



The Importance of Glare and Calculating UGR July 2019

1. What is glare?

Glare is a sensation where the eye perceives areas of brightness within the visual field, which can result in a person having difficulty seeing or carrying out a visual task. The light source maybe the sun or artificial, and glare can arise from windows, roof lights, luminaires or reflections of these from other surfaces. Often the natural reaction will be to shield our eyes from it. Excessive glare can lead to errors, accidents and fatigue.

There are several forms of glare, but when we talk about glare in the built environment, we are generally talking about two particular types, disability and discomfort.

1.1 Disability glare

In its simplest form, disability glare is where a light source makes difficult or prevents a person from carrying out a visual task. Often this occurs when a high luminance is present in a low luminance scene. Light from the high luminance source is scattered in the eye making it difficult to see in a dimly lit environment. The best example of this is oncoming headlights from a vehicle at night. Contrast is a significant factor, as the below image, Fig 1, shows. The motor cycle headlight luminance does not change between the day and night scene; however in the day there is no disability glare due to the higher surrounding luminance.

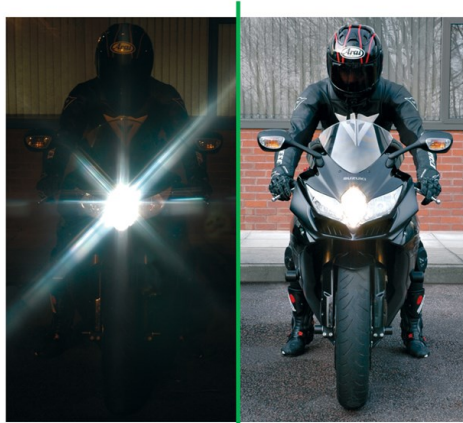


Fig 1

Within interior applications, disability glare is not often experienced, and is more associated with the outdoor environment. However, disability glare can be experienced where computer visual display terminal (VDT) screens are being used. Reflections from luminaires or windows can be problematic, often preventing the operator from seeing the content on the screen. Fig 2 below shows an example of this.



Fig 2

More information and guidance on how to avoid the issues with luminaire brightness and reflections in screens can be found in the SLL Code for lighting - chapter 2.

1.2 Discomfort Glare

This is the most common form of glare, and the one most complained about. This is where people feel visual discomfort from a light source. We should be mindful that discomfort glare can be subjective as it depends on a person's visual system, and as we are all different, what is 'bright' to one person, is not necessarily 'bright' to another.

The level of discomfort glare from artificial lighting depends on several factors, such as the luminance of the luminaire, the size of the area the light is being emitted from, the background luminance the luminaire is viewed against, and the luminaire position relative to the line of sight. All of these factors can influence the level of discomfort glare.

As a general rule, high levels of discomfort glare can be avoided by considering the following things:

- The type of luminaire used along with its anti-glare properties.
- The luminaires position relative to the users of the space.
- The reflectance levels of the room surfaces.
- The luminance of the background or surrounding area to the luminaire

The optical performance of the luminaire is one of the most critical elements, poor luminance control at the key viewing angles will result in high levels of glare. Similarly the higher the lumen output of the luminaire, the greater the levels of glare will likely be. The mounting position is also key. The more the luminaires are within the typical field of view, the higher the levels of glare. Therefore, lower mounting heights or buildings with very low ceilings can often pose a problem. Reflectance's, particularly the walls and ceiling also play a part as this will affect the luminance of the background the luminaire is viewed against. The brighter the background, the lower the levels of glare. Often luminaires with dedicated upward light can help by raising the luminance of the background, this can work particularly well in industrial applications as an example, however the ceiling does need to have a sufficiently high reflectance factor.

Levels of discomfort glare can be calculated using the International Commission on Illumination (CIE) Unified Glare Rating (UGR) calculation method.

2. What is UGR?

UGR is a metric for defining the level of discomfort glare for interior applications. UGR values range from 13 to 30, and the lower the value the less the discomfort will likely be.

The metric takes into account the luminance of the luminaire, the luminance of the background, the geometry between the observer and the luminaires, and the Guth position index, which relates to the displacement from the line of sight. Fig 3 below shows the formula:-

$$UGR = 8 \log_{10} \left[\sum \frac{0.25 L^2 \omega}{L_b p^2} \right]$$

where

- L_b is the background luminance in $cd \cdot m^{-2}$, calculated as $E_{ind} \cdot \pi^{-1}$, in which E_{ind} is the vertical indirect illuminance at the observer's eye in $cd \cdot m^{-2}$,
- L is the luminance of the luminous parts of each luminaire in the direction of the observer's eye in $cd \cdot m^{-2}$,
- ω is the solid angle in steradian of the luminous parts of each luminaire at the observer's eye,
- p is the Guth position index for each individual luminaire which relates to its displacement from the line of sight.

Fig 3

It is important to note that UGR is calculated from an observer position. Therefore consideration has to be given to the type of task being carried out and the likely position of the observer. For example, is the observer standing or sitting? Based on this the correct geometry should then be used between the observer and the luminaires.

Guidance is available on the maximum UGR values permissible for particular applications. For example, the maximum UGR advised for corridors is UGR 28, whereas an office is UGR 19. This guidance can be found within various application standards such as the British Standard for Interior places of work - BSEN12464-1 or the SLL Code for Lighting. Generally, if discomfort glare limits are met, disability glare should not be a problem.

Using modern lighting design software packages, such as DIALux, the calculation of UGR is simple; therefore it does not need to be a cumbersome or time-consuming task. Most reputable manufacturers can also provide a table of UGR values for their luminaires. These tables provide UGR values for a specific luminaire within a range of typical room sizes. This can be a good way of quickly establishing a products glare performance. Fig 4 below is an example of a typical UGR table.

Luminaire Details

Luminaire Name: JUBILEE XL LED
 Luminaire Part Number: JUB16697

Table of Corrected Unified Glare Ratings

SHR:1.00

		Reflectances									Reflectances								
		0.80	0.80	0.80	0.70	0.70	0.70	0.50	0.50	0.50	0.80	0.80	0.80	0.70	0.70	0.70	0.50	0.50	0.50
		0.70	0.50	0.30	0.70	0.50	0.30	0.70	0.50	0.30	0.70	0.50	0.30	0.70	0.50	0.30	0.70	0.50	0.30
		0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
X	Y	UGR(Crosswise)									UGR(Endwise)								
2H	2H	11.3	12.7	14.1	11.5	12.9	14.3	12.0	13.3	14.7	11.0	12.3	13.8	11.2	12.5	14.0	11.7	13.0	14.4
	3H	13.2	14.5	15.8	13.5	14.7	15.9	13.9	15.1	16.4	12.2	13.5	14.8	12.5	13.7	15.0	13.0	14.1	15.4
	4H	14.1	15.2	16.4	14.3	15.4	16.6	14.8	15.9	17.1	12.7	13.8	15.0	12.9	14.0	15.2	13.4	14.5	15.7
	6H	14.7	15.8	16.9	15.0	16.0	17.2	15.5	16.5	17.6	13.0	14.1	15.2	13.3	14.3	15.4	13.8	14.8	15.9
	8H	15.0	16.1	17.1	15.3	16.3	17.4	15.8	16.8	17.8	13.1	14.2	15.3	13.4	14.4	15.5	13.9	14.9	15.9
	12H	15.3	16.3	17.3	15.5	16.5	17.5	16.1	17.0	18.0	13.2	14.2	15.2	13.5	14.5	15.5	14.0	15.0	15.9
4H	2H	11.8	13.0	14.2	12.1	13.2	14.4	12.6	13.7	14.8	11.5	12.7	13.9	11.8	12.9	14.1	12.3	13.4	14.6
	3H	14.0	15.0	16.1	14.3	15.3	16.3	14.8	15.7	16.7	13.0	14.0	15.1	13.3	14.3	15.3	13.8	14.8	15.7
	4H	15.1	16.0	16.9	15.3	16.2	17.1	15.9	16.7	17.6	13.6	14.5	15.4	13.9	14.7	15.7	14.4	15.2	16.1
	6H	16.0	16.7	17.6	16.2	17.0	17.8	16.8	17.5	18.3	14.1	14.9	15.7	14.4	15.1	15.9	14.9	15.6	16.4
	8H	16.3	17.1	17.8	16.6	17.3	18.1	17.2	17.9	18.6	14.3	15.0	15.8	14.6	15.3	16.0	15.1	15.8	16.5
	12H	16.7	17.4	18.0	17.0	17.6	18.3	17.5	18.2	18.8	14.4	15.1	15.8	14.7	15.4	16.0	15.3	15.9	16.6
8H	4H	15.4	16.2	16.9	15.7	16.4	17.2	16.3	17.0	17.7	14.2	14.9	15.6	14.4	15.1	15.9	15.0	15.7	16.4
	6H	16.5	17.1	17.8	16.8	17.4	18.0	17.4	18.0	18.6	14.8	15.5	16.1	15.1	15.7	16.3	15.7	16.3	16.9
	8H	17.0	17.6	18.2	17.3	17.9	18.4	17.9	18.4	19.0	15.1	15.7	16.2	15.4	15.9	16.5	16.0	16.5	17.0
	12H	17.5	18.0	18.5	17.8	18.3	18.8	18.4	18.9	19.3	15.4	15.9	16.3	15.7	16.1	16.6	16.2	16.7	17.2
12H	4H	15.5	16.2	16.9	15.8	16.4	17.1	16.3	17.0	17.6	14.3	15.0	15.6	14.6	15.2	15.9	15.1	15.8	16.4
	6H	16.7	17.2	17.8	16.9	17.5	18.0	17.5	18.0	18.6	15.1	15.6	16.2	15.3	15.9	16.4	15.9	16.4	17.0
	8H	17.2	17.7	18.2	17.5	18.0	18.5	18.1	18.5	19.0	15.4	15.9	16.4	15.7	16.2	16.6	16.3	16.7	17.2

Corrected for Total Luminous Flux - 2965.0 lm

Fig 4

The geometry of the scene is determined in the X (room length) and Y (room width) columns on the left, with the 'H' values representing the length or width of the room divided by the height between the observers eye and the luminaires. As glare is dependent on the background illuminance, UGR values are given for a range of room surface reflectance values. The UGR values will also change based upon the lumen output of the luminaire, so it is important that the UGR table is corrected for the lumen output of the luminaire.

For more information about UGR tables, see SLL Code for lighting - section 12.3.5.

3. How applicable is UGR today?

Over the years, lighting technology has come and gone, luminaires styles and form factors have changed, but the human eye is still the same. In the more recent period ranging from the 1980's to the late 2000's one of the most predominant light controlling technologies was a louvre. This type of optic controlled the light from the source, which was typically a fluorescent lamp, which then redistributed it in the desired direction. They also provided very good levels of glare control, which was primarily to avoid reflections in computer VDT screens. Luminaires with louvres were prominent in many applications ranging from offices, schools, healthcare, retail and industry to name a few. The technology was favoured for its high efficiency and relative low cost. Fig 5 below shows such an example.



Fig 5

Through the widespread use of louvres and its associated good levels of glare control, the issues of glare seem to have become forgotten along with the importance of calculating UGR for a room. However, with most modern luminaires now using LED technology as the light source, conventional optics such as louvres are no longer being used, and instead diffusers and prismatic' s are now more commonplace. With such a great demand for high efficiency luminaires, these diffusers are becoming thinner and less opaque in order to meet the demands of the consumer. Because of these changes, glare from modern LED luminaires is on the rise, so the importance of checking UGR is now paramount to ensure that discomfort glare is within acceptable levels.

The change to LED technology has also brought with it problems for the CIE UGR method of calculation. This method was based upon luminaires that had homogenously illuminated surfaces which were common at the time the method was determined. LED luminaires do not have evenly illuminated surfaces, and sometimes intense spots of light can be seen, particularly where the LEDs are located directly behind a diffuser. The UGR metric does not consider this; however, until such times as research is carried out on the impact of this, the CIE UGR method still remains the best metric for determining discomfort glare.

4. Conclusion

The Workplace (Health, Safety and Welfare) Regulations requires workplaces to have suitable and sufficient lighting. A workplace that has high levels of discomfort glare will likely lead to unhappy workers, increased sickness days, lower productivity and increased accidents and errors. In the current age where the wellbeing of people within buildings is a major focus of attention, we should not forget the basics when it comes to good lighting. There is a continuing trend of 600x600 opal "panel" type luminaires replacing fluorescent luminaires with louvres. Often this happens with no consideration or calculation of glare. Discomfort glare should be calculated using the CIE UGR method for all types of application to ensure that glare is not excessive and within the guideline limits recommended.

5. Glossary

Brightness

Attribute of a visual sensation according to which an area appears to emit more or less light

Contrast

1. In the perceptual sense: assessment of the difference in appearance of two or more parts of a field seen simultaneously or successively (hence: brightness contrast, lightness contrast, colour contrast, simultaneous contrast, successive contrast, etc)

2. In the physical sense: quantity intended to correlate with the perceived brightness contrast, usually defined by one of a number of formulae which involve the luminances of the stimuli considered, for example: $\Delta L/L$ near the luminance threshold, or $L1/L2$ for much higher luminances.

Luminance

The luminance is the 'apparent brightness' of an object or surface. The intensity of light emitted in a given direction from a projected area.

Visual field

Area or extent of physical space visible to an eye at a given position and direction of view.

Visual task

Visual elements of the activity being undertaken.

6. Bibliography

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