4	4	N/A
2	1	2	3	3	N/A
3	1	2	N/A	3	5

For geometry A, a single pane of glass was used with an external shade. For geometry B there was double glazing with an external shade.

<u>Internal Gains</u>

All 18 test models have the same pattern of internal gains. The heat gains are 50% radiative and 50% convective.

11pm – 7am:	No gains
7am – 11am:	1 W/m^2
11am – 3pm:	10 W/m^2
3pm – 6pm:	1 W/m^2
6pm – 10pm:	15 W/m^2
10pm – 11pm:	10 W/m^2

The view coefficient of these internal gains was set to zero.

<u>Weather</u>

The values for external dry bulb and solar gain on a horizontal surface were given in the standard as instantaneous values at each hour. These were converted to average values over the course of the hour. As specified in the standard, the dry bulb temperature and solar gain varies linearly from point to point, making it straightforward to calculate hourly values:

Weather data for Geometry A (latitude 40°N) on day 196

Hour	external air dry bulb temperature (°C)	Total solar radiation on a horizontal surface (W/m^2)	Total solar radiation on a west facing vertical surface (W/m^2)
00:00 – 01:00	23.9	0	0
01:00 – 02:00	23.3	0	0
02:00 – 03:00	22.75	0	0
03:00 – 04:00	22.3	0	0
04:00 – 05:00	22.05	2	1
05:00 – 06:00	22.1	86	32
06:00 – 07:00	22.5	268.5	88.5
07:00 – 08:00	23.35	463	137
08:00 – 09:00	24.85	638	176.5
09:00 – 10:00	26.55	780.5	207.5
10:00 – 11:00	28.3	881	229
11:00 – 12:00	30.25	933	246
12:00 – 13:00	31.95	933	364

13:00 – 14:00	33.15	881	566.5
14:00 – 15:00	33.8	780.5	726
15:00 – 16:00	33.8	638	818
16:00 – 17:00	33.2	463	811
17:00 – 18:00	32.15	268.5	653
18:00 – 19:00	30.7	86	274
19:00 – 20:00	29.15	2	10
20:00 – 21:00	27.7	0	0
21:00 – 22:00	26.4	0	0
22:00 – 23:00	25.35	0	0
23:00 – 24:00	24.55	0	0

Weather data for Geometry B (latitude 52°N) on day 196

Hour	external air dry bulb temperature (°C)	Total solar radiation on a horizontal surface (W/m^2)	Diffuse solar radiation on a west facing vertical surface (W/m^2)
00:00 – 01:00	14.5	0	0
01:00 – 02:00	13.7	0	0
02:00 – 03:00	12.95	0	0
03:00 – 04:00	12.4	0	0
04:00 – 05:00	12.1	34.5	11
05:00 – 06:00	12.15	147	38.5
06:00 – 07:00	12.7	306.5	68
07:00 – 08:00	13.85	463.5	91
08:00 – 09:00	15.6	604	109
09:00 – 10:00	17.8	718.5	122.5
10:00 – 11:00	20.4	799.5	131.5
11:00 – 12:00	23.05	841.5	142
12:00 – 13:00	25.25	841.5	257
13:00 – 14:00	26.85	799.5	461.5
14:00 – 15:00	27.75	718.5	630.5
15:00 – 16:00	27.75	604	740.5
16:00 – 17:00	26.95	463.5	767
17:00 – 18:00	25.5	306.5	680
18:00 – 19:00	23.6	147	437.5
19:00 – 20:00	21.55	34.5	135.5
20:00 – 21:00	19.6	0	0
21:00 – 22:00	17.9	0	0
22:00 – 23:00	16.45	0	0
23:00 – 24:00	15.35	0	0

Ventilation

Three ventilation patterns were considered:
A: constant 1 ACH
B: 0.5 ACH from 6am – 6pm, 10 ACH at other times
C: constant 10 ACH

In each case air was brought in at the outside air temperature.

Other inputs

- **Heat transfer coefficients**
    - Section 8.3.6 of the standard specifies 13.5 W/(m^2K) for the external surface heat transfer coefficient (convective plus long wave).
      In the Tas model the external surface emissivities were set to zero and the wind speed was set to a constant 2.375 m/s, to give a total external heat transfer coefficient of 13.5 W/(m^2K) (4 + 4*windspeed).
    - Section 8.3.6 of the standard specifies 5.5 W/(m^2K) for the internal long-wave radiative heat transfer coefficient.
      Tas calculates long wave radiation exchange based on emissivities, these values were set to get as close as possible to the required 5.5 W/(m^2K).
      Convective heat transfer coefficients depended on the direction of heat flow, as in section 8.3.6 of the standard.
    - Section 8.3.4 of the standard specifies the following thermal resistances for the glazing:
        - 0.074 m^2K/W for the external surface of the blind – this is equivalent to the 13.5 W/(m^2K) heat transfer coefficient set on all external surfaces in the Tas model (see above).
        - 0.080 m^2K/W for the air gap between the blind and the outer pane – in the Tas model a convection coefficient of 12.5 W/(m^2K) was applied in the air gap with the surface emissivities set to zero.
        - 0.173 m^2K/W for the air gap between the outer and inner panes – in the Tas model a convection coefficient of 5.78 W/(m^2K) was applied in the air gap with the surface emissivities set to zero.
        - 0.125 m^2K/W for the internal surface of the inner pane – this is equivalent to the total 8 W/(m^2K) heat transfer coefficient set on all internal surfaces in the Tas model (see above).
- **Solar distribution**
  Surface reflectances were set up to achieve the solar distribution specified in section 8.3.5.
- **Solar-to-air factor**
  10% of the solar heat entering the room through the window was added directly into the internal air.
- **External Surface Solar Absorptances**
  The external wall had an external solar absorptance of 0.6. The roof had an external solar absorptance of 0.9.

Results

The test names are in three parts, indicating the geometry used, the construction set used, and the ventilation method used. For example, test B2a uses geometry B, construction set 2, and ventilation method A.

Below: Target temperatures, Tas results, and the differences between them. In each case this is shown for the maximum, average, and minimum operative temperatures. For compliance with the standard, the results should be within 0.5°C of the target values.

	Target Operative Temps			Results			Difference		
	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min
A1a	40.0	37.2	34.8	40.15	37.16	34.70	0.15	0.04	0.10
A1b	33.6	29.5	25.5	34.05	29.58	25.58	0.45	0.08	0.07
A1c	33.8	29.3	25.6	33.88	29.32	25.57	0.08	0.02	0.03
A2a	38.8	37.2	35.6	38.99	37.15	35.61	0.19	0.05	0.00
A2b	32.8	30.0	26.8	33.11	30.11	26.90	0.31	0.11	0.10
A2c	32.6	29.4	26.6	32.71	29.42	26.63	0.10	0.02	0.02
A3a	41.7	39.7	37.9	41.77	39.61	37.76	0.06	0.09	0.14
A3b	35.7	32.0	28.1	35.99	32.04	28.15	0.29	0.04	0.05
A3c	34.0	30.5	27.5	34.07	30.47	27.49	0.06	0.03	0.02
B1a	35.8	30.5	27.1	35.97	30.87	27.26	0.17	0.36	0.15
B1b	29.9	22.1	16.4	30.21	22.27	16.50	0.31	0.17	0.10
B1c	28.1	21.5	16.2	28.21	21.53	16.26	0.10	0.03	0.05
B2a	33.7	30.8	28.5	33.72	30.82	28.61	0.02	0.02	0.11
B2b	26.7	22.2	17.9	26.82	22.31	18.03	0.12	0.11	0.13
B2c	26.4	21.7	17.7	26.45	21.66	17.81	0.05	0.04	0.11
B3a	36.0	32.7	30.3	35.82	32.62	30.21	0.18	0.08	0.09
B3b	29.6	24.2	19.2	29.45	24.06	19.19	0.15	0.14	0.01
B3c	27.7	22.7	18.6	27.62	22.62	18.62	0.09	0.08	0.01