Daylighting design with lightscoop skylights: Towards an optimization of shape under overcast sky conditions

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Abstract

The main aim of this article is to determine a suitable shape for lightscoop skylights, whose main characteristic is a vertical opening oriented in the opposite direction to the solar trajectory, in order to ensure maximum illuminance on the work plane within a room. This type of skylight has a reflector, which is usually rectangular, curved or sawtooth shape, behind the vertical opening. Lightscape 3.2 software was used to carry out the simulations of different rooms with three different shapes of skylight. After trials, it was finally concluded that for this type of skylight, considering a height/width ratio of 4/3, the curved shape produces an increase of average daylight factors close to 3.5% compared with the rectangular shape, while the sawtooth shape produces a decrease of average daylight factors close to 3.5% in a room under overcast sky conditions.

Keywords: skylight, lightscoop, daylighting, overcast sky, lighting software.

1. Introduction and objective

The use of skylights is frequent in modern architecture since these allow access to daylight in rooms lacking façades, while providing homogeneous lighting over the horizontal plane. Most researchers in this field have based their methodology on classic treatises on daylighting [1] and computer simulation [2].

Lightscoops, with their characteristic vertical opening oriented in opposition to the solar trajectory, are frequently used in museum exhibition rooms, library reading rooms, etc. The term lightscoop should be further clarified, since this type of skylight has been described using a variety of architectural terms. The most widely used definition is provided by Lam [3], who defines this type of skylight as a lightscoop if the opening is oriented towards the open sky, or as a sunscoop if oriented towards the solar trajectory.

The shape of the reflector can also be a conditioning factor in the definition of this type of skylight. The CIBSE lighting guide points out [4] that there is a great variety of rooflights depending on the position of the opening and shape of the reflector, most notably the sawtooth and monitor rooflight. This guide also shows the most common advantages and disadvantages of each skylight shape, although it does not quantify the differences between them.

Despite the fact that lightscoops are a frequent feature in contemporary architecture, few studies have been carried out on the luminous distribution they generate. Lam is one of the few authors to carry out in-depth studies on their behaviour for daylighting, concluding that lightscoops provide the lowest and steadiest light levels with minimum annual heat gain. In the conclusion to his research with scaled models, Lam suggests different light distributions depending on the shape of the lightscoop reflector.

Among recent studies on lightscoops and sunscoops it is worth calling attention to research carried out by García-Hansen et al. [5]. Using 1:20 scale models and different skylight types, the authors used nine photometers to measure luminous distribution within the rooms.

One of the latest studies on lightscoops was carried out by Acosta et al. [6,7], and analyzed the correct height/width ratio of the skylight reflector for maximizing lighting inside a room. Using Lightscape 3.2 and Daysim 3.1 simulation programs, the authors concluded that a lightscoop with a rectangular reflector and a 4/3 height/width ratio provided the highest daylight factors under overcast sky conditions.

Despite the fact that numerous studies have shown the efficiency of this type of skylight, little attention appears to have been paid to the efficiency of the design in making the most of daylight.

The main aim of this article is to determine a suitable shape for lightscoop skylights, in order to obtain higher daylight factors within the spaces they light.

2. Description of Methodology for Calculation

2.1. Choosing the calculation conditions

By definition, the calculation of daylight factor components is carried out considering an unobstructed sky of assumed or known illuminance distribution, excluding direct sunlight. The definition of traditional overcast sky is used to calculate the sky component.

The overcast sky model, used in the methodology, is that defined by Moon-Spencer [8], where the luminance values are distributed according to the following:

$L_\theta = L_Z \cdot (1+2\sin\theta)/3$

where "L_Z" is the luminance at the zenith of the sky vault and "θ" the projection angle. This implies that the lowest luminance value in an overcast sky vault occurs on the horizon, and is equivalent to a third of the maximum luminance at the zenith:

$L_0 = L_Z/3$

The formulation established by Moon-Spencer corresponds to the definition of overcast sky accepted by the CIE [9], which is known as traditional overcast sky: Sky type 16.

2.2. Choosing the calculation program

The analysis of the daylight factors was carried out using simulation program Lightscape 3.2, which calculates luminous distribution using a radiosity process. Several studies have confirmed the correct behaviour of this calculation program [10,11]. The calculation parameters used by this program are shown in table 1.

Lightscape 3.2			
Sky Conditions	Overcast Sky		
Mesh Spacing	Min		0.10 m
	Max		0.20 m
Subdivision Contrast Threshold			0.65
Skylight Accuracy			0.60
Source	Direct Source	Min	0.12
		Subdivision Accuracy	0.42
	Indirect Source	Min	0.24
		Subdivision Accuracy	0.42
	Shadow Grid Size		Five
Tolerances	Length		0.0005
	Ray Offset		0.001
	Initialization Min Area		0.01

Table 1: Parameters of the calculation program.

2.3. Choosing the calculation model

The model used in the trials to determine the efficiency of different shapes of lightscoop reflectors is a room with variable floor size and a height of 4.5 m, with a skylight in the centre of the ceiling. Three different sizes of floor plan were considered to ensure general conclusions that did not depend on room measurements:

1. Square room, 9 m wide by 9 m long.
2. Rectangular room, 12 m wide by 6 m long.
3. Rectangular room, 6 m wide by 12 m long.

Three different shapes of skylight (R, C and S) were studied for each room and defined according to floor measurements (1, 2 and 3):

R. Rectangular skylight

C. Curved skylight

S. Sawtooth skylight

Figure 1 represents the different room and skylight shape combinations.

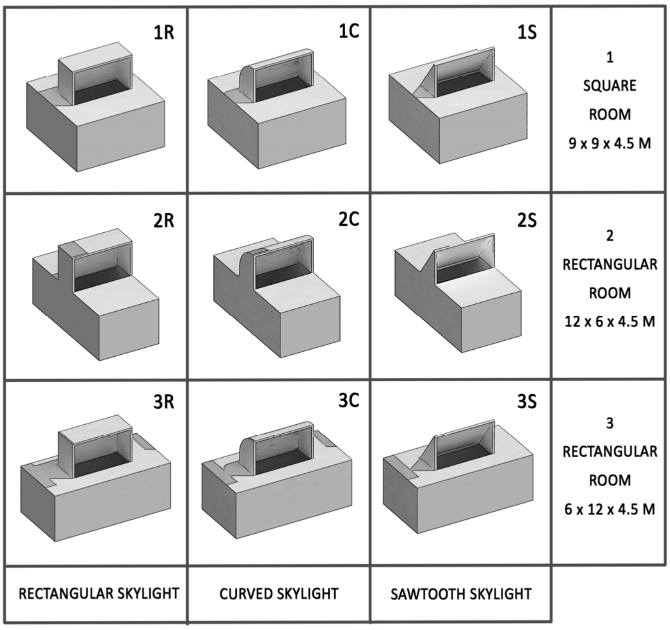


Figure 1: Calculation models.

The skylight on the roof is 6 m long with variable height (Y) and width (X) (fig. 2). The roof and walls of the skylight are 0.20 m thick. The work plane on which daylight factors are studied is located 1.00 m above the floor.

The model represents the typical dimensions of a museum or library room. The low height of the ceiling in relation to the measurements of the space allows a distribution of light that is largely dependent on the Sky Component and is therefore suitable for analyzing the efficiency of the skylight proportions under study.

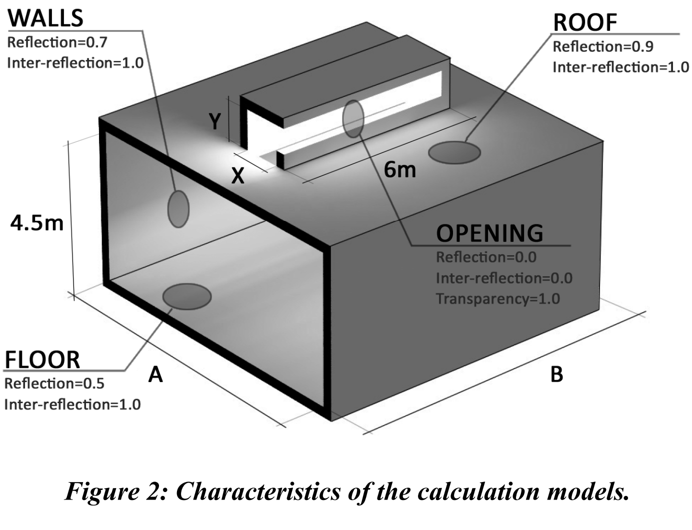


Figure 2: Characteristics of the calculation models.

To adapt the results to the skylight proportions the optical properties of surfaces –reflection, inter-reflection and transmission– are considered invariable. The inter-reflection of all the surfaces is completely diffuse under Lambert's cosine law, and as a result the light falling on a surface is reflected in all directions. Each surface has a different reflection index: the ceiling and skylight have an index of 0.9, the walls 0.7, and the floor 0.5, normal values in the design of interiors.

Nine different proportions were analyzed for each shape of reflector, considering a length for the variable "X" of 1 to 5 m, as well as a value for variable "Y" of 1 to 5 m. As a result, the surface of the horizontal area corresponding to the hole in the ceiling, and that of the vertical area corresponding to the opening of the skylight always add up to the same surface area for all models. This is to say, 9 skylight measurements were analyzed for each of the 3 shapes studied, taking into consideration 3 different room models, totalling 81 trials (fig. 3).

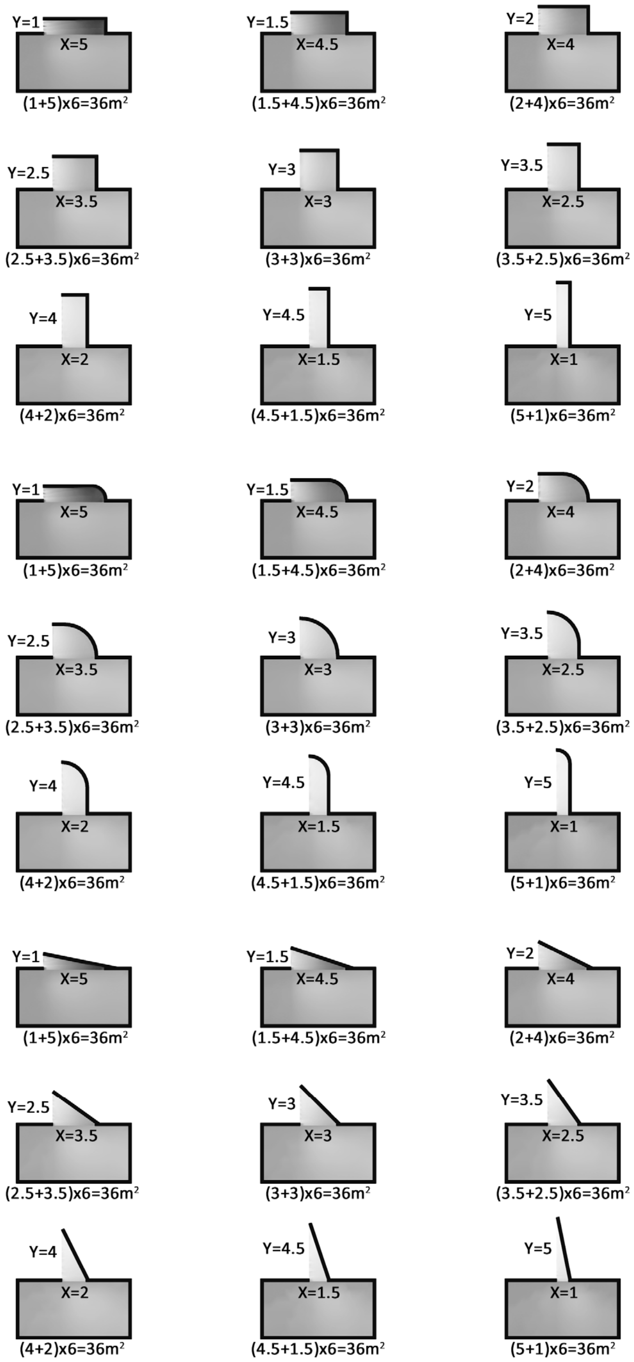


Figure 3: Longitudinal section of trial models.

The maximum, average, and minimum values of the daylight factors observed on the work plane were simulated using the calculation model. These values were the result both of the Sky Component and the Internally Reflected Component. All the definitions used in this article are included in the CIE glossary [12].

3. Calculation

3.1. Calculation of the skylight shapes for a square room, 9 m wide by 9 m long

3.1.1. Daylight factors calculation

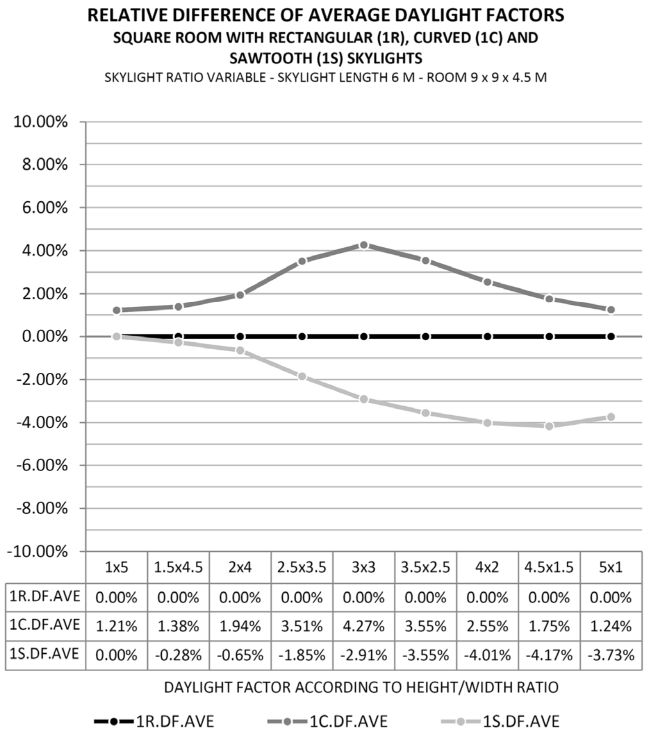
The first trial analyzed a square room with a lightscoop skylight in the centre of the ceiling and a variable reflector shape (models 1R, 1C and 1S as represented in fig. 1). The maximum, average, and minimum daylight factors on the work plane were calculated following the methodology described and considering 9 ratios for each skylight shape (fig. 3). Table 2 shows the results obtained. Grey-shaded cells represent the highest daylight factors for each skylight shape.

SQUARE ROOM 9 x 9			
RECTANGULAR SKYLIGHT (1R)			
HEIGHT/WIDTH RATIO	DAYLIGHT FACTOR		
	MAX	AVE	MIN
1x5	2.38%	1.51%	0.47%
1.5x4.5	3.49%	2.22%	0.71%
2x4	4.50%	2.84%	0.94%
2.5x3.5	5.27%	3.31%	1.14%
3x3	5.69%	3.58%	1.28%
3.5x2.5	5.80%	3.62%	1.30%
4x2	5.48%	3.36%	1.17%
4.5x1.5	4.79%	2.79%	0.95%
5x1	3.65%	1.97%	0.70%
CURVED SKYLIGHT (1C)			
HEIGHT/WIDTH RATIO	DAYLIGHT FACTOR		
	MAX	AVE	MIN
1x5	2.38%	1.53%	0.48%
1.5x4.5	3.55%	2.25%	0.73%
2x4	4.62%	2.89%	0.93%
2.5x3.5	5.48%	3.42%	1.17%
3x3	6.02%	3.73%	1.29%
3.5x2.5	6.08%	3.75%	1.32%
4x2	5.70%	3.44%	1.19%
4.5x1.5	4.86%	2.84%	0.94%
5x1	3.66%	1.99%	0.68%
SAWTOOTH SKYLIGHT (1S)			
HEIGHT/WIDTH RATIO	DAYLIGHT FACTOR		
	MAX	AVE	MIN
1x5	2.34%	1.51%	0.48%
1.5x4.5	3.45%	2.21%	0.70%
2x4	4.45%	2.82%	0.89%
2.5x3.5	5.18%	3.25%	1.00%
3x3	5.61%	3.47%	1.09%
3.5x2.5	5.76%	3.49%	1.09%
4x2	5.47%	3.22%	1.03%
4.5x1.5	4.75%	2.67%	0.83%
5x1	3.65%	1.90%	0.59%

Table 2: Maximum, average and minimum daylight factors on the work plane. Room of 9 x 9 x 4.5 m. Rectangular, curved and sawtooth skylights 6 m long with a variable height and width.

3.1.2. Relative difference calculation

Figure 4 shows the relative difference of the average daylight factors on the work plane produced by the different skylight shapes. The relative difference is calculated by comparing the different skylight shapes with the same height/width ratio, taking the average daylight factors obtained from the skylight with a rectangular reflector as reference value.



	1x5	1.5x4.5	2x4	2.5x3.5	3x3	3.5x2.5	4x2	4.5x1.5	5x1
1R.DF.AVE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1C.DF.AVE	1.21%	1.38%	1.94%	3.51%	4.27%	3.55%	2.55%	1.75%	1.24%
1S.DF.AVE	0.00%	-0.28%	-0.65%	-1.85%	-2.91%	-3.55%	-4.01%	-4.17%	-3.73%

Figure 4: Relative difference of the average daylight factors on the work plane. Room of 9 x 9 x 4.5 m. Rectangular, curved and sawtooth skylights 6 m long with variable height and width.

3.1.3. Analysis of results

From table 2 it can be deduced that regardless of the shape of the reflector, the highest average daylight factors are found for a skylight measuring 3.5 x 2.5 m with a height/width ratio of approximately 4/3.

As observed in figure 4, the curved reflector produces an increase in the average daylight factors over those obtained with the rectangular reflector. This difference increases in the case of the room with a 3 x 3 m skylight and a reflector height/width ratio of 1/1, reaching a maximum relative difference of 4.27%.

In contrast, the sawtooth reflector brings about a decrease when compared with the average daylight factors obtained with the rectangular reflector. This difference is greater for the room with a 4.5 x 1.5 m skylight, with a reflector height/width ratio of 3/1, where a maximum relative difference of 4.17% is reached.

Finally, it was observed that in the case of a 3.5 x 2.5 m skylight with a height/width ratio of approximately 4/3, the curved reflector produces a 3.55% increase of the average daylight factors over those found for rectangular shapes, while the sawtooth reflector causes a decrease of 3.55%.

These assessments were carried out on the work plane of a square room using the method described under overcast sky conditions.

3.2. Calculation of the skylight shapes for a rectangular room, 12 m wide by 6 m long

3.2.1. Daylight factor calculation

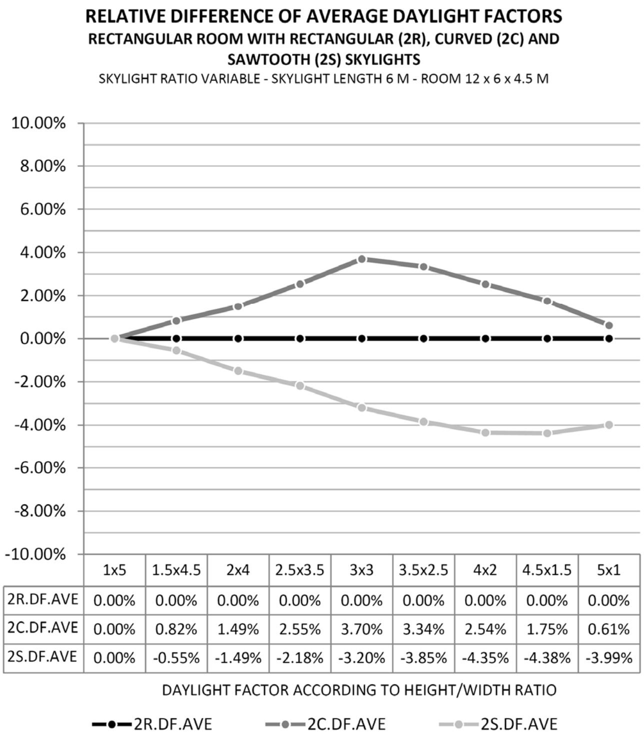
The second trial analyzed a rectangular floor plan room measuring 12 m wide by 6 m long. The room has a lightscoop skylight in the centre of the ceiling, and variable reflector shapes (models 2R, 2C and 2S as represented in fig. 1). The maximum, average and minimum daylight factors on the work plane were calculated considering 9 measurements for each skylight shape and following the method described (fig. 3). The results obtained are shown in table 3. Grey-shaded cells represent the highest daylight factors for each skylight shape.

RECTANGULAR ROOM 12 x 6			
RECTANGULAR SKYLIGHT (2R)			
HEIGHT/WIDTH RATIO	DAYLIGHT FACTOR		
	MAX	AVE	MIN
1x5	2.49%	1.51%	0.42%
1.5x4.5	3.69%	2.23%	0.64%
2x4	4.77%	2.87%	0.84%
2.5x3.5	5.61%	3.36%	1.03%
3x3	6.08%	3.63%	1.11%
3.5x2.5	6.21%	3.66%	1.14%
4x2	5.87%	3.38%	1.06%
4.5x1.5	5.06%	2.79%	0.84%
5x1	3.90%	1.99%	0.59%
CURVED SKYLIGHT (2C)			
HEIGHT/WIDTH RATIO	DAYLIGHT FACTOR		
	MAX	AVE	MIN
1x5	2.51%	1.51%	0.42%
1.5x4.5	3.75%	2.25%	0.63%
2x4	4.87%	2.91%	0.82%
2.5x3.5	5.81%	3.45%	1.03%
3x3	6.42%	3.77%	1.13%
3.5x2.5	6.50%	3.78%	1.16%
4x2	6.09%	3.46%	1.08%
4.5x1.5	5.20%	2.84%	0.90%
5x1	3.91%	2.01%	0.57%
SAWTOOTH SKYLIGHT (2S)			
HEIGHT/WIDTH RATIO	DAYLIGHT FACTOR		
	MAX	AVE	MIN
1x5	2.51%	1.51%	0.43%
1.5x4.5	3.66%	2.22%	0.59%
2x4	4.70%	2.82%	0.75%
2.5x3.5	5.53%	3.29%	0.86%
3x3	6.03%	3.52%	0.95%
3.5x2.5	6.14%	3.52%	0.96%
4x2	5.83%	3.23%	0.90%
4.5x1.5	5.07%	2.67%	0.78%
5x1	3.89%	1.91%	0.56%

Table 3: Maximum, average and minimum daylight factors on the work plane. Room of 12 x 6 x 4.5 m. Rectangular, curved and sawtooth skylights 6 m long with variable height and width.

3.2.2. Relative difference calculation

Figure 5 shows the relative difference of the average daylight factors on the work plane produced by the different skylight shapes. The relative difference between different skylight shapes with the same height/width ratio is calculated, taking the average daylight factors obtained with the skylight with a rectangular reflector as a reference value.



	1x5	1.5x4.5	2x4	2.5x3.5	3x3	3.5x2.5	4x2	4.5x1.5	5x1
2R.DF.AVE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2C.DF.AVE	0.00%	0.82%	1.49%	2.55%	3.70%	3.34%	2.54%	1.75%	0.61%
2S.DF.AVE	0.00%	-0.55%	-1.49%	-2.18%	-3.20%	-3.85%	-4.35%	-4.38%	-3.99%

Figure 5: Relative difference of the average daylight factors on the work plane. Room of 12 x 6 x 4.5 m. Rectangular, curved and sawtooth skylight 6 m long with variable height and width.

3.2.3. Analysis of results

As was observed in the previous trial and described in table 3, the highest average daylight factors for the rectangular floor plan of the calculation model, regardless of the shape of reflector, were observed for a 3.5 x 2.5 m skylight with a height/width ratio of close to 4/3.

In addition, the curved reflector produced an increase of the average daylight factors over those observed in the room with a rectangular reflector. This is greater in the room with a 3 x 3 m skylight and a height/width ratio of 1/1. The maximum relative difference for the rectangular room is 3.34%, substantially less than that observed between both skylights in the square room.

In contrast, the sawtooth reflector causes a decrease of the average daylight factors over those obtained with the rectangular reflector. As in the previous trial, this difference is greater for the room with a 4.5 x 1.5 m skylight and a height/width ratio of 3/1. The maximum relative difference in the model under study is 4.38%, similar to that observed in a room with a square floor plan.

Finally, it was observed that, with a 3.5 x 2.5 m skylight with a height/width ratio of close to 4/3, the curved reflector produced a 3.34% increase of average daylight factors over the rectangular reflector, while the sawtooth reflector generated a decrease of 3.85%.

As expressed in previous trials, these assessments were carried out on the work plane of a rectangular room under overcast sky conditions.

3.3. Calculation of the skylight shapes for a rectangular room, 6 m wide by 12 m long

3.3.1. Daylight factor calculation

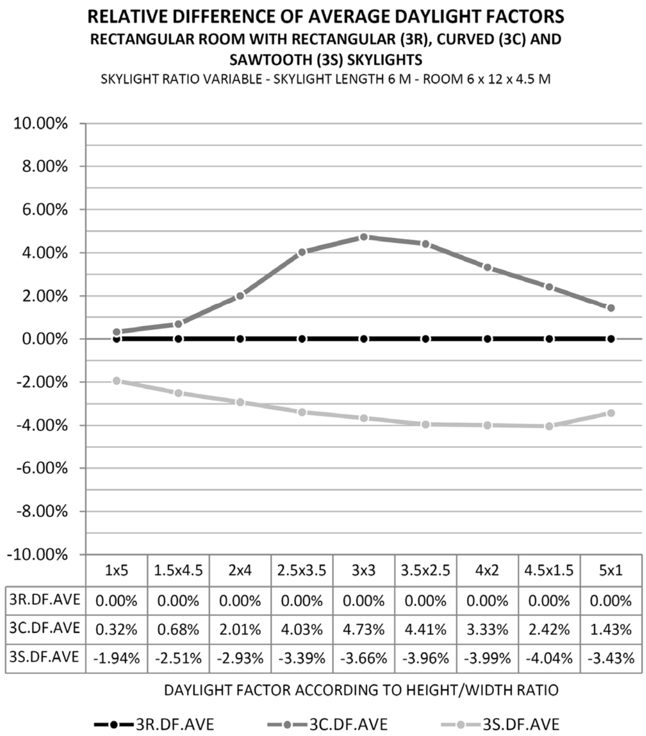
The final trial on daylight factors analyzed a rectangular room measuring 6 m wide by 12 m long. The room has a lightscoop skylight in the centre of the ceiling, with a variable reflector shape (models 1R, 1C and 1S as represented in fig. 1). The maximum, average and minimum daylight factors on the work plane were calculated considering the 9 measurements for each skylight shape and following the method described (fig. 3). The results obtained are included in table 4. The grey-shaded cells represent the highest daylight factors for each skylight shape.

RECTANGULAR ROOM 6 x 12			
RECTANGULAR SKYLIGHT (3R)			
HEIGHT/WIDTH RATIO	DAYLIGHT FACTOR		
	MAX	AVE	MIN
1x5	2.92%	1.90%	0.66%
1.5x4.5	4.23%	2.68%	0.92%
2x4	5.33%	3.34%	1.15%
2.5x3.5	6.13%	3.79%	1.33%
3x3	6.48%	4.01%	1.41%
3.5x2.5	6.51%	4.02%	1.44%
4x2	6.02%	3.67%	1.31%
4.5x1.5	5.06%	3.03%	1.06%
5x1	3.82%	2.14%	0.73%
CURVED SKYLIGHT (3C)			
HEIGHT/WIDTH RATIO	DAYLIGHT FACTOR		
	MAX	AVE	MIN
1x5	2.93%	1.90%	0.66%
1.5x4.5	4.24%	2.70%	0.92%
2x4	5.47%	3.41%	1.15%
2.5x3.5	6.37%	3.94%	1.39%
3x3	6.83%	4.19%	1.48%
3.5x2.5	6.84%	4.19%	1.48%
4x2	6.22%	3.80%	1.35%
4.5x1.5	5.19%	3.10%	1.06%
5x1	3.82%	2.17%	0.75%
SAWTOOTH SKYLIGHT (3S)			
HEIGHT/WIDTH RATIO	DAYLIGHT FACTOR		
	MAX	AVE	MIN
1x5	2.82%	1.86%	0.64%
1.5x4.5	4.08%	2.62%	0.89%
2x4	5.17%	3.24%	1.09%
2.5x3.5	5.90%	3.66%	1.21%
3x3	6.31%	3.86%	1.28%
3.5x2.5	6.36%	3.86%	1.28%
4x2	5.92%	3.53%	1.14%
4.5x1.5	5.06%	2.90%	0.96%
5x1	3.79%	2.07%	0.66%

Table 4: Maximum, average and minimum daylight factors on the work plane. Room of 6 x 12 x 4.5 m. Rectangular, curved and sawtooth skylights 6 m long with variable height and width.

3.3.2. Relative difference calculation

Figure 6 shows the relative difference of the average daylight factors on the work plane produced by the different skylight shapes. The relative difference was studied for different skylight shapes with the same height/width ratio, taking the average daylight factors obtained by the rectangular reflector as reference value.



	1x5	1.5x4.5	2x4	2.5x3.5	3x3	3.5x2.5	4x2	4.5x1.5	5x1
3R.DF.AVE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
3C.DF.AVE	0.32%	0.68%	2.01%	4.03%	4.73%	4.41%	3.33%	2.42%	1.43%
3S.DF.AVE	-1.94%	-2.51%	-2.93%	-3.39%	-3.66%	-3.96%	-3.99%	-4.04%	-3.43%

Figure 6: Relative difference of the average daylight factors on the work plane. Room of 6 x 12 x 4.5 m. Rectangular, curved and sawtooth skylights 6 m long with variable height and width.

3.3.3. Analysis of results

As can be seen from table 4 and was clearly shown in previous trials, the highest average daylight factors in the rectangular floor plan of the calculation model, regardless of the reflector shape, were observed for a 3.5 x 2.5 m skylight with an approximate height/width ratio of 4/3.

Just as in previous trials, the curved reflector produces higher average daylight factors than the rectangular reflector. Equally, this becomes even more apparent for skylights with a height/width ratio of 1/1. In contrast to the previous tests, the maximum relative difference in the study model is 4.73%, greater than those observed for the curved and rectangular reflectors in previous calculation models.

Conversely, the sawtooth reflector causes a decrease of the average daylight factors over those obtained with the rectangular reflector. Just as with earlier trials this difference is higher for the room with a skylight with a height/width ratio of 3/1. The maximum relative difference between the sawtooth and the rectangular reflector in the study model is 4.04%, similar to that observed for a square room.

Finally, it was observed that in the case of a 3.5 x 2.5 m skylight, with a height/width ratio of close to 4/3, the curved reflector produces an increase in average daylight factors of 4.41% compared with the rectangular one, while the sawtooth reflector generates a decrease of 3.96%.

These studies were carried out on the work plane of a rectangular room under overcast sky conditions as explained in earlier tests.

3.4. Calculation of the coefficients of uniformity

3.4.1. Coefficients of uniformity calculation

Finally, an additional study on the coefficients of uniformity observed in the work plane was performed. The aim of this was to obtain a measurement of the light distribution generated by each skylight shape. The coefficient of uniformity is defined as the ratio of minimum over maximum value of illuminance measured on a surface. The results obtained are included in table 5.

ROOMS 1, 2 AND 3			
RECTANGULAR SKYLIGHT			
HEIGHT/WIDTH RATIO	COEFFICIENT OF UNIFORMITY		
	1R	2R	3R
1x5	0.20	0.17	0.23
1.5x4.5	0.20	0.17	0.22
2x4	0.21	0.18	0.22
2.5x3.5	0.22	0.18	0.22
3x3	0.22	0.18	0.22
3.5x2.5	0.22	0.18	0.22
4x2	0.21	0.18	0.22
4.5x1.5	0.20	0.17	0.21
5x1	0.19	0.15	0.19
CURVED SKYLIGHT			
HEIGHT/WIDTH RATIO	COEFFICIENT OF UNIFORMITY		
	1C	2C	3C
1x5	0.20	0.17	0.23
1.5x4.5	0.20	0.17	0.22
2x4	0.20	0.17	0.21
2.5x3.5	0.21	0.18	0.22
3x3	0.21	0.18	0.22
3.5x2.5	0.22	0.18	0.22
4x2	0.21	0.18	0.22
4.5x1.5	0.19	0.17	0.20
5x1	0.19	0.15	0.20
SAWTOOTH SKYLIGHT			
HEIGHT/WIDTH RATIO	COEFFICIENT OF UNIFORMITY		
	1S	2S	3S
1x5	0.21	0.17	0.23
1.5x4.5	0.20	0.16	0.22
2x4	0.20	0.16	0.21
2.5x3.5	0.19	0.16	0.21
3x3	0.19	0.16	0.20
3.5x2.5	0.19	0.16	0.20
4x2	0.19	0.15	0.19
4.5x1.5	0.17	0.15	0.19
5x1	0.16	0.14	0.17

Table 5: Coefficients of uniformity on the work plane. Rooms 1, 2 and 3. Rectangular, curved and sawtooth skylights 6 m long with variable height and width.

3.4.3. Analysis of results

As shown in Table 5, the coefficients of uniformity are very similar in almost all trials, regardless of the dimensions of the room and the shape and proportion of the skylight. Specifically, the higher sawtooth skylights, whose height/width ratio is greater than 1, produce a slightly lower coefficient of uniformity, compared with other shapes of reflector.

Consequently, the light distribution generated by different forms of skylight is similar, although the illuminance values produced can differ greatly depending on the shape of the reflector.

4. Conclusion

The results of the trials carried out under overcast sky conditions following the method described confirm that lightscoop skylights produce the highest daylight factors when the height/width ratio is close to 4/3, regardless of the reflector shape.

Considering a lightscoop skylight under overcast sky conditions, a curved reflector generates an increase in daylight factors over those obtained with a rectangular reflector. The relative increase of the average daylight factors produced by the curved reflector in comparison to the rectangular one is between 3.5 and 4.5%, using a height/width ratio of 4/3 for the skylight. This increase varies depending on the room and skylight measurements. For a height/width ratio of 1/1, there is the highest relative increase of the average daylight factors, reaching values close to 5%. In the case of a reflector height/width ratio of 3/1, the relative increase of the average daylight factors falls to approximately 2%. Over all, it is confirmed that the curved reflector is more efficient than the rectangular one in terms of efficient use of daylighting.

In contrast, under identical calculation conditions a lightscoop skylight with a sawtooth reflector generates a reduction of the daylight factors compared with those obtained with a rectangular reflector. The relative decrease of the average daylight factors produced by the sawtooth reflector in relation to the rectangular one is between 3.5 and 4%, considering a skylight height/width ratio of 4/3. As with other shapes of lightscoops this decrease varies depending on the size of the room and skylight. The greatest relative reduction of average daylight factors occurs for a reflector height/width ratio of 3/1, reaching values close to 4.5%. In the case of a reflector height/width ratio of 1/1, the relative decrease of the average daylight factors falls to about 3%. Over all, it is confirmed that the sawtooth reflector is less efficient than the rectangular shape in terms of daylighting.

In summary, considering overcast sky conditions, lightscoop skylights are more efficient when the height/width ratio is close to 4/3. With the same ratio, a curved reflector is more efficient, while a sawtooth skylight allows less illuminance. The performance of the rectangular reflector is somewhere between that of the two previous shapes. Finally, it is concluded that, with any given shape or proportion of skylight, the coefficients of uniformity produced in the work plane are similar.

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