Institute of Energy and Sustainable Development
De Montfort University

CONFIDENTIAL

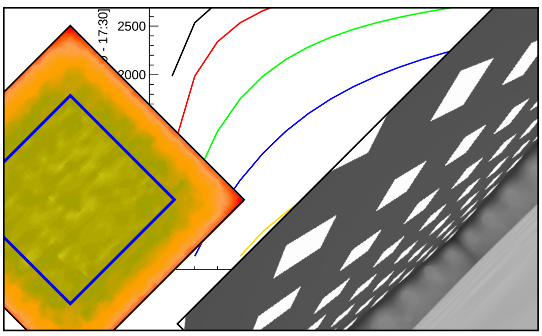
DAYLIGHTING AND SOLAR ANALYSIS FOR ROOFLIGHTS

RESOLVING THE PERCEIVED CONFLICT IN PART L RECOMMENDATIONS

Dr. J. Mardaljevic
Prof. K. Lomas

May. 2003

For NARM - the National Association of Rooflight Manufacturers



Daylighting and Solar Analysis for Rooflights

Resolving the Perceived Conflict in Part L Recommendations

1 Introduction

There is a perceived conflict in the current Part L Regulations with respect to the recommendations for daylighting and solar gain for typical large-span industrial (e.g. manufacturing and storage) buildings. The Part L Regulations state that:

a) If rooflight areas are less than 20%, then “special care needs to be given to confirm that levels of daylight are adequate”.

b) Rooflight areas should not such that they cause solar overheating.

However, routine application of the Part L Regulations for solar gain results in rooflight areas that are significantly less than 20%. Furthermore, there is considerable anecdotal evidence from users to indicate that rooflight areas up to 20% provide good levels of daylight without causing undue solar overheating.

This report describes the findings of an investigation into the origin of the perceived conflicting recommendations in Part L. The daylight and solar transmission properties of rooflights are examined using lighting simulation techniques, and the notion of “adequate” daylighting is given a quantitative basis. Factors relating to the design/operation of rooflights and the level of expected internal gains are identified as likely causes for the perceived conflict in Part L. Refinements to the assessment method for daylighting and solar gain are proposed. The refinements serve to both resolve the perceived conflict in Part L and also offer recommendations that are consistent with the reported favourable conditions in large-span industrial buildings with high rooflight areas.

The Part L Regulations as they stand are taken from the Approved Document L2, referred to as ADL2 in this report.

2 Background to Part L

2.1 Daylighting

ADL2 treats daylight provision in a largely non-prescriptive manner. For example:

> *Lighting systems should be reasonably efficient and make effective use of daylight where appropriate* (paragraph 1.41).

Alternatively it can be roof-lit, with a glazing area at least 10% of the floor area. The normal light transmittance of the glazing should be at least 70%, or, if the light transmittance is reduced below 70%, the glazing area could be increased proportionately, but subject to the considerations given in paragraphs 1.12, 1.20 & 1.23 (paragraph 1.45).

Where it is practical, the aim of lighting controls should be to encourage the maximum use of daylight and to avoid unnecessary lighting during the times when spaces are unoccupied (paragraph 1.55).

Local switching can be supplemented by other controls such as time switching and photo-electric switches where appropriate (paragraph 1.57).

It is usual to describe daylighting in largely qualitative terms because of the highly variable nature of actually occurring sky and sun conditions. As a consequence, daylighting is normally assessed in terms of the daylight factor which is indicative of daylighting under particular conditions (i.e. overcast) but it is not a true measure of actual daylighting performance (see Section 3). Significant for this investigation is the following recommendation from Part L for instances where the rooflight areas are below 20%:

...special care needs to be given to confirm that levels of daylight are adequate (paragraph 1.14).

What constitutes “adequate” daylight is however vague. As already noted, this is because the usual evaluative technique (i.e. daylight factors) does not give a quantitative measure of actual daylighting performance.

2.2 Solar Gain

The Part L Regulations for solar gain recommend a number of different methods by which compliance with the overheating requirement can be demonstrated. These include the use of solar shading and/or exposed thermal mass (in combination with night venting) to reduce solar gain. These methods are not generally practicable for large-span industrial buildings. Another method to achieve compliance for “glazing facing only one orientation” (e.g. horizontal rooflights) is to limit the maximum allowable area of the opening. For horizontal rooflights the maximum area is recommend to be 12% (Table 4 in ADL2). As noted, there are many large-span industrial buildings with rooflight areas greater than 12% that are believed to be free from undue solar overheating. An alternative approach to achieving compliance is to determine the maximum permissible rooflight area using a precise estimate of solar gain (Paragraph 1.23a in ADL2). For typical large-span industrial buildings (i.e. with horizontal rooflights), the maximum permissible rooflight area is calculated with respect to the potential for solar overheating using Equation H2 in ADL2:

$$Q_{slr} = q_{sr} g_{rr} f_c (1 - f_{rr})$$

Where:

Q_{slr} is the solar cooling load (W/m^2).

q_{sr} is the average solar load for horizontal openings (W/m^2).

g_{rr} is the ratio of the total area of rooflight to the floor area.

f_c is a correction factor for glazing/blind combination.

f_{rr} is the framing ratio for the rooflight.

It is recommended in ADL2 that the solar cooling load (Q_{slr}) does not exceed 25W/m^2. The average solar load for horizontal openings (q_{sr}) is given in Table H1 of ADL2 as 327W/m^2. This is an average based on hourly solar cooling loads from 07:30 to 17:30 during the month of July and for the reference glazing type, i.e. a *"building with single clear glazing: SE England, intermittent shading"* (Table 5.21 in the CIBSE Guide A, 1999). Note that rooflights in industrial buildings are not generally subject to intermittent shading, and so the correction factor f_c must include an additional term to account for this (see Section 4).

2.3 The 'Conflict'

Routine application of Equation H2 for typical double skin rooflight constructions used in large-span industrial buildings gives a maximum rooflight area of around 12%. This is significantly less than the 20% rooflight area which is recommended as an upper limit in paragraph 1.14 of ADL2. The stipulation that "*special care needs to be given to confirm that levels of daylight are adequate"* does not, on its own, help to resolve this conflict because the meaning of "adequate" is vague. It is understood that the recommendations for rooflights in ADL2 are, to a degree, based on generalisations and extrapolations from other building scenarios. They were not specifically formulated for typical large-span industrial buildings such as manufacturing and storage facilities.

The aim of this investigation is to examine the basis and assumptions in ADL2 relating specifically to rooflight design and to show how they can be refined to better describe the daylighting and solar overheating characteristics of typical large-span industrial buildings. In addition to examining the basis for calculating Q_{slr} (Equation H2), the role of the daylighting provision of rooflights is investigated more thoroughly than has been the case to date.

3 Daylight

As noted in Section 2, there are no explicit recommendations for daylight provision in ADL2. Where recommendations are given for daylight in buildings (e.g. CIBSE Lighting Guide LG10), the norm is to base estimates of the daylighting potential on the magnitude of the predicted daylight factor.

3.1 The Daylight Factor

The daylight factor at any point is the ratio of the interior illuminance at that point to the global horizontal illuminance under CIE standard overcast sky conditions. The daylight factor is normally expressed as a percentage:

$$DF = \frac{E_{in}}{E_{out}} \cdot 100\%$$

Because the luminance of the CIE standard sky does not vary with azimuth, the orientation of the building model has no effect on the daylight factor. And of course, the contribution of the sun plays no direct part in the estimation of daylight illumination. It has long been appreciated that the daylight factor is a fairly crude indicator of daylighting potential. For example, the daylight factor distribution for identical North and South facing offices will be the same. Yet it is evident that they are subject to very different levels of daylight illumination; principally because one admits direct sun and the other does not. The daylight factor alone provides little indication of crucial indicators such as the likely number of hours in the year that a given daylight level is achieved. These indicators are needed to assess the potential for daylight to displace artificial lighting usage and so lower primary energy demand.

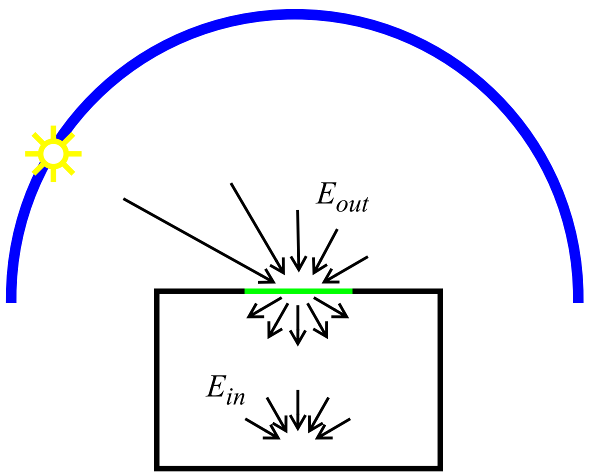
3.2 Horizontal Rooflights: A Special Case for Daylight Modelling

Buildings with horizontal rooflights however, particularly those with diffusing panels, present a special design case where the daylight factor may be used as a basis to derive fairly robust indicators of actual daylight illumination throughout the year. This is because:

a) horizontal diffusing panels are very effective in redistributing transmitted light regardless of the angular distribution of the incident light; and,

b) building orientation is not a factor for horizontal panels.

In other words, for these particular buildings, the ratio between the internal and external illuminance (i.e. the daylight factor) remains constant regardless of the sun and sky conditions. This is illustrated in Figure 1. Therefore, the daylight factor, used in conjunction with an annual time-series for global horizontal illuminance, can form the basis of a technique to derive a time-series of internal daylight illuminance values. In fact, rather than deal with time-series, the data are processed to give the cumulative availability of internal daylight illuminance.



$$\frac{E_{in}}{E_{out}} = \text{Constant}$$

Figure 1. Constant daylight factor under horizontal diffusing rooflights

3.3 Predicting Cumulative Daylight Availability

The cumulative availability of daylight was predicted as a function of the rooflight to floor area ratio. A generic building model was devised for the simulations so that the findings would be applicable to the majority of typical rooflight configurations used in large span industrial buildings. The primary consideration was the mean illumination for the core area of the building. The edge effects - notably diminished illumination relative to the core - are building specific, and generally affect a comparatively small area. To preserve the generality of the findings, the edge effects were eliminated from the analysis.

The Building Model

The model used to represent a generic building had a square cross-section and the roof comprised a 10 by 10 array of rooflights. All opaque surfaces were assigned a diffuse reflectance of 0.20 (i.e. 20%). The rooflights were square apertures placed central in square panels, Figure 2.[1] The overall transmissivity of a rooflight is subject to a number of factors related to its construction and operation. Firstly, there is the intrinsic daylight transmission properties of the rooflight material. The construction of the rooflight (e.g. framing, purlins, etc.) further reduces the effective transmission of the installed rooflight from that of the unfinished (transparent) material. Lastly, the operational conditions and maintenance of the rooflight can further reduce the effective transmission of the installed rooflight due to the deposition of dirt, dust etc. Usually called daylight correction factors, these effects are examined in Section 3.4.

Daylight Prediction

Daylight factors were calculated for rooflight to floor area ratios of 0.04 to 0.20 in steps of 0.02 (i.e. 4% to 20% in steps of 2%). The rooflight panels were modelled as ideal diffuse material with a daylight transmittance of 0.67 (i.e. 67%). This is typical of a twin skin rooflight. To ensure that the findings would have general application to any building and rooflight configuration, the reduced daylight factor across the perimeter of the space was ignored. Thus, all subsequent daylighting evaluation was based on the mean daylight factor across the core of the space, Figure 2.

As noted, the daylight factor value is only *indicative* of daylighting potential; it needs to be processed in conjunction with locale-specific meteorological data to give estimates of the actual daylighting levels. Applying a simple technique, cumulative internal daylight illuminance availability can be calculated from daylight factor values and an annual time-series of global horizontal illuminance for the UK. For the special case of diffusing, horizontal rooflights this gives a fairly robust estimation of annual daylighting provision from which supplementary lighting requirements can be estimated. The annual time-series used for this study was the Kew Test Reference Year (TRY), i.e. applicable to the SE of England. The details of the approach are described in a separate Technical Annex.

---

1. Rooflights in large-span industrial buildings are usually rectangular with a maximum aspect ratio of approximately five. The square rooflights are used for the 'baseline' calculations. However, the effect of the aspect ratio is accounted for in the estimation of the roof-void loss factor (Section 3.4).

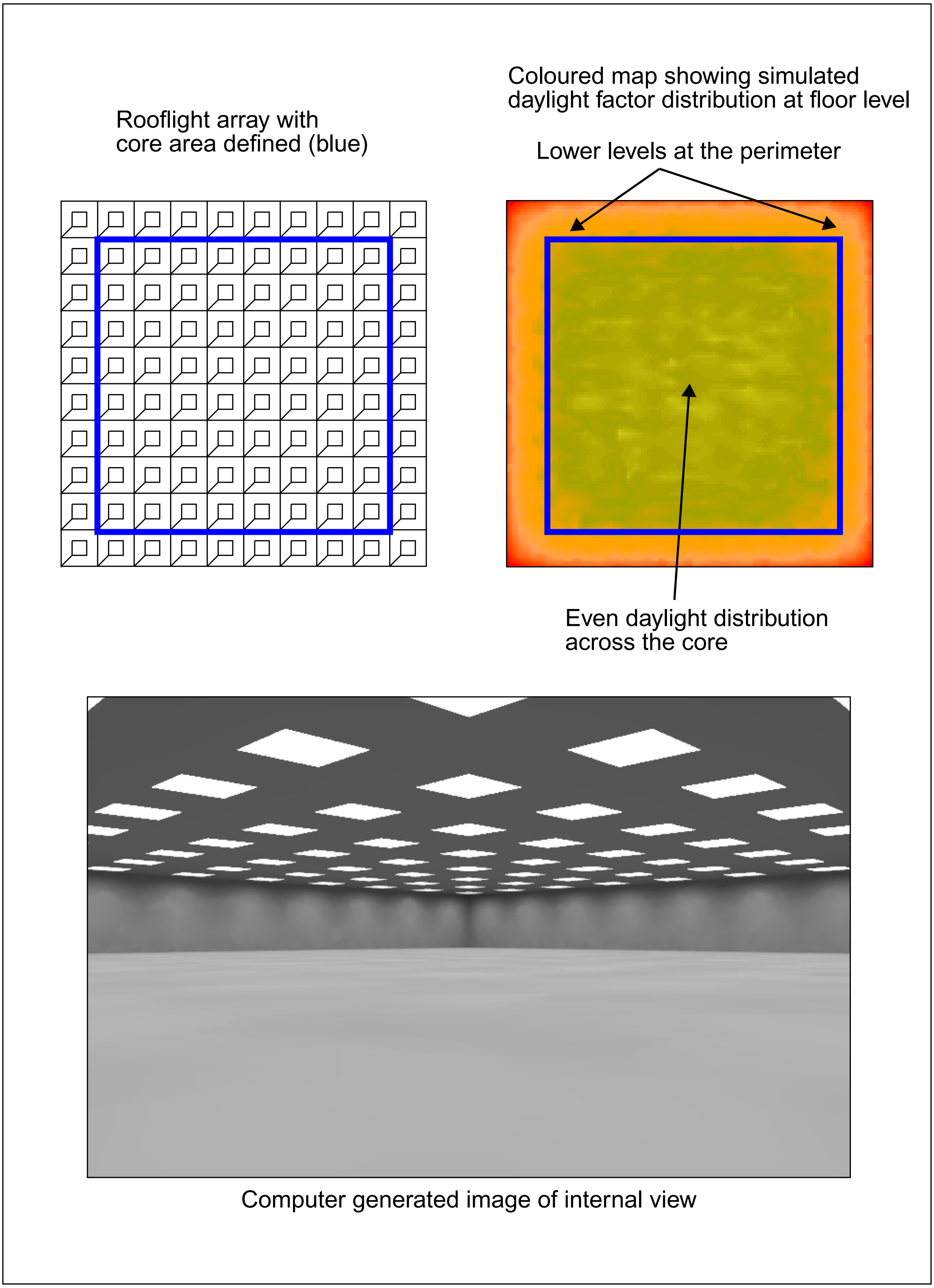


Figure 2. Simplified building models

Horizontal and Vertical Daylight Illumination

It is usual for office spaces to predict daylight illumination incident on horizontal surfaces, i.e. the work plane at desk-top height. For large-span industrial buildings used for manufacturing, the work plane where tasks are carried out is usually horizontal, and so daylight illuminance on the horizontal plane gives the best measure of useful illumination. For storage facilities however, the daylight illuminance on vertical surfaces (e.g. racking) may be more relevant to the tasks carried out in these buildings, e.g. the identification, placement and retrieval of vertically-stacked objects. Accordingly, we have predicted the cumulative daylight availability in the horizontal and vertical planes. Note that vertical daylight illumination from rooflights will always be less than horizontal illumination at the same point in space. This is because in the vertical plane, half of the 'view' is of the floor.

3.4 Daylight Correction Factors

As noted in the previous Section, the transmissivity of an installed rooflight is subject to various daylight correction factors. In addition to those factors normally used, this investigation has revealed an additional correction factor not previously identified.

Correction Factors in Part L

The glazing maintenance factor is used in daylight calculations to account for transmission losses caused by dirt on the surface(s) of the glazing. For horizontal and low pitch (<10˚) rooflights, this factor can be quite large because of the ease with which dirt can accumulate on horizontal surfaces. The current recommendation for horizontal rooflights in industrial urban settings is to use a (daylight) maintenance factor f_{md} of 0.64, i.e. a transmission loss of 36% [CIBSE LG10]. Recent research however has shown that the maintenance factor given in LG 10 is likely to be on the low side and that values around 0.70 are more likely for urban-commercial settings [Tregenza, 1999]. Accordingly, a maintenance factor of 0.70 was used to predict daylight levels. Note that any loss of visible radiation will, in reality, be accompanied by an approximately comparable loss in total radiation (i.e. solar heat gain). The consequences of this for solar gain are examined in Section 4.

The correction factor known as the framing ratio accounts for the area of rooflight that is effectively lost due to overlap with and obstruction by components of the roof construction (e.g. purlins). For large span industrial buildings, this loss factor f_{rr} is determined to be 0.13 (NARM: Private communication). Note that this loss factor is mainly due to overlap and generally insensitive to projection effects.

Additional Factor

Most common rooflight constructions used today are double or triple skin. Dimensions for in-plane rooflights in large span metal clad buildings are typically 1m wide with a length up to 5m, typically with a gap of 0.18m between the skins. This gap will serve to reduce the effective overall transmission of the aperture depending on the aperture's dimensions and material properties. This is shown in Figure 3 where it is evident that a portion of the radiation transmitted through the outer layer is lost to the roof-void.

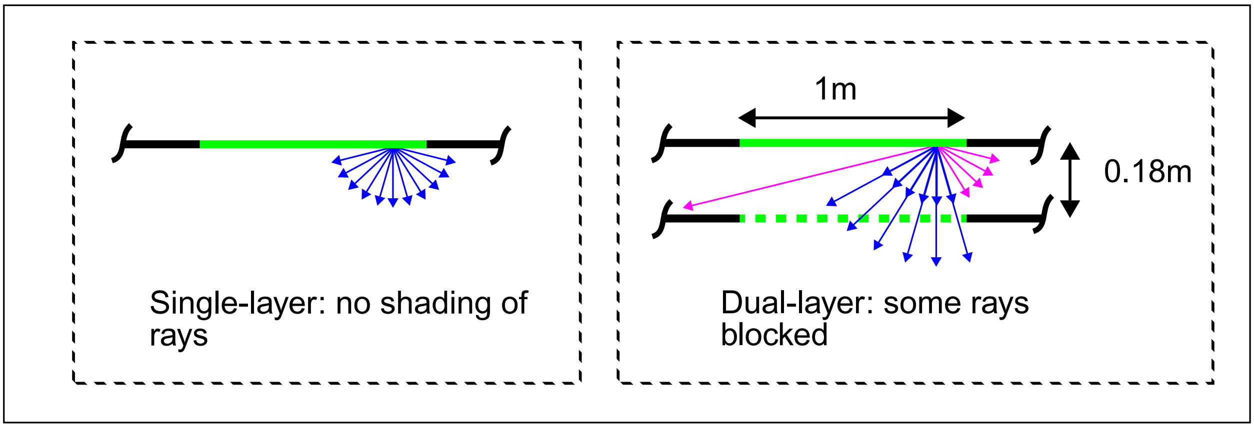


Figure 3. Schematic showing losses to roof-void resulting from duel-layer construction.

The magnitude of this effect was determined using lighting simulation techniques for a range of likely rooflight aspect ratios and was found to result in an effective loss of transmission of at least 10%. As this loss is intrinsic to the construction of double skin rooflights, we recommend that it is accounted for in the calculation of daylight and solar gain (see Section 4). We have named this the roof-void loss factor and given it the symbol f_{rv}. For an attenuation of 10%, $f_{rv} = 0.9$.

3.5 Cumulative Availability of Daylight

The cumulative availability of daylight between the hours of 08:30am and 17:30pm as a function of rooflight to floor area ratio in the horizontal and planes is shown in Figure 4 (horizontal plane) and Figure 5 (vertical plane) respectively. Data are also given in tabular form in Table 1 (horizontal plane) and Table 2 (vertical plane).

To read the plots, first select a target illuminance value, say, 500lux in the horizontal plane (the green curve in Figure 4). For 10% and 18% rooflights, a daylight illuminance of 500lux is achieved for ~2,000hrs and ~2,500hrs respectively throughout the year. Or alternatively, 60% and 75% of the working year (right-hand ordinate). As there is linear relation between rooflight to floor area ratio and daylight factor, both quantities are shown (i.e. two abscissa axes).

These data reveal the potential for daylight to provide adequate illumination throughout the year. Depending on the task and desired levels of illumination, the analysis provides a basis for the reported user-preference of higher rooflight area ratios. This is particularly the case for illumination in the vertical plane (i.e. for storage facilities). For example, a vertical illuminance of 500lux is achieved for 36% of the working year with a rooflight area ratio of 0.10. Whereas, for a ratio of 0.18, the same illumination is achieved for 57% of the working year. In other words a rooflight area ratio of 0.18 could provide daylight illumination of 500lux for 21% of the working year over and above that provided by a rooflight area ratio of only 0.10.

An illuminance of 500lux is generally considered on the high side for activities in warehouses. Note however that illuminances were predicted for empty spaces. Any form of racking etc. will serve to reduce the daylight illumination. The degree of reduction will depend on the arrangement and height (relative to eaves height) of the racking. The illuminance availability data presented in the plots and tables should therefore be considered as representing maximum possible values; the illuminance levels in buildings with any vertical obstructions will be less.

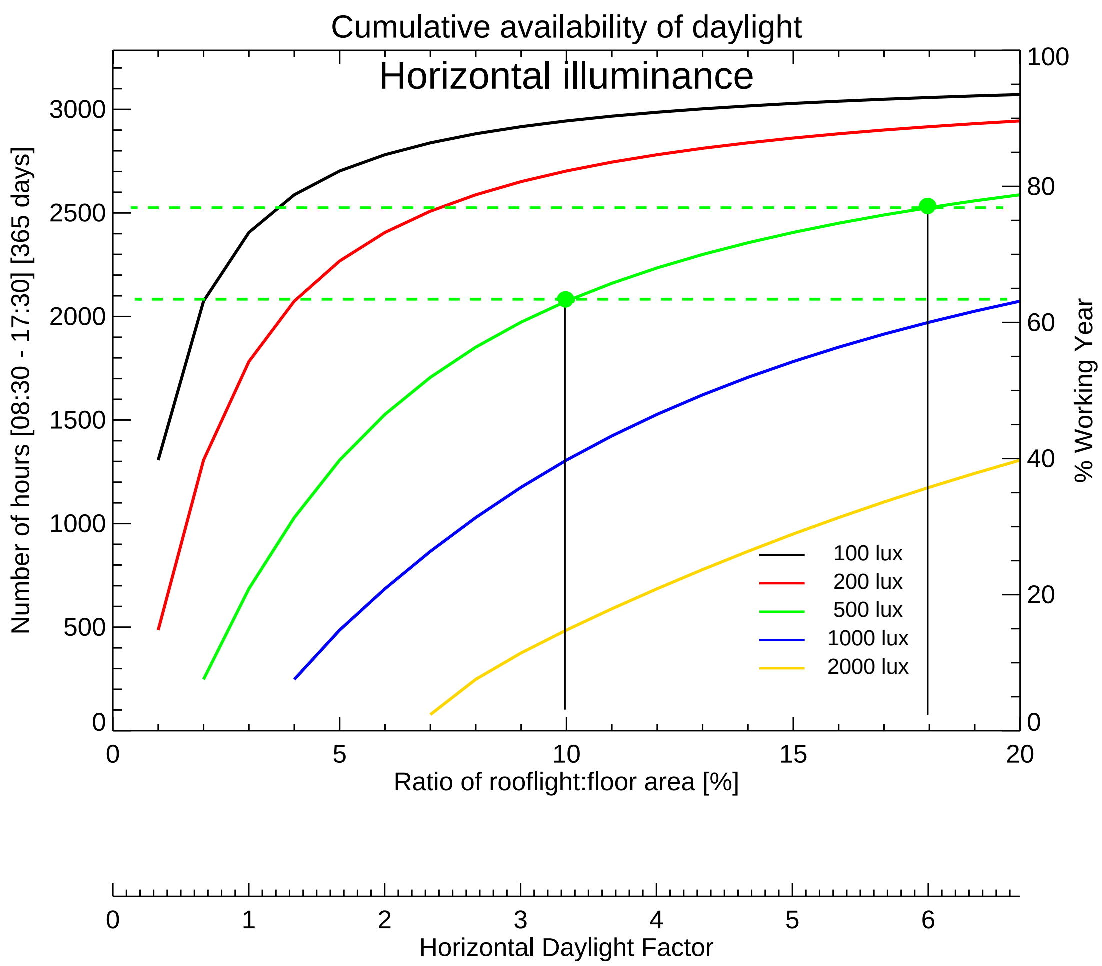


Figure 4. Cumulative availability of horizontal daylight illuminance

Rooflight area ratio	Cumulative availability [% of working year]			Cumulative availability [% of working year] over rooflight area ratio of 0.10		
	200lux	500lux	1000lux	200lux	500lux	1000lux
0.10	82	63	40	-	-	-
0.15	87	73	54	5	10	14
0.18	89	77	60	7	14	20
0.20	90	79	63	8	16	23

Table 1. Cumulative daylight availability in the horizontal plane

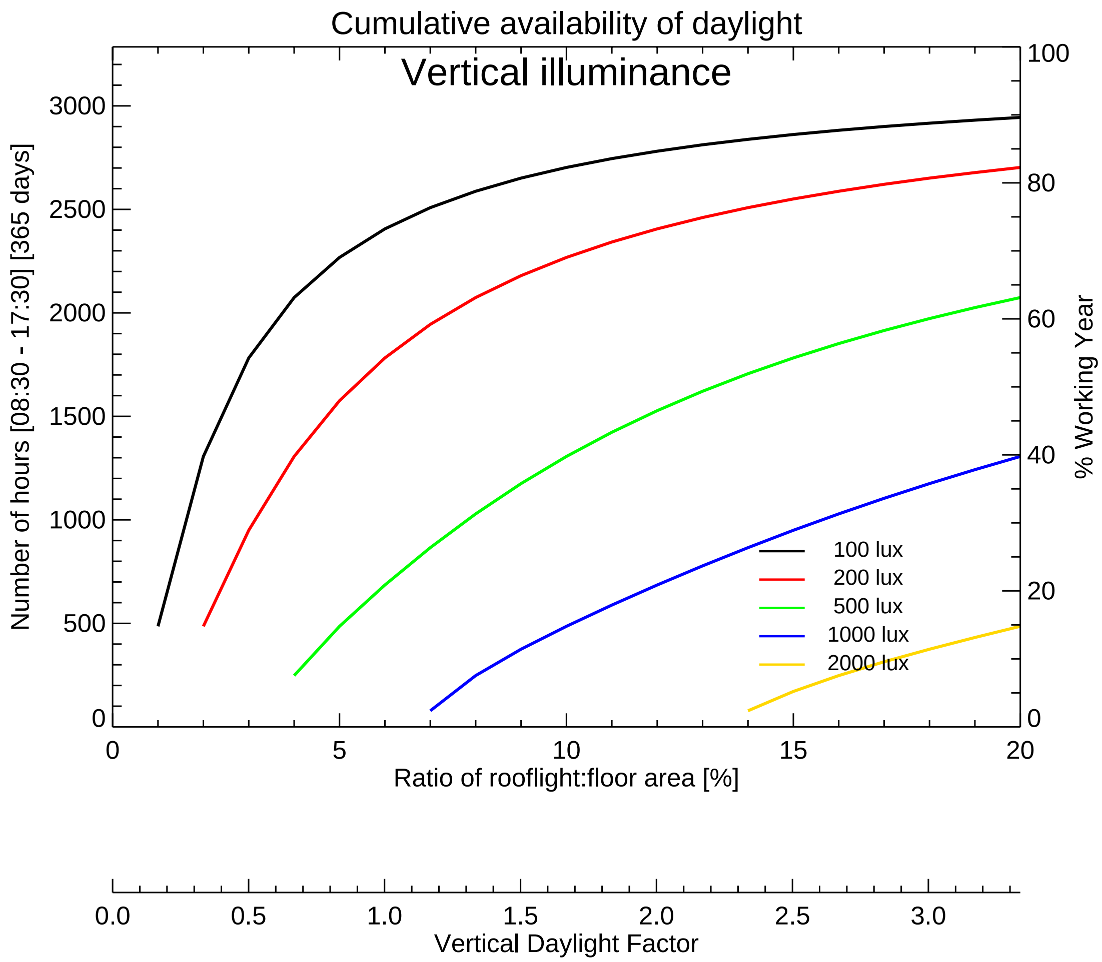


Figure 5. Cumulative availability of vertical daylight illuminance

Rooflight area ratio	Cumulative availability [% of working year]			Cumulative availability [% of working year] over rooflight area ratio of 0.10		
	200lux	500lux	1000lux	200lux	500lux	1000lux
0.10	69	40	15	-	-	-
0.15	78	54	29	9	14	14
0.18	81	60	36	12	20	21
0.20	82	63	40	13	23	25

Table 2. Cumulative daylight availability in the vertical plane

4 Solar Overheating

In this Section, the role of two key factors (shading coefficient and internal gains) relating to the use of Equation H2 are clarified. Additional factors that, in practice, are believed to reduce the effective solar cooling load beyond that given in Equation H2 are introduced.

4.1 Shading Coefficient

The application of Equation H2 to an actual rooflight scenario is not as straightforward as the simplicity of the equation suggests. For a 'fixed shading device' (i.e. rooflight), the correction factor f_c is determined using Equation H3:

$$f_c = \frac{S_c}{0.7}$$

where S_c is the shading coefficient of the rooflight. There are three different shading coefficients that are quoted in the literature: short-wave shading coefficient; long-wave shading coefficient; and, the total shading coefficient.

The one to use in Equation H3 is the total shading coefficient which is equal to the total solar transmittance (direct plus re-radiated) divided by 0.87. The factor 0.7 in Equation H3 is to convert from the reference system which has intermittent shading (e.g. blinds) to rooflights that do not (Steve Irving: Private communication). For example, a measured total solar transmittance of 0.5 produces a correction factor:

$$f_c = \frac{0.5/0.87}{0.7} = 0.82$$

4.2 Maintenance Factor and Solar Gain

The maintenance factor term in the daylight calculation acts as a "worst case" value. It is *excluded* from the solar gain calculation (Equation H2) for precisely the same reason: the worst case for solar gain is (perfectly) clean rooflights (i.e. maintenance factor = 1). Note that there is significant asymmetry in the realization of the daylighting and solar gain worst case scenarios with respect to the maintenance factor. The daylighting worst case may be realized through simple neglect: the rooflights are never cleaned (other than passively by rainfall). In contrast, the solar gain worst case could only be realized when the rooflights are without any dirt: after a thorough clean (or immediately following installation) <u>and</u> during an exceptionally hot spell.

There is a high probability therefore that, throughout the course of the year, there will be persistent daylighting reduction due to dirt. Accordingly, there is a low probability that the rooflights will be (perfectly) clean at any time, let alone during the warmest part of the year. It is evident that partial cleansing of the rooflights by rain is more likely during the winter months. Furthermore, it has been noted that "measured concentrations of airborne pollutants tended to increase with a rise in temperature; particulates are suspended in the atmosphere and then deposited on glazing" [Tregenza, 1999]. In other words, attenuation of daylight (and solar radiation) due to dirt is more likely in summer than in winter. It is recommended that rooflights are cleaned every three to four years. In practice however, rooflights are often never cleaned at all (NARM: Private communication).

It is understood that the solar gain calculation should not normally include a factor to account for dirt (Steve Irving: Private communication). However, from the reasoning given above, we expect it to be a significant factor, operational throughout the effective life of the rooflight. And so we consider it reasonable to include it in calculations of solar gain to demonstrate its likely effect. We would expect the solar gain maintenance factor to be broadly comparable to the daylight maintenance factor ($f_{md} = 0.70$); perhaps slightly higher to represent the small downwards re-radiated component of long-wave radiation. Accordingly, we have used a fairly conservative value of 0.80. We have called this the solar maintenance factor f_{ms}. We caution that this factor is only applicable to horizontal rooflights for large-span industrial buildings where the soiling of rooflights from new reaches a stable value after a few months; thereafter it is expected to be a permanent presence [Tregenza, 1999].

4.3 The Roof-Void Loss Factor

As noted is Section 3.4, this loss factor is intrinsic to the construction of double skin rooflights and we recommend that it is used for both the daylight and solar gain calculations. For solar gain, we use the same value as daylight: $f_{rv} = 0.9$.

4.4 Internal Gains

The maximum recommended Q_{slr} of 25W/m^2 is actually based on an assumed internal gains of 15W/m^2 to give a total of 40W/m^2. Where internal gains can be shown to be less than 15W/m^2, a Q_{slr} higher than 25W/m^2 is allowed so long as the total does not exceed 40W/m^2 (Steve Irving: Private communication). Internal gains are given the symbol q_{ig}.

Data on internal gains for typical rooflight buildings such as warehouses are sparse. However, the authoritative Probe Technical Review [PROBE] gives 5W/m^2 as typical for storage warehouses. These gains result entirely from artificial lighting; occupant densities are very low in storage warehouses and the gains from these can be considered negligible.

Another type of rooflight building is the retail outlet exemplified by the D-I-Y stores. Occupant internal gains from these may be significant and can be estimated. In the absence of readily available data, an estimate of occupant densities was made on the basis of a visit to a B&Q store at a likely peak-time: 3pm on a Sunday. This indicative survey suggested that internal gains resulting from occupants was of the order of 4W/m^2. Retail spaces are usually well lit and internal gains due to lighting can be of the order 15W/m^2 to 20W/m^2 [CIBSE, 1999]. However, for a well daylit building, the period of greatest solar gain will be simultaneous with the highest levels of daylight illuminance. Thus the internal gains due to electric lighting can be greatly reduced, if not eliminated altogether, by switching off the lights either manually, or more reliably, by daylight-linked controls.

4.5 Solar Gain as a Function of Rooflight Area

The solar overheating Equation H2 was modified to account for:

- The transmission losses due to the roof-void.
- The transmission losses due to the maintenance factor, i.e. accumulated dirt.
- Variable internal gains, i.e. values less than the assumed 15W/m^2.

To account for the losses due to the roof-void and the accumulated dirt, the factors f_{rv} is and f_{ms} respectively were introduced to Equation H2 as multiplying factors:

$$Q_{slr} = q_{sr}g_{rr}f_{rv}f_{ms}f_c(1-f_{rr}) \quad \textbf{(1)}$$

The effect of variable internal gains q_{ig} is included by adding it to Q_{slr}:

$$Q_{tot} = q_{sr}g_{rr}f_{rv}f_{ms}f_c(1-f_{rr}) + q_{ig} \quad \textbf{(2)}$$

Where Q_{tot} is the sum of the solar gain and the internal gains. To comply with the existing schema, Q_{tot} should be less than 40W/m^2.

We propose that this equation (Eq 2) is more appropriate than H2 for assessing the solar gain for large span industrial buildings. The solar gain as a function of rooflight to floor area ratio is computed using Eq 2 for a range of internal heat gains, Table 3. Values of Q_{tot} in excess of 40W/m^2 are shaded red. The assessment is clearly dependant on the level of expected internal gains. For large-span industrial buildings the usage is likely to remain constant for the lifetime of building, e.g. storage, retail or manufacture. Where process-intensive manufacture is intended, the associated high-internal gains may require localised extraction to prevent overheating.

Rooflight to floor area ratio	Total gain Q_{tot} = Computed solar + internal gains (range 0 to 20W/m^2)				
g_{rr}	0W/m^2	5W/m^2	10W/m^2	15W/m^2	20W/m^2
0.10	16.8	21.8	26.8	31.8	36.8
0.11	18.5	23.5	28.5	33.5	38.5
0.12	20.2	25.2	30.2	35.2	40.2
0.13	21.9	26.9	31.9	36.9	41.9
0.14	23.5	28.5	33.5	38.5	43.5
0.15	25.2	30.2	35.2	40.2	45.2
0.16	26.9	31.9	36.9	41.9	46.9
0.17	28.6	33.6	38.6	43.6	48.6
0.18	30.3	35.3	40.3	45.3	50.3
0.19	32.0	37.0	42.0	47.0	52.0
0.20	33.6	38.6	43.6	48.6	53.6

Table 3. Total gain calculated using Eq 2.

5 Summary

Simulation techniques have been employed to quantify the daylighting and solar gain characteristics of rooflights. Transmission loss factors present in the Part L scheme were examined, and an additional factor resulting from the roof-void gap was uncovered. The worst case aspect of the solar gain calculation was examined and the omission of an attenuation factor due to dirt was found to be in all likelihood unrealistic.

Daylighting provision was based on the cumulative availability of daylight illuminance. This assessment method provides far greater insight into the actual performance of buildings than daylight factors alone. The daylight availability predictions provide an objective basis to explain the often reported user-preference for higher rooflight ratios.

The daylighting study has shown that rooflight to floor area ratios in the range 0.15 to 0.20 provide significantly higher levels of useful daylight illuminance than ratios of, say, 0.10. In addition to the noted user-preference for daylight illumination, the higher rooflight ratios offer the potential for considerable energy savings by using daylight to displace the use of electric lighting. It is acknowledged that suitable lighting controls - ideally, daylight responsive - are needed to realise these energy savings.

From the reasoning given in Section 4.2, it seems highly likely that the solar gain worst case of (perfectly) clean rooflights during the warmest period is only very rarely achieved in practice. Thus, we propose that our Eq 2 and the values given in Table 3 may offer a more realistic guide to allowable rooflight areas than the existing Part L recommendations. This may be one of the principal reasons why user experience of buildings with rooflight area ratios of 0.15 to 0.20 appears to be at odds with the recommendations given in Part L where the propensity for solar overheating from rooflights appears to be over-estimated. We note here that the B&Q store in Sutton-in-Ashfield, which has 15% rooflights over the sales floor, has been awarded a 'very good' rating for its environmental performance by the Building Research Establishment's Environmental Assessment Scheme (BREEAM). Under Part L, the rooflight area for the B&Q building would have been considered too great on the grounds of solar gain. However, the modified scheme described in this report would have passed the award-winning building as not unduly at risk from solar overheating. Furthermore, the degree of daylight provision can be quantified using the proposed scheme.

The assessment scheme recommended in Part L for daylighting and solar gain from rooflights has been investigated. It is noted that Part L serves as a guide to recommended values, and that supplementary information may be presented to justify design parameters outside of the recommended range. The authors propose that the refined scheme presented in this report offers an assessment of daylighting and solar gain for large span industrial buildings that better describes the actual operating conditions than the existing Part L formulation.

References

[CIBSE, 1999] CIBSE Guide A: Environmental design, Chartered Institution of Building Services Engineers, 1999

[CIBSE LG10] CIBSE lighting guide LG10 Daylighting and window design London: Chartered Institution of Building Services Engineers, 1999

[PROBE, 1999] PROBE Technical Reports **http://www.usablebuildings.co.uk/**

[Tregenza, 1999] Tregenza P R, Stewart L, Sharples S "Reduction of glazing transmittance due to atmospheric pollutants", Lighting Research and Technology 31(4) 135-138 (1999)

Appendix: Building Parameters and Correction Factors

The parameters and correction factors used in the computation of daylight and solar gain are listed in Table 4. The transmission properties are based on a GRP in-plane rooflight.

Symbol	Value	Description	Used in comp. of:		Source
			Solar gain	Daylight	
f_c	0.82	Correction factor for glazing/blind combination -based on total solar transmittance of 0.5	✓	✗	NARM, Steve Irving
T_v	0.67	Transmission of visible radiation	✗	✓	NARM
f_{rv}	0.90	The roof-void correction factor	✓	✓	Calculated
f_{rr}	0.13	Framing ratio for rooflights	✓	✓	NARM
q_{ig}	0 to 20W/m^2	Internal gains	✓	✗	PROBE Report
f_{md}	0.70	Daylight maintenance factor - accounts for dirt on horizontal rooflights	✗	✓	Tregenza, 1999
f_{ms}	0.80	Solar maintenance factor - accounts for dirt on horizontal rooflights	✓	✗	See Section 4.5
ρ	0.20	Reflectance of internal surfaces	✗	✓	Typical low value

Table 4. Building parameters and correction factors