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DESIGN OF ENERGY-EFFICIENT BUILDINGS AND BENEFITS OF ENHANCING RELIANCE ON NATURAL LIGHTING THROUGH MAXIMIZING THE EXTERNAL REFLECTED COMPONENT

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ملخص البحث

يركز البحث على الفوائد العملية و الصحية للمستخدم نتيجة الإعتماد على الإضاءة الطبيعية داخل تصميم المساحات الداخلية بالمبانى بإستخدام معامل (ERC). و يقدم البحث عدد من البيانات التخطيطية التى تمكن المصمم من تقدير الإضاءة الطبيعية إعتمادا بشكل رئيسى على معامل الإنعكاس الخارجى و ذلك لجميع الواجهات و عند كل الأدوار.

ABSTRACT

Daylight can be provided via windows and glazed doors, as well as via skylights and other forms of top lighting. These glazed openings are collectively referred to as "fenestration." The placement, design, and selection of materials for fenestration are extremely important and can tip the balance between a high performance and low performance building. Fenestration impacts building energy efficiency by affecting cooling loads, heating loads, and lighting loads. Visual comfort is strongly affected by the window location, shading, and glazing materials. Well-designed windows can be a visual delight. But poorly designed windows can create a major source of glare. Thermal comfort can also be compromised by poor fenestration design. Poorly insulated windows add to a winter chill or summer sweat, while windows with low U-values keep glass surface temperatures closer to the interior air temperature, improving thermal comfort. In addition, east-west windows and unshaded south windows can cause excessive cooling loads. And although windows and skylights provide opportunities for natural ventilation, they must be designed to ensure a safe, secure, and easily maintained facility. The table below specifies the recommended minimum illumination levels. Any shortage in meeting these levels should therefore be supplemented via artificial means.

According to Hofman in his textbook *Handbook of Lighting Design*, the table below (Table 1) provides a summary of the minimum illumination levels measured in lux.

The Lx value indicated for each building use is the required illumination level needed to perform the specific task. The table also provides codes that should later be used by the designer in another table(s) to aid in the final selection of an efficient lighting source.

The above steps should be carried out after completion of the daylighting analysis and design. In order to establish a complete, energy efficient, and sustainable lighting design, the designer must implement an integrated approach for the entire facility. This dictates consideration of both Natural and Artificial design elements withing the Egyptian building code of lighting.

2. BUILDING PERFORMANCE

A high performance, cost-effective, comfortably daylighted building requires the design team to practice integration as per the following points**:**

- Adopt a holistic design approach, where the building is viewed as a whole and not just a collection of parts. Common practice often fails to address the critical interactions between the building façade (which admits heat and light) and the electric lighting system, resulting in an uncomfortable and inefficient building that is expensive and difficult to maintain.

- Share appropriate decisions across disciplines.
- Regularly evaluate decisions for any building wide ramifications.

Table 1 - Guide values for illuminance E for various areas of activity in accordance international standards

Space/ activity	Recomr min. illu E (lx)	Natural + Artificial
Office	300	T, TC
Team office	500	T
Open plan office	750	T, TC
Technical drawing office	750	T, TC
Data processing	500	T, TC
CAD	200/500	A, QT, T, TC
Control room	200	TC
Corridor	50	TC
Staircase	100	T, TC
Canteen	200	A, QT, QT-LV, TC
Bathroom, WC	100	T, TC
Sales area	300	QT, QT-LV, T, TC, HST, HSE, HIT
Department store	300	QT, QT-LV, T, TC, HST, HSE, HIT
Cashdesk	500	T, TC
Supermarket	500	T, HIT
Reception	200	A, QT, QT-LV, TC
Restaurant	200	A, PAR, R, QT, QT-LV, TC
Café, bistro	200	A, PAR, R, QT, QT-LV, TC
Self-service restaurant	300	T, TC
Canteen kitchen	500	T
Museum, gallery	200	A, PAR, R, QT, QT-LV, T, TC
Exhibition space	300	PAR, R, QT, QT-LV, T, TC, HST, HSE, HIT
Trade fair hall	300	T, HME, HIT
Library, media library	300	T, TC
Reading room	500	T, TC
Gymnasium, competition	400	T, HME, HIE, HIT
Gymnasium, training	200	T, HME, HIE, HIT
Laboratory	500	T
Beauty salon	750	QT, QT-LV, T, TC
Hairdressing salon	500	T, TC
Hospital, ward – ambient lighting	100	T, TC
– reading light	200	A, QT-LV, T, TC
– examination light	300	QT, T, TC
Hospital, examination	500	T
Reception, lobby	100	QT, T, TC
Circulation area	200	QT, T, TC
Classroom	300/500	T, TC
Large classoom	750	T, TC
College hall	500	T, TC
Art studio	500	T, TC
Laboratory	500	T, TC
Lecture hall, auditorium	500	QT, T, TC
Multi-purpose space	300	QT, T, TC
Concert, theatre, festival hall	300	A, PAR, R, QT
Concert platform	750	PAR, R, QT
Meeting room	300	A, QT, TC

3. OCCUPANT PERFORMANCE

Studies indicate that well-designed daylighting is associated with enhanced student performance, evidenced by 13% to 26% higher scores on standardized tests, while poor daylighting design has been shown to correlate with reduced student performance. The study confirms that it makes sense that students and teachers perform better in stimulating, well-lit environments. It provides evidence that Daylighting can provide high quality light, stimulating views, and an important communication link between the classroom and adjacent spaces.

Fig. 1 - Gentle, diffuse daylight permeates a classroom with both sidelight and toplight. Note that all surfaces are painted white to distribute light more efficiently and reduce contrast glare

4. ENERGY SAVINGS

Daylighting can save energy and reduce peak electricity demand if electric lights are turned off or dimmed when daylight is abundant. According to a study conducted in the United States, K-12 schools spend more than $6 billion a year on energy[1].

Daylighting, however, saves no energy unless the electric lighting system is appropriately controlled. To be effective, daylighting must be thoughtfully designed, avoiding glare and overheating, and must include dimming or switching of the electric lighting system, preferably with automatic photocell control.

Daylighting is the use of light from the sun and sky to complement or replace electric light. Appropriate fenestration and lighting controls are used to modulate daylight admittance and to reduce electric lighting, while meeting the occupants' lighting quality and quantity requirements. Daylighting is a beneficial design strategy for several reasons,

Until recent years most workspaces were lit by tungsten or fluorescent lamps, with high-pressure discharge lamps sometimes being used for sports-related and industrial buildings that require additional lighting. But newer compact metal halide and high-pressure sodium lamps with good colour rendering characteristics are now being used in offices and shops, particularly for decorative or display lighting. The development of ‘energy-efficient’ lamps, in addition to the availability of a wider range of luminaire designs, has made possible very significant energy savings in general purpose lighting and has brought extreme lighting effects within reach of relatively modest budgets.

The table below provides examples of some of today’s lighting sources available in the market:

1. Egan, M. David and Olgay, Victor W.; "Architectural Lighting", McGraw-Hill, 2nd edition, 2003

Lamp	Lumens/W	Hours
100W Tungsten	14	1000
20W 38mm Fluorescent	36	9000
18W 26mm Fluorescent	50	9000
20W Compact Fluorescent	60	8000
18W Low Pressure Sodium	66	7000
250W High Pressure Sodium	96	12000
40W LED Bulb	800	10000

Table 2 – Lighting Sources and Corresponding lifespans and energy

The table above provides basic general data of different lamp illumination levels and corresponding life spans. This was an effort which was later analyzed further by Dr. Philips in the following page in order to assess each type of lamp efficiency measured in (Lm/W), in addition to general data such as Rated Average Life, and Colour Temperature (K).

Table 4.1 List of artificial light sources (originally printed in *Lit Environment*, pp. 92)

Lamp	*Type*	*Lamp efficacy (Lm/W)**	*Circuit efficacy (Lm/W)†*	*Rated average life (hr)‡*	*Wattages (W)*	*Colour temp (K)§*	*CIE group¶*	*CRI***
Incandescent	Tungsten Filament	7 to 14	7 to 14	1000	15 to 500	2700	1A	99
	HV Tung. Halogen	16 to 22	16 to 22	2000	25 to 2000	2800 to 3100	1A	99
	LV Tung. Halogen	12 to 27	10 to 25	2000 to 5000	5 to 150	2800 to 3100	1A	99
High Intensity discharge	Low pressure sodium (SOX)	100 to 200	85 to 166	16 000	18 to 180	N/A	N/A	N/A
Fluorescent tubes	Cold cathode	70	60	35 to 50 000	23 to 40 W/m	2800 to 5000	1A 2	55 to 65 85 to 90
	Halophosphate (T8 & T12)	32 to 86	13 to 77	10 000	15 to 125	3000 to 6500	2 to 3	c. 50
	Triphosphor (T5 & T8)	75 to 104	CCG: 48 to 82 ECG: 71 to 104	10 000 20 000	4 to 80	2700 to 6500	1A & 1B	85 to 98
Compact fluorescent twinbased	Triphosphor	40 to 87	CCG: 25 to 63 ECG: 33 to 74	8000 10 000	5 to 80	2700 to 5400	1A/1B 1B	85 to 98
Compact twinbased integral ballast	Triphosphor	30 to 65		15 000	3 to 23	2700	1B	85
Induction (fluorescent)	Triphosphor	65 to 86	60 to 80	60 000 (service life)	55 to 150	2700 to 4000	1B	85
High intensity discharge	High pressure sodium (SON)	75 to 150	60 to 140	28 000	50 to 1000	1900 to 2300	2 & 4	23 to 60
High intensity discharge (not recommended for new installations)	High pressure mercury (MBF)	32 to 60	25 to 56	24 000	50 to 1000	3300 to 4200	2 & 3	31 to 57
High intensity discharge	Metal halide (quartz) (ceramic)	 60 to 120 87 to 95	 44 to 115 71 to 82	 3000 to 15 000 9000 to 12 000	 35 to 2000 20 to 250	 3000 to 6000 3000 to 4200	 1A to 2 1A to 2	 60 to 93 80 to 92

The Lit Environment, Osram Lighting, Updated to June 2003.

*Lamp efficacy indicates how well the lamp converts electrical power into light. It is always expressed in Lumens per Watt (Lm/W).

†Circuit efficacy takes into account the power losses of any control gear used to operate the lamps and is also expressed in Lm/W.

‡Rated average life is the time to which 50% of the lamps in an installation can be expected to have failed. For discharge and fluorescent lamps, the light output declines with burning hours and is generally more economic to group replace lamps before significant numbers of failures occur.

§Colour temperature is a measure of how 'warm' or 'cold' the light source appears. It is always expressed in Kelvin (K), e.g. warm white 3000 K, cool white 4000 K.

¶CIE colour rendering groups: A (excellent); 1B (very good); 2 (fairly good); 3 (satisfactory); 4 (poor).

**CIE colour rendering index: scale 0 to 100 where: 100 (excellent, e.g. natural daylight); 85 (very good, e.g. triphosphor tubes); 50 (fairly good, e.g. halophosphate tubes); 20 (poor, e.g. high pressure sodium lamps).

In the case of reflector lamps, where the light output is directional, luminous performance is generally expressed as *Intensity* – the unit of which is the *Candela (Cd) (1 Candela is an intensity produced by 1 Lumen emitting through unit solid angle, i.e. Steradian).*

Table 3 - List of Artificial Light Sources

In order to realize considerable cost/energy savings, the designer must carefully select a combination of artificial lighting sources from the list above, to cover the deficit from natural lighting. One of the problems has been in the 'cheap energy policy' of Governments; there may be other good reasons for this, but it has led in the past to excessive use of cheap energy, and it is only recently, with a looming energy crisis, that governments have woken up to the vital need for savings to be made. The first line of defence must be in avoidance of waste; particularly a situation when a building with every light burning in the middle of the day when daylight is quite adequate, or after dark when the building is largely unoccupied.

Dr. Philips argues that the total amount of energy wasted on a daily basis may not have been calculated, but it is considerable and equals the amount of savings which can be made in other ways (2). He provided the example of a transport building where artificial light is used all day irrespective of the level of daylight. There is no doubt a need for the level of daylight never to drop below the statutory design level, but this can be solved by adopting a system of control which links artificial light to the available daylight to ensure that the design level is maintained, whilst allowing significant reductions in the use of artificial light, which can be off for most of the day.

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