Fundamentals of lighting and lighting design

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It takes a lighting design expert to remind us that selecting the correct lighting should not be taken for granted.

Lighting design generally considers the following main factors:

- Whether the lighting is required for indoor or outdoor purposes
- Whether it will be in a safe or hazardous area
- The required illumination level necessary for the task to be performed
- The working plane level at which the recommended or required lux is to be achieved
- The type of lamps to be used and their lumen outputs
- Mounting height and provisions available
- The uniformity to be achieved
- The colour rendition acceptable for the task

Closed and open areas

The lighting application is referred to indoor or outdoor depending on whether the lighting is in a closed or open area, relating to the protection of the luminaires against atmospheric and environmental conditions like weather conditions, corrosion, etc. It is also possible that indoor luminaires are adopted where there are no side walls but only ceilings are provided (pump sheds, etc).

Whether for indoor or outdoor lighting, no contribution from natural light is considered in the calculations.

Interior

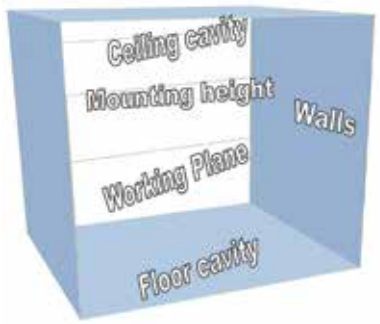
However, for design purposes and for better energy savings, the interiors in old plants used to consider maximum possible natural lighting as part of building designs. But these approaches have changed considerably in current designs. Nevertheless, the reflectance factors play a major role in improving the lux levels.

Exterior

For outdoor areas, it is necessary to consider that the light fittings are made of enclosures and materials to withstand the weather conditions and corrosion factors associated in the area of use. Furthermore, no reflectance factors are considered in the calculations. More attention is paid on focused lighting and localised lighting in areas where specific tasks are to be carried out.

Working plane and mounting heights

- A working plane in a reading area or an assembly shop level is generally at desk level (about 750 mm to 900 mm (2,5 to 3 feet) from the finished floor level) whereas in a verandah or an indoor stadium, it can be floor level itself
- The light falling on the working plane will depend on the mounting height of the lamps
- The indoor lighting is affected by the cavities above the mounting height (ceiling cavity) and below the working plane (floor cavity) as well as the walls surrounding the area



Reflectance factors

- The reflectances are given the abbreviations L, M and D to signify light, medium and dark reflectance respectively
- The average values of these factors for ceiling, walls and floor are generally considered as per *Table 1*.
- The COU factors are given by the manufacturers generally based on these reflectance factors for different room indices, for use in indoor lighting calculations.

Surface reflectance →	Light	Medium	Dark
Ceiling cavity	0,70	0,50	0,30
Walls	0,50	0,30	0,10
Floor cavity	0,30	0,20	0,10

Table 1: Average values of Light, Medium and Dark for ceilings, walls and floor.

Material	% Reflectance
Glossy silver	95
Gold	75
Matt silver	85
Iron	50
Mirrors	80
Polished aluminum	70
Light green	75
Light blue	50
Light red	40
Dark brown, green and blue	15
Black	3 - 4

Table 2: Reflectance percentages (typical).

Coefficient of utilisation (COU)

- COU is the ratio of the luminous flux that reaches the working plane and the total flux emitted by the lamps mounted taking into account the floor and ceiling cavities as well as the reflectances.
- For a closed room, COU is based on the room's internal dimensions (room length, width and luminaire mounting height) and is governed by the formula:

$$\text{Room Index} = \frac{Length \times Width}{H\text{ m} \times (Length + Width)}$$

- COU factors are provided by luminaire manufacturers for each type of luminaire with different room indices and reflectance factors, which are used in the lighting calculations to decide on the number of luminaires

Luminaire or lamp depreciation factors

- Luminaire depreciation factor refers to the depreciation in the output of the luminaire as it ages with dirt accumulation, degradation of materials used, being the main reasons.
- In a similar way, the lamp output gradually reduces as it ages due to evaporation of filaments, etc and this is referred to as lamp depreciation factor
- In lighting calculations, sometimes separate factors are considered to take care of the possible reduction in the light output as time goes by provided the designer is able to justify the values considered
- However to simplify, it is also usual to assume a single factor called maintenance factor (MF) during design stages to take care of reduced light outputs attributed by luminaires/ lamps
- Without detailed knowledge of a maintenance plan or luminaire or lamp to be selected and their properties, it is very common to consider a MF of around 0,70 to 0,80 in the design calculations

Spacing of luminaires

- The design criteria should also take into account the ratio of spacing between successive luminaires to their mounting height to ensure aesthetics and uniformity of the luminaire layout.
- This can be on the two horizontal axis of the room along 0 - 180^0 axis as well as along 90 - 270^0 axis, considering vertically downward light
- Maximum Recommended Spacing = S x (H_m - H_w) where
  S = Recommended spacing
  H_m = Height of the luminaires above the working plane
  H_w = Height of the work plane above the floor.
- As a rule of thumb, to achieve uniform lighting it is recommended that the spacing between adjacent luminaries is not more than 1,5 times their mounting height ie luminaire Spacing <1,5 H_w

Simple calculation

The IES Zonal Cavity Method (also known as the Lumen Method) is used to decide the number of luminaires to achieve the required lux level on a work plane in an interior space, taking into account the room index, COU, maintenance factor, etc. Typical steps involved are

- Decide on the type of luminaires you plan to use for an application as well as the number of lamps it can hold or you would prefer.
- Take the room dimensions and decide the COU based on the manufacturers' luminaire catalogues and the reflection factors of the ceiling, the floor and the walls. It is also common to assume some nominal factors based on experience and knowledge
- Consider a suitable MF based on your previous experiences or assume it to be 0,7 to 0,8
- Use the simple formula below to decide the quantity (integer)
- Make a practical and feasible layout for the calculated quantity
- Re-calculate and check the actual illuminance achievable for the layout planned

Simple formulae

- Make a rough estimate on the approximate number of proposed luminaire-type lamps based on the average lux required for the task using the formula

Number of luminaires =

$$\frac{\text{(Desired average lux) x (workplane area)}}{\text{(lamps per luminaire) x (lumens per lamp) x COU x MF}}$$

- Decide on the layout considering spacing uniformity, aesthetics, etc and re-calculate the achieved lux for the proposed layout to ensure it gives the desired lux level using the formula

Average lux achieved =

$$\frac{\text{(lumens per lamp) x (lamps per luminaire) x (number of luminaires) x COU x MF}}{\text{workplane area}}$$

For outdoor areas, it is necessary to ensure that light fittings are made to withstand the weather conditions and corrosion factors that prevail in the area.

Conclusion

There is no doubt that if you follow this process you will get the best lighting solution for your application.

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