XI th national conference on lighting Bulgaria 13 – 15 June 2001 Light' 2001 pp. 27-32

Daylight and Domestic Buildings

M.P.Wilson and L.Brotas

Summary

In northern Europe the average daylight factor may be used to characterise the daylight in a room. The paper discusses calculation techniques and their limitations in practice. It further deals with daylighting in urban canyons in predominantly sunny climates particularly those north facing rooms lit by reflected sunlight.

Introduction

The increased emphasis on energy efficiency as a result of global warming has unfortunately led to forms of building design and construction where there has been reduced daylighting in domestic buildings.

With windows as the main source of heat loss from buildings there has been a tendency to reduce their size with some encouragement from national building regulations. In addition the replacement of single glazing by double or double low-e glazing has led to a reduction in transmitted daylight between 10-25%. Windows with thermal breaks tend to have increased opaque elements again reducing daylight transmission.

As opposed to non-domestic buildings where many arguments exist for the energy benefits of well daylit buildings, there is little research into energy benefits of well daylit domestic buildings. In fact the benefits may be small. Many dwellings are unoccupied during the daylight hours. However while the main source of domestic lighting remains the tungsten filament lamp considerable potential savings are possible if there is 24 hour occupation.

But the main argument for well daylit domestic buildings comes from the preferences of the occupants. A well daylit space is perceived as more healthy, allows greater contact with the outside world, is more open and therefore to many more democratic.

Daylighting in the UK

The Building Regulations are legally enforceable regulations which with questions of the conservation of energy and the health and safety of occupants. They therefore deal with such issues as adequate ventilation, noise insulation between dwellings and the structural integrity of the buildings. There has been a proposal recently to include daylighting criteria in the building regulations in relation to occupant health safety. No conclusions have yet been reached.

Recommendations as to daylight in domestic buildings are to be found in the British Standards on Lighting, specifically the section on daylighting, in the publications of the CIBSE and in publications of the BRE (1,2,3).

The recommendations for new spaces are expressed in three ways:

- a minimum average daylight factor (2% kitchens, 1.5% living rooms, 1% bedrooms);
- the position of the no sky line at working plane height (0.85m). If the area beyond the no-sky line is more than 50% the room will look gloomy;
- a limiting depth criteria.

To put the first recommendation in context, a room with an average daylight factor of more than 5% is regarded as well daylit, that is electric lights would be used infrequently during daylight hours, but below 2% electric lights would be used frequently (2). The requirements are therefore minimal.

Orientation is not considered. Orientation factors can however be used to reflect the higher levels of illuminace on the south façade.

Of course these recommendations are 'illumination' based and the perception of how well a space is daylit may be influenced by factors such as shading control and view. Some recent research in the UK has suggested that rooms can have too much daylight (4).

In regard to a new building affecting an existing building the recommendations have an origin in solar access in the UK. The new building should not reduce the vertical sky component below 27% or if it does it should not reduce it by more than 20%. In most city centres the vertical sky component is already below 27% at many windows of building. Planning authorities have tended to use the 20% reduction guideline when assessing planning permission in such areas. This unfortunately has its drawbacks, leading to creeping increased heights in urban areas reducing daylight access and there is some demand from the planning authorities in these areas (eg City of Westminster in London) for improved guidelines, possibly based on typical daylight access in particular city zones. Many countries and cities themselves have planning regulations that affect daylight but would not be found as a daylighting regulation. In Portugal, for instance, there exists a 45^o rule that in practice limits urban canyon dimensions to a ratio of 1:1.

Rights of Light

In the UK 'Rights of Light' legally protects individuals against neighbouring properties to be newly constructed or extended that will affect their daylighting. It is defined in terms of the position of the 0.2% sky factor contour (5).

Average Daylight Factor

The average daylight factor is the ratio between the mean illuminance in a space and that from an unobstructed sky externally expressed as a percentage. In calculation terms the sky is generally assumed to be the CIE overcast sky. It is measured or predicted on the working plane that for domestic buildings is assumed at 0.85m. There are two formulae that give an average daylight factor, Sumpner's and the BRE average daylight factor formulae. Both are based on a ratio of the window area to the surface area of the room, with corrections for any obstructions, glass transmission and room reflectance.

BRE formula : $DF = \theta TW/A\ (1-R^2)$

Sumpner's formula: $DF = \theta TW/2A(1-R)$

θ is the angle of obstruction measured from the mid-point of the window
T is the light transmission of glazing
W is the window area
A is the area of all the surfaces of the room
R is the average reflection factor of the room

Alternatively the average daylight factor can be calculated using a variety of computer programs which determine the daylight factor on predefined grid and take the average. It is clear that the latter method will give a more accurate result, but the former is particularly useful at an early design stage.

Applications in practice

During a recent energy efficient housing refurbishment project supported by the EC 'Thermie' programme that included 6 individual projects, questions arose as to the affect of glazing balconies and creating add-on glazed balconies as a passive solar measure on daylighting. The buildings have been discussed fully in a recent paper (6) but the issues arising are outlined here. Glazing an existing balcony can easily lead to a reduction of 30-45% of the daylight entering a room while creating a 'tower' of add-on glazed balconies may lead to a reduction of 60%. In the German building, an 8 storey social housing block near Flensberg (Fig 1), an additional window was created on each floor in the most affected room. The size was estimated using the simple 'Daylight' program. Reports from the tenants have been very positive, and most interestingly the tenants have commented mainly on the view of a previously unseen aspect. The total installation cost of each new window was about 1500 euros. The building won first prize in a German competition for implementation of solar energy in renovation (Messepreis Solar'99). The French building in Lyon (Fig 2) raised some interesting issues. The add-on glazed balconies as originally conceived severely reduced the amount of daylight to the room attached. For access to the balcony the original window that had a sill height just above working plane height was extended to the floor creating glazed doors. As a result of the daylighting concerns the balcony was fitted with full height glazing. While the computer prediction techniques showed little benefit from the use of full height glazing, no direct daylight being available from window below working plane height, the formulae give a result directly proportional to the window area independent of location of window and showed considerable benefit. Surprisingly the tenants have commented that the quality of their daylight has improved. How can this be explained? Is the average daylight factor on the working plane the best means of characterising daylight? The full height window allows more ground reflected light, which is of relative importance where the ground is sunlit but the sun is not directly on the facade. The full height window improves the view particularly of the foreground and middle ground even for a seated person within the room. The side windows in the glazed balcony permit easier views parallel to the building facade. Future research will need to decide the importance of these factors.

Figure 1
Refurbishment in Englesby, Germany

Figure 2
Refurbishment in Lyon, France

XI th national conference on lighting Bulgaria 13 – 15 June 2001 Light' 2001 pp. 27-32

Sunny Climates

In sunny climates the windows on south facing facades are invariably shaded. Shade adjustment controls in domestic buildings allow user control to optimise the balance between solar admission and daylight. Prediction of lighting levels can be made from the direct solar illumince on the facade and the transmission of the shading system. The design of the windows on the north side which do not require shade, except for perhaps early morning and evening in summer, are of interest particularly in urban situations where the primary source of daylight will be reflected sunlight.

Several methods have been developed for the calculation (eg 7,8), but they do not lend themselves to a simple calculation for architects. Experiments have been conducted in an typical urban canyon in Lisbon (38ºN). Experiments so far have been conducted in August and January. Measurements of external vertical illuminance were made at 1st floor and 5th floor level as well as global horizontal illuminance. It can be seen that in August during sunny days there is a linear relationship between the vertical illuminance at both levels and the global horizontal illuminance (figs 3 and 4).

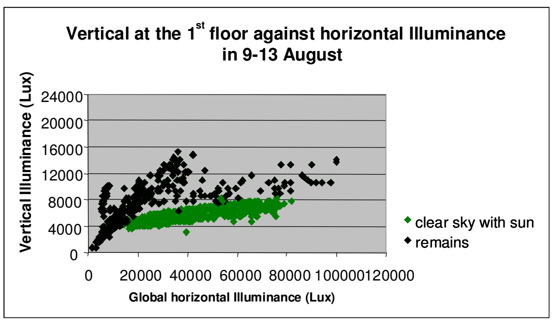

Figure 3
Relation between the vertical Illuminance at the 1st floor on a North façade facing a South obstruction and the global horizontal Illuminance in 9th –13th of August

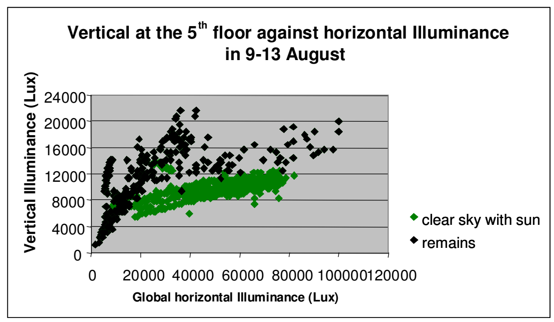

Figure 4
Relation between the vertical Illuminance at the 5th floor on a North façade facing a South obstruction and the global horizontal Illuminance in 9th –13th of August

A simulation undertaken with RADIANCE of a 1:1 canyon shows that for most of the day (apart from when there is direct sun on the façade) there is an approximate linear relationship. The proportionality changes according to the reflection factor of the opposite facade, the floor level and also with the time of year.

The vertical illuminance on the facade could be described by the equation:

$$Ev = k \times Egh + C$$

where k and C are constants and Ev is the vertical illuminance on the facade and Egh is the global horizontal illuminance.

At the higher levels diffuse (blue) sky is making a large contribution to the daylighting in the room. Under these conditions the value of C is relatively large but becomes at the lower levels relatively small. Under such conditions it can be ignored.

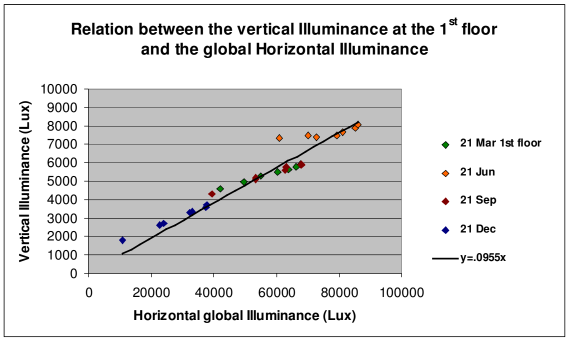

Figure 5
Simulated values of the vertical Illuminance at the 1st floor on a North façade facing a South obstruction and the global horizontal Illuminance for the equinox and solstice days

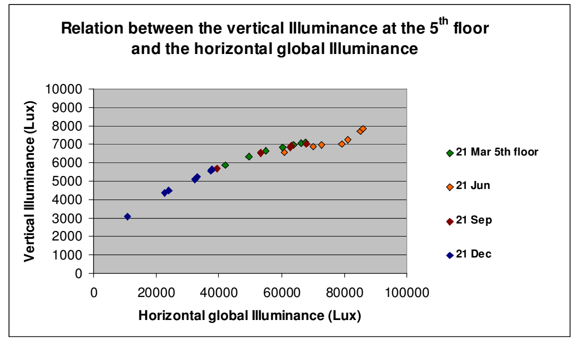

Figure 6
Simulated values of the vertical Illuminance at the 5th floor on a North façade facing a South obstruction and the global horizontal Illuminance for the equinox and solstice days

In the case shown (figs 5 and 6) for an obstruction refection factor of .2, the constant k is around .1. It is therefore possible to create an approximate daylight factor formula for north facing facades under predominantly sunny skies for spaces mainly lit by reflected sunlight. We might call this an SNDF (sunny north facing daylight factor).

Using the standard interreflection formula the equation would have the form:

SNDF = KTW/A(1-R) where K is a function of the canyon ratio, latitude, and reflection factor of opposite facade.

Despite the errors, and these exist in a substantial form anyway in the overcast sky formula, this does allow initial estimation of window sizes and a characterisation of the space in similar terms to the 2% and 5% average daylight factor criteria for an overcast sky.

Acknowledgements

Luisa Brotas wishes to thank the financial support of INETI – Instituto Nacional de Engenharia e Tecnologia Industrial and the FCT – Fundação para a Ciência e Tecnologia from the MCT – Ministério da Ciência e Tecnologia for her PhD scholarship.

References

1.BS 8206 Part 2 *Code of practice for daylighting* (London: British Standards Institution) (1992)
2.CIBSE *Daylighting and Window design* Lighting Guide LG10 (1999)
3. Littlefair P J *Site layout and planning for daylight and sunlight: a guide on good practice* BRE report BR209 (London: Construction Resaerch Communications) (1991)
4. Roche L et al. Occupant reactions to daylight in offices, *Lighting Research and Technology* 32 (3) pp119-126 (2000)
5. Anstey J *Rights of Light and how to deal with them* (London: Surveyors Publications/RICS) (1988)
6. Wilson M et al Daylighting, energy and glazed balconies: a study of a refurbishment project in Englesby, near Flensberg, Germany Lighting *Research and Technology* 32 (3) pp127-132 (2000)
7.Tsangrassoulis A et al A method to investigate the potential of south oriented vertical surfaces for

reflecting daylight onto oppositely facing vertical surfaces under sunny conditions, *Solar Energy* 66 (6) pp 439-446 (1999)
8. Tregenza P Mean daylight illuminance in rooms facing sunlit streets *Building and Environment* 30 (1) pp 83-89 (1995)

Contact Addresses

Professor Mike Wilson
Luisa Brotas
Low Energy Architecture Research Unit
University of North London
40-44 Holloway Rd
London N7 8JL

+44 207 753 7006 (t)
+44 207 753 5780 (f)
emails m.wilson@unl.ac.uk, l.brotas@unl.ac.uk