TEST REPORT

on the validation of Relux Desktop 2019 against CIE 171:2006

MAY 2019

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Abbreviations used in this report

CFL	Compact Fluorescent Lamp
TC	Test Case
TCX.X	Test Case number X.X as referred in CIE 171:2006
SC	Sky component
ERC	External reflected component
TE UL	Measurement upper limit including global error
MB UL	Measurement upper limit
MB LL	Measurement lower limit
TE LL	Measurement lower limit including global error

Definitions
(acc. to CIE 171:2006)

Test case:	A given building design scenario associated with reference data
Reference data:	A set of values that are calculated or measured to be uses as reference
Experimental test case:	A real world test case where reference data is based of real measurements
Analytical test case:	A theoretical test case where reference data is based on analytical calculations

Acknowledgements

Authors want to thank Relux Informatik A.G. for their valuable feedback in several points regarding the use of the Relux Desktop software. This ensured that the validation of the software was made in the most representative way for the average user of the software.

Citation

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1. Introduction

1.1. Scope

The scope of this work was to validate the software Relux Desktop 2019 against the technical report CIE 171:2006 [1]. CIE 171 defines and proposes a set of several test cases (TC) in order to validate the calculations accuracy of a lighting simulation software.

1.2. Software under test

The software under test is Relux Desktop developed by Relux Informatik A.G, Switzerland [2]. The software is available for free download at Relux website [3]. Relux Desktop is capable for performing lighting calculations for indoor and outdoor installations including streets and tunnels. Both artificial and daylight calculations can be made using Relux Desktop. Relux Desktop supports two calculation engine types, Radiosity and Raytracing. This report test covers only the most commonly used Radiosity calculation mode.

The version that was tested is Relux Desktop v2019.1.0.0.

1.3. Software settings

Relux Desktop offers a variety of different setting for calculations including direct and indirect light calculation, normal or dynamic raster of calculations, etc. For the purposes of this validation, the default settings where selected in all test cases except from the settings that are asked by the CIE report (e.g. number of raster points, reflectivity of the walls, etc.). This was selected in order to simulate the use of the software by an average user.

1.4. General assumptions

The Technical Report CIE 171:2006 describes several test cases for both artificial and daylight conditions. In artificial test cases, the reference data derived from real measurements of lamps luminaires and rooms. These test cases define a tolerance of the expected simulation results related to measurement uncertainties. Therefore, it is relatively easy for one to check if the simulation results of a software under test are in or out of the defined tolerances. On the other hand, analytical test cases rely on mathematical equations and thus the results (ideally) should be exactly as expected. Any disparity from the expected results should be calculated as an error precedence or absolute error.

The only point worth mentioning is the analytical test cases that are based on daylight calculations using CIE standard sky types. For these test cases, the Technical Committee that prepared the CIE 171 used the software Skylux. As mentioned in the Technical Report, this software was validated only for CIE sky types 5 and 16. Moreover, it was assumed (by the Technical Committee) that the reference data derived by this software were also valid for all the remaining CIE sky types. Therefore, it must be noted that in Test Cases 5.9 to 5.14 the software under test is actually compared with the accuracy of the Skylux software.

A discussion for potential errors in Test Case definitions and the corresponding reference data is made for test cases 5.7, 5.13 and 5.14.

All 3D models were designed and built exclusively in Relux Desktop using built-in tools and functionalities. No 3D models were imported by third party providers. The models shown in Figures of this report are screenshots from Relux Desktop software.

1.5. Photometric files and CIE General Sky types

CIE 171 defines the TCs for either use of artificial light sources or daylighting. The artificial light sources are described in the CIE document as tabulated text/numbers or as text descriptions. Therefore, using these data we prepared all artificial light sources as photometric files (.ies and .ldt). The luminous intensity distribution of these sources is shown in Figure 1.

a. Diffuse light source   b. Isotropic source   c. CIE daylight T9 area source

d. CFL Lamp   e. Opal luminaire   f. Semi Specular Reflector luminaire

(f) luminaire with type-4 symmetry
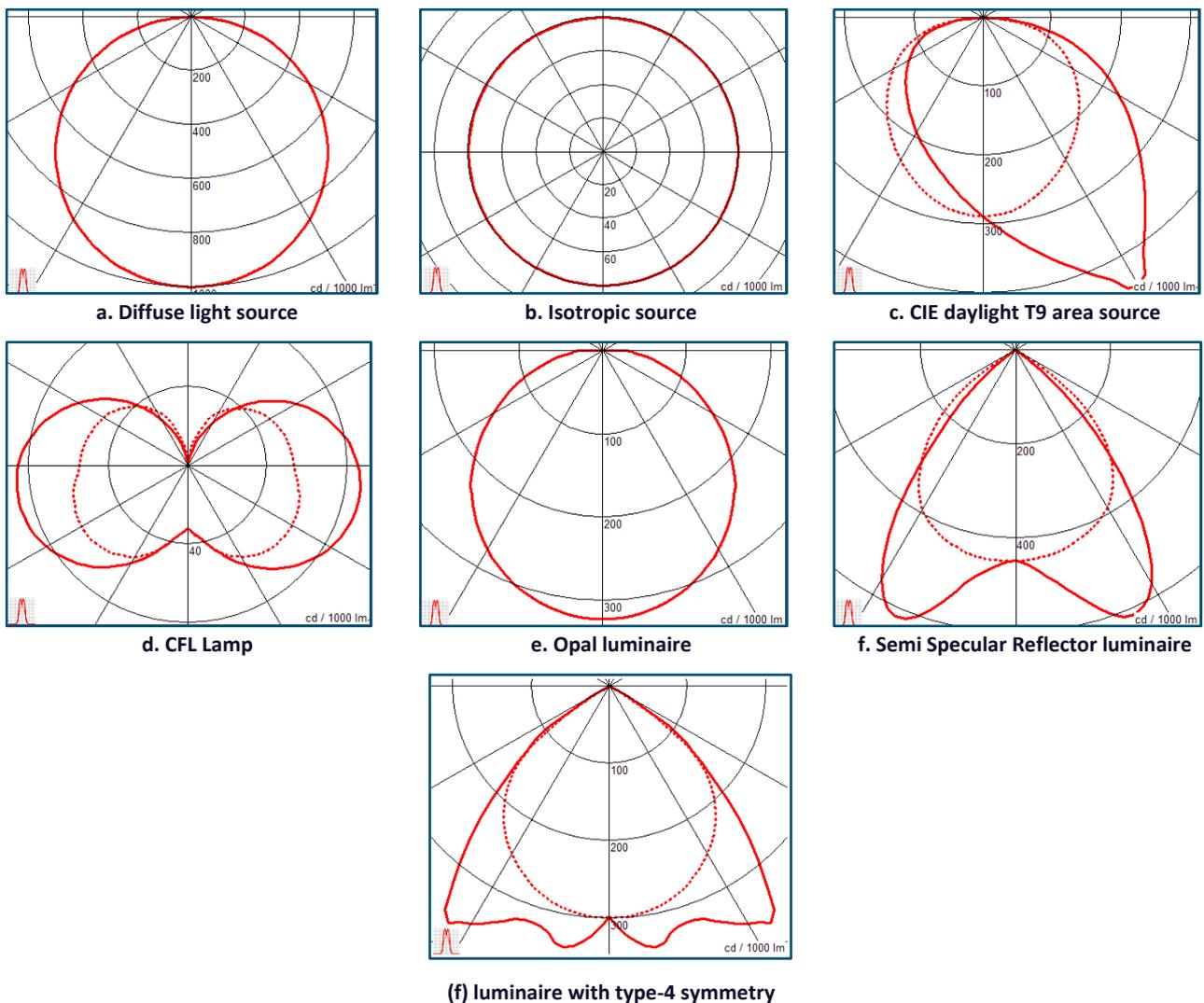
Figure 1 – Luminous intensity distribution of the artificial light sources used in various TCs

Regarding the CIE standard sky types, Relux Desktop (in Radiosity mode) supports the two common sky types, namely, CIE Sky type 1 (overcast sky) and CIE Sky type 12 (clear sky).

Notes related to artificial light sources

- Regarding the Semi Specular Reflector luminaire, 4 luminaire files were created using data from CIE 171. From these luminaires, only one is shown in Figure 1(f) as the luminous distribution of the other 3 luminaires were almost identical but with different total luminous flux.

- Regarding Opal luminaire, 4 luminaires files were created with the luminous distribution shown in Figure 1(e) but with different total luminous flux

- Regarding the CFL lamps, 4 lamp files were created with the luminous distribution shown in Figure 1(d) but with different total luminous flux.

- CIE 171 defines the total luminous flux of the luminaires (opal and semi specular reflector) in the corresponding chapters. However, this is equal to the total luminous flux of the light sources of the luminaires. Therefore, these values were multiplied by the corresponding Light Output Ration of each luminaire (LOR), as shown in the appendices of the CIE document.

2. Experimental test cases – Artificial lighting scenarios

2.1. Introduction

Experimental test cases were developed in order to simulate real lighting scenarios using existing rooms and lighting equipment. These test cases consider simple rooms with grey or black walls (covered with black velvet) that are illuminated by 4 lighting sources. Regarding the sources, each of these cases use one type of source between CFL, opal luminaire or semi specular reflector luminaire. The reflectivity characteristics and the photometric properties of the luminaires were derived by real measurements. The reference values were also derived by on-site measurements. The upper and lower limits shown in the following experimental test cases are the boundaries of the calculated measurement uncertainties.

The tables including the simulation results and the upper and lower limits as well as the corresponding figures follows the proposed presentation recommendation according to CIE 171.

2.2. CFL – Grey wall (CIE TC4.1)

2.2.1. Description

This test case describes a room with grey walls illuminated by 4 CFL lamps positioned at defined points on the ceiling (Figure 2). The room dimensions and the walls, ceiling and floor reflectance are described in CIE document. The calculation grid is 7x7 with half spacing at the edges 0.8m above the floor level.
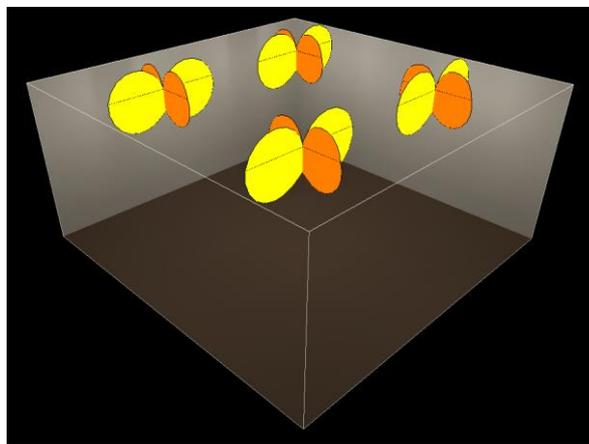
Figure 2 - General view of the scene for Test Case 4.1 including light sources (shown by their C0-180 and C90-270 C-planes)

2.2.2. Test results

Lighting calculations were performed using the default settings of Relux Desktop. The results for each row of the calculation grid are shown in Table 1 to Table 7, while the average is shown in Table 8. The same tables include also the reference values. The graphic representation of the simulation results versus the field measurements tolerances are shown in Figure 3.

Table 1 – Calculated results and reference values for the Row No1 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	91	107	115	118	116	107	93
MB UL	85	100	108	110	108	100	87
Relux - Row 1	68	79	88	90	88	79	68
MB LL	65	77	83	85	83	77	67
TE LL	59	70	75	77	76	70	61

Table 2 - Calculated results and reference values for the Row No2 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	103	124	130	129	129	124	105
MB UL	96	116	122	120	121	116	98
Relux - Row 2	77	91	99	98	99	92	77
MB LL	74	89	94	93	93	89	75
TE LL	67	81	85	84	84	81	68

Table 3 - Calculated results and reference values for the Row No3 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	112	132	141	141	141	131	113
MB UL	105	123	132	132	132	122	106
Relux - Row 3	85	99	110	111	110	99	86
MB LL	81	95	101	102	101	94	81
TE LL	73	86	92	92	92	86	74

Table 4 - Calculated results and reference values for the Row No4 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	115	133	143	146	143	133	116
MB UL	108	124	133	137	133	124	108
Relux - Row 4	89	101	112	115	112	101	88
MB LL	83	96	103	105	103	96	83
TE LL	75	87	93	96	93	87	76

Table 5 - Calculated results and reference values for the Row No5 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	113	132	141	140	141	132	112
MB UL	105	124	131	131	131	123	105
Relux - Row 5	86	100	110	112	111	99	85
MB LL	81	95	101	101	101	95	81
TE LL	74	86	92	92	92	86	73

Table 6 - Calculated results and reference values for the Row No6 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	103	124	130	127	130	123	104
MB UL	97	116	121	119	121	115	97
Relux - Row 6	77	91	98	98	98	91	77
MB LL	74	89	93	92	93	89	75
TE LL	68	81	85	83	85	81	68

Table 7 - Calculated results and reference values for the Row No7 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	92	108	116	117	115	108	92
MB UL	86	100	108	109	107	100	86
Relux - Row 7	67	79	86	89	87	78	67
MB LL	66	77	83	84	83	77	66
TE LL	60	70	76	76	75	70	60

Table 8 – Average simulation results and reference values.

Summary	Average illuminance (lx)
CIE Upper limit	112
Relux Eav (lx)	**92**
CIE Lower limit	88
Verdict	**PASS**
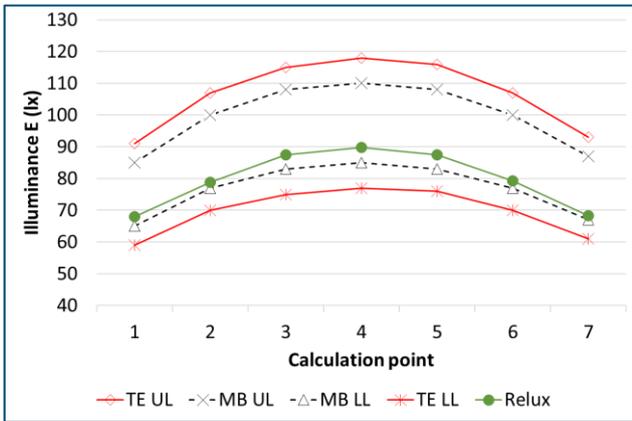
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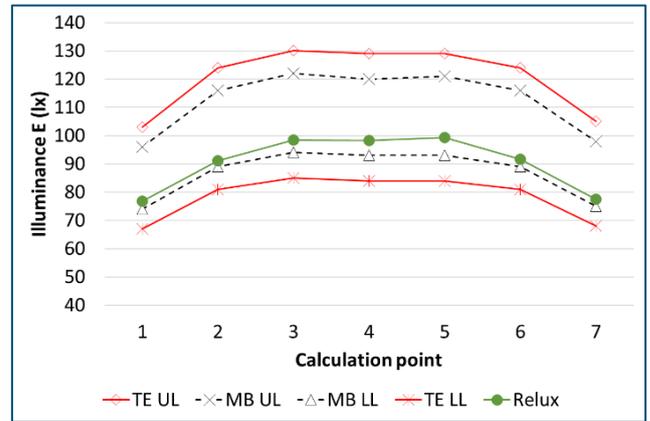
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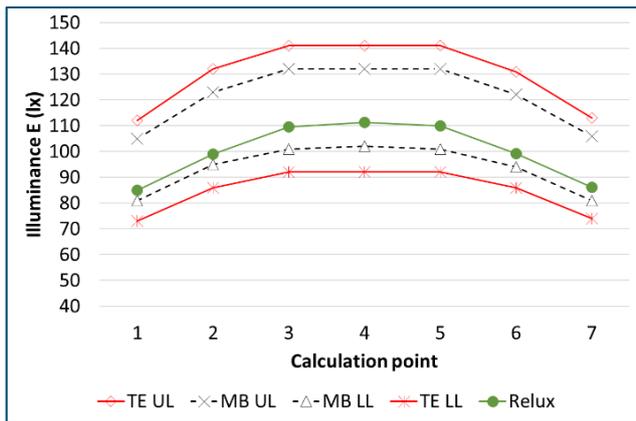
(c)
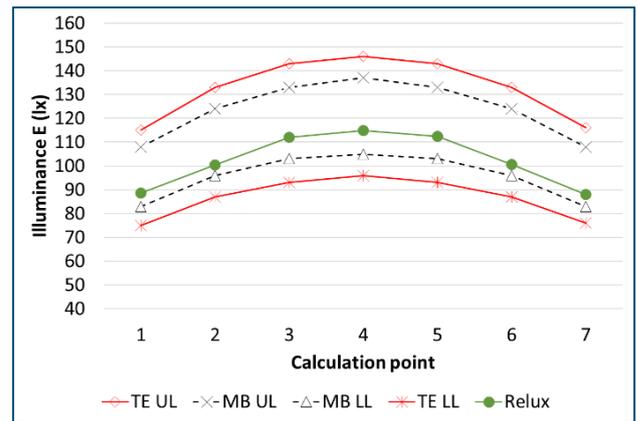
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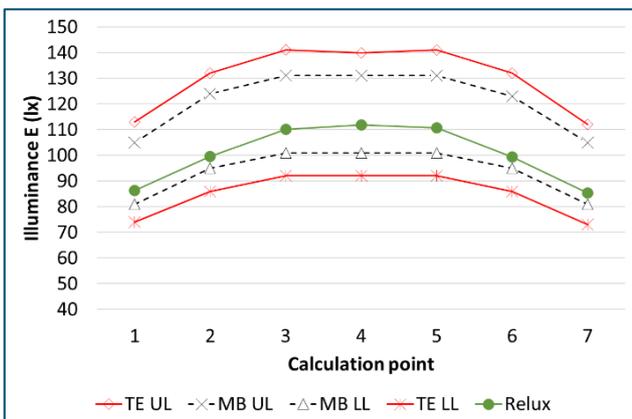
(e)
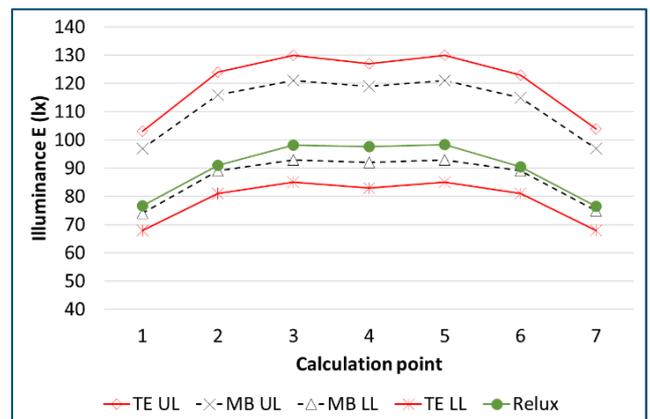
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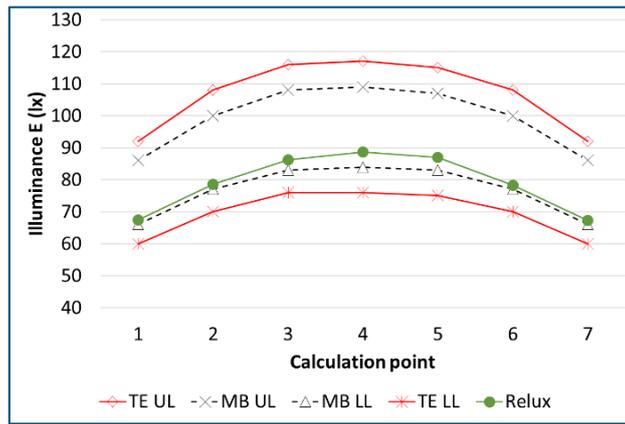
(g)

Figure 3 – Calculated results versus tolerances of the TC 4.1

2.3. Opal luminaire – Grey wall (CIE TC4.2)

2.3.1. Description

This test case describes the same room as in TC4.1 but using 4 opal luminaires. The reflectance of the room surfaces remains the same as in TC4.1, while the position and the luminous flux of the luminaires are defined in the CIE document (Figure 4).
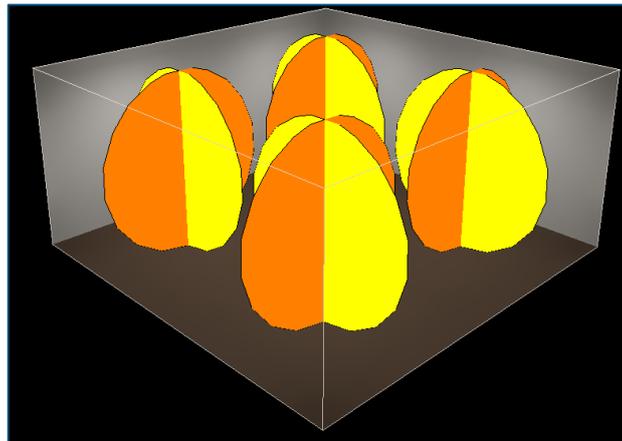
Figure 4 - General view of the scene for Test Case 4.2 including light sources (shown by their C0-180 and C90-270 C-planes)

2.3.2. Test results

Lighting calculations were performed using the default settings of Relux Desktop. The results for each row of the calculation grid are shown in Tables 9-15, while the average is shown in Table 16. These tables include also the reference values. The graphic representation of the simulation results versus the field measurements tolerances are shown in Figure 5.

Table 9 - Calculated results and reference values for the Row No1 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	**2**	**3**	**4**	**5**	**6**	**7**
TE UL	50	68	66	60	66	68	51
MB UL	47	63	62	56	61	63	48
Relux - Row 1	37	48	48	45	49	48	37
MB LL	36	49	48	43	47	49	37
TE LL	33	44	43	39	43	44	33

Table 10 - Calculated results and reference values for the Row No2 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	65	93	88	77	87	93	67
MB UL	61	87	83	72	81	87	62
Relux - Row 2	48	66	64	57	65	67	48
MB LL	47	67	64	55	63	67	48
TE LL	43	61	58	50	57	61	44

Table 11 - Calculated results and reference values for the Row No3 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	65	90	87	77	85	90	66
MB UL	61	84	81	72	80	84	62
Relux - Row 3	48	64	64	59	65	66	49
MB LL	47	65	62	56	61	65	48
TE LL	42	59	57	50	56	59	43

Table 12 - Calculated results and reference values for the Row No4 of the calculation grid.

Description	Illuminance per calculation point						
	1	2	3	4	5	6	7
TE UL	61	79	77	72	77	79	61
MB UL	57	74	72	67	72	73	57
Relux - Row 4	45	57	59	57	61	60	47
MB LL	44	57	55	52	55	56	44
TE LL	40	52	50	47	50	51	40

Table 13 - Calculated results and reference values for the Row No5 of the calculation grid.

Description	Illuminance per calculation point						
	1	2	3	4	5	6	7
TE UL	66	89	85	75	83	87	64
MB UL	61	83	79	70	78	82	60
Relux - Row 5	48	64	64	60	68	70	52
MB LL	47	64	61	54	60	63	46
TE LL	43	58	55	49	54	57	42

Table 14 - Calculated results and reference values for the Row No6 of the calculation grid.

| Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	65	92	85	74	83	89	63
MB UL	61	86	80	69	78	83	59
Relux -Row 6	47	66	65	59	69	72	52
MB LL	47	66	61	53	60	64	46
TE LL	43	60	56	48	54	58	41

Table 15 - Calculated results and reference values for the Row No7 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	50	66	64	57	62	64	48
MB UL	47	62	60	54	58	60	45
Relux -Row 7	36	48	49	47	52	53	40
MB LL	36	48	46	41	45	46	35
TE LL	33	43	42	38	41	42	31

Table 16 - Average simulation results and reference values.

Summary	Average illuminance (lx)
CIE Upper limit	67.5
Relux Eav (lx)	55.2
CIE Lower limit	53.1
Verdict	PASS
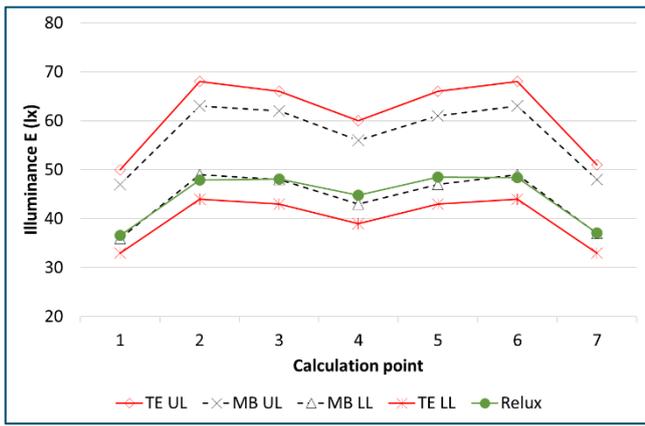
(a)
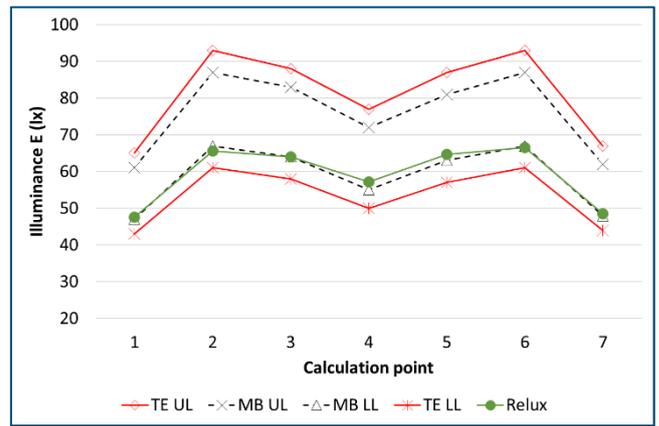
(b)
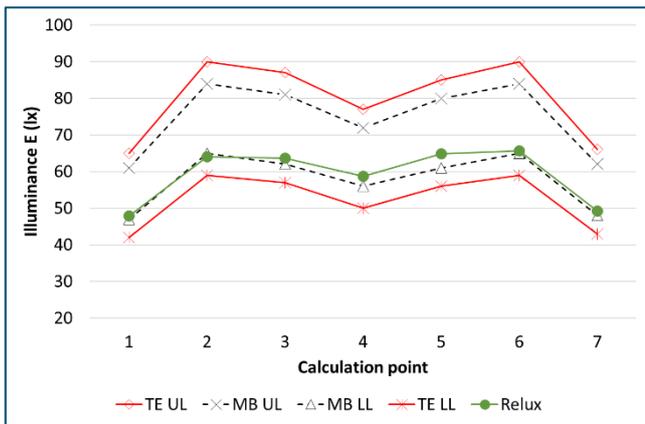
(c)
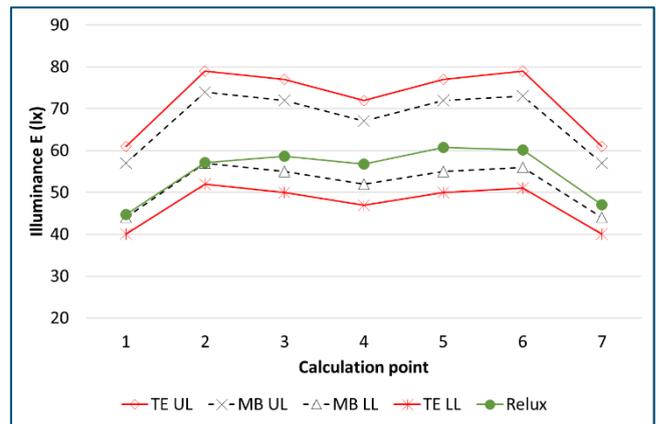
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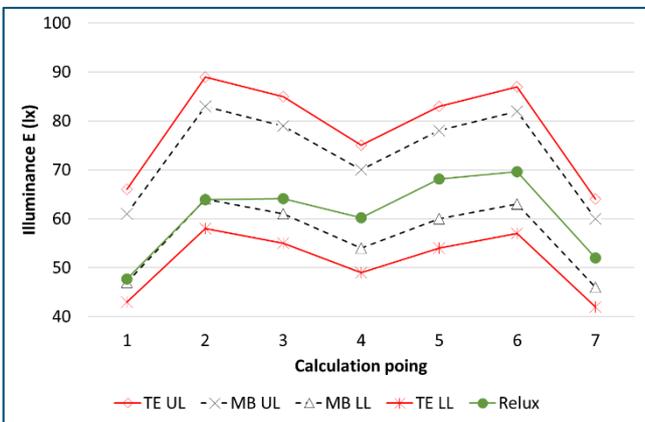
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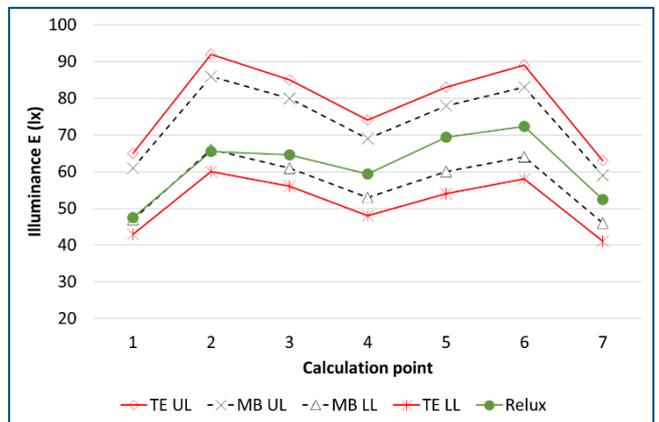
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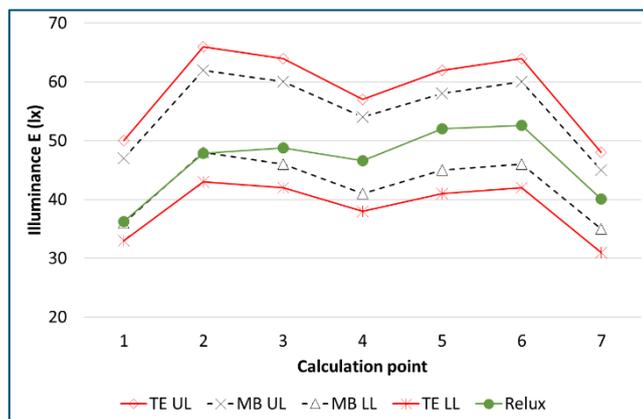
(g)

Figure 5 - Calculated results versus tolerances of the TC 4.2

2.4. Semi-specular reflector luminaire – Grey wall (CIE TC4.3)

2.4.1. Description

This test case describes the same room as in TC4.1 but using 4 luminaires with semi specular reflectors. The reflectance of the room surfaces remains the same as in TC4.1, while the position and the luminous flux of the luminaires are defined in the CIE document (Figure 6).
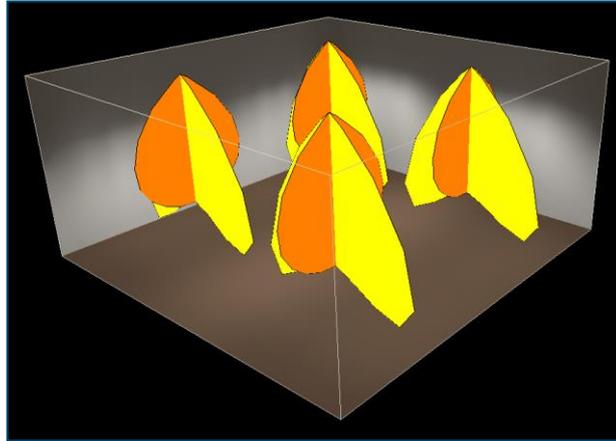

Figure 6 - General view of the scene for Test Case 4.3 including light sources (shown by their C0-180 and C90-270 C-planes)

2.4.2. Test results

Lighting calculations were performed using the default settings of Relux Desktop. The results for each row of the calculation grid are shown in Tables 17-23, while the average is shown in Table 24. These tables include also the reference values. The graphic representation of the simulation results versus the field measurements tolerances are shown in Figure 7.

Table 17 - Calculated results and reference values for the Row No1 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	178	279	265	222	265	279	180
MB UL	166	261	248	207	248	261	168
Relux - Row 1	160	245	239	202	235	248	164
MB LL	128	201	191	159	191	201	130
TE LL	116	182	173	145	173	182	118

Table 18 - Calculated results and reference values for the Row No2 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	206	312	305	258	308	317	214
MB UL	192	291	285	241	288	296	200
Relux - Row 2	174	252	250	219	252	261	178
MB LL	148	224	219	186	222	228	154
TE LL	135	203	199	169	201	207	140

Table 19 - Calculated results and reference values for the Row No3 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	229	353	337	281	342	358	232
MB UL	214	330	315	262	319	334	217
Relux - Row 3	192	291	290	245	283	296	199
MB LL	165	254	242	202	246	257	167
TE LL	149	230	220	183	223	234	152

Table 20 - Calculated results and reference values for the Row No4 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	209	310	303	265	311	315	207
MB UL	195	290	283	247	290	294	193
Relux - Row 4	189	287	279	246	271	286	191
MB LL	150	223	218	191	224	227	149
TE LL	136	203	198	173	203	206	135

Table 21 - Calculated results and reference values for the Row No5 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	230	358	345	286	344	356	229
MB UL	215	334	322	267	321	332	214
Relux - Row 5	197	296	291	246	282	294	195
MB LL	165	257	248	206	247	256	165
TE LL	150	234	225	187	225	232	150

Table 22 - Calculated results and reference values for the Row No6 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	221	329	317	264	312	317	209
MB UL	206	308	296	247	291	296	196
Relux - Row 6	174	254	251	214	239	247	172
MB LL	159	237	228	190	224	228	151
TE LL	144	215	207	173	204	207	137

Table 23 - Calculated results and reference values for the Row No7 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	188	289	273	229	274	283	180
MB UL	176	270	255	214	255	264	168
Relux - Row 7	158	245	238	199	232	247	163
MB LL	135	208	196	165	197	204	129
TE LL	123	189	178	150	179	185	117

Table 24 - Average simulation results and reference values.

Summary	Average illuminance (lx)
CIE Upper limit	254.2
Relux Eav (lx)	233.8
CIE Lower limit	199.8
Verdict	PASS

(a)

(b)
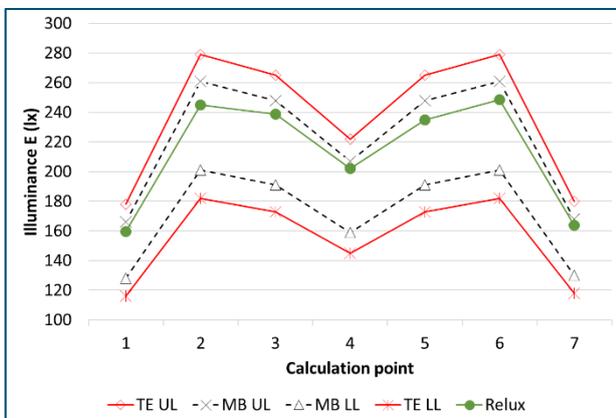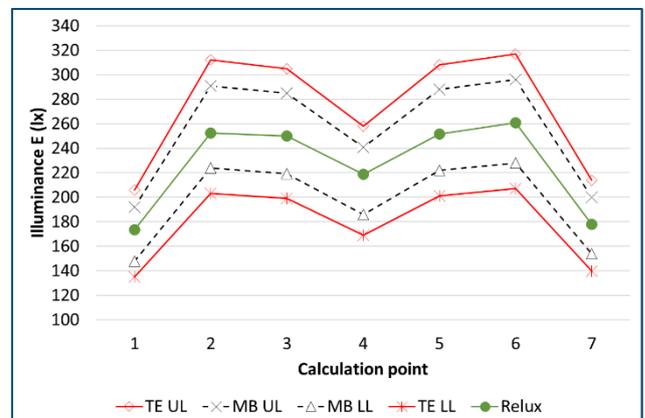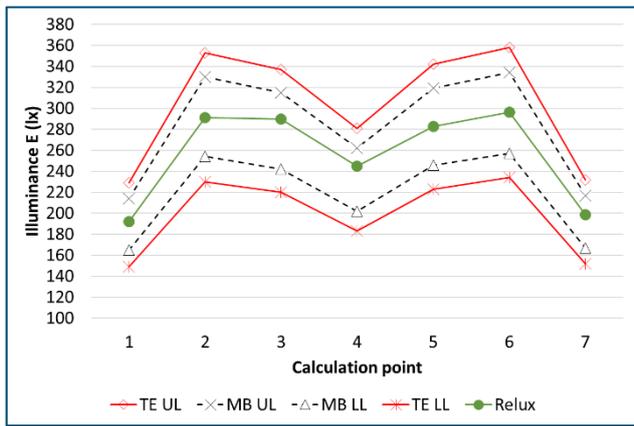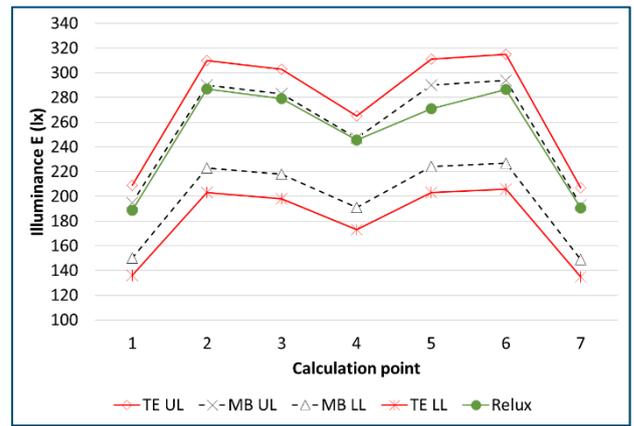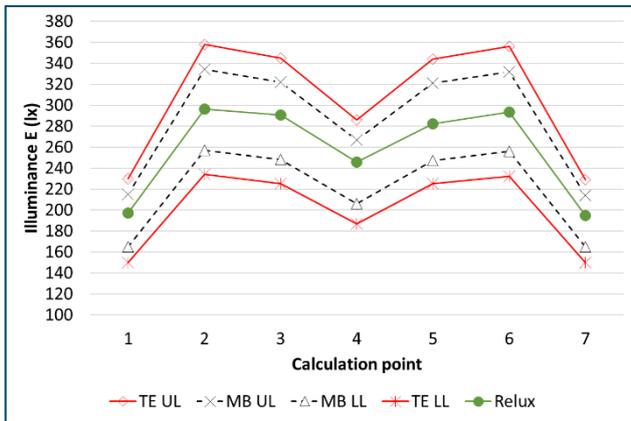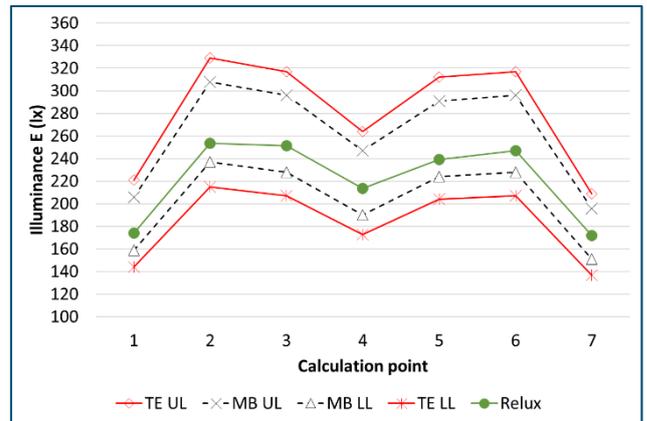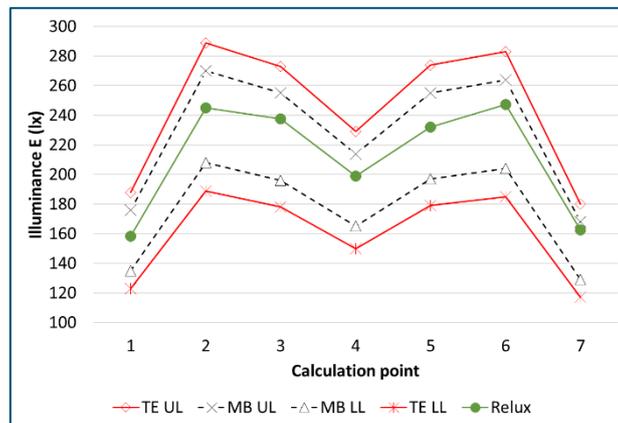
Figure 7 - Calculated results versus tolerances of the TC 4.3

2.5. CFL – Black wall (CIE TC4.4)

2.5.1. Description

This test case describes a room with black walls illuminated by 4 CFL lamps positioned at defined points on the ceiling (Figure 8). The room dimensions and the walls, ceiling and floor reflectance are described in CIE document. The calculation grid is 7x7 with half spacing at the edges 0.8m above the floor level.
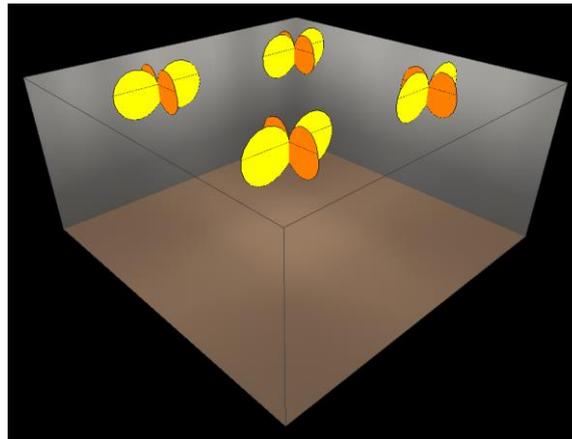
Figure 8 - General view of the scene for Test Case 4.4 including light sources (shown by their C0-180 and C90-270 C-planes)

2.5.2. Test results

Lighting calculations were performed using the default settings of Relux Desktop. The results for each row of the calculation grid are shown in Tables 25-31, while the average is shown in Table 32. These tables include also the reference values. The graphic representation of the simulation results versus the field measurements tolerances are shown in Figure 9.

Table 25 - Calculated results and reference values for the Row No1 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	30	32	39	43	40	33	31
MB UL	28	29	37	40	38	30	29
Relux - Row 1	27	29	36	39	36	29	27
MB LL	22	23	28	31	29	23	22
TE LL	20	21	26	28	26	21	20

Table 26 - Calculated results and reference values for the Row No2 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	31	32	39	42	41	33	31
MB UL	28	30	37	39	38	31	29
Relux - Row 2	28	30	35	38	36	30	28
MB LL	22	23	28	30	29	24	23
TE LL	20	21	26	28	27	21	21

Table 27 - Calculated results and reference values for the Row No3 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	39	41	51	54	51	40	38
MB UL	36	38	48	51	47	38	35
Relux - Row 3	34	36	45	50	45	36	35
MB LL	28	29	37	39	37	29	27
TE LL	25	27	33	36	33	26	25

Table 28 - Calculated results and reference values for the Row No4 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	43	46	57	62	57	46	43
MB UL	40	43	53	57	53	43	40
Relux - Row 4	38	40	50	55	51	40	38
MB LL	31	33	41	44	41	33	31
TE LL	28	30	37	40	37	30	28

Table 29 - Calculated results and reference values for the Row No5 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	38	40	51	54	51	41	38
MB UL	35	38	48	51	48	38	36
Relux - Row 5	35	37	46	50	46	36	34
MB LL	27	29	37	39	37	29	28
TE LL	25	26	33	35	34	27	25

Table 30 - Calculated results and reference values for the Row No6 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	31	33	41	43	40	33	31
MB UL	29	30	39	40	38	31	29
Relux - Row 6	27	29	35	38	35	29	27
MB LL	23	23	30	31	29	23	23
TE LL	20	21	27	28	26	21	20

Table 31 - Calculated results and reference values for the Row No7 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	31	33	42	44	41	33	32
MB UL	29	31	39	41	38	31	30
Relux - Row 7	26	29	34	38	35	29	26
MB LL	22	24	30	32	29	24	23
TE LL	20	21	27	29	26	22	21

Table 32 - Average simulation results and reference values.

Summary	Average illuminance (lx)
CIE Upper limit	37.5
Relux Eav (lx)	**36.0**
CIE Lower limit	29.5
Verdict	**PASS**

(a)

(b)

(c)

(d)

(e)

(f)

(g)
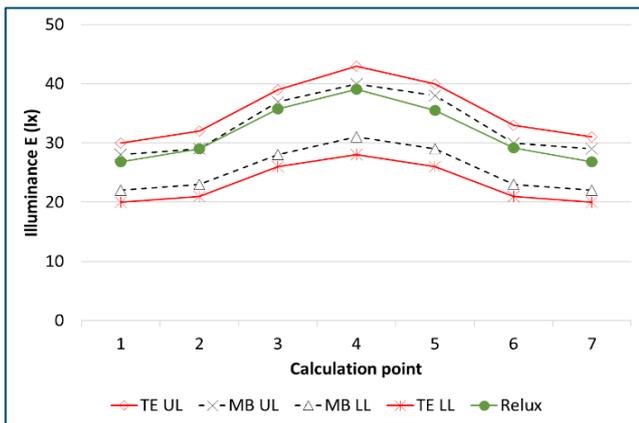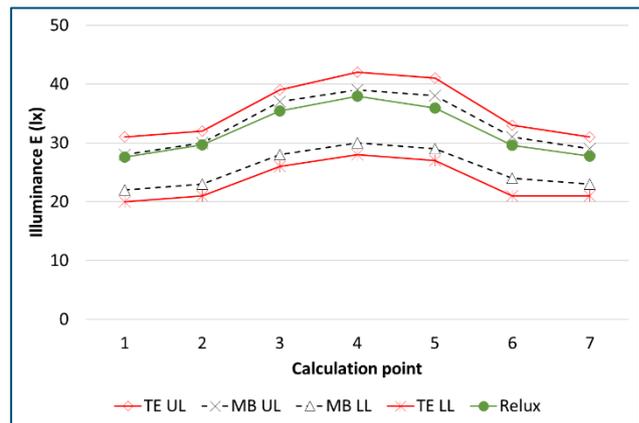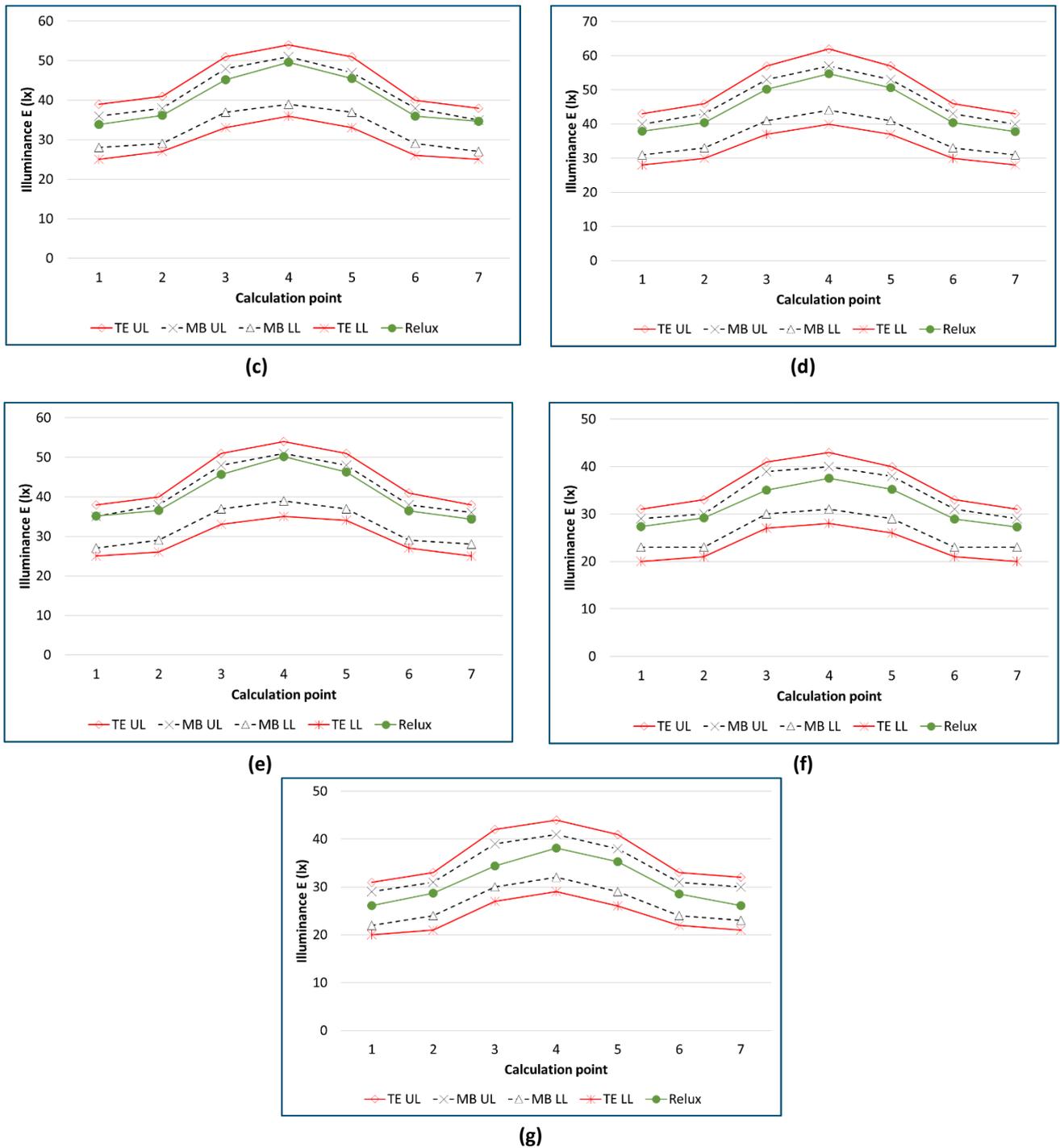
Figure 9 - Calculated results versus tolerances of the TC 4.4

2.6. **Opal luminaire – Black wall (CIE TC4.5)**

2.6.1. *Description*

This test case describes the same room as in TC4.4 but using 4 opal luminaires. The reflectance of the room surfaces remains the same as in TC4.1, while the position and the luminous flux of the luminaires are defined in the CIE document (Figure 10).
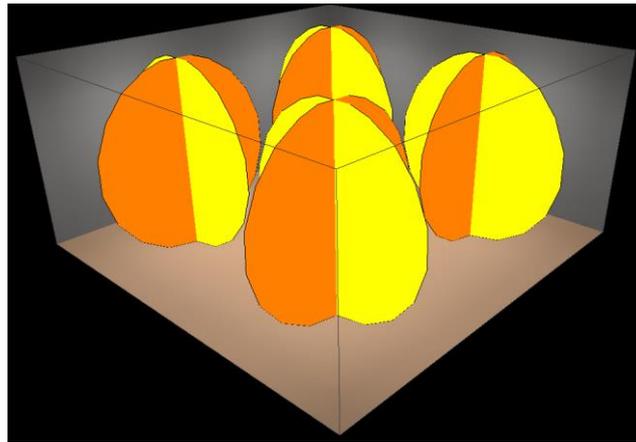
Figure 10 - General view of the scene for Test Case 4.5 including light sources (shown by their C0-180 and C90-270 C-planes)

2.6.2. Test results

Lighting calculations were performed using the default settings of Relux Desktop. The results for each row of the calculation grid are shown in Tables 33-39, while the average is shown in Table 40. These tables include also the reference values. The graphic representation of the simulation results versus the field measurements tolerances are shown in Figure 11.

Table 33 - Calculated results and reference values for the Row No1 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	32	48	47	42	47	48	33
MB UL	30	44	44	40	44	45	31
Relux - Row 1	25	36	37	34	37	37	26
MB LL	23	34	34	31	34	35	24
TE LL	21	31	31	28	31	31	22

Table 34 - Calculated results and reference values for the Row No2 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	46	73	70	60	69	74	48
MB UL	43	68	66	56	64	69	44
Relux - Row 2	36	55	54	47	55	56	37
MB LL	33	53	51	43	49	53	34
TE LL	30	48	46	39	45	48	31

Table 35 - Calculated results and reference values for the Row No3 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	47	71	70	61	69	72	48
MB UL	44	66	65	57	65	67	45
Relux - Row 3	37	54	54	50	55	55	38
MB LL	34	51	50	44	50	52	34
TE LL	30	46	45	40	45	47	31

Table 36 - Calculated results and reference values for the Row No4 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	43	61	62	56	61	61	43
MB UL	40	57	57	53	57	57	40
Relux - Row 4	34	47	50	48	51	50	36
MB LL	31	44	44	40	44	44	31
TE LL	28	40	40	37	40	40	28

Table 37 - Calculated results and reference values for the Row No5 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	47	71	68	60	68	70	47
MB UL	44	66	64	56	63	65	43
Relux - Row 5	36	54	55	51	59	59	40
MB LL	34	51	49	43	49	50	33
TE LL	31	46	44	39	44	46	30

Table 38 - Calculated results and reference values for the Row No6 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	46	72	68	57	66	71	45
MB UL	43	67	63	54	62	66	42
Relux - Row 6	36	55	54	49	59	61	40
MB LL	33	52	49	41	47	51	33
TE LL	30	47	44	37	43	46	30

Table 39 - Calculated results and reference values for the Row No7 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	32	47	46	40	45	45	31
MB UL	30	44	43	38	42	42	29
Relux - Row 7	25	36	37	36	40	40	28
MB LL	23	34	33	29	32	33	23
TE LL	21	30	30	26	29	30	20

Table 40 - Average simulation results and reference values.

Summary	Average illuminance (lx)
CIE Upper limit	51.1
Relux Eav (lx)	44.5
CIE Lower limit	40.1
Verdict	PASS

(a)   (b)

(c)

(d)

(e)

(f)

(g)
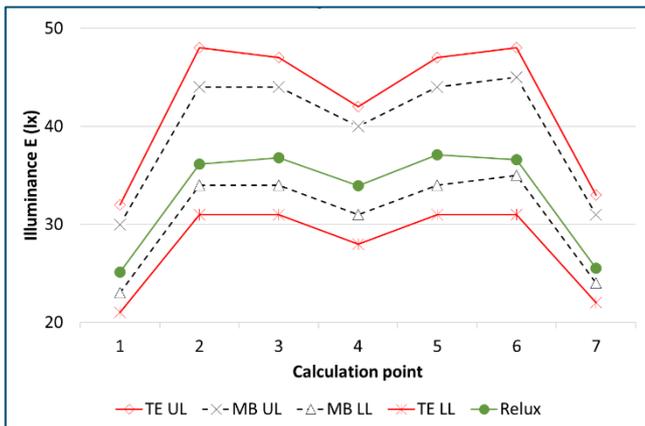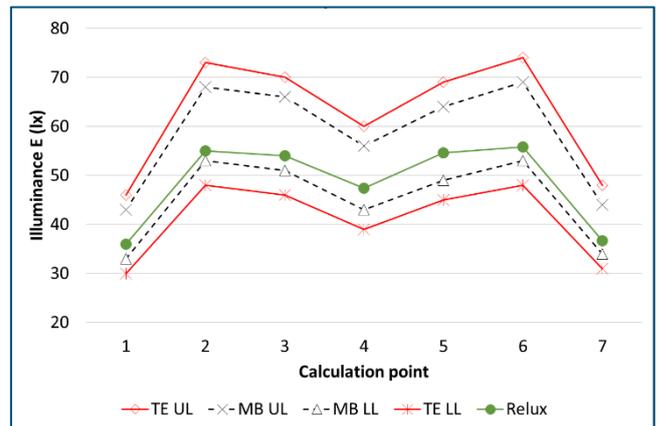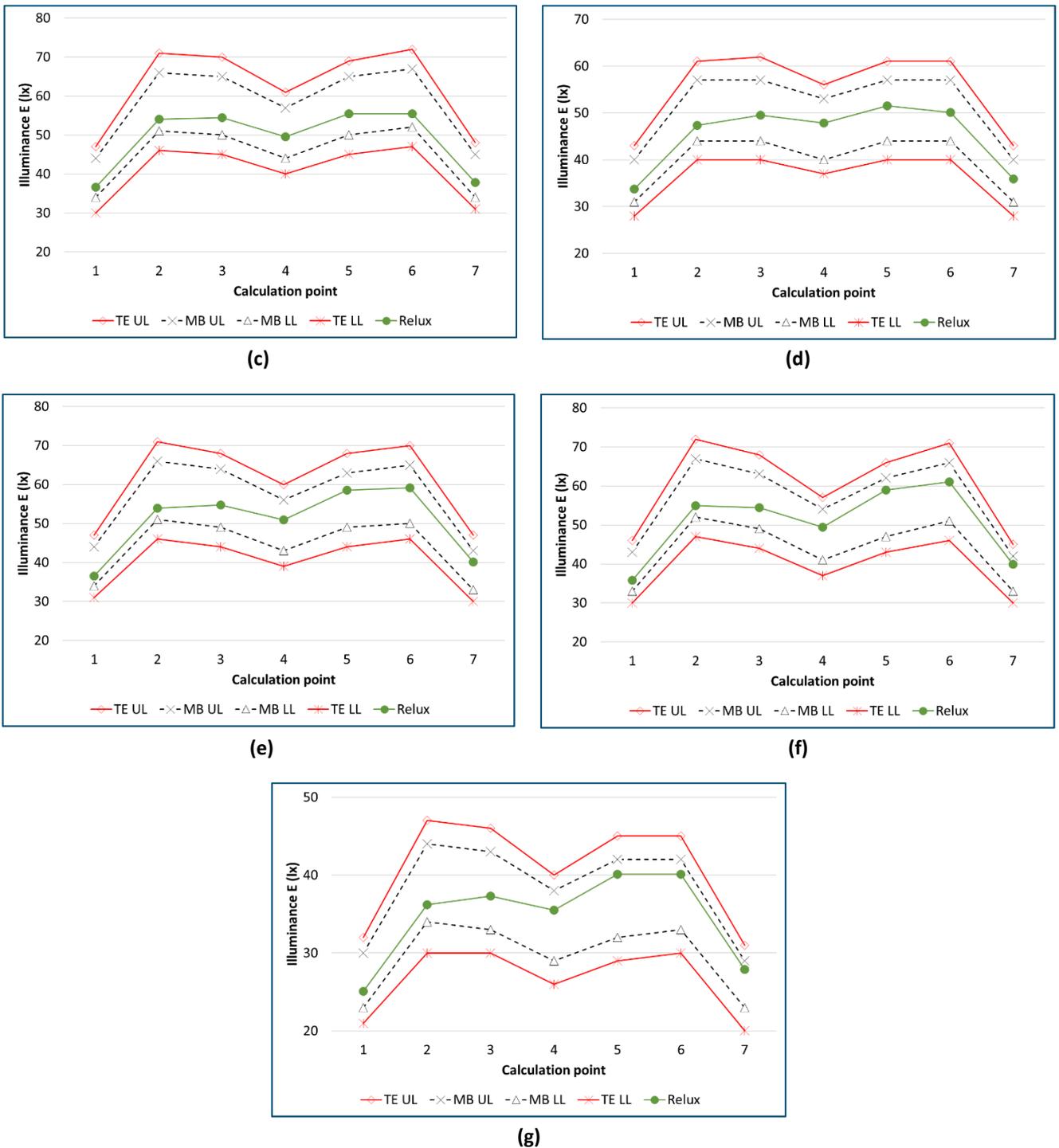
Figure 11 - Calculated results versus tolerances of the TC 4.5

2.7. Semi-specular reflector luminaire – Black wall (CIE TC4.6)

2.7.1. Description

This test case describes the same room as in TC4.4 but using 4 luminaires with semi specular reflectors. The reflectance of the room surfaces remains the same as in TC4.1, while the position and the luminous flux of the luminaires are defined in the CIE document (Figure 12).
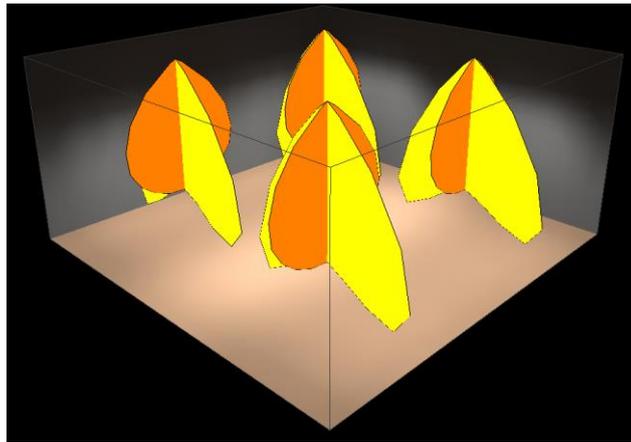
Figure 12 - General view of the scene for Test Case 4.6 including light sources (shown by their C0-180 and C90-270 C-planes)

2.7.2. Test results

Lighting calculations were performed using the default settings of Relux Desktop. The results for each row of the calculation grid are shown in Tables 41-47, while the average is shown in Table 48. These tables include also the reference values. The graphic representation of the simulation results versus the field measurements tolerances are shown in Figure 13.

Table 41 - Calculated results and reference values for the Row No1 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	146	249	237	197	237	252	149
MB UL	136	232	221	184	221	235	139
Relux - Row 1	135	222	217	182	213	225	139
MB LL	105	179	170	142	170	181	107
TE LL	95	162	155	129	155	164	97

Table 42 - Calculated results and reference values for the Row No2 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	172	288	282	236	284	294	179
MB UL	161	269	263	221	265	275	168
Relux - Row 2	150	235	235	204	236	244	154
MB LL	124	207	202	170	204	211	129
TE LL	113	188	184	154	185	192	117

Table 43 - Calculated results and reference values for the Row No3 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	195	329	313	258	317	335	196
MB UL	182	307	292	241	296	312	183
Relux -Row 3	169	275	275	231	268	280	176
MB LL	140	237	225	185	228	241	141
TE LL	127	215	204	168	207	218	128

Table 44 - Calculated results and reference values for the Row No4 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	178	287	278	242	285	290	176
MB UL	166	268	259	226	266	271	164
Relux - Row 4	168	271	265	232	257	271	171
MB LL	128	206	200	174	205	209	126
TE LL	116	187	181	158	186	190	115

Table 45 - Calculated results and reference values for the Row No5 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	196	334	320	262	319	333	196
MB UL	183	312	299	244	298	311	183
Relux - Row 5	175	280	276	232	268	278	172
MB LL	141	240	230	188	230	239	141
TE LL	128	218	209	171	208	217	128

Table 46 - Calculated results and reference values for the Row No6 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	186	306	292	242	287	292	175
MB UL	174	286	273	226	268	273	163
Relux - Row 6	150	237	236	199	224	230	149
MB LL	134	220	210	174	206	210	126
TE LL	122	200	191	158	178	191	114

Table 47 - Calculated results and reference values for the Row No7 of the calculation grid.

Description	Illuminance per calculation point (lx)						
	1	2	3	4	5	6	7
TE UL	155	258	241	202	242	251	146
MB UL	145	241	225	189	226	234	136
Relux - Row 7	135	223	217	180	212	225	139
MB LL	111	186	173	145	174	180	105
TE LL	101	169	157	132	158	164	95

Table 48 - Average simulation results and reference values.

Summary	Average illuminance (lx)
CIE Upper limit	228.5
Relux Eav (lx)	215.1
CIE Lower limit	179.5
Verdict	PASS
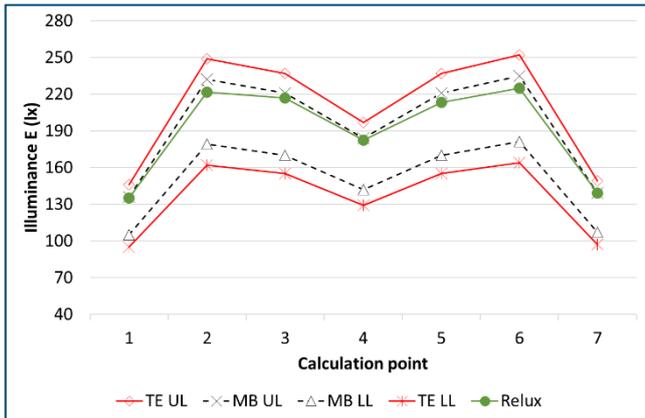
(a)
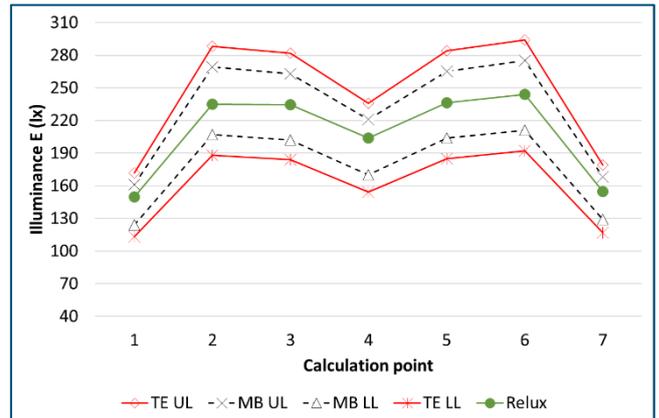
(b)
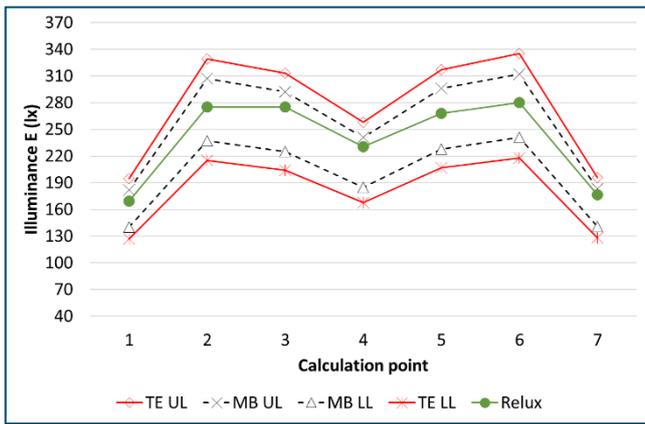
(c)
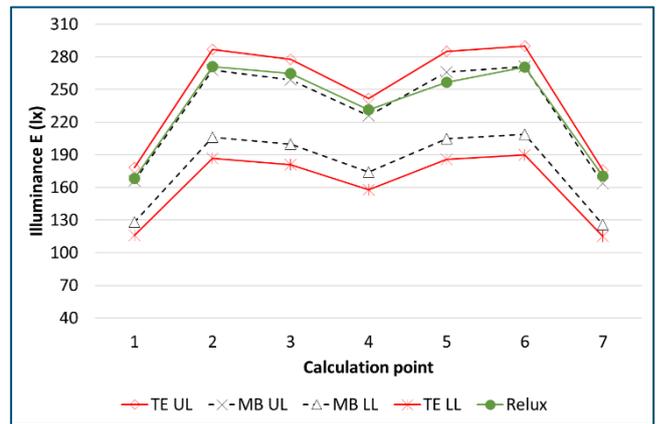
(d)
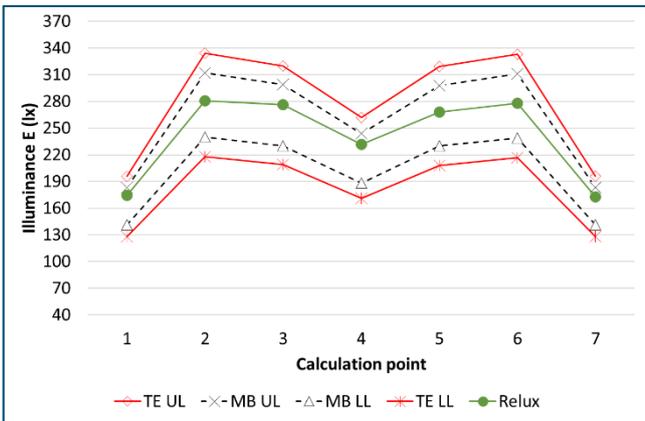
(e)
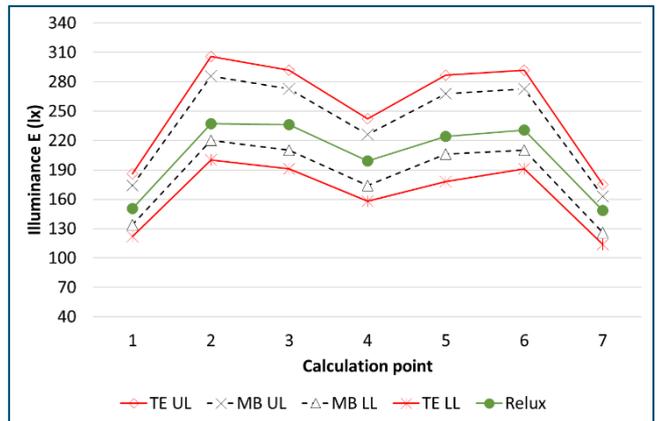
(f)
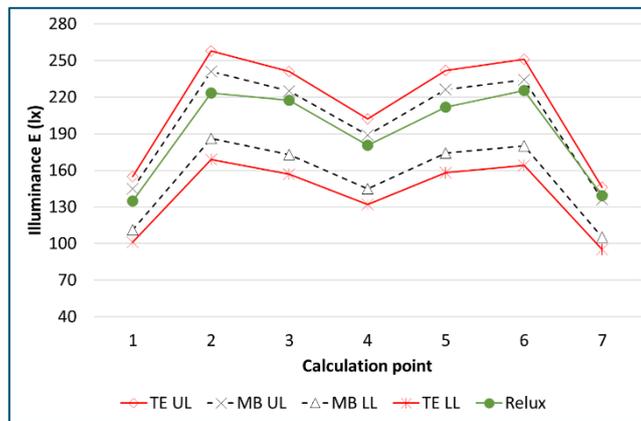
(g)

Figure 13 - Calculated results versus tolerances of the TC 4.6

3. Test cases with analytical references

3.1. Introduction

3.2. Simulation of point light sources (CIE TC5.2)

3.2.1. Description

The scope of this test case is to assess the capability of the lighting simulation software to calculate the direct illuminance on a point or grid of points under various point light sources. For the purpose of this test case, a set of calculations points were defined on a horizontal 4x4m surface as shown in Figure 14.
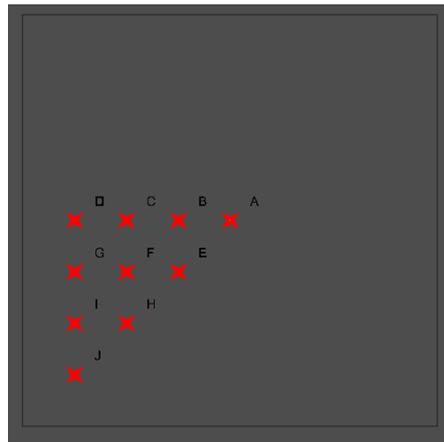
Figure 14 – Illuminance and luminous intensity calculation points according to TC5.2.

Two point light sources were used. The first is a diffuse light source and the second a light source simulating the CIE general sky Type 9 with the sun at an elevation of 60 degrees. Each source was placed at a height of 3m at the centre of the 4x4m surface (Figure 15). The reference values given in the CIE document were derived by analytical calculations.
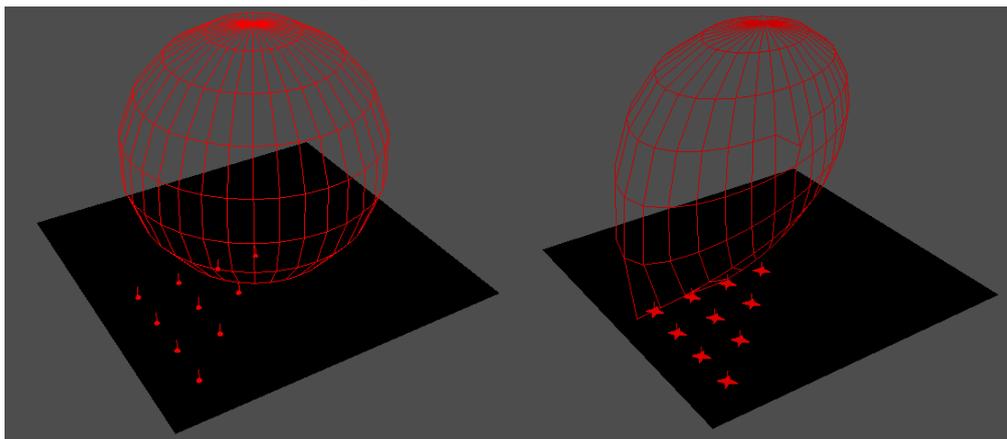
Figure 15 – The light sources over the calculation points as defined in TC5.2.

3.2.2. Test results

Lighting calculations were performed using the default settings of Relux Desktop in direct calculation mode. The results for illuminance and luminous intensity using each one of the two light sources respectively are shown in Tables 49-52. These tables include also the reference values. The graphic representation of the simulation results versus the field measurements tolerances are shown in Figures 16-19.

Calculated results show that the average error in all cases is below 0.1%.

Table 49 – Calculated results and reference values for illuminance under diffuse light source.

Illuminance (lx)	A	B	C	D	E	F	G	H	I	J	Average
CIE Diffuse	111.11	105.21	90.02	71.11	99.73	85.64	68.06	74.36	59.98	49.39	**81.46**
Relux	111.24	105.30	90.09	71.17	99.83	85.74	68.11	74.45	60.02	49.42	**81.54**
Error	0.13	0.09	0.07	0.06	0.10	0.10	0.05	0.08	0.04	0.03	**0.07**
Error (%)	0.11	0.08	0.07	0.09	0.10	0.12	0.07	0.11	0.07	0.05	**0.09**
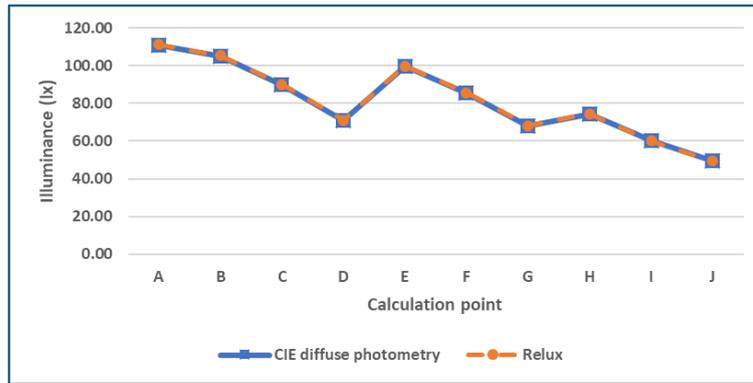
Figure 16 – Illuminance calculated results against reference values for under diffuse light source.

Table 50 - Calculated results and reference values for luminous intensity under diffuse light source.

Intensity (cd)	A	B	C	D	E	F	G	H	I	J	Average
CIE Diffuse	1000.00	986.40	948.70	894.40	973.30	937.00	884.70	904.50	857.20	816.50	**920.27**
Relux	1000.00	987.00	949.00	895.00	974.00	937.00	885.00	905.00	858.00	817.00	**920.70**
Error	0.00	0.60	0.30	0.60	0.70	0.00	0.30	0.50	0.80	0.50	**0.43**
Error (%)	0.00	0.06	0.03	0.07	0.07	0.00	0.03	0.06	0.09	0.06	**0.05**
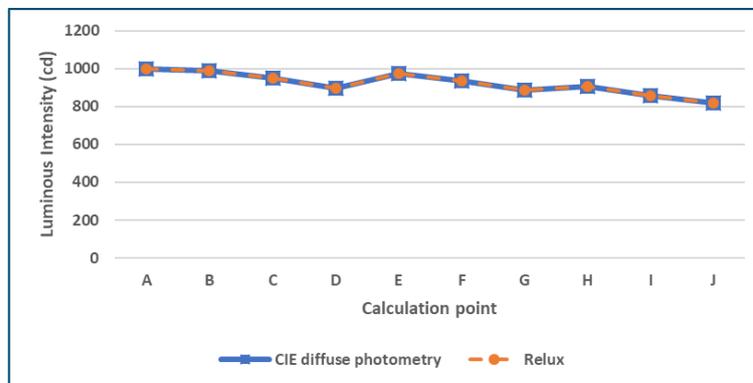
Figure 17 – Luminous intensity calculated results against reference values under the diffuse light source.

Table 51 - Calculated results and reference values for illuminance under T9 light source.

Illuminance (lx)	A	B	C	D	E	F	G	H	I	J	Average
CIE T9	111.11	122.25	124.08	117.31	113.65	113.41	102.74	91.57	81.65	62.16	**103.99**
Relux	111.15	122.26	124.10	117.34	113.71	113.42	102.70	91.61	81.66	62.14	**104.01**
Error	0.04	0.01	0.02	0.03	0.06	0.01	-0.04	0.04	0.01	-0.02	**0.01**
Error (%)	0.04	0.01	0.01	0.03	0.05	0.01	-0.04	0.04	0.01	-0.03	**0.03**
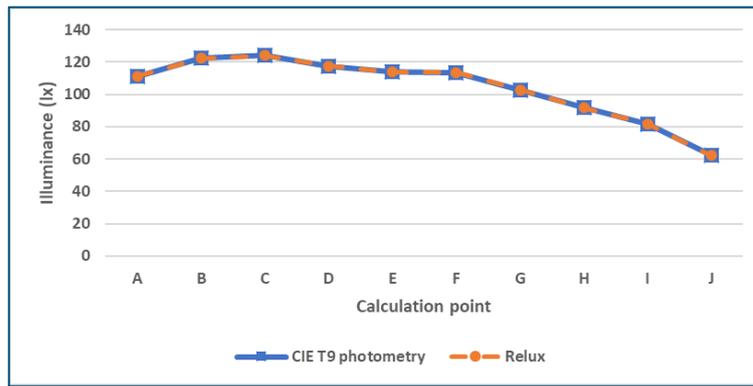
Figure 18 - Illuminance calculated results against reference values under the T9 light source.

Table 52 - Calculated results and reference values for luminous intensity under T9 light source.

Intensity (cd)	A	B	C	D	E	F	G	H	I	J	Average
CIE T9	1000.00	1146.10	1307.70	1475.50	1109.10	1240.90	1335.40	1113.80	1166.80	1027.50	**1192.28**
Relux	1000.00	1146.00	1307.00	1475.00	1109.00	1240.00	1334.00	1114.00	1167.00	1027.00	**1191.90**
Error	0.00	-0.10	-0.70	-0.50	-0.10	-0.90	-1.40	0.20	0.20	-0.50	**-0.38**
Error (%)	0.00	-0.01	-0.05	-0.03	-0.01	-0.07	-0.10	0.02	0.02	-0.05	**0.04**
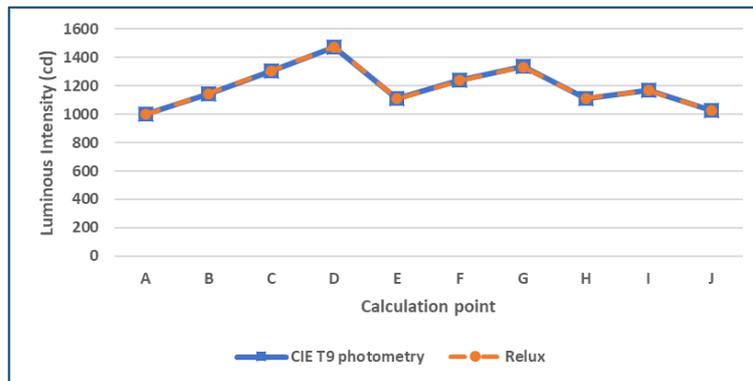
Figure 19 - Luminous intensity calculated results against reference values under the T9 light source.

3.3. Simulation of area light sources (CIE TC5.3)

3.3.1. Description

This test case assesses the capability of the lighting software to handle area light sources in a relatively small sized room. For this purpose, CIE document proposes the design of a 4x4x3m room with black walls, illuminated under the same diffuse and asymmetrical sources as in TC5.1. The calculation points are placed in a row on the floor level and on one wall of the room (Figure 20). The evaluation is performed against the reference values defined in the CIE document.
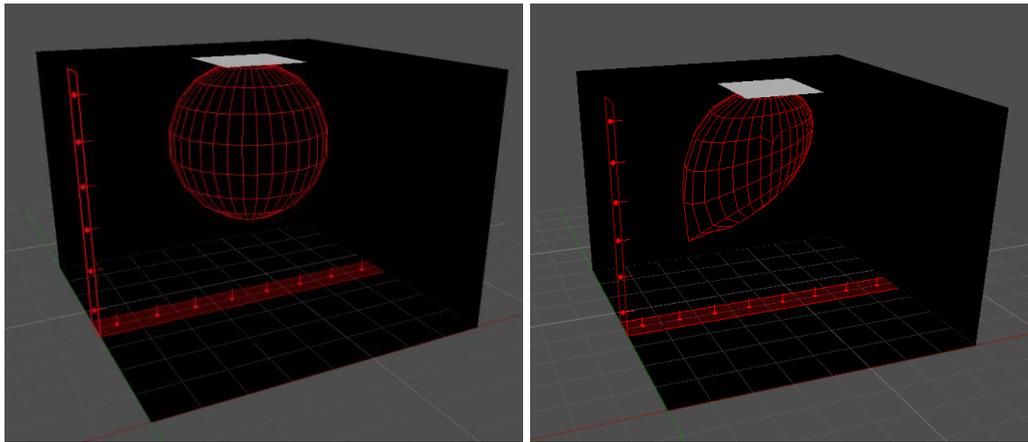
**Figure 20 – The 3D model, the light sources and the calculation points as defined in TC5.3.**

3.3.2. Test results

Lighting calculations were performed using the default settings of Relux Desktop while the calculation grid was considered as described in the CIE document. The results for illuminance using each one of the two light sources respectively are shown in Tables 53, 54. These tables include also the reference values. The graphic representation of the simulation results versus the field measurements tolerances are shown in Figure 21, 22.

Calculated results show that the average errors are 0.27% and 0.36% respectively.

Table 53 - Calculated results and reference values for illuminance under the diffuse light source.

Illuminance (lx)	A	B	C	D	E	F	G	H
CIE diffuse	32.68	75.09	81.38	69.12	53.41	39.9	61.27	79.18
Relux	32.50	75.00	81.30	69.20	53.50	40.10	61.50	79.40
Error	-0.18	-0.09	-0.08	0.08	0.09	0.20	0.23	0.22
Error (%)	-0.55	-0.12	-0.10	0.12	0.17	0.50	0.38	0.28

| Illuminance (lx)	I	J	K	L	M	N	Average	
Diffuse source	95.52	105.89	105.89	95.52	79.18	61.27	73.95	
Relux	95.90	106.00	106.00	95.90	79.40	61.50	74.09	
Error	0.38	0.11	0.11	0.38	0.22	0.23	0.14	
Error (%)	0.40	0.10	0.10	0.40	0.28	0.38	0.27	
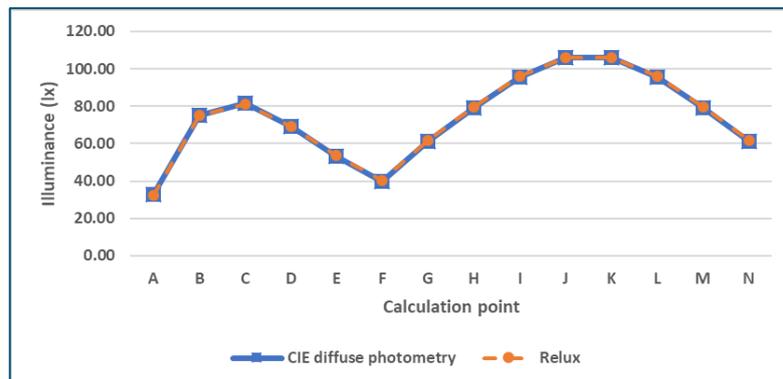
Figure 21 - Illuminance calculated results against reference values under the diffuse light source.

Table 54 - Calculated results and reference values for illuminance under the T9 light source

Illuminance (lx)	A	B	C	D	E	F	G	H
CIE T9	56.73	122.1	126.95	108.61	86.13	66.07	99.62	115.53
Relux	56.20	122.00	127.00	109.00	86.30	66.40	100.00	116.00
Error	-0.53	-0.10	0.05	0.39	0.17	0.33	0.38	0.47
Error (%)	-0.93	-0.08	0.04	0.36	0.20	0.50	0.38	0.41

Illuminance (lx)	I	J	K	L	M	N	Average	
Diffuse source	119.34	113.8	99.97	81.98	63.3	47.39	93.39	
Relux	120.00	114.00	100.00	82.00	63.50	47.30	93.55	
Error	0.66	0.20	0.03	0.02	0.20	-0.09	0.16	
Error (%)	0.55	0.18	0.03	0.02	0.32	-0.19	0.36	
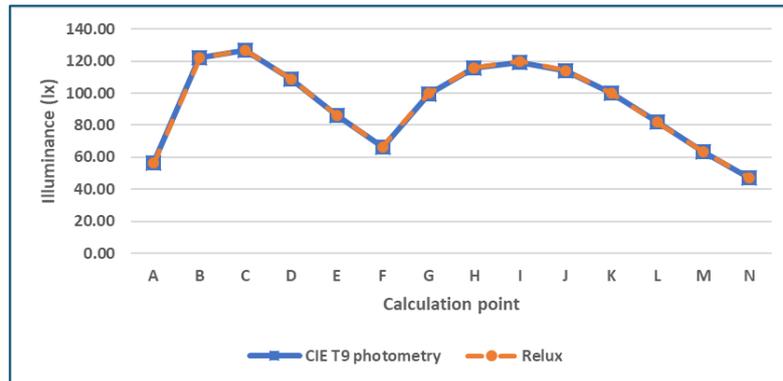
Figure 22 - Illuminance calculated results against reference values under the T9 light source.

3.4.   Luminous flux conservation (CIE TC5.4)

3.4.1.   Description

The objective of this test case was to assess the ability of the software to maintain the luminous flux between a source and the surfaces of the space. This includes the flux conservation in both open structures (under daylight) and closed structures (under artificial light sources). For this purpose, the 3D structures shown in Figure 23 were designed according to the CIE document. The assessment of the flux conservation was derived by the illuminance values under the defined surfaces against the illuminance values (incident flux) at the openings. For the enclosed scenario, the assessment is straight forward between the source luminous flux and the achieved illumination on all surfaces.

3.4.2.   Test results

Lighting calculations were performed using the default settings of Relux Desktop. Calculation grids are placed in all surfaces plus the openings (except from the closed room) The illuminance results for all the cases and for all the surfaces are summarised and the corresponding luminous flux was calculated using equation (1).

$$\Phi = E \cdot S \qquad\qquad (1)$$

where:

Φ =   the calculated incident luminous flux (in lm)

E =   the average illuminance at the surface or at the opening respectively (in lx)

S =   the corresponding surface area (in m^2)

The calculated results are shown in the following tables (55-57) and graphically in Figures 24, 25 respectively. The errors in flux comparison range from 1.2% up to 2.95% for the models with roof and wall openings and 0.04% at the closed room model.

a. Roof opening 1x1m
b. Roof opening 2x2m
c. Roof opening 3x3m
d. Roof opening 4x4m (full)
e. Wall opening 2x1m
f. Wall opening 3x2m
g. Wall opening 4x3 (full)
h. Enclosed area
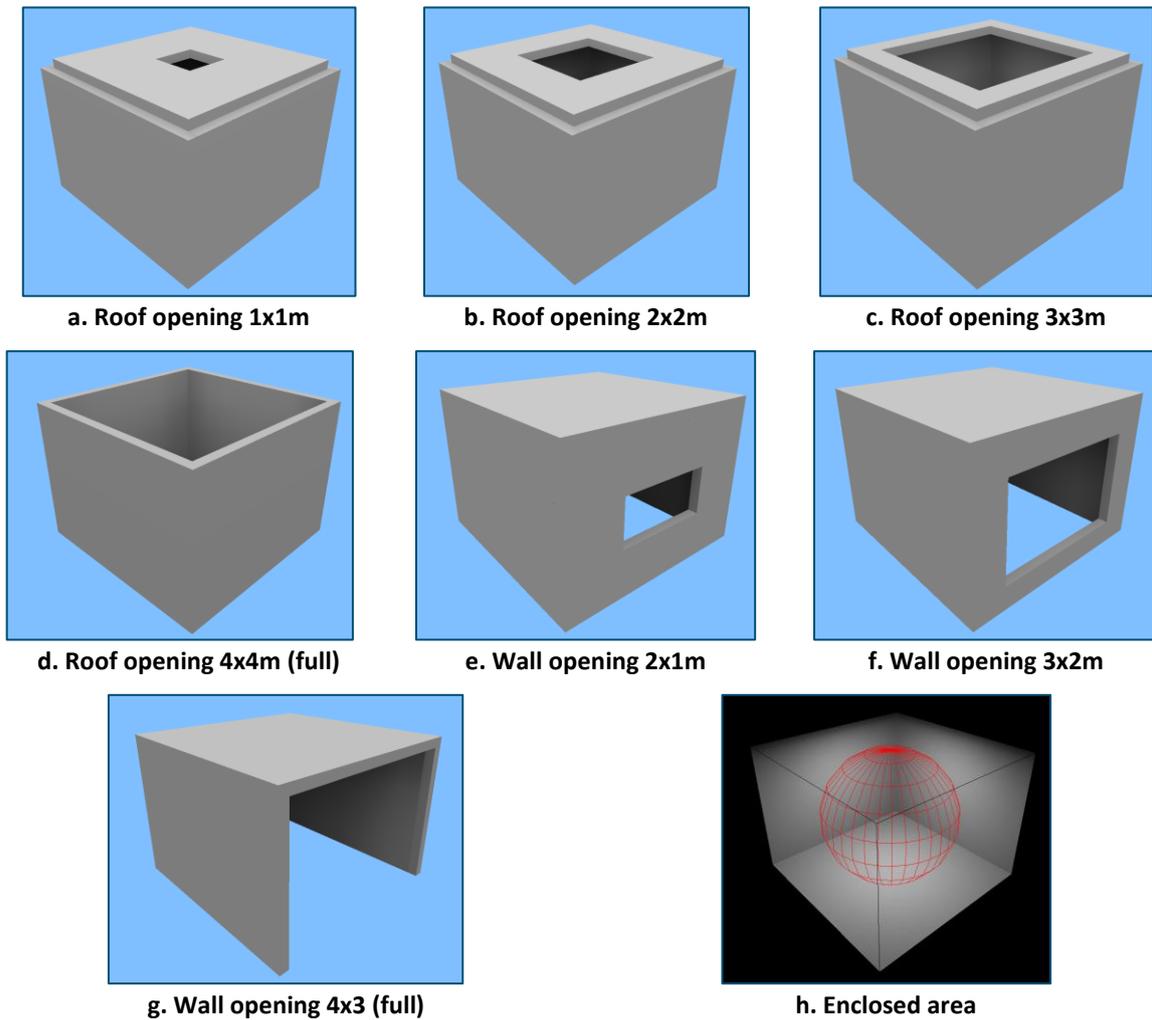
Figure 23 – 3D models that were created for the TC5.4

Table 55 – Calculation of luminous flux at the surfaces and at the opening in all roof openings.

Roof opening dimensions	1x1m	2x2m	3x3m	4x4m
Incident flux at the opening (lm)	12100	48400	108900	193600
Total flux in the room	12328	49280	111528	198112
Error	228	880	2628	4512
Error (%)	1.88	1.82	2.41	2.33
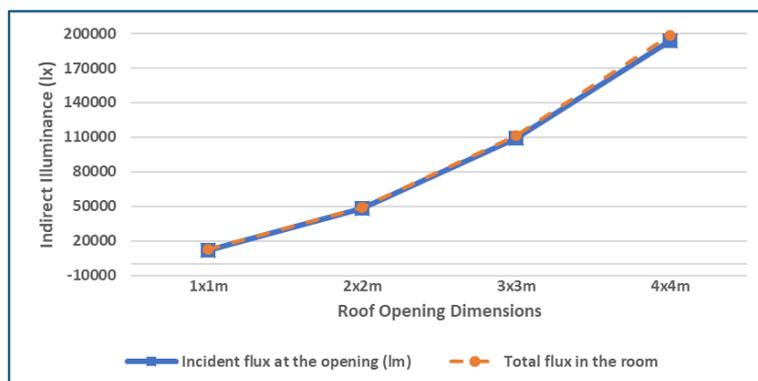
Figure 24 – Comparison of the incident flux against the total flux of the models with roof openings.

Table 56 - Calculation of luminous flux at the surfaces and at the opening in all wall openings.

North wall opening dimensions	2x1m	3x2m	4X3m
Incident flux at the opening (lm)	9180	27540	55080
Total flux in the room	9290	28352	56282
Error	110	812	1202
Error (%)	1.20%	2.95%	2.18%
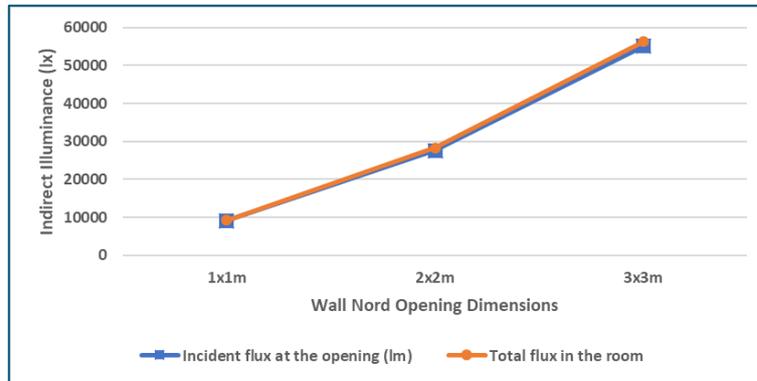
Figure 25 - Comparison of the incident flux against the total flux of the models with wall openings.

Table 57 - Calculation of the luminous flux at the surfaces and of the light source in the closed room.

Closed room dimension	4x4x3m
Total flux of the light source (lm)	3142
Total flux in the room	3141
Error	1
Error (%)	-0.04

3.5. Light reflection over diffuse surfaces (CIE TC5.6)

3.5.1. Description

The test case 5.6 aims to assess the capability of the simulation software to incorporate accurately the diffuse reflectance characteristics of a surface under various lighting conditions. This is important in terms of interreflections of the light inside rooms and of the reflection of daylight on the external ground and masks. For this purpose, a single two-element structure was designed with a calculation grid of 7+7 points along the centre of each surface (Figure 26a). The internal surfaces are illuminated by means of the reflected light from a surface (S2) placed on the ground. Three different S2 surfaces are considered. The first is 50x50cm at the centre below the structure (Figure 26b), the second is 4x4m (Figure 26c)and the third 500x500m adjusted to the structure (Figure 26d).

The illumination source in these models is direct uniform light at an incident angle of 45°, 35° and 45° respectively in the three abovementioned models. This angle ensures that the light does not illuminates the grid points directly but only the S2 surface. For the same reason, calculation point A (at the base of the structure) is not considered in the second model.

The assessment is made in terms of the reflection ratio (or variation) between the surfaces. The reference values are derived by the analytical equations and are described in the CIE document.

a. Calculation grid

b. Model with 50x50cm S2 surface

c. Model with 4x4m S2 surface

d. Model with 500x500m S2 surface
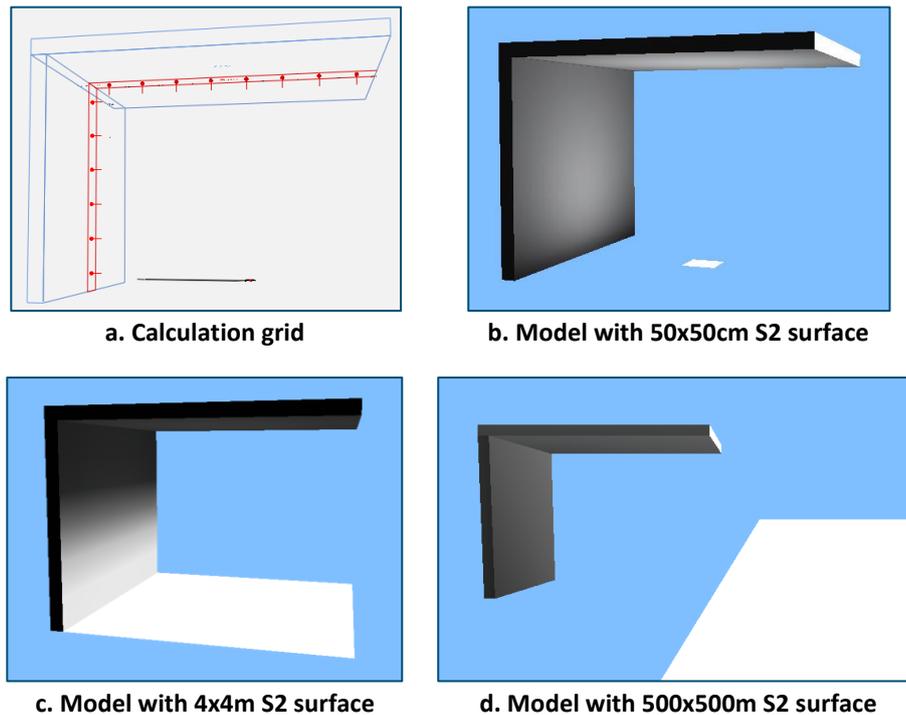
Figure 26 – 3D models and the calculation grid used in the TC5.6

3.5.2. Test results

Lighting calculations were performed using the default settings of Relux Desktop. Calculation grids were as described in the model and the illumination angle per model was selected as needed. The variation on each point of the grid was calculated using equation (2)

$$V = \frac{E}{E_{hz} \cdot \rho} \tag{2}$$

where:

    V =   illuminance variation

    E =   illuminance at the calculation point (in lx)

    E_{hz} =   average illuminance at the horizontal surface S2

    ρ =   reflectance of the horizontal surface S2

The calculated results are shown in Tables 58-60 and graphically in Figures 27-29. The results show zero average error in the model with 50x50cm S2 surface, an average error in the variation of around 0.22 in the model with 4x4m S2 surface and an average error of 1.31 in the model with 500x500m S2 surface.

Table 58 - Calculated illuminance variation and reference values of the model with 50x50cm S2 surface

Variation	A	B	C	D	E	F	G	H
CIE daylight	0.246	0.58	0.644	0.556	0.433	0.325	0.491	0.639
Relux	0.246	0.580	0.644	0.557	0.433	0.325	0.492	0.639
Error	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.000

Variation	I	J	K	L	M	N	Average	
CIE daylight	0.778	0.864	0.864	0.778	0.639	0.491	0.595	
Relux	0.778	0.866	0.866	0.778	0.639	0.492	0.595	
Error	0.000	0.002	0.002	0.000	0.000	0.001	0.000	
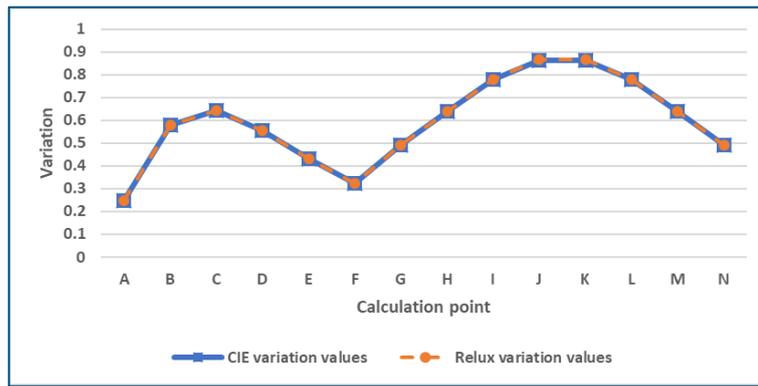
Figure 27 – Comparison between calculated and reference variation values of model with 50x50cm S2 surface.

Table 59 - Calculated illuminance variation and reference values of the model with 4x4m S2 surface

Variation	A	B	C	D	E	F	G	H
CIE daylight	-	35.901	27.992	21.639	16.716	12.967	26.800	30.940
Relux	-	37.004	28.369	21.831	16.828	13.036	26.879	31.057
Error		1.103	0.377	0.192	0.112	0.069	0.079	0.117
Variation	I	J	K	L	M	N	Average	
CIE daylight	33.980	35.570	35.570	33.980	30.940	26.800	28.446	
Relux	34.117	35.718	35.717	34.116	31.057	26.878	28.662	
Error	0.137	0.148	0.147	0.136	0.117	0.078	0.216	
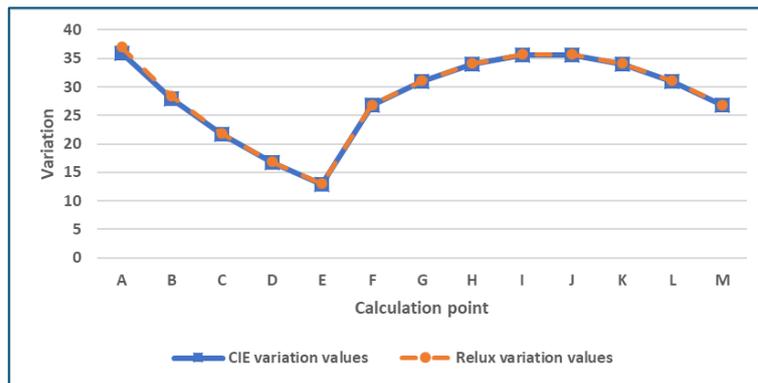
Figure 28 - Comparison between calculated and reference variation values of the model with 4x4m S2 surface.

Table 60 - Calculated illuminance variation and reference values of the model with 500x500m S2 surface

Variation	A	B	C	D	E	F	G	H
CIE daylight	3.080	9.097	14.718	19.767	24.161	27.896	10.950	13.260
Relux	2.789	8.279	13.518	18.372	22.749	26.604	9.266	11.012
Error	-0.291	-0.818	-1.200	-1.395	-1.412	-1.292	-1.684	-2.248
Variation	I	J	K	L	M	N	Average	
CIE daylight	16.210	20.000	24.800	30.770	37.870	45.840	21.316	
Relux	13.214	19.298	23.982	29.794	36.719	44.478	20.005	
Error	-2.996	-0.702	-0.818	-0.976	-1.151	-1.362	-1.310	
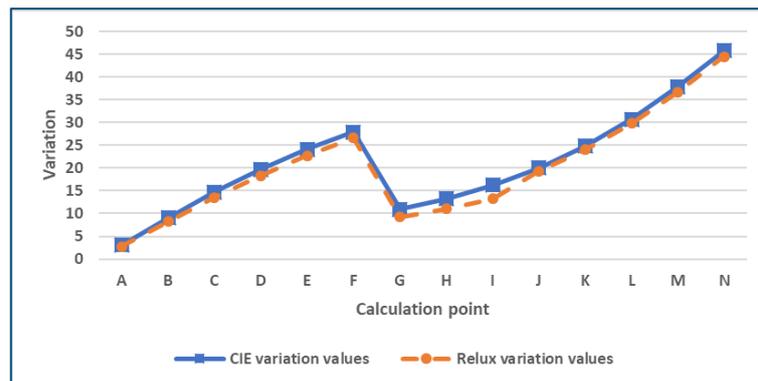
Figure 29 - Comparison between calculated and reference variation values of the model with 500x500m S2 surface.

3.6. Diffuse reflection with internal obstructions (CIE TC5.7)

3.6.1. Description

The test case 5.7 is similar with the TC5.6 while in this case is assessed the ability of the software to simulate the influence of an obstruction to the diffuse reflection. Therefore, the model shown in Figure 30 was designed. The dimensions and the reflectance of the surfaces are set as described in the CIE document. Similar to the TC5.6 the assessment is done by means of the variation of the reflected light on the calculation points against the illuminance at the S2 surface (vertical obstacle).

At this point it must be noted that the reference values given in the CIE documents are not correctly calculated using the analytical equations due to an error in the configuration factor (F_{12} in CIE document). Existing reports of NVIDIA Iray [4], Radiance [5], AGi-32 [6] and Velux [7] software have also reported this issue while they provide the updated reference values. For simplicity, the updated data calculated in the NVIDIA report was taken as reference vales.

In the context of this report, we use both sets of reference values (CIE and NVIDIA) and therefore personal conclusions are possible to be drawn.
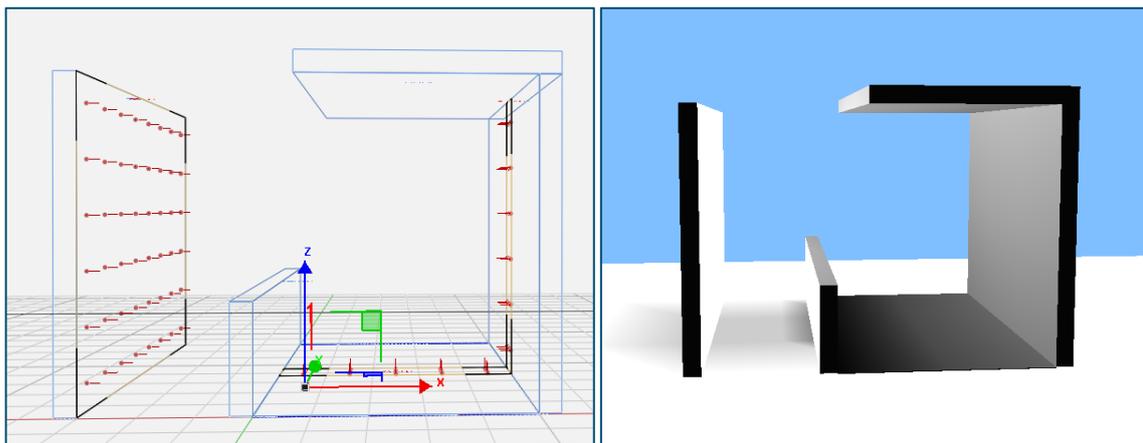

Figure 30 - 3D model and the calculation grid used in the TC5.7

3.6.2. Test results

Lighting calculations were performed using the default settings of Relux Desktop. Calculation grids were as described in the model and the illumination angle per model was set as direct light with 60º inclination. The variation results using Relux calculations against CIE original reference data are shown in Table 61 and graphically in Figure 31. The variation results using Relux calculations against the updated data reference data are shown in

Table 62 and graphically in Figure 32. The results between Relux and updated reference values are almost identical.

Table 61 – Calculated illuminance variation against CIE erroneous reference data from CIE 171:2006

Variation	A	B	C	D	E	F	G	H	I	J	Average
CIE daylight	0.2090	0.2120	0.1990	0.1730	0.1410	0.0980	0.0480	0.0530	0.0000	0.0000	0.1133
Relux	0.1594	0.1634	0.1565	0.1320	0.0999	0.0679	0.0331	0.0370	0.0291	0.0053	0.0884
Error	-0.0497	-0.0486	-0.0425	-0.0410	-0.0411	-0.0301	-0.0149	-0.0160	0.0291	0.0053	-0.0249
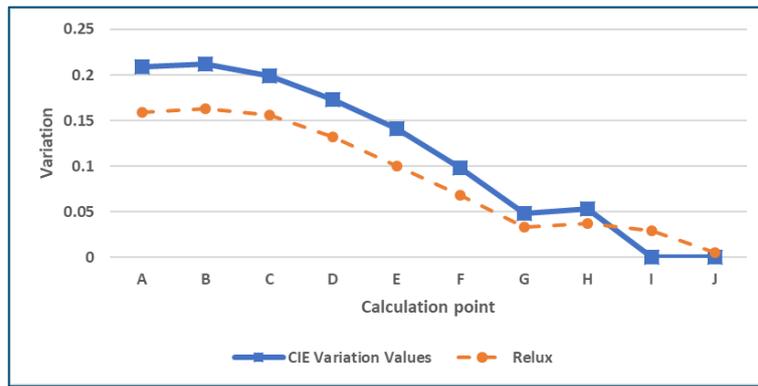
Figure 31 – Comparison between calculated and reference variation values <u>using erroneous CIE data</u>.

Table 62 - Calculated illuminance variation <u>against updated (corrected) reference data</u> from NVIDIA report

Variation	A	B	C	D	E	F	G	H	I	J	Average
Nvidia	0.1607	0.1633	0.1540	0.1332	0.1032	0.0708	0.0338	0.0363	0.0301	0.0000	0.0885
Relux	0.1594	0.1634	0.1565	0.1320	0.0999	0.0679	0.0331	0.0370	0.0291	0.0053	0.0884
Error	-0.0014	0.0001	0.0025	-0.0012	-0.0033	-0.0029	-0.0007	0.0007	-0.0010	0.0053	-0.0002
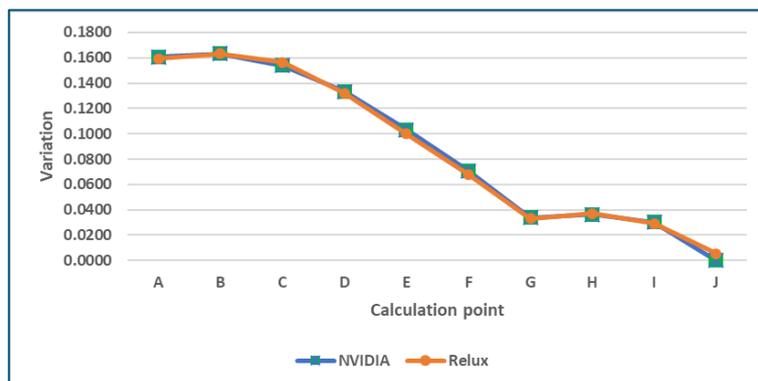
Figure 32 - Comparison between calculated and reference variation values <u>using updated (corrected) reference data</u>.

3.7.   Internal reflected component calculation for diffuse surfaces (CIE TC5.8)

3.7.1. Description

This test cases assesses the accuracy of the simulation software on the diffuse interreflections inside a room. For the scope of this test case, a room with dimensions of 4x4x4m was designed. The reflectance of the internal walls was set from 0 to 95% (Figure 33). The illumination source for all variants is an isotropic source with luminous flux equal to 10000lm. The assessment is done against the reference data derived by analytical equations in the CIE document.
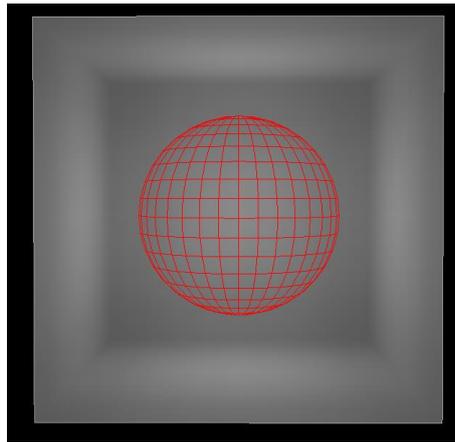
Figure 33 – 3D model of the closed room and the isotropic source in the centre as used in the TC5.8

3.7.2. Test results

Lighting calculations were performed using the default settings of Relux Desktop. The calculation method was average indirect fraction for all variants including 0% reflectance. The calculation grids in the internal surfaces were kept at their default density. The calculated results and the reference data are shown in Table 63 and graphically in Figure 34. The test results show average error less than 2%.

Table 63 - Calculated results against reference for all reflectance values.

Indirect illuminance (lx)	rho 0%	rho 5%	rho 10%	rho 20%	rho 30%	rho 40%
CIE daylight	0.00	5.48	11.60	26.00	44.60	69.40
Relux	0.01	5.60	11.80	26.30	44.80	69.30
Error	0.01	0.12	0.20	0.30	0.20	-0.10
Error (%)	-	2.15	1.29	1.08	0.51	-0.14
Indirect illuminance (lx)	rho 50	rho 60	rho 70	rho 80	rho 90	rho 95
CIE daylight	104.00	156.00	243.00	417.00	937.00	1979.00
Relux	103.00	153.20	235.90	400.40	902.10	1964.10
Error	-1.00	-2.80	-7.10	-16.60	-34.90	-14.90
Error (%)	-0.92	-1.78	-2.94	-3.97	-3.73	-0.75
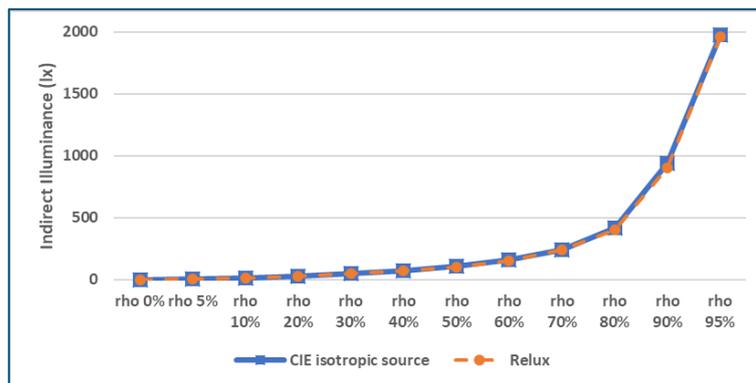
Figure 34 - Calculated results against reference values

3.8. **Sky component for a roof unglazed opening (CIE TC5.9)**

3.8.1. *Description*

The purpose of this test case and of all the remaining analytical test cases up to TC5.14 is to assess the ability of the simulation software to calculate the sky component under various illumination conditions. In general, these TCs incorporate small to big openings with or without glazing and with or without external obstacles.

It must be noted again (as in the Section 1.4) that the analytically calculated, by CIE, reference values in these TCs are not calculated by hand but using the software Skylux. Therefore, one has to has in mind that the comparison of achieved results is actually a comparison between Skylux and the software under test (Relux in this report). Furthermore, the validation of the Skylux software was done (by CIE) only for CIE general skies T5 and T16 and was assumed that the same accuracy is valid for the remaining CIE general skies.

Regarding the current test case 5.9, the scope is to calculate the sky component (SC) for an unglazed opening under CIE general skies. For this purpose, two variants of a 4x4x3m room were designed: the first one with an opening of 1x1m at the centre of the roof and the second with an opening of 4x4m (full open roof). In order to test also the alternative design options in Relux Desktop additional variants were created for each room. The first room (Figure 35) was created using a) Boolean operations for all structural elements mentioned as Room 1, b) Boolean operations for room opening and partition walls for the wall elements mentioned as Room 2 and c) all structural elements using 3D cubes mentioned as Room 3. The second room (Figure 36) was designed in the same way as the first one by only using option a) and c) due to the absence of the roof. The calculation grid is a set of 7+7 points along the floor and the wall of the room. All internal walls have zero reflectance (black walls). All openings are without any glazing.

CIE document includes the reference values for all CIE general skies (15 in total). In the current version, Relux Desktop offers two types of CIE general skies, namely, CIE type 1 – overcast and CIE type 12 – clear. Therefore, the results shown below refer to these two sky types. The sun position in all simulations was defined to the South facing at the wall with the calculation grid at 60° elevation. The direct sun illuminance was not taken into consideration. The sky component was calculated using equation (3).

$$DF(\%) = SC + ERC + IRC = \frac{E_p}{E_{hz}} \cdot 100 \qquad (3)$$

where:

DF =	the daylight factor
SC =	the sky component
ERC =	the external reflected component
IRC =	the internal reflected component
E_p =	the illuminance at a point P
E_{hz} =	the horizontal illuminance at the roof (with no obstructions)

Given that the internal walls have zero reflectance and there is no external obstruction, the SC is equal to the DF.
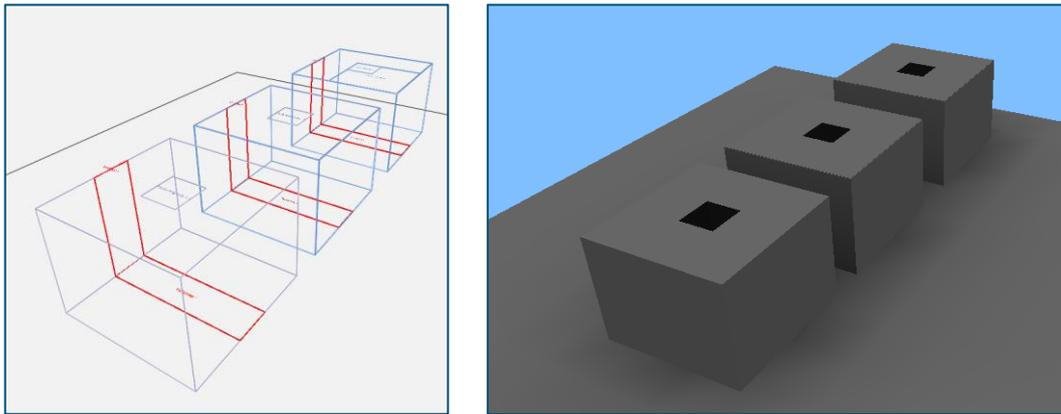
Figure 35 – The variants of the 3D models of the room with 1x1m roof opening and the calculation grids as used in the TC5.9
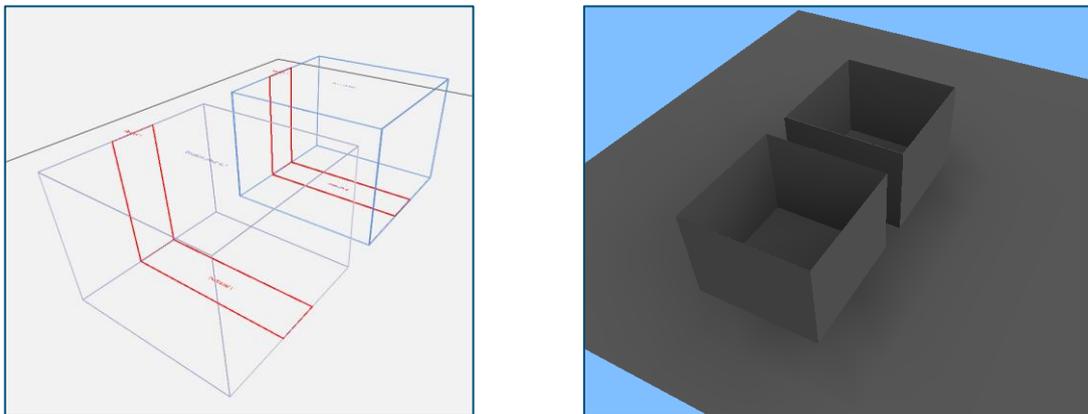
**Figure 36 - The variants of the 3D models of the room with 4x4m roof opening and the calculation grids as used in the TC5.9**

3.8.2. Test results

The calculations were performed using the default settings of Relux Desktop. The calculation grid was as defined in the previous paragraph. For the calculation of the SC an additional calculation grid was placed externally to measure the unobstructed incident illuminance (shown as External Illuminance in the corresponding tables).

The analytical illuminance calculated results for the rooms with 1x1m roof opening and the two CIE general skies are shown in Tables 64-69. The calculation of the SC of the corresponding rooms are shown in Tables 70-71. The graphical representation of the SC comparison is shown in Figures 37, 38.The analytical illuminance calculated results for the rooms with 4x4m roof opening and the two CIE general skies are shown in Tables 72-75. The calculation of the SC of the corresponding rooms are shown in Tables 76, 77. The graphical representation of the SC comparison is shown in Figures 39, 40.

The results also verify that the design method of the 3D structures (cuboids, partition walls, Boolean operations, etc) has no effect on the accuracy of the calculations.

Table 64 – Calculated illuminance values using CIE T1 - Room 1 with 1x1m roof opening

Relux (Room 1) / CIE Sky T1	External illuminance: 18600 lx							
Calculation point	A	B	C	D	E	F		
Illuminance (lx)	144	272	357	388	248	318		
Calculation point	G	H	I	J	K	L	M	N
Illuminance (lx)	386	751	727	755	727	724	779	446

Table 65 - Calculated illuminance values using CIE T1 - Room 2 with 1x1m roof opening

Relux (Room 2) / CIE Sky T1	External illuminance: 18600 lx							
Calculation point	A	B	C	D	E	F		
Illuminance (lx)	97	272	357	388	248	354		
Calculation point	G	H	I	J	K	L	M	N
Illuminance (lx)	386	802	778	755	727	725	779	388

Table 66 - Calculated illuminance values using CIE T1 - Room 3 with 1x1m roof opening

Relux (Room 3) / CIE Sky T1	External illuminance: 18600 lx							
Calculation point	A	B	C	D	E	F		
Illuminance (lx)	97	272	357	388	248	354		
Calculation point	G	H	I	J	K	L	M	N
Illuminance (lx)	386	802	778	755	727	673	728	388

Table 67 - Calculated illuminance values using CIE T12 - Room 1 with 1x1m roof opening

Relux (Room 1) / CIE Sky T12	External illuminance: 10700 lx							
Calculation point	A	B	C	D	E	F		
Illuminance (lx)	317	356	400	466	335	450		
Calculation point	G	H	I	J	K	L	M	N
Illuminance (lx)	540	862	536	383	282	222	202	93

Table 68 - Calculated illuminance values using CIE T12 - Room 2 with 1x1m roof opening

Relux (Room 2) / CIE Sky T12	External illuminance: 10700 lx							
Calculation point	A	B	C	D	E	F		
Illuminance (lx)	215	356	400	466	335	494		
Calculation point	G	H	I	J	K	L	M	N
Illuminance (lx)	540	903	577	383	282	222	202	93

Table 69 - Calculated illuminance values using CIE T12 - Room 3 with 1x1m roof opening

Relux (Room 3) / CIE Sky T12	External illuminance: 10700 lx							
Calculation point	A	B	C	D	E	F		
Illuminance (lx)	215	356	400	466	335	494		
Calculation point	G	H	I	J	K	L	M	N
Illuminance (lx)	540	903	577	383	282	207	187	93

Table 70 - Calculated and reference SC values using CIE T1 – Rooms with 1x1m roof opening

SC (%)	A	B	C	D	E	F	G	H	I	J	K	L	M	N	Average
CIE Sky - T1	0.46	1.64	2.34	2.26	1.88	1.47	2.33	3.11	3.84	4.29	4.29	3.84	3.11	2.33	**2.66**
Relux (Room 1)	0.77	1.46	1.92	2.09	1.34	1.71	2.07	4.04	3.91	4.06	3.91	3.90	4.19	2.40	**2.70**
Relux (Room 2)	0.52	1.46	1.92	2.09	1.33	1.90	2.07	4.31	4.19	4.06	3.91	3.90	4.19	2.09	**2.71**
Relux (Room 3)	0.52	1.46	1.92	2.09	1.33	1.90	2.07	4.31	4.19	4.06	3.91	3.62	3.91	2.09	**2.67**
Error - Room 1	0.31	-0.18	-0.42	-0.17	-0.54	0.24	-0.26	0.93	0.07	-0.23	-0.38	0.06	1.08	0.07	**0.04**
Error - Room 2	0.06	-0.18	-0.42	-0.17	-0.55	0.43	-0.26	1.20	0.35	-0.23	-0.38	0.06	1.08	-0.24	**0.05**
Error - Room 3	0.06	-0.18	-0.42	-0.17	-0.55	0.43	-0.26	1.20	0.35	-0.23	-0.38	-0.22	0.80	-0.24	**0.01**

Table 71 - Calculated and reference SC values using CIE T1 – Rooms with 1x1m roof opening

SC (%)	A	B	C	D	E	F	G	H	I	J	K	L	M	N	Average
CIE Sky - T12	1.74	3.76	4.55	4.61	4.24	3.63	5.72	6.01	5.12	3.97	2.9	2.03	1.4	0.96	**3.62**
Relux (Room 1)	2.96	3.33	3.74	4.35	3.13	4.21	5.05	8.05	5.01	3.58	2.63	2.07	1.89	0.87	**3.63**
Relux (Room 2)	2.01	3.33	3.74	4.35	3.13	4.62	5.05	8.44	5.39	3.58	2.63	2.07	1.89	0.87	**3.65**
Relux (Room 3)	2.01	3.33	3.74	4.35	3.13	4.62	5.05	8.44	5.39	3.58	2.63	1.94	1.75	0.87	**3.63**
Error - Room 1	1.22	-0.43	-0.81	-0.26	-1.11	0.58	-0.67	2.04	-0.11	-0.39	-0.27	0.04	0.49	-0.09	**0.02**
Error - Room 2	0.27	-0.43	-0.81	-0.26	-1.11	0.99	-0.67	2.43	0.27	-0.39	-0.27	0.04	0.49	-0.09	**0.03**
Error - Room 3	0.27	-0.43	-0.81	-0.26	-1.11	0.99	-0.67	2.43	0.27	-0.39	-0.27	-0.09	0.35	-0.09	**0.01**
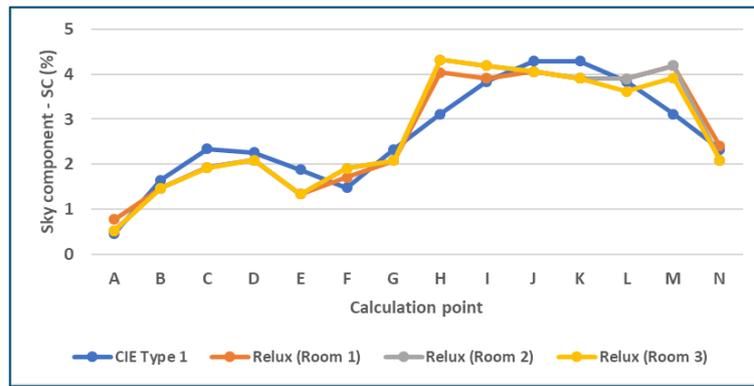
Figure 37 – Comparison between calculated and reference SC values using CIE T1 - Rooms with 1x1m roof opening
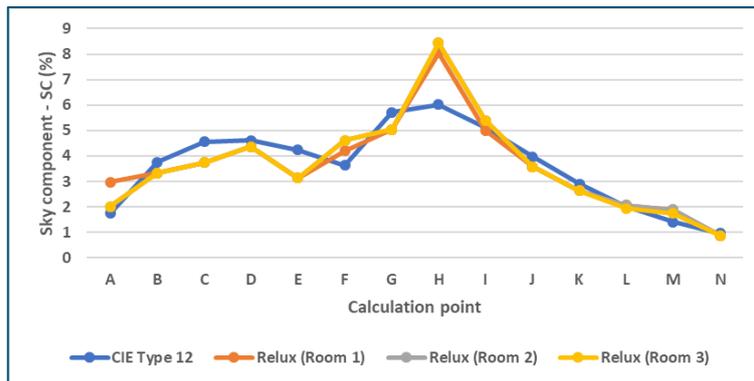
Figure 38 - Comparison between calculated and reference SC values using CIE T12 - Rooms with 1x1m roof opening

Table 72 - Calculated illuminance values using CIE T1 - Room 1 with 4x4m roof opening

Relux (Room 1) / CIE Sky T1	External illuminance: 18600 lx						
Calculation point	A	B	C	D	E	F	
Illuminance (lx)	6817	5857	4964	4197	3391	6817	
Calculation point	G	H	I	J	K	L	M	N
Illuminance (lx)	5882	6677	7518	8051	8051	7520	6652	5885

Table 73 - Calculated illuminance values using CIE T1 - Room 3 with 4x4m roof opening

Relux (Room 3) / CIE Sky T1	External illuminance: 18600 lx						
Calculation point	A	B	C	D	E	F	
Illuminance (lx)	6860	5857	4964	4145	3391	2668	
Calculation point	G	H	I	J	K	L	M	N
Illuminance (lx)	5882	6677	7518	8051	8051	7520	6652	5885

Table 74 - Calculated illuminance values using CIE T12 - Room 1 with 4x4m roof opening

Relux (Room 1) / CIE Sky T12	External illuminance: 10600 lx						
Calculation point	A	B	C	D	E	F	
Illuminance (lx)	7508	5779	4723	3942	3223	2586	
Calculation point	G	H	I	J	K	L	M	N
Illuminance (lx)	4520	4543	4666	4301	4000	3015	2298	1785

Table 75 - Calculated illuminance values using CIE T12 - Room 3 with 4x4m roof opening

Relux (Room 3) / CIE Sky T12	External illuminance: 10600 lx						
Calculation point	A	B	C	D	E	F	
Illuminance (lx)	7596	5780	4723	3900	3223	2593	
Calculation point	G	H	I	J	K	L	M	N
Illuminance (lx)	4520	4543	4666	4301	4000	3015	2298	1785

Table 76 - Calculated and reference SC values using CIE T1 – Rooms with 4x4m roof opening

SC (%)	A	B	C	D	E	F	G	H	I	J	K	L	M	N	Average
CIE Sky - T1	37.84	31.72	26.85	22.10	17.89	14.38	31.87	37.30	41.27	43.35	43.35	41.27	37.30	31.87	**32.74**
Relux (Room 1)	36.65	31.49	26.69	22.57	18.23	14.27	31.62	35.90	40.42	43.28	43.29	40.43	35.76	31.64	**32.30**
Relux (Room 3)	36.88	31.49	26.69	22.28	18.23	14.34	31.63	35.90	40.42	43.28	43.29	40.43	35.76	31.64	**32.30**
Error - Room 1	-1.19	-0.23	-0.16	0.47	0.34	-0.11	-0.25	-1.40	-0.85	-0.07	-0.06	-0.84	-1.54	-0.23	**-0.44**
Error - Room 3	-0.96	-0.23	-0.16	0.18	0.34	-0.04	-0.24	-1.40	-0.85	-0.07	-0.06	-0.84	-1.54	-0.23	**-0.44**

Table 77 - Calculated and reference SC values using CIE T12 – Rooms with 4x4m roof opening

SC (%)	A	B	C	D	E	F	G	H	I	J	K	L	M	N	Average
CIE Sky - T12	66.34	54.33	44.25	36.10	29.48	24.25	42.33	43.82	43.54	40.85	35.92	29.17	22.62	16.79	**37.84**
Relux (Room 1)	70.83	54.52	44.56	37.19	30.40	24.40	42.65	42.86	44.02	40.58	37.74	28.45	21.67	16.84	**38.34**
Relux (Room 2)	71.66	54.52	44.56	36.79	30.40	24.46	42.65	42.86	44.02	40.58	37.74	28.45	21.68	16.84	**38.37**
Error - Room 1	4.49	0.19	0.31	1.09	0.92	0.15	0.32	-0.96	0.48	-0.27	1.82	-0.72	-0.95	0.05	**0.49**
Error - Room 3	5.32	0.19	0.31	0.69	0.92	0.21	0.32	-0.96	0.48	-0.27	1.82	-0.72	-0.94	0.05	**0.53**
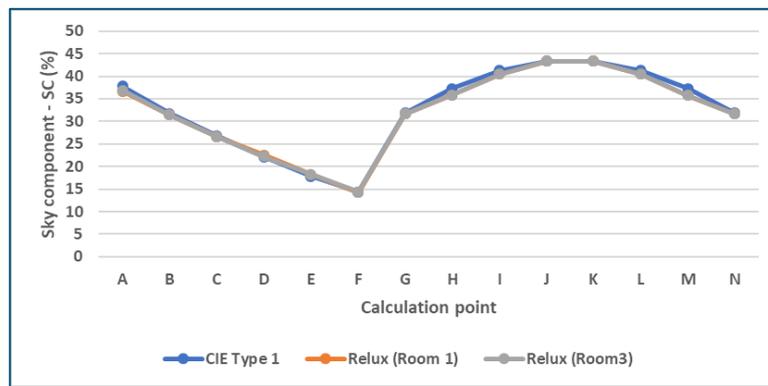
Figure 39 - Comparison between calculated and reference SC values using CIE T1 – Rooms with 4x4m roof opening
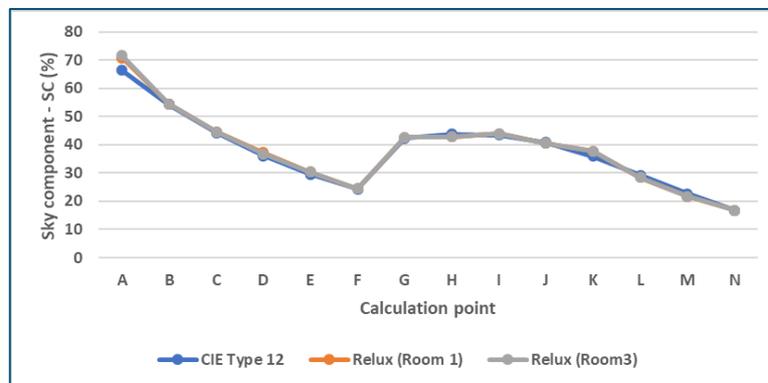
Figure 40 - Comparison between calculated and reference SC values using CIE T12 – Rooms with 4x4m roof opening

3.9. Sky component under a roof glazed opening (CIE TC5.10)

3.9.1. Description

This test case follows the same concept as TC5.9 but in this case the roof opening is covered by a thin glass. The design of this model is considered in Relux Desktop as an internal room and therefore there is only one method for the design (in contrast with TC5.9). CIE document defines the glass thickness equal to 6mm. Relux Desktop handles all glazed openings as a material without thickness. Therefore, this type of material was used in this assessment. Similar to the TC5.9, two rooms were designed, one with 1x1m glazed roof opening (Figure 41) and one with 4x4m glazed roof opening (Figure 42). The calculation grid and the CIE general sky types remain the same as in TC5.9. The reference values were obtained from the CIE document.
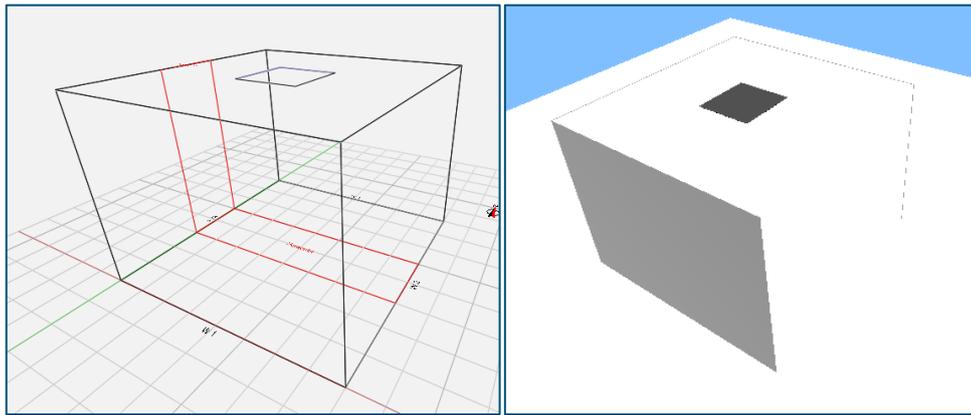
Figure 41 - 3D model of the room with 1x1m roof glazed opening and the calculation grid as used in the TC5.10
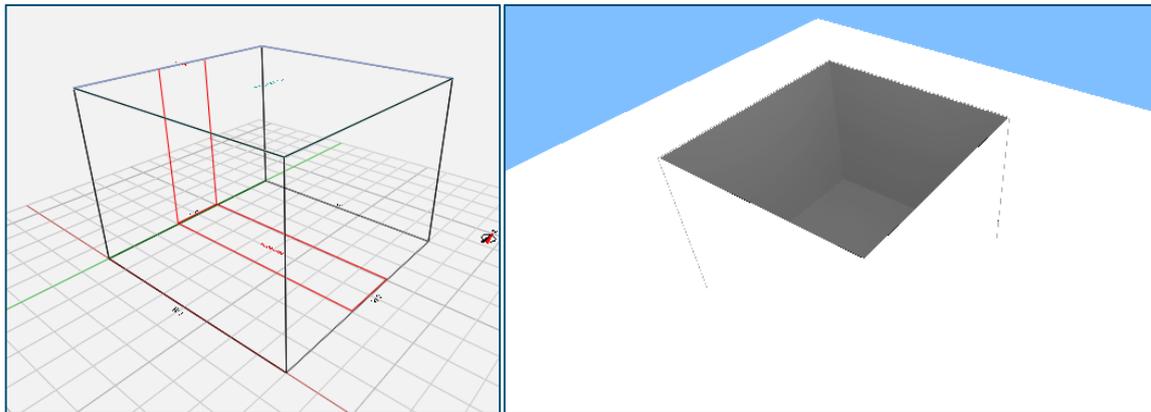
Figure 42 - 3D model of the room with 4x4m roof glazed opening and the calculation grid as used in the TC5.10

3.9.2. Test results

The calculations were performed using the default settings of Relux Desktop. The calculation grid was as defined in the previous paragraph. For the calculation of the SC an additional calculation grid was placed externally to measure the unobstructed incident illuminance (shown as External Illuminance in the corresponding tables).

The analytical illuminance calculated results for the rooms with 1x1m glazed roof opening and the two CIE general skies are shown in Tables 78, 79. The calculation of the SC of the corresponding rooms are shown in Tables 80, 81. The graphical representation of the SC comparison is shown in Figures 43, 44.

The analytical illuminance calculated results for the rooms with 4x4m glazed roof opening and the two CIE general skies are shown in Tables 82, 83. The calculation of the SC of the corresponding rooms are shown in Tables 84, 85. The graphical representation of the SC comparison is shown in Figures 45, 46.

Table 78 - Calculated illuminance values using CIE T1 - Room with 1x1m glazed roof opening

Relux / CIE Sky T1	External illuminance: 18500 lx							
Calculation point	A	B	C	D	E	F		
Illuminance (lx)	89	254	395	387	309	239		
Calculation point	G	H	I	J	K	L	M	N
Illuminance (lx)	400	547	647	716	725	647	534	398

Table 79 - Calculated illuminance values using CIE T12 - Room with 1x1m glazed roof opening

Relux / CIE Sky T12	External illuminance: 10600 lx							
Calculation point	A	B	C	D	E	F		
Illuminance (lx)	197	339	456	458	402	336		
Calculation point	G	H	I	J	K	L	M	N
Illuminance (lx)	566	601	491	382	281	199	138	96

Table 80 - Calculated and reference SC values using CIE T1 – Room with 1x1m glazed roof opening

SC (%)	A	B	C	D	E	F	G	H	I	J	K	L	M	N	Average
CIE Sky - T1	0.15	1.17	1.91	1.92	1.62	1.28	2.04	2.73	3.38	3.78	3.78	3.38	2.73	2.04	**2.28**
Relux	0.48	1.37	2.14	2.09	1.67	1.29	2.16	2.95	3.50	3.87	3.92	3.50	2.89	2.15	**2.43**
Error	0.33	0.20	0.23	0.17	0.05	0.01	0.12	0.22	0.12	0.09	0.14	0.12	0.16	0.11	**0.15**

Table 81 - Calculated and reference SC values using CIE T12 – Room with 1x1m glazed roof opening

SC (%)	A	B	C	D	E	F	G	H	I	J	K	L	M	N	Average
CIE Sky - T12	0.58	2.65	3.72	3.92	3.66	3.16	5.01	5.28	4.51	3.49	2.55	1.79	1.23	0.84	**3.03**
Relux	1.86	3.20	4.30	4.32	3.79	3.17	5.34	5.67	4.63	3.60	2.66	1.88	1.30	0.90	**3.33**
Error	1.28	0.55	0.58	0.40	0.13	0.01	0.33	0.39	0.12	0.11	0.11	0.09	0.07	0.06	**0.30**
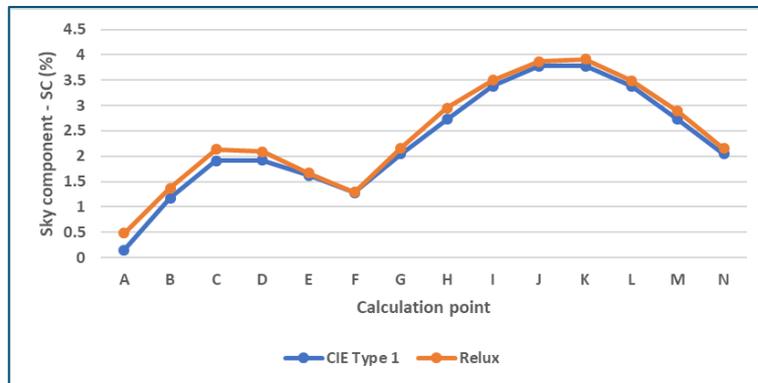
Figure 43 - Comparison between calculated and reference SC values using CIE T1 - Room with 1x1m glazed roof opening
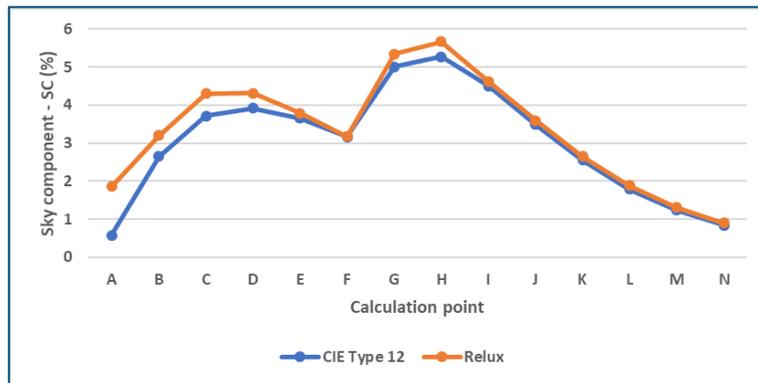
Figure 44 - Comparison between calculated and reference SC values using CIE T12 - Room with 1x1m glazed roof opening

Table 82 - Calculated illuminance values using CIE T1 - Room with 4x4m glazed roof opening

Relux / CIE Sky T1	External illuminance: 18500 lx							
Calculation point	A	B	C	D	E	F		
Illuminance (lx)	6145	5382	4556	3765	3042	2437		
Calculation point	G	H	I	J	K	L	M	N
Illuminance (lx)	5404	6304	6966	7338	7325	6969	6296	5397

Table 83 - Calculated illuminance values using CIE T12 - Room with 4x4m glazed roof opening

Relux / CIE Sky T12	External illuminance: 10700 lx							
Calculation point	A	B	C	D	E	F		
Illuminance (lx)	6639	5357	4349	3542	2902	2365		
Calculation point	G	H	I	J	K	L	M	N
Illuminance (lx)	4125	4276	4223	3981	3513	2825	2197	1645

Table 84 - Calculated and reference SC values using CIE T1 – Room with 4x4m glazed roof opening

SC (%)	A	B	C	D	E	F	G	H	I	J	K	L	M	N	Average
CIE Sky - T1	28.64	25.36	22.25	18.71	15.34	12.43	27.88	32.69	36.22	38.07	38.07	36.22	32.69	27.88	**28.03**
Relux	33.22	29.09	24.63	20.35	16.44	13.17	29.21	34.08	37.65	39.67	39.59	37.67	34.04	29.17	**29.86**
Error	4.58	3.73	2.38	1.64	1.10	0.74	1.33	1.39	1.43	1.60	1.52	1.45	1.35	1.29	1.82

Table 85 - Calculated and reference SC values using CIE T12 – Room with 4x4m glazed roof opening

SC (%)	A	B	C	D	E	F	G	H	I	J	K	L	M	N	Average
CIE Sky - T12	46.30	42.34	36.37	30.47	25.25	20.95	36.96	38.34	38.16	35.86	31.56	25.63	19.85	14.71	**31.63**
Relux	62.04	50.06	40.65	33.10	27.13	22.10	38.55	39.96	39.47	37.21	32.83	26.40	20.54	15.37	**34.67**
Error	15.74	7.72	4.28	2.63	1.88	1.15	1.59	1.62	1.31	1.35	1.27	0.77	0.69	0.66	**3.05**
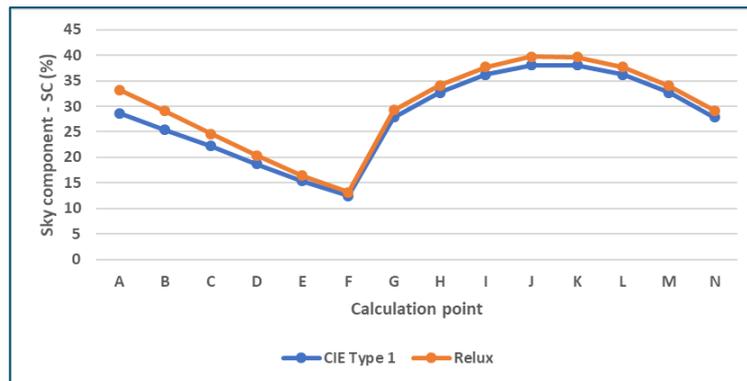
Figure 45 - Comparison between calculated and reference SC values using CIE T1 - Room with 4x4m glazed roof opening
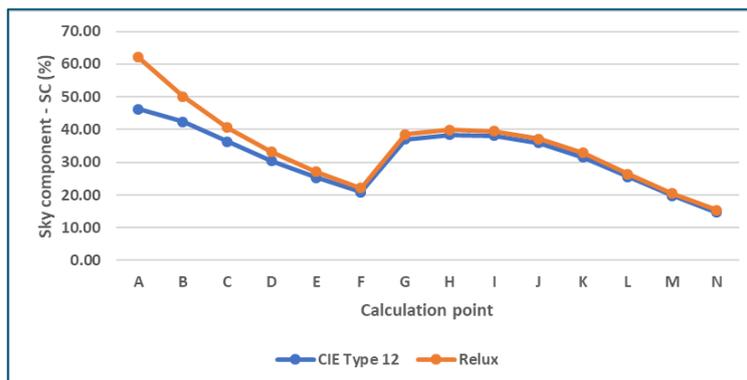
Figure 46 - Comparison between calculated and reference SC values using CIE T12 - Room with 4x4m glazed roof opening

3.10. Sky component and external reflected component for a façade unglazed opening (CIE TC5.11)

3.10.1. Description

This test case is similar to the test cases that incorporate a roof opening but now the opening is on one of the room walls. This is due to assess the ability of the simulation software to calculate the SC but also the ERC (External Reflected Component). Therefore, the concept of simulation is the same while the reference values include also the ERC. For the purpose of this TC, two rooms were designed. The first with a wall/façade opening (unglazed) of 2x1m (Figure 47) and the second with a wall/façade opening of 4x3m (Figure 48). The calculation grid is a set of 7+7+7 points across the floor, the wall and the ceiling of the room. All internal walls have zero reflectance (black walls). All openings are without any glazing.

CIE general skies T1 and T12 were tested. The sun position, in all simulations, was defined to the South facing towards the wall which has the calculation grid at the elevation of 60º. The direct sun illuminance was not taken into consideration
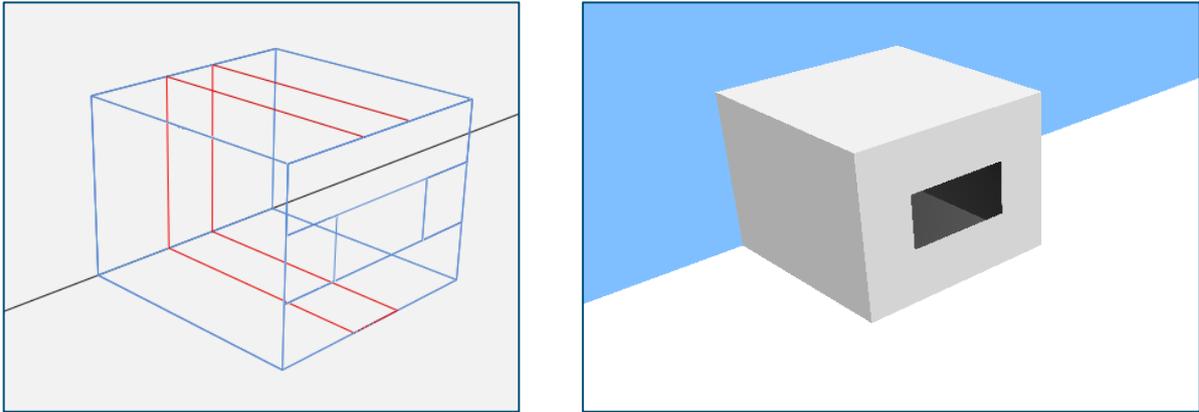

Figure 47 -3D model of the room with 2x1m wall opening and the calculation grid as used in the TC5.11
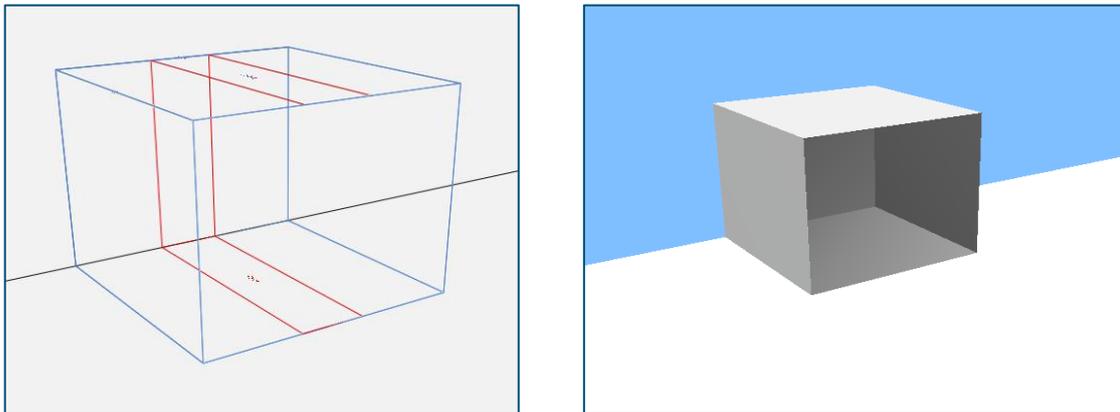
Figure 48 -3D model of the room with 4x3m wall opening and the calculation grid as used in the TC5.11

3.10.2. Test results

The calculations were performed using the default settings of Relux Desktop. The calculation grid was as defined in the previous paragraph. For the calculation of the SC and the ERC an additional calculation grid was placed externally to measure the unobstructed incident illuminance (shown as External Illuminance in the corresponding tables).

The analytical illuminance calculated results for the rooms with 1x1m glazed roof opening and the two CIE general skies are shown in Tables 86, 87. The calculation of the SC+ERC for the corresponding rooms are shown in Tables 88, 89. The graphical representation of the SC+ERC comparison is shown in Figures 49, 50.

The analytical illuminance calculated results for the rooms with 4x4m glazed roof opening and the two CIE general skies are shown in Table 90, 91. The calculation of the SC+ERC for the corresponding rooms are shown in Table 92, 93. The graphical representation of the SC+ERC comparison is shown in Figures 51, 52.

Table 86 - Calculated illuminance values using CIE T1 - Room with 2x1m wall opening

Relux / CIE Sky T1	External illuminance: 18600 lx						
Calculation point	A	B	C	D	E	F	
Illuminance (lx)	175	221	154	235	312	242	
Calculation point	G	H	I	J	K	L	M	N
Illuminance (lx)	183	294	307	640	943	1414	1689	878
Calculation point	G'	H'	I'	J'	K'	L'	M'	N'
Illuminance (lx)	115	148	192	198	267	361	0	0

Table 87 - Calculated illuminance values using CIE T12 - Room with 2x1m wall opening

Relux / CIE Sky T12	External illuminance: 10700 lx						
Calculation point	A	B	C	D	E	F	
Illuminance (lx)	60	92	89	459	633	377	
Calculation point	G	H	I	J	K	L	M	N
Illuminance (lx)	256	354	347	718	1034	1516	1625	470
Calculation point	G'	H'	I'	J'	K'	L'	M'	N'
Illuminance (lx)	0	0	0	192	244	0	0	0

Table 88 - Calculated and reference SC + ERC values using CIE T1 – Room with 2x1m wall opening

SC+ERC (%)	A	B	C	D	E	F	G	H	I	J	K	L	M	N
CIE Sky - T1	0.95	1.06	1.25	1.51	1.70	1.86	0.87	1.31	2.02	3.20	5.07	7.64	9.33	5.09
Relux	0.94	1.19	0.83	1.26	1.68	1.30	0.99	1.58	1.65	3.44	5.07	7.60	9.08	4.72
Error	-0.01	0.13	-0.42	-0.25	-0.02	-0.56	0.12	0.27	-0.37	0.24	0.00	-0.04	-0.25	-0.37
SC+ERC	G'	H'	I'	J'	K'	L'	M'	N'	Average (all calculation points)					
CIE Sky - T1	0.38	0.53	0.75	1.08	1.56	2.14	2.4	1.24	2.41					
Relux	0.62	0.79	1.03	1.06	1.43	1.94	0.00	0.00	2.19					
Error	0.24	0.26	0.28	-0.02	-0.13	-0.20	-2.40	-1.24	-0.21					

Table 89 - Calculated and reference SC + ERC values using CIE T12 – Room with 2x1m wall opening

SC+ERC (%)	A	B	C	D	E	F	G	H	I	J	K	L	M	N
CIE Sky - T12	0.95	1.06	2.39	4.93	5.8	5.01	2	2.8	4.06	6.13	9.54	14.57	16.35	5.03
Relux	0.56	0.86	0.83	4.29	5.92	3.53	2.39	3.31	3.24	6.71	9.67	14.17	15.19	4.39
Error	-0.39	-0.20	-1.56	-0.64	0.12	-1.48	0.39	0.51	-0.82	0.58	0.13	-0.40	-1.16	-0.64
SC+ERC	G'	H'	I'	J'	K'	L'	M'	N'	Average (all calculation points)					
CIE Sky - T12	0.38	0.53	0.75	1.08	1.56	2.14	2.4	1.24	4.12					
Relux	0.00	0.00	0.00	1.79	2.28	0.00	0.00	0.00	3.60					
Error	-0.38	-0.53	-0.75	0.71	0.72	-2.14	-2.40	-1.24	-0.53					
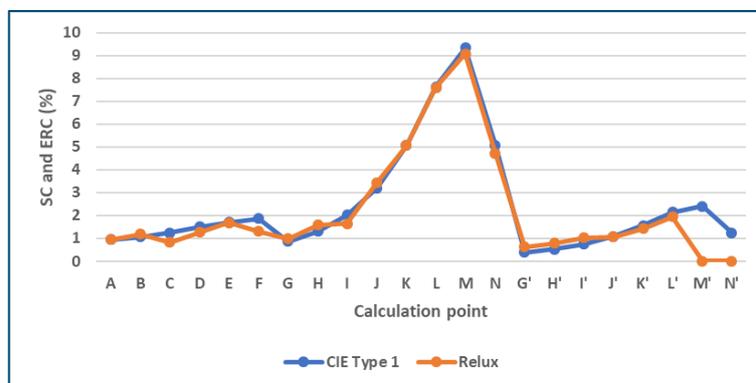
Figure 49 - Comparison between calculated and reference SC+ERC values using CIE T1 - Room with 2x1m wall opening
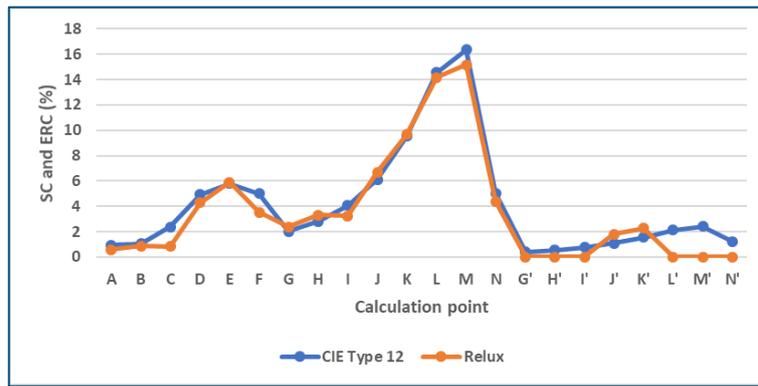
Figure 50 - Comparison between calculated and reference SC+ERC values using CIE T12 - Room with 2x1m wall opening

Table 90 - Calculated illuminance values for CIE T1 - Room with 4x4m wall opening

Relux / CIE Sky T1	External illuminance: 18600 lx						
Calculation point	A	B	C	D	E	F	
Illuminance (lx)	619	999	1182	1370	1604	1813	
Calculation point	G	H	I	J	K	L	M	N
Illuminance (lx)	784	1292	1401	2441	3227	4384	6147	8304
Calculation point	G'	H'	I'	J'	K'	L'	M'	N'
Illuminance (lx)	196	243	324	514	647	939	1187	1556

Table 91 - Calculated illuminance values using CIE T12 - Room with 4x4m wall opening

Relux / CIE Sky T12	External illuminance: 10700 lx						
Calculation point	A	B	C	D	E	F	
Illuminance (lx)	405	1372	1765	2110	2435	2717	
Calculation point	G	H	I	J	K	L	M	N
Illuminance (lx)	989	1534	1634	2759	3476	4608	5840	7004
Calculation point	G'	H'	I'	J'	K'	L'	M'	N'
Illuminance (lx)	132	161	211	262	325	577	729	932

Table 92 - Calculated and reference SC + ERC values using CIE T1 – Room with 4x4m wall opening

SC+ERC (%)	A	B	C	D	E	F	G	H	I	J	K	L	M	N
CIE Sky - T1	5.25	6.11	6.98	7.99	8.77	9.35	4.27	5.92	8.33	11.82	16.84	23.83	33.05	44.06
Relux	3.33	5.37	6.35	7.36	8.62	9.75	4.21	6.95	7.53	13.12	17.35	23.57	33.05	44.65
Error	-1.92	-0.74	-0.63	-0.63	-0.15	0.40	-0.06	1.03	-0.80	1.30	0.51	-0.26	0.00	0.59
SC+ERC	G'	H'	I'	J'	K'	L'	M'	N'	Average (all calculation points)					
CIE Sky - T1	1.74	2.29	3.06	4.14	5.63	7.65	10.27	13.59	10.95					
Relux	1.05	1.31	1.74	2.76	3.48	5.05	6.38	8.36	10.06					
Error	-0.69	-0.98	-1.32	-1.38	-2.15	-2.60	-3.89	-5.23	-0.89					

Table 93 - Calculated and reference SC + ERC values using CIE T12 – Room with 4x4m wall opening

SC+ERC (%)	A	B	C	D	E	F	G	H	I	J	K	L	M	N
CIE Sky - T12	7.63	12.15	15.8	19.96	22.13	23.68	9.26	12.35	16.79	23.17	32.1	43.03	54.44	65.07
Relux	3.79	12.82	16.50	19.72	22.76	25.39	9.24	14.34	15.27	25.79	32.49	43.07	54.58	65.46
Error	-3.84	0.67	0.70	-0.24	0.63	1.71	-0.02	1.99	-1.52	2.62	0.39	0.04	0.14	0.39
SC+ERC	G'	H'	I'	J'	K'	L'	M'	N'	Average (all calculation points)					
CIE Sky - T12	1.74	2.29	3.06	4.14	5.63	7.65	10.27	13.59	18.45					
Relux	1.23	1.51	1.97	2.45	3.04	5.39	6.81	8.71	17.83					
Error	-0.51	-0.78	-1.09	-1.69	-2.59	-2.26	-3.46	-4.88	-0.62					
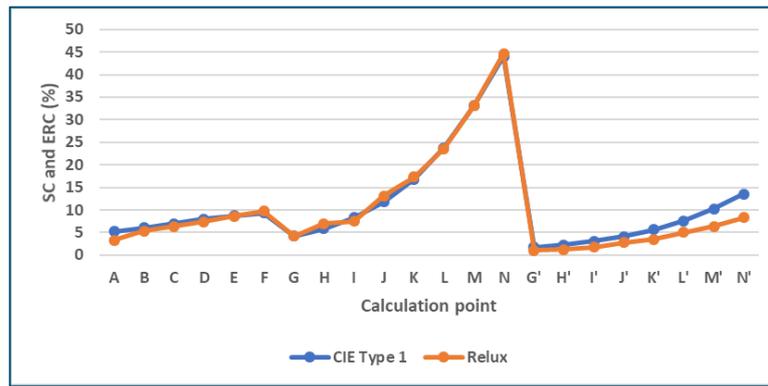
Figure 51 - Comparison between calculated and reference SC+ERC values using CIE T1 - Room with 4x4m wall opening
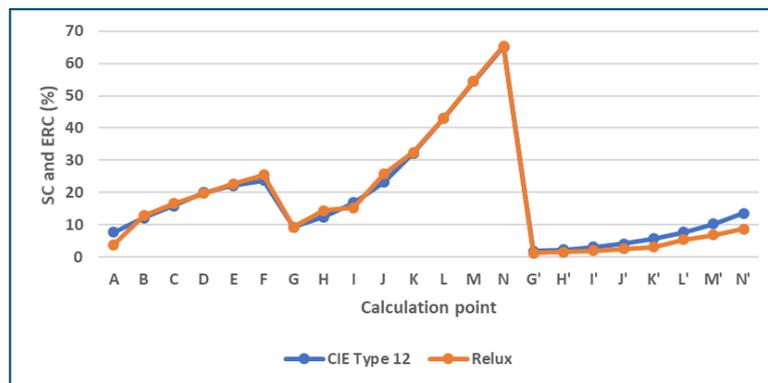
Figure 52 - Comparison between calculated and reference SC+ERC values using CIE T12 - Room with 4x4m wall opening

3.11. Sky component + External reflected component for a façade glazed opening (CIE TC5.12)

3.11.1. Description

The test case 5.12 is similar to the TC5.11 but here the façade openings are covered by glass. Therefore, two rooms were designed. The first with a wall/façade opening (unglazed) of 2x1m (Figure 53) and the second with a wall/façade opening of 4x3m (Figure 54). The calculation grid is a set of 7+7+7 points across the floor, the wall and the ceiling of the room. All internal walls have zero reflectance (black walls). All openings are with default glass material.

CIE general skies T1 and T12 were tested. The sun position in all simulations was defined to the South facing at the wall with the calculation grid at 60° elevation. The direct sun illuminance was not taken into consideration

It must be noted that the CIE document calculates the reference values at the ceiling calculation points G' to N' using only one type of sky. This is in general not correct as the shadow casting and therefore the reflected component strongly depends on the type of the sky. This is probably the source of the disparities shown in some of the following results at the above-mentioned calculation points.
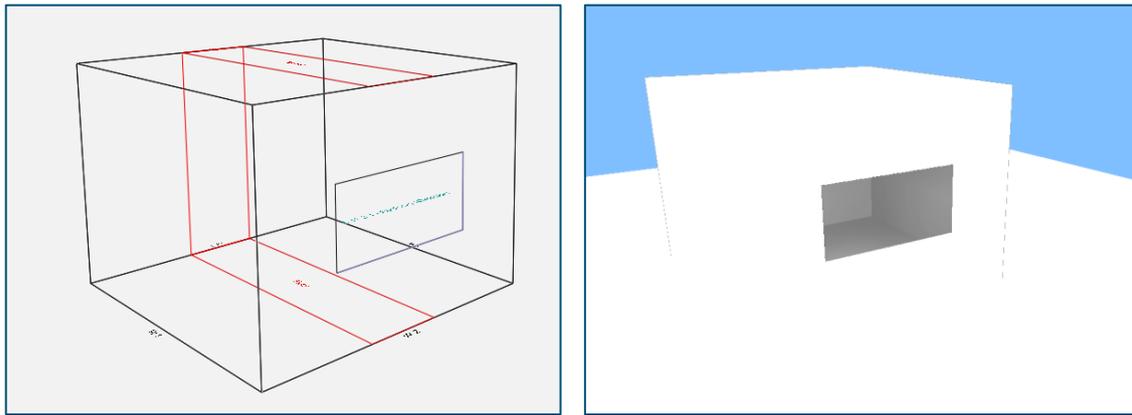
Figure 53 -3D model of the room with 2x1m glazed wall opening and the calculation grid as used in the TC5.12
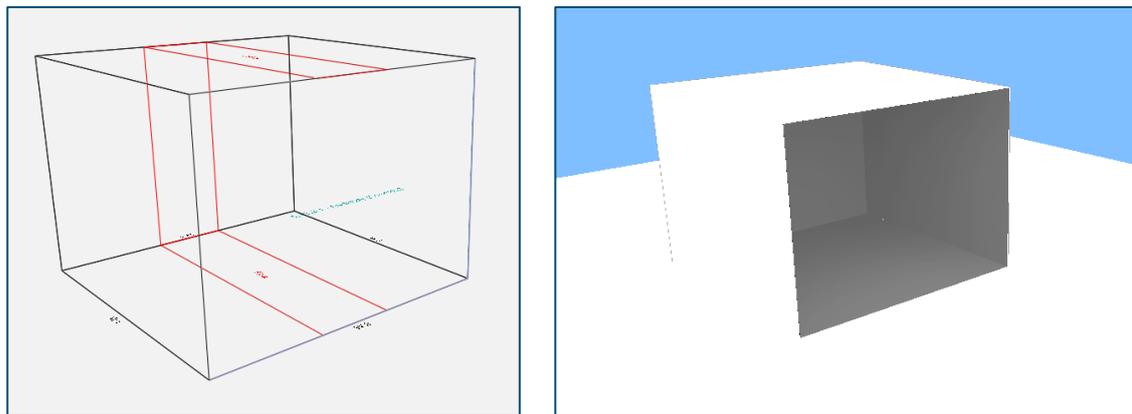
Figure 54 -3D model of the room with 4x4m glazed wall opening and the calculation grid as used in the TC5.12

3.11.2. Test results

The calculations were performed using the default settings of Relux Desktop. The calculation grid was as defined in the previous paragraph. For the calculation of the SC and the ERC an additional calculation grid was placed externally to measure the unobstructed incident illuminance (shown as External Illuminance in the corresponding tables).

The analytical illuminance calculated results for the rooms with 1x1m glazed roof opening and the two CIE general skies are shown in Tables 94, 95. The calculation of the SC+ERC of the corresponding rooms is shown in Tables 96, 97. The graphical representation of the SC+ERC comparison is shown in Figures 55, 56. The analytical illuminance calculated results for the rooms with 4x4m glazed roof opening and the two CIE general skies are shown in Tables 98, 99. The calculation of the SC+ERC of the corresponding rooms are shown in Table 100, 101. The graphical representation of the SC+ERC comparison is shown in Figures 57, 58.

Table 94 - Calculated illuminance values using CIE T1 - Room with 2x1m glazed wall opening

Relux / CIE Sky T1	External illuminance: 18500 lx							
Calculation point	A	B	C	D	E	F		
Illuminance (lx)	99	85	101	208	295	337		
Calculation point	G	H	I	J	K	L	M	N
Illuminance (lx)	38	47	35	107	478	855	591	4
Calculation point	G'	H'	I'	J'	K'	L'	M'	N'
Illuminance (lx)	38	47	35	107	478	855	591	4

Table 95 - Calculated illuminance values using CIE T12 - Room with 2x1m glazed wall opening

Relux / CIE Sky T12	External illuminance: 10700 lx							
Calculation point	A	B	C	D	E	F		
Illuminance (lx)	57	50	173	464	569	519		
Calculation point	G	H	I	J	K	L	M	N
Illuminance (lx)	194	278	396	604	928	1418	1558	467
Calculation point	G'	H'	I'	J'	K'	L'	M'	N'
Illuminance (lx)	22	27	20	65	318	556	407	3

Table 96 - Calculated and reference SC + ERC values using CIE T1 – Room with 2x1m glazed wall opening

SC+ERC	A	B	C	D	E	F	G	H	I	J	K	L	M	N
CIE Sky - T1	0.84	0.94	1.1	1.33	1.5	1.63	0.77	1.15	1.77	2.79	4.38	6.44	7.19	2.16
Relux	0.53	0.46	0.54	1.12	1.59	1.82	0.21	0.25	0.19	0.58	2.59	4.62	3.19	0.02
Error	-0.31	-0.48	-0.56	-0.21	0.09	0.19	-0.56	-0.90	-1.58	-2.21	-1.79	-1.82	-4.00	-2.14
SC+ERC	G'	H'	I'	J'	K'	L'	M'	N'	Average (all calculation points)					
CIE Sky - T1	0.33	0.46	0.65	0.94	1.34	1.8	1.85	0.53	1.90					
Relux	0.21	0.25	0.19	0.58	2.59	4.62	3.19	0.02	1.34					
Error	-0.12	-0.21	-0.46	-0.36	1.25	2.82	1.34	-0.51	-0.57					

Table 97 - Calculated and reference SC + ERC values using CIE T12 – Room with 2x1m glazed wall opening

| SC+ERC	A	B	C	D	E	F	G	H	I	J	K	L	M	N
CIE Sky - T12	0.84	0.94	2.1	4.34	5.11	4.41	1.75	2.45	3.55	5.34	8.23	12.28	12.69	2.16
Relux	0.54	0.46	1.62	4.33	5.32	4.85	1.81	2.60	3.70	5.65	8.67	13.25	14.56	4.36
Error	-0.30	-0.48	-0.48	-0.01	0.21	0.44	0.06	0.15	0.15	0.31	0.44	0.97	1.87	2.20
SC+ERC	G'	H'	I'	J'	K'	L'	M'	N'	Average (all calculation points)					
CIE Sky - T12	0.33	0.46	0.65	0.94	1.34	1.8	1.85	0.53	3.37					
Relux	0.21	0.26	0.19	0.61	2.97	5.19	3.80	0.03	3.86					
Error	-0.12	-0.20	-0.46	-0.33	1.63	3.39	1.95	-0.50	0.50					
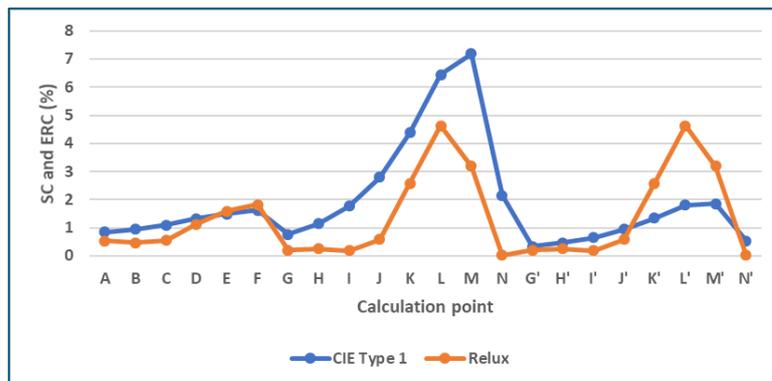
Figure 55 - Comparison between calculated and reference SC+ERC values using CIE T1 - Room with 2x1m glazed wall opening
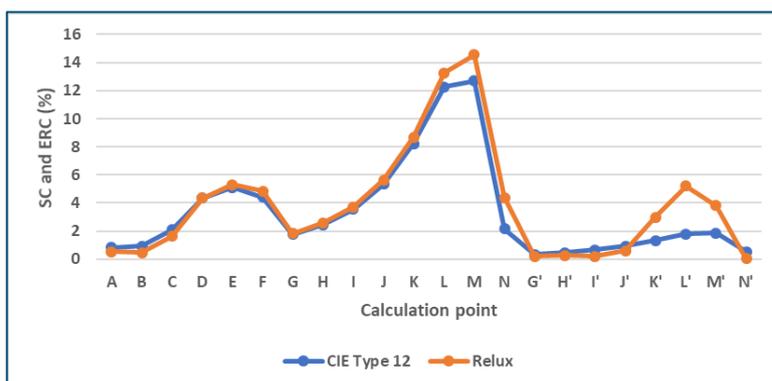
Figure 56 - Comparison between calculated and reference SC+ERC values using CIE T12 - Room with 2x1m glazed wall opening

Table 98 - Calculated illuminance values using CIE T1 - Room with 4x4m glazed wall opening

Relux / CIE Sky T1	External illuminance: 18600 lx						
Calculation point	A	B	C	D	E	F	
Illuminance (lx)	643	849	1060	1260	1436	1595	
Calculation point	G	H	I	J	K	L	M	N
Illuminance (lx)	742	1040	1429	2030	2890	4091	5648	7511
Calculation point	G'	H'	I'	J'	K'	L'	M'	N'
Illuminance (lx)	276	355	462	624	868	1252	1625	2348

Table 99 - Calculated illuminance values using CIE T12 - Room with 4x4m glazed wall opening

Relux / CIE Sky T12	External illuminance: 10700 lx						
Calculation point	A	B	C	D	E	F	
Illuminance (lx)	586	1116	1536	1895	2152	2389	
Calculation point	G	H	I	J	K	L	M	N
Illuminance (lx)	926	1250	1665	2299	3162	4262	5350	6372
Calculation point	G'	H'	I'	J'	K'	L'	M'	N'
Illuminance (lx)	170	220	287	388	539	775	1006	1444

Table 100 - Calculated and reference SC + ERC values using CIE T1 – Room with 4x4m glazed wall opening

SC+ERC	A	B	C	D	E	F	G	H	I	J	K	L	M	N
CIE Sky - T1	4.62	5.38	6.15	7.03	7.72	8.21	3.74	5.17	7.23	10.18	14.3	19.66	25.63	30.02
Relux	3.46	4.56	5.70	6.77	7.72	8.58	3.99	5.59	7.69	10.92	15.54	21.99	30.37	40.38
Error	-1.16	-0.82	-0.45	-0.26	0.00	0.37	0.25	0.42	0.46	0.74	1.24	2.33	4.74	10.36
SC+ERC	G'	H'	I'	J'	K'	L'	M'	N'	Average (all calculation points)					
CIE Sky - T1	1.52	2.00	2.66	3.57	4.80	6.36	8.09	9.55	8.80					
Relux	1.48	1.91	2.49	3.35	4.66	6.73	8.74	12.63	9.78					
Error	-0.04	-0.09	-0.17	-0.22	-0.14	0.37	0.65	3.08	0.98					

Table 101 - Calculated and reference SC + ERC values using CIE T12 – Room with 4x4m glazed wall opening

SC+ERC	A	B	C	D	E	F	G	H	I	J	K	L	M	N
CIE Sky - T12	6.71	10.7	13.92	17.58	19.48	20.82	8.11	10.79	14.60	20.00	27.33	35.75	43.26	47.73
Relux	5.48	10.43	14.35	17.71	20.12	22.33	8.65	11.68	15.56	21.48	29.55	39.83	50.00	59.55
Error	-1.23	-0.27	0.43	0.13	0.64	1.51	0.54	0.89	0.96	1.48	2.22	4.08	6.74	11.82
SC+ERC	G'	H'	I'	J'	K'	L'	M'	N'	Average (all calculation points)					
CIE Sky - T12	1.52	2.00	2.66	3.57	4.8	6.36	8.09	9.55	15.24					
Relux	1.59	2.05	2.68	3.62	5.04	7.24	9.40	13.50	16.90					
Error	0.07	0.05	0.02	0.05	0.24	0.88	1.31	3.95	1.66					
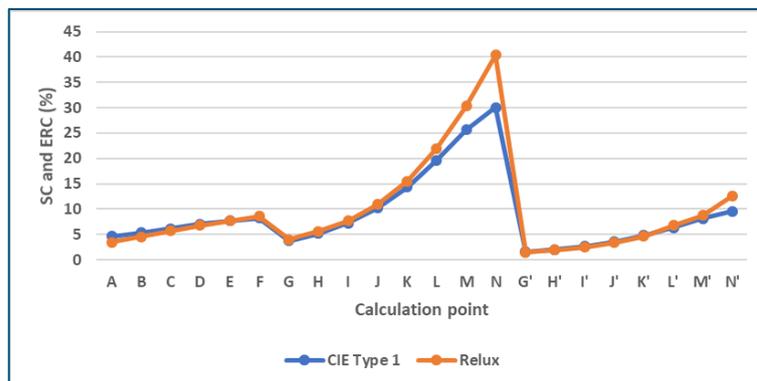
Figure 57 - Comparison between calculated and reference SC+ERC values using CIE T1 - Room with 4x4m glazed wall opening
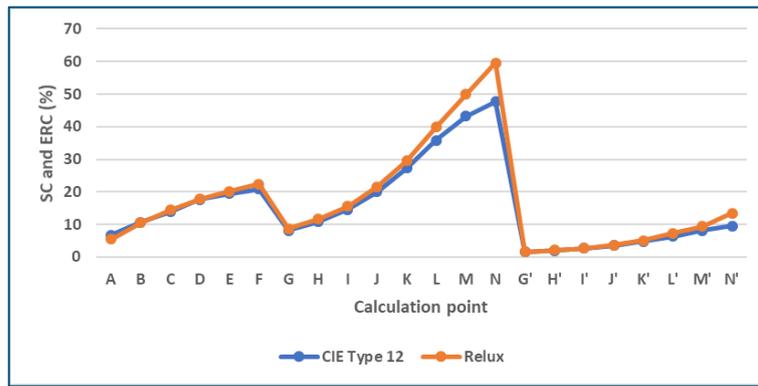
Figure 58 - Comparison between calculated and reference SC+ERC values using CIE T12 - Room with 4x4m glazed wall opening

3.12. Sky component + External reflected component for unglazed façade opening with a continuous external horizontal mask (CIE TC5.13)

3.12.1. Description

This test case aims to assess the ability of the lighting software to simulate the influence of an external horizontal mask on the internal direct illuminance. For this purpose, CIE document proposes the design of the 3D models shown in Figure 59. However, according to the experience of some past reports [4-6], the CIE document is erroneous in many aspects of the design of this Test Case. Especially, the reference values have been found incorrect for some sky types and while some critical reflectances have not been defined. There are some suggestions on how this test case should be completed but nothing is officially approved or suggested.

Therefore, authors decided to omit this test case as it could lead to ambiguous and misleading results.
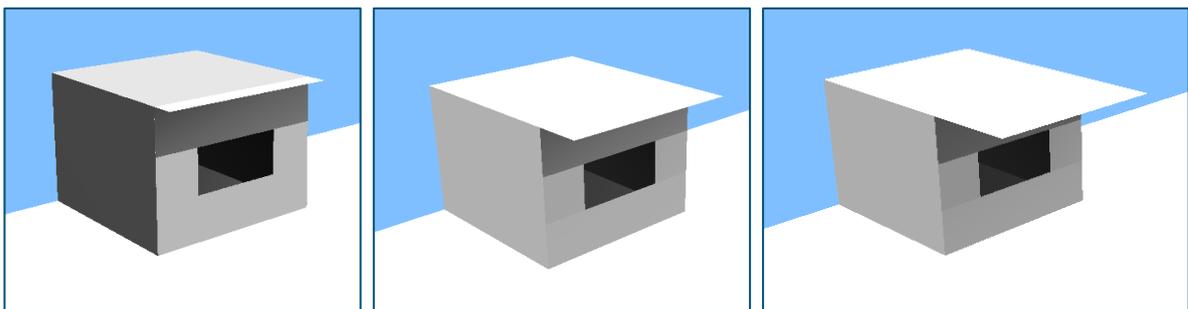
Figure 59 -3D room models with wall opening and different canopies as used in the TC5.13

3.13. Sky component + External reflected component for unglazed façade opening with a continuous external vertical mask (CIE TC5.14)

3.13.1. Description

This test case aims to assess the ability of the lighting software to simulate the influence of an external vertical mask on the internal direct illuminance. For this purpose, CIE document proposes the design of the 3D models shown in Figure 60. However, similar problems with TC5.13 have also been revealed in this test case.

Therefore, authors decided to omit this test case as it could lead to ambiguous and misleading results.
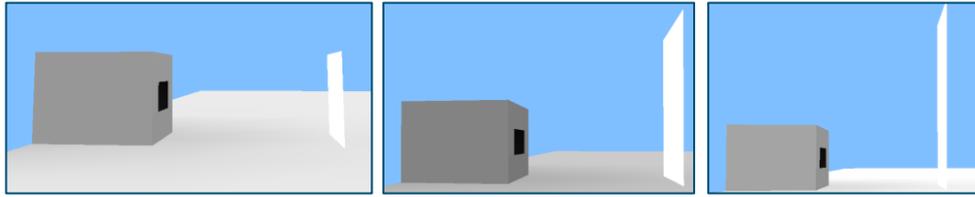
Figure 60 -3D room models with wall opening and different external vertical obstacles as used in the TC5.14

4. Additional analytical test cases

4.1. Introduction

This section includes the validation results for test cases proposed by the CIE 171:2006 as additional analytical test cases. There are 13 proposed test cases. It is currently possible to reproduce only 4 of them (TC 6.9 to 6.12) in Relux Desktop. The remaining test cases are not applicable as such specialized daylight simulations (e.g. sun patches, bi-directional glazing's, etc.) are out of the scope of Relux software.

4.2. Light leaks into enclosed areas (CIE TC6.9)

4.2.1. Description

This test case investigates the behaviour of the lighting simulation software in case of a closed area that is under high illumination. The scope is to reveal possible light leakages due to interpolation algorithm during lighting calculations. For this purpose, the model under test was designed using separated elements (walls and ceiling), merged in order to form a box. This is considered as the worst possible way to construct a 3D box due to possible leakages at the joints. The model is shown in Figure 61.
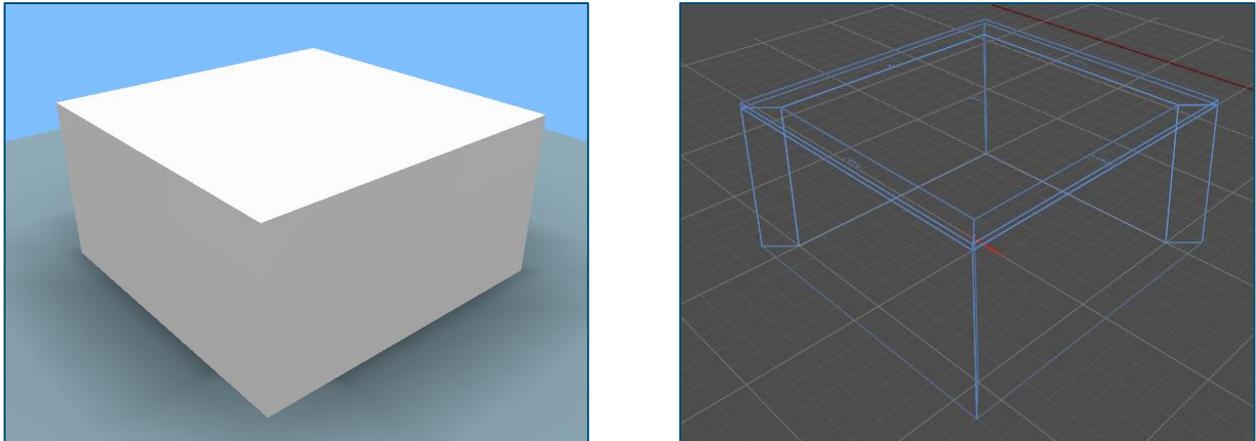
Figure 61 – 3D model of the enclosed area used for the TC6.9

4.2.2. Test results

The calculations were made with the default settings of Relux Desktop including automatic raster and average indirect fraction. CIE Sky type 12 was used in this case. The average external illuminance at the ground level was in average 17000 lx. The average illuminance inside the closed structure was equal to 0.0027 lx as shown in Table 102. This result is considered as a zero leakage of lighting in the enclosed area.

Table 102 – Calculated illuminance at all grid points on the floor and average value of the enclosed area

Floor		Calculated illuminance at points across the length (lx)									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Calculated illuminance at points across the width (lx)	**1**	0.0010	0.0014	0.0019	0.0027	0.0037	0.0051	0.0066	0.0082	0.0094	0.0098
	2	0.0010	0.0013	0.0019	0.0026	0.0036	0.0049	0.0065	0.0078	0.0089	0.0094
	3	0.0009	0.0013	0.0017	0.0024	0.0033	0.0044	0.0057	0.0069	0.0078	0.0082
	4	0.0009	0.0012	0.0016	0.0021	0.0028	0.0037	0.0047	0.0057	0.0065	0.0066
	5	0.0008	0.0010	0.0013	0.0018	0.0023	0.0030	0.0037	0.0044	0.0049	0.0051
	6	0.0007	0.0009	0.0011	0.0015	0.0019	0.0023	0.0028	0.0033	0.0036	0.0037
	7	0.0006	0.0007	0.0009	0.0012	0.0015	0.0018	0.0021	0.0024	0.0026	0.0027
	8	0.0005	0.0006	0.0008	0.0009	0.0011	0.0013	0.0016	0.0017	0.0019	0.0019
	9	0.0004	0.0005	0.0006	0.0007	0.0009	0.0010	0.0012	0.0013	0.0013	0.0014
	10	0.0004	0.0004	0.0005	0.0006	0.0007	0.0008	0.0009	0.0009	0.0010	0.0010
Average illuminance: 0.0027 lx											

4.3. Room surface symmetry (CIE TC6.10)

4.3.1. Description

The purpose of this test case was to investigate the symmetry of the surface calculation of a cuboid room under the illumination of the symmetric source. For this purpose, a 4x4x4m room was created and the isotropic point light source was placed in the centre of the room. Two sets of calculations were performed using surface reflectance of 0% and 50% respectively. Each one of the 6 surfaces has a calculation grid of 10x10 points (Figure 62).
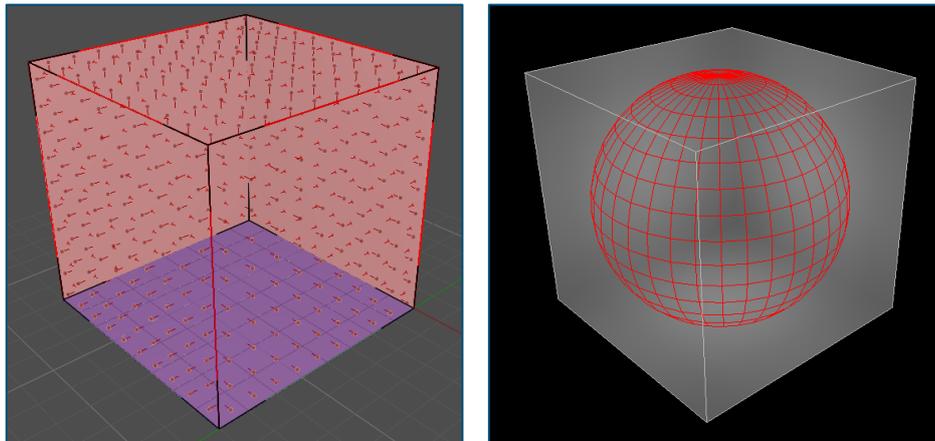
Figure 62 -3D model of the room, calculation grids on the surfaces and the isotropic source used in the TC6.10

4.3.2. Test results

The calculations were made with the default settings of Relux Desktop. The calculated results for surfaces reflectance of 0% are shown in Tables 103-108. The results with surfaces reflectance of 50% are shown in Tables 109-114. Calculated results show symmetry on the surfaces for both tests. The maximum illuminance difference between walls, ceiling and floor is less than 0.1%

Table 103 – Calculated illuminance at all grid points at the ceiling and average value (reflectance 0%)

Ceiling		Calculated illuminance at points across the length (lx)									
		1	2	3	4	5	6	7	8	9	10
Calculated illuminance at points across the width (lx)	1	3.753	4.564	5.384	6.078	6.484	6.484	6.078	5.384	4.564	3.753
	2	4.564	5.714	6.936	8.016	8.666	8.666	8.016	6.936	5.714	4.564
	3	5.384	6.936	8.666	10.264	11.257	11.257	10.264	8.666	6.936	5.384
	4	6.078	8.016	10.264	12.422	13.802	13.802	12.422	10.264	8.016	6.078
	5	6.484	8.666	11.257	13.802	15.457	15.457	13.802	11.257	8.666	6.484
	6	6.484	8.666	11.257	13.802	15.457	15.457	13.802	11.257	8.666	6.484
	7	6.078	8.016	10.264	12.422	13.802	13.802	12.422	10.264	8.016	6.078
	8	5.384	6.936	8.666	10.264	11.257	11.257	10.264	8.666	6.936	5.384
	9	4.564	5.714	6.936	8.016	8.666	8.666	8.016	6.936	5.714	4.564
	10	3.753	4.564	5.384	6.078	6.484	6.484	6.078	5.384	4.564	3.753
Average illuminance: 8.356 lx											

Table 104 - Calculated illuminance at all grid points on the floor and average value (reflectance 0%)

Floor		Calculated illuminance at points across the length (lx)									
		1	2	3	4	5	6	7	8	9	10
Calculated illuminance at points across the width (lx)	1	3.754	4.564	5.385	6.080	6.486	6.486	6.080	5.385	4.564	3.754
	2	4.564	5.715	6.938	8.020	8.670	8.670	8.020	6.938	5.715	4.564
	3	5.385	6.938	8.670	10.270	11.265	11.265	10.270	8.670	6.938	5.385
	4	6.080	8.020	10.270	12.431	13.813	13.813	12.431	10.270	8.020	6.080
	5	6.486	8.670	11.265	13.813	15.472	15.472	13.813	11.265	8.670	6.486
	6	6.486	8.670	11.265	13.813	15.472	15.472	13.813	11.265	8.670	6.486
	7	6.080	8.020	10.270	12.431	13.813	13.813	12.431	10.270	8.020	6.080
	8	5.385	6.938	8.670	10.270	11.265	11.265	10.270	8.670	6.938	5.385
	9	4.564	5.715	6.938	8.020	8.670	8.670	8.020	6.938	5.715	4.564
	10	3.754	4.564	5.385	6.080	6.486	6.486	6.080	5.385	4.564	3.754
Average illuminance: 8.361 lx											

Table 105 - Calculated illuminance at all grid points at the wall 1 and average value (reflectance 0%)

Wall 1		Calculated illuminance at points across the length (lx)									
		1	2	3	4	5	6	7	8	9	10
Calculated illuminance at points across the width (lx)	1	3.753	4.563	5.383	6.077	6.482	6.482	6.077	5.383	4.563	3.753
	2	4.563	5.713	6.935	8.015	8.665	8.665	8.015	6.935	5.713	4.563
	3	5.384	6.936	8.666	10.264	11.258	11.258	10.264	8.666	6.936	5.384
	4	6.079	8.017	10.265	12.424	13.805	13.805	12.424	10.265	8.017	6.079
	5	6.484	8.668	11.260	13.807	15.464	15.464	13.807	11.260	8.668	6.484
	6	6.485	8.669	11.262	13.808	15.466	15.466	13.808	11.262	8.669	6.485
	7	6.080	8.019	10.269	12.429	13.810	13.810	12.429	10.269	8.019	6.080
	8	5.386	6.939	8.670	10.270	11.264	11.264	10.270	8.670	6.939	5.386
	9	4.565	5.716	6.939	8.020	8.671	8.671	8.020	6.939	5.716	4.565
	10	3.755	4.565	5.386	6.081	6.487	6.487	6.081	5.386	4.565	3.755
Average illuminance: 8.359 lx											

Table 106 - Calculated illuminance at all grid points at the wall 2 and average value (reflectance 0%)

Wall 2		Calculated illuminance at points across the length (lx)									
		1	2	3	4	5	6	7	8	9	10
Calculated illuminance at points across the width (lx)	1	3.753	4.563	5.383	6.077	6.482	6.482	6.077	5.383	4.563	3.753
	2	4.563	5.713	6.935	8.015	8.665	8.665	8.015	6.935	5.713	4.563
	3	5.384	6.936	8.666	10.264	11.258	11.258	10.264	8.666	6.936	5.384
	4	6.079	8.017	10.265	12.424	13.805	13.805	12.424	10.265	8.017	6.079
	5	6.484	8.668	11.260	13.807	15.464	15.464	13.807	11.260	8.668	6.484
	6	6.485	8.669	11.262	13.808	15.466	15.466	13.808	11.262	8.669	6.485
	7	6.080	8.019	10.269	12.429	13.810	13.810	12.429	10.269	8.019	6.080
	8	5.386	6.939	8.670	10.270	11.264	11.264	10.270	8.670	6.939	5.386
	9	4.565	5.716	6.939	8.020	8.671	8.671	8.020	6.939	5.716	4.565
	10	3.755	4.565	5.386	6.081	6.487	6.487	6.081	5.386	4.565	3.755
Average illuminance: 8.359 lx											

Table 107 - Calculated illuminance at all grid points at the wall 3 and average value (reflectance 0%)

Wall 3		Calculated illuminance at points across the length (lx)									
		1	2	3	4	5	6	7	8	9	10
Calculated illuminance at points across the width (lx)	1	3.753	4.563	5.383	6.077	6.482	6.482	6.077	5.383	4.563	3.753
	2	4.563	5.713	6.935	8.015	8.665	8.665	8.015	6.935	5.713	4.563
	3	5.384	6.936	8.666	10.264	11.258	11.258	10.264	8.666	6.936	5.384
	4	6.079	8.017	10.265	12.424	13.805	13.805	12.424	10.265	8.017	6.079
	5	6.484	8.668	11.260	13.807	15.464	15.464	13.807	11.260	8.668	6.484
	6	6.485	8.669	11.262	13.808	15.466	15.466	13.808	11.262	8.669	6.485
	7	6.080	8.019	10.269	12.429	13.810	13.810	12.429	10.269	8.019	6.080
	8	5.386	6.939	8.670	10.270	11.264	11.264	10.270	8.670	6.939	5.386
	9	4.565	5.716	6.939	8.020	8.671	8.671	8.020	6.939	5.716	4.565
	10	3.755	4.565	5.386	6.081	6.487	6.487	6.081	5.386	4.565	3.755

Average illuminance: 8.359 lx

Table 108 - Calculated illuminance at all grid points at the wall 4 and average value (reflectance 0%)

Wall 4		Calculated illuminance at points across the length (lx)									
		1	2	3	4	5	6	7	8	9	10
Calculated illuminance at points across the width (lx)	1	3.753	4.563	5.383	6.077	6.482	6.482	6.077	5.383	4.563	3.753
	2	4.563	5.713	6.935	8.015	8.665	8.665	8.015	6.935	5.713	4.563
	3	5.384	6.936	8.666	10.264	11.258	11.258	10.264	8.666	6.936	5.384
	4	6.079	8.017	10.265	12.424	13.805	13.805	12.424	10.265	8.017	6.079
	5	6.484	8.668	11.260	13.807	15.464	15.464	13.807	11.260	8.668	6.484
	6	6.485	8.669	11.262	13.808	15.466	15.466	13.808	11.262	8.669	6.485
	7	6.080	8.019	10.269	12.429	13.810	13.810	12.429	10.269	8.019	6.080
	8	5.386	6.939	8.670	10.270	11.264	11.264	10.270	8.670	6.939	5.386
	9	4.565	5.716	6.939	8.020	8.671	8.671	8.020	6.939	5.716	4.565
	10	3.755	4.565	5.386	6.081	6.487	6.487	6.081	5.386	4.565	3.755

Average illuminance: 8.359 lx

Table 109 - Calculated illuminance at all grid points at the ceilling and average value (reflectance 50%)

Ceiling		Calculated illuminance at points across the length (lx)									
		1	2	3	4	5	6	7	8	9	10
Calculated illuminance at points across the width (lx)	1	10.274	11.794	13.064	14.028	14.545	14.545	14.027	13.064	11.795	10.275
	2	11.789	13.610	15.167	16.505	17.252	17.252	16.504	15.167	13.611	11.793
	3	13.057	15.165	17.217	18.957	20.024	20.024	18.957	17.217	15.166	13.059
	4	14.019	16.501	18.956	21.197	22.618	22.618	21.197	18.956	16.502	14.020
	5	14.535	17.248	20.022	22.618	24.299	24.299	22.618	20.023	17.249	14.536
	6	14.536	17.249	20.022	22.618	24.299	24.299	22.618	20.023	17.249	14.536
	7	14.020	16.502	18.956	21.197	22.619	22.619	21.197	18.957	16.502	14.019
	8	13.060	15.166	17.218	18.957	20.024	20.024	18.958	17.218	15.167	13.058
	9	11.797	13.613	15.167	16.503	17.251	17.252	16.505	15.169	13.614	11.793
	10	10.286	11.795	13.061	14.022	14.539	14.544	14.029	13.067	11.802	10.289

Average illuminance: 16.579 lx

Table 110 - Calculated illuminance at all grid points on the floor and average value (reflectance 50%)

Floor		Calculated illuminance at points across the length (lx)									
		1	2	3	4	5	6	7	8	9	10
Calculated illuminance at points across the width (lx)	1	10.261	11.771	13.047	14.023	14.545	14.546	14.029	13.067	11.801	10.286
	2	11.783	13.603	15.163	16.504	17.255	17.256	16.508	15.170	13.614	11.791
	3	13.057	15.165	17.219	18.962	20.031	20.031	18.964	17.222	15.168	13.057
	4	14.025	16.505	18.962	21.206	22.630	22.630	21.206	18.962	16.504	14.019
	5	14.544	17.255	20.031	22.630	24.314	24.314	22.630	20.029	17.251	14.536
	6	14.544	17.255	20.031	22.630	24.314	24.314	22.629	20.029	17.251	14.535
	7	14.025	16.507	18.963	21.207	22.630	22.630	21.205	18.960	16.501	14.016
	8	13.059	15.168	17.222	18.964	20.031	20.031	18.961	17.217	15.161	13.049
	9	11.788	13.612	15.170	16.508	17.256	17.255	16.505	15.163	13.598	11.772
	10	10.280	11.797	13.065	14.029	14.546	14.545	14.026	13.057	11.774	10.234

Average illuminance: 16.581 lx

Table 111 - Calculated illuminance at all grid points at the wall 1 and average value (reflectance 50%)

Wall 1		Calculated illuminance at points across the length (lx)									
		1	2	3	4	5	6	7	8	9	10
Calculated illuminance at points across the width (lx)	1	10.286	11.795	13.056	14.017	14.534	14.535	14.018	13.058	11.796	10.289
	2	11.796	13.612	15.165	16.501	17.247	17.248	16.501	15.165	13.613	11.797
	3	13.062	15.167	17.218	18.957	20.023	20.023	18.957	17.217	15.167	13.064
	4	14.025	16.505	18.959	21.199	22.621	22.621	21.199	18.958	16.504	14.025
	5	14.546	17.254	20.027	22.624	24.305	24.305	22.623	20.026	17.251	14.539
	6	14.545	17.254	20.028	22.625	24.307	24.307	22.624	20.026	17.251	14.538
	7	14.024	16.506	18.961	21.203	22.626	22.626	21.202	18.959	16.503	14.023
	8	13.058	15.166	17.220	18.961	20.029	20.028	18.960	17.218	15.164	13.059
	9	11.785	13.606	15.165	16.504	17.252	17.252	16.502	15.162	13.604	11.785
	10	10.258	11.782	13.054	14.019	14.537	14.537	14.017	13.043	11.771	10.262
Average illuminance: 16.579 lx											

Table 112 - Calculated illuminance at all grid points at the wall 2 and average value (reflectance 50%)

Wall 2		Calculated illuminance at points across the length (lx)									
		1	2	3	4	5	6	7	8	9	10
Calculated illuminance at points across the width (lx)	1	10.284	11.794	13.063	14.026	14.543	14.543	14.025	13.062	11.797	10.288
	2	11.794	13.612	15.167	16.504	17.251	17.251	16.504	15.167	13.612	11.793
	3	13.057	15.165	17.217	18.958	20.024	20.024	18.957	17.218	15.166	13.060
	4	14.018	16.502	18.958	21.199	22.622	22.622	21.199	18.958	16.503	14.022
	5	14.536	17.250	20.026	22.623	24.305	24.305	22.623	20.025	17.250	14.537
	6	14.537	17.251	20.027	22.625	24.308	24.307	22.624	20.026	17.249	14.535
	7	14.020	16.505	18.962	21.204	22.627	22.627	21.203	18.958	16.500	14.016
	8	13.060	15.169	17.223	18.964	20.031	20.030	18.961	17.217	15.159	13.040
	9	11.799	13.616	15.172	16.510	17.258	17.256	16.506	15.164	13.599	11.758
	10	10.291	11.801	13.068	14.031	14.549	14.547	14.028	13.060	11.781	10.240
Average illuminance: 16.580 lx											

Table 113 - Calculated illuminance at all grid points at the wall 3 and average value (reflectance 50%)

Wall 3		Calculated illuminance at points across the length (lx)									
		1	2	3	4	5	6	7	8	9	10
Calculated illuminance at points across the width (lx)	1	10.288	11.792	13.059	14.023	14.539	14.535	14.017	13.054	11.787	10.272
	2	11.801	13.613	15.166	16.502	17.249	17.248	16.500	15.164	13.609	11.793
	3	13.066	15.168	17.218	18.957	20.023	20.023	18.956	17.217	15.167	13.064
	4	14.026	16.505	18.959	21.199	22.621	22.621	21.199	18.959	16.506	14.028
	5	14.539	17.252	20.026	22.623	24.305	24.306	22.624	20.027	17.254	14.547
	6	14.538	17.252	20.027	22.625	24.308	24.308	22.625	20.029	17.255	14.547
	7	14.024	16.505	18.961	21.204	22.627	22.627	21.204	18.962	16.508	14.029
	8	13.062	15.169	17.221	18.963	20.030	20.030	18.962	17.221	15.170	13.065
	9	11.793	13.614	15.169	16.507	17.254	17.254	16.506	15.168	13.612	11.795
	10	10.283	11.798	13.062	14.023	14.540	14.539	14.021	13.058	11.791	10.275
Average illuminance: 16.581 lx											

Table 114 - Calculated illuminance at all grid points at the wall 4 and average value (reflectance 50%)

Wall 4		Calculated illuminance at points across the length (lx)									
		1	2	3	4	5	6	7	8	9	10
Calculated illuminance at points across the width (lx)	1	10.286	11.800	13.066	14.027	14.542	14.543	14.026	13.063	11.792	10.271
	2	11.791	13.613	15.168	16.504	17.251	17.251	16.504	15.166	13.609	11.787
	3	13.058	15.167	17.219	18.958	20.025	20.024	18.958	17.217	15.165	13.057
	4	14.023	16.504	18.959	21.200	22.622	22.622	21.200	18.958	16.504	14.022
	5	14.543	17.253	20.027	22.624	24.306	24.306	22.624	20.026	17.252	14.543
	6	14.543	17.253	20.028	22.625	24.308	24.308	22.625	20.028	17.253	14.543
	7	14.023	16.505	18.961	21.203	22.627	22.627	21.203	18.961	16.505	14.023
	8	13.058	15.167	17.220	18.962	20.029	20.029	18.962	17.220	15.166	13.057
	9	11.792	13.610	15.167	16.505	17.253	17.254	16.506	15.168	13.611	11.788
	10	10.282	11.793	13.060	14.022	14.539	14.539	14.023	13.062	11.797	10.282
Average illuminance: 16.581 lx											

4.4. Light source symmetry (CIE TC6.11)

4.4.1. Description

This test case is similar to the TC6.10 but in this case the parameter under investigation is the ability of the software to handle symmetric sources correctly. For this purpose, a 4x4x3m room is designed with black walls (0% reflectance). The room is illuminated by two types of light sources respectively. The first has a circular symmetry and the second has a type 4 symmetry. The goal is to have a perfect symmetric illuminance results on the floor.
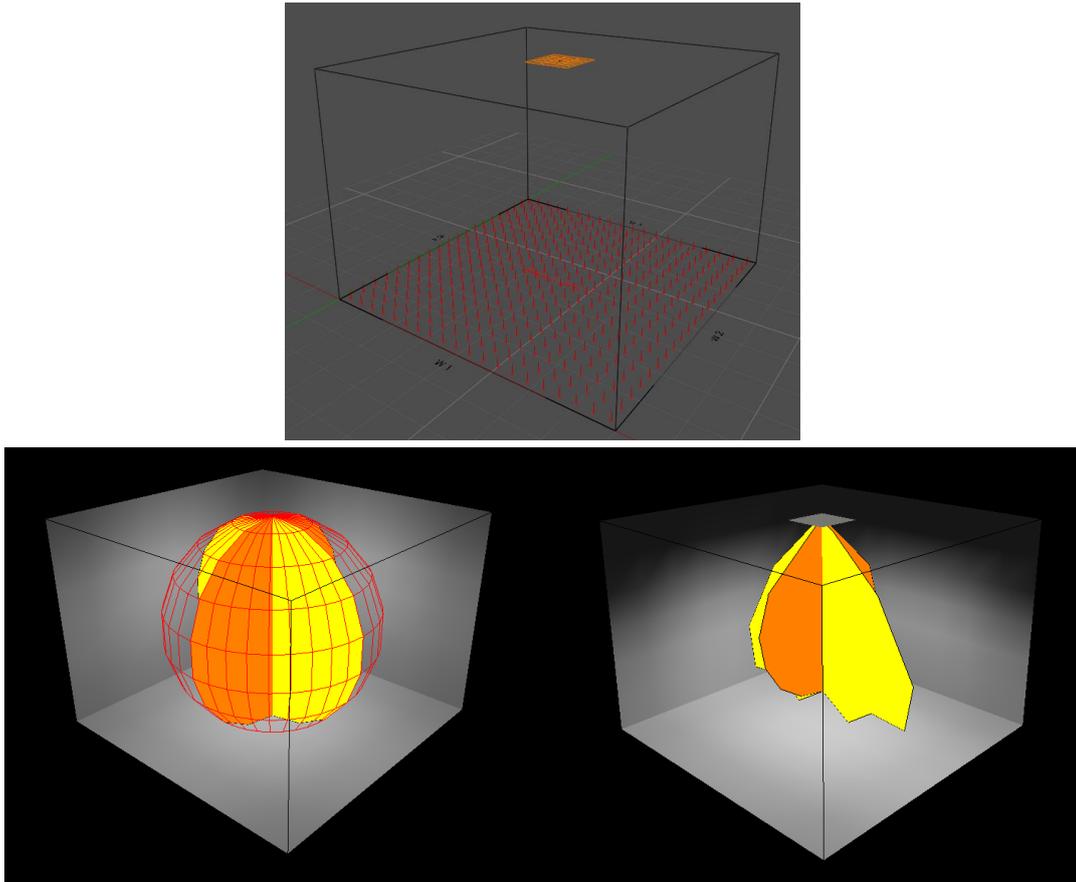
Figure 63 – 3D model of the room. calculation grid and the two light sources used for the TC6.11

4.4.2. Test results

The calculations were made with the default settings of Relux Desktop while the calculation grid on the floor was set to 20x20 point as described in the CIE document. The calculated results for the source with circular symmetry are shown in Table 115 and with symmetry type 4 in Table 116. Both tables show a perfect symmetry related to the source's symmetry.

Table 115 – Calculated illuminance at all grid points on the floor using the source with circular symmetry.

Floor		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		Calculated illuminance at points across the length (lx)
	1	35	38	41	45	48	51	53	55	57	57	57	57	55	53	51	48	45	41	38	35
	2	38	42	46	49	53	57	60	62	64	64	64	64	62	60	57	53	49	46	42	38
	3	41	46	50	54	59	63	66	69	71	72	72	71	69	66	63	59	54	50	46	41
	4	45	49	54	60	64	69	73	76	79	80	80	79	76	73	69	64	60	54	49	45
	5	48	53	59	64	70	75	80	83	86	87	87	86	83	80	75	70	64	59	53	48
	6	51	57	63	69	75	81	86	90	93	95	95	93	90	86	81	75	69	63	57	51
	7	53	60	66	73	80	86	92	96	99	101	101	99	96	92	86	80	73	66	60	53
	8	55	62	69	76	83	90	96	101	105	106	106	105	101	96	90	83	76	69	62	55
	9	57	64	71	79	86	93	99	105	108	110	110	108	105	99	93	86	79	71	64	57
	10	57	64	72	80	87	95	101	106	110	112	112	110	106	101	95	87	80	72	64	57
	11	57	64	72	80	87	95	101	106	110	112	112	110	106	101	95	87	80	72	64	57
	12	57	64	71	79	86	93	99	105	108	110	110	108	105	99	93	86	79	71	64	57
	13	55	62	69	76	83	90	96	101	105	106	106	105	101	96	90	83	76	69	62	55
	14	53	60	66	73	80	86	92	96	99	101	101	99	96	92	86	80	73	66	60	53
	15	51	57	63	69	75	81	86	90	93	95	95	93	90	86	81	75	69	63	57	51
	16	48	53	59	64	70	75	80	83	86	87	87	86	83	80	75	70	64	59	53	48
	17	45	49	54	60	64	69	73	76	79	80	80	79	76	73	69	64	60	54	49	45
	18	41	46	50	54	59	63	66	69	71	72	72	71	69	66	63	59	54	50	46	41
	19	38	42	46	49	53	57	60	62	64	64	64	64	62	60	57	53	49	46	42	38
	20	35	38	41	45	48	51	53	55	57	57	57	57	55	53	51	48	45	41	38	35

(Row label: Calculated illuminance at points across the width (lx))

Table 116 - Calculated illuminance at all grid points on the floor using the source with symmetry type 4.

Floor		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		Calculated illuminance at points across the length (lx)
	1	47	50	52	54	55	57	60	63	62	60	60	62	63	60	57	55	54	52	50	47
	2	52	56	59	60	62	64	68	71	70	68	68	70	71	68	64	62	60	59	56	52
	3	58	62	65	67	69	72	76	80	79	77	77	79	80	76	72	69	67	65	62	58
	4	65	69	72	74	77	80	85	89	88	86	86	88	89	85	80	77	74	72	69	65
	5	71	75	79	81	85	89	94	98	98	95	95	98	98	94	89	85	81	79	75	71
	6	76	81	85	88	92	97	103	107	107	104	104	107	107	103	97	92	88	85	81	76
	7	81	86	89	93	97	103	111	115	115	111	111	115	115	111	103	97	93	89	86	81
	8	84	89	93	97	102	109	117	122	121	118	118	121	122	117	109	102	97	93	89	84
	9	86	91	96	100	105	112	120	126	125	122	122	125	126	120	112	105	100	96	91	86
	10	87	92	97	102	107	114	122	127	127	124	124	127	127	122	114	107	102	97	92	87
	11	87	92	97	102	107	114	122	127	127	124	124	127	127	122	114	107	102	97	92	87
	12	86	91	96	100	105	112	120	126	125	122	122	125	126	120	112	105	100	96	91	86
	13	84	89	93	97	102	109	117	122	121	118	118	121	122	117	109	102	97	93	89	84
	14	81	86	89	93	97	103	111	115	115	111	111	115	115	111	103	97	93	89	86	81
	15	76	81	85	88	92	97	103	107	107	104	104	107	107	103	97	92	88	85	81	76
	16	71	75	79	81	85	89	94	98	98	95	95	98	98	94	89	85	81	79	75	71
	17	65	69	72	74	77	80	85	89	88	86	86	88	89	85	80	77	74	72	69	65
	18	58	62	65	67	69	72	76	80	79	77	77	79	80	76	72	69	67	65	62	58
	19	52	56	59	60	62	64	68	71	70	68	68	70	71	68	64	62	60	59	56	52
	20	47	50	52	54	55	57	60	63	62	60	60	62	63	60	57	55	54	52	50	47

(Row label: Calculated illuminance at points across the width (lx))

4.5. Light source aiming (CIE TC6.12)

4.5.1. Description

Test Case 6.12 validates the ability of the lighting simulation software to handle the aiming of lighting sources. For this purpose, a room with dimensions 4x4x4m with black walls (0% reflectance) was designed. A narrow beam luminaire was used for this test case. The luminaire is placed in the centre of the room pointing perpendicular towards a different surface each time (Figure 64) and thus, 6 different simulations were performed.
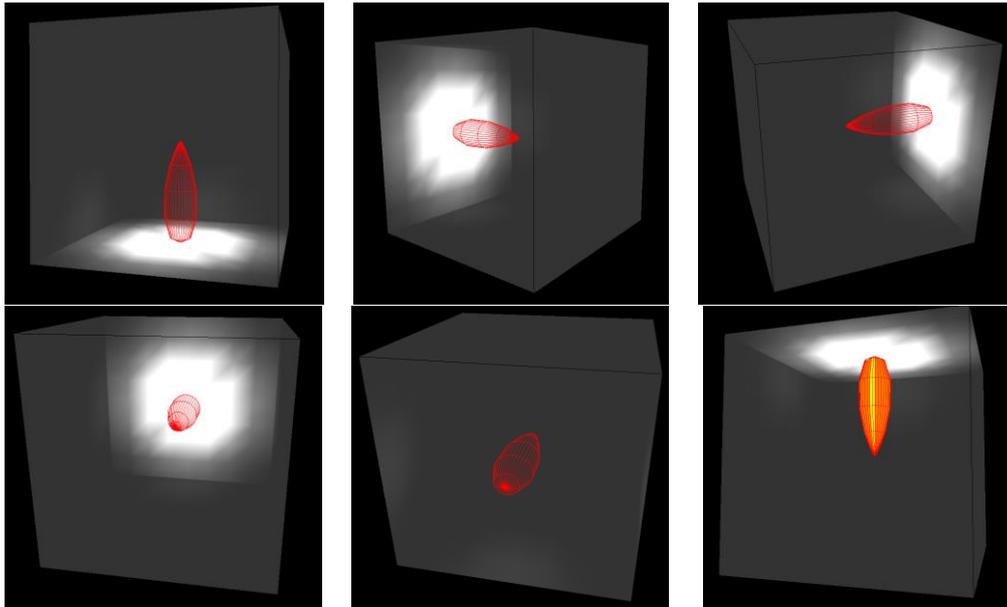

Figure 64 – 3D model of the room under test and the light source pointing at different directions (TC6.12)

4.5.2. Test results

The calculations were made with the default settings of Relux Desktop while the calculation grid on each surface was a set of 10x10 points according to the CIE document. The calculated results with the source pointing at each surface are shown in Tables 117-122 respectively. All tables show identical calculated results and therefore the aiming of the light source is absolutely symmetrical.

Table 117 – Calculated illuminance at all grid points with the light source is pointing towards ceiling.

Ceiling		Calculated illuminance at points across the length (lx)									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Calculated illuminance at points across the width (lx)	**1**	0.77	1.18	1.92	2.80	3.41	3.41	2.80	1.92	1.18	0.77
	2	1.18	2.31	4.15	6.40	8.45	8.45	6.40	4.15	2.31	1.18
	3	1.92	4.15	8.45	20.18	37.30	37.30	20.18	8.45	4.15	1.92
	4	2.80	6.40	20.18	73.81	147.55	147.55	73.81	20.18	6.40	2.80
	5	3.41	8.45	37.30	147.55	288.13	288.13	147.55	37.30	8.45	3.41
	6	3.41	8.45	37.30	147.55	288.13	288.13	147.55	37.30	8.45	3.41
	7	2.80	6.40	20.18	73.81	147.55	147.55	73.81	20.18	6.40	2.80
	8	1.92	4.15	8.45	20.18	37.30	37.30	20.18	8.45	4.15	1.92
	9	1.18	2.31	4.15	6.40	8.45	8.45	6.40	4.15	2.31	1.18
	10	0.77	1.18	1.92	2.80	3.41	3.41	2.80	1.92	1.18	0.77
Average illuminance: 33.61 lx											

Table 118 - Calculated illuminance at all grid points with the light source pointing towards floor.

Floor		Calculated illuminance at points across the length (lx)									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Calculated illuminance at points across the width (lx)	**1**	0.77	1.18	1.92	2.80	3.41	3.41	2.80	1.92	1.18	0.77
	2	1.18	2.31	4.15	6.40	8.45	8.45	6.40	4.15	2.31	1.18
	3	1.92	4.15	8.45	20.18	37.30	37.30	20.18	8.45	4.15	1.92
	4	2.80	6.40	20.18	73.81	147.55	147.55	73.81	20.18	6.40	2.80
	5	3.41	8.45	37.30	147.55	288.13	288.13	147.55	37.30	8.45	3.41
	6	3.41	8.45	37.30	147.55	288.13	288.13	147.55	37.30	8.45	3.41
	7	2.80	6.40	20.18	73.81	147.55	147.55	73.81	20.18	6.40	2.80
	8	1.92	4.15	8.45	20.18	37.30	37.30	20.18	8.45	4.15	1.92
	9	1.18	2.31	4.15	6.40	8.45	8.45	6.40	4.15	2.31	1.18
	10	0.77	1.18	1.92	2.80	3.41	3.41	2.80	1.92	1.18	0.77
Average illuminance: 33.61 lx											

Table 119 - Calculated illuminance at all grid points with the light source pointing towards wall 1.

Wall 1		Calculated illuminance at points across the length (lx)									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Calculated illuminance at points across the width (lx)	**1**	0.77	1.18	1.92	2.80	3.41	3.41	2.80	1.92	1.18	0.77
	2	1.18	2.31	4.15	6.40	8.45	8.45	6.40	4.15	2.31	1.18
	3	1.92	4.15	8.45	20.18	37.30	37.30	20.18	8.45	4.15	1.92
	4	2.80	6.40	20.18	73.81	147.55	147.55	73.81	20.18	6.40	2.80
	5	3.41	8.45	37.30	147.55	288.13	288.13	147.55	37.30	8.45	3.41
	6	3.41	8.45	37.30	147.55	288.13	288.13	147.55	37.30	8.45	3.41
	7	2.80	6.40	20.18	73.81	147.55	147.55	73.81	20.18	6.40	2.80
	8	1.92	4.15	8.45	20.18	37.30	37.30	20.18	8.45	4.15	1.92
	9	1.18	2.31	4.15	6.40	8.45	8.45	6.40	4.15	2.31	1.18
	10	0.77	1.18	1.92	2.80	3.41	3.41	2.80	1.92	1.18	0.77
Average illuminance: 33.61 lx											

Table 120 - Calculated illuminance at all grid points with the light source pointing towards wall 2.

Wall 2		Calculated illuminance at points across the length (lx)									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Calculated illuminance at points across the width (lx)	**1**	0.77	1.18	1.92	2.80	3.41	3.41	2.80	1.92	1.18	0.77
	2	1.18	2.31	4.15	6.40	8.45	8.45	6.40	4.15	2.31	1.18
	3	1.92	4.15	8.45	20.18	37.30	37.30	20.18	8.45	4.15	1.92
	4	2.80	6.40	20.18	73.81	147.55	147.55	73.81	20.18	6.40	2.80
	5	3.41	8.45	37.30	147.55	288.13	288.13	147.55	37.30	8.45	3.41
	6	3.41	8.45	37.30	147.55	288.13	288.13	147.55	37.30	8.45	3.41
	7	2.80	6.40	20.18	73.81	147.55	147.55	73.81	20.18	6.40	2.80
	8	1.92	4.15	8.45	20.18	37.30	37.30	20.18	8.45	4.15	1.92
	9	1.18	2.31	4.15	6.40	8.45	8.45	6.40	4.15	2.31	1.18
	10	0.77	1.18	1.92	2.80	3.41	3.41	2.80	1.92	1.18	0.77
Average illuminance: 33.61 lx											

Table 121 - Calculated illuminance at all grid points with the light source pointing towards wall 3.

Wall 3		Calculated illuminance at points across the length (lx)									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Calculated illuminance at points across the width (lx)	**1**	0.77	1.18	1.92	2.80	3.41	3.41	2.80	1.92	1.18	0.77
	2	1.18	2.31	4.15	6.40	8.45	8.45	6.40	4.15	2.31	1.18
	3	1.92	4.15	8.45	20.18	37.30	37.30	20.18	8.45	4.15	1.92
	4	2.80	6.40	20.18	73.81	147.55	147.55	73.81	20.18	6.40	2.80
	5	3.41	8.45	37.30	147.55	288.13	288.13	147.55	37.30	8.45	3.41
	6	3.41	8.45	37.30	147.55	288.13	288.13	147.55	37.30	8.45	3.41
	7	2.80	6.40	20.18	73.81	147.55	147.55	73.81	20.18	6.40	2.80
	8	1.92	4.15	8.45	20.18	37.30	37.30	20.18	8.45	4.15	1.92
	9	1.18	2.31	4.15	6.40	8.45	8.45	6.40	4.15	2.31	1.18
	10	0.77	1.18	1.92	2.80	3.41	3.41	2.80	1.92	1.18	0.77
Average illuminance: 33.61 lx											

Table 122 - Calculated illuminance at all grid points with the light source pointing towards wall 4.

Wall 4		Calculated illuminance at points across the length (lx)									
		1	2	3	4	5	6	7	8	9	10
Calculated illuminance at points across the width (lx)	1	0.77	1.18	1.92	2.80	3.41	3.41	2.80	1.92	1.18	0.77
	2	1.18	2.31	4.15	6.40	8.45	8.45	6.40	4.15	2.31	1.18
	3	1.92	4.15	8.45	20.18	37.30	37.30	20.18	8.45	4.15	1.92
	4	2.80	6.40	20.18	73.81	147.55	147.55	73.81	20.18	6.40	2.80
	5	3.41	8.45	37.30	147.55	288.13	288.13	147.55	37.30	8.45	3.41
	6	3.41	8.45	37.30	147.55	288.13	288.13	147.55	37.30	8.45	3.41
	7	2.80	6.40	20.18	73.81	147.55	147.55	73.81	20.18	6.40	2.80
	8	1.92	4.15	8.45	20.18	37.30	37.30	20.18	8.45	4.15	1.92
	9	1.18	2.31	4.15	6.40	8.45	8.45	6.40	4.15	2.31	1.18
	10	0.77	1.18	1.92	2.80	3.41	3.41	2.80	1.92	1.18	0.77
Average illuminance: 33.61 lx											

5. Conclusions and overall verdict

The technical report CIE 171:2006 defines 32 test cases for the validation of the accuracy of the lighting simulation software. Relux Desktop 2019 was tested against 22 Test Cases. Two test cases out of the 10, that were not tested, have fundamental flaws in the design and in the reference values. Therefore, authors decided to omit these test cases as it could lead to ambiguous and misleading results. Other 8 Test Cases are not applicable for testing in Relux Desktop.

Table 123 shows an overview of the CIE 171:2006 test cases and indicates the cases where tested and some remarks.

Table 123 – Summary of all test cases according to CIE 171:2006

Test Cases according to CIE 171:2006		Status	Comments
Artificial Test Cases	Test case 4.1	Tested	Test results are acceptable
	Test case 4.2	Tested	Test results are acceptable
	Test case 4.3	Tested	Test results are acceptable
	Test case 4.4	Tested	Test results are acceptable
	Test case 4.5	Tested	Test results are acceptable
	Test case 4.6	Tested	Test results are acceptable
Analytical Test Cases	Test case 5.2	Tested	Test results are acceptable
	Test case 5.3	Tested	Test results are acceptable
	Test case 5.4	Tested	Test results are acceptable
	Test case 5.5	Not tested	Not applicable in Relux Desktop radiosity method
	Test case 5.6	Tested	Test results are acceptable
	Test case 5.7	Tested	Test results are acceptable
	Test case 5.8	Tested	Test results are acceptable
	Test case 5.9	Tested	Test results are acceptable
	Test case 5.10	Tested	Test results are acceptable
	Test case 5.11	Tested	Test results are acceptable
	Test case 5.12	Tested	Test results are acceptable using updated reference data
	Test case 5.13	Tested	Erroneous reference data and uncomplete definition of the test case.
	Test case 5.14	Tested	Erroneous reference data and uncomplete definition of the test case.
Additional Test Cases	Test cases 6.1-6.8	Not tested	Not applicable in Relux Desktop
	Test case 6.9	Tested	Test results are acceptable
	Test case 6.10	Tested	Test results are acceptable
	Test case 6.11	Tested	Test results are acceptable
	Test case 6.12	Tested	Test results are acceptable
	Test case 6.13	Not tested	Not applicable in Relux Desktop

The verdict of the validation procedure can be summarised as follows.
- Relux Desktop performed accurately, within the limits and with very low error percentages in all test cases that used artificial light sources or direct external illumination independently of the structure of the tested room.
- Relux Desktop performed accurately, within the limits in most of the test cases that used CIE general Sky types. Few disparities, that were shown in some of the test cases, where due to the erroneous reference data given in CIE 171 and since the Skylux software was used as the calculation source of the reference data that are included in the CIE document. Furthermore, the analytical equations for the calculation of the reference data (related to the CIE general skies), where derived using CIE T5 and T16 and using some assumptions and simplified formulas.

In general, authors found Relux Desktop 2019 accurate with adequate lighting simulation performance in all the tested cases.

6. References

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