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THE EFFECT OF DAY LIGTHING ON REDUCING ENERGY CONSUMPTION IN BUILDINGS

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الملخص العربى:

الإضاءة الطبيعية احد الوسائل لتوفير الطاقة. كذلك الاضاءة الطبيعية تساعد على اسعاد الناس, و تؤثر على الإنتاجية, و لها فوائد إيجابية على صحة الإنسان, و تحسن الأداء الأكاديمى.

أوضح البحث مبادئ الأساسية لتصميم الإضاءة الطبيعية و العناصر الأساسية لتحقيق ذلك مثال شكل و توجيه المبانى, و تصميم النوافذ, و إختيار نوع الزجاج. الألوان المستخدمة, و تأثير الإضاءة الطبيعية على التخطيط المدنى. بالإضافة إلى ذلك أوضح البحث تأثير الإضاءة الطبيعية على تخفيض الطاقة المستهلكة فى المبانى.

و قد خلص البحث أن الطاقة المستخدمة فى المبانى تنخفض باستخدام الإضاءة الطبيعية بناءا على عدة عوامل مثال النسبة بين الحائط و النافذة, و اتجاه واجهة المبنى, نافذية الضوء المرئى, و إرتفاع حافة النافذة.

الكلمات المفتاحية: الضوء الطبيعى, تصميم الإضاءة الطبيعية, توفير الطاقة, فوائد الإضاءة الطبيعية

ABSTRACT:

Day lighting is one of the ways of saving energy. Also, day lighting makes the people feel happier**,** has an impact on the productivity, has positive benefits to human health and improves the academic performance**.**

The research showed the principles of designing day lighting and the main elements to achieve this such as Orientation and shape of the buildings, design of windows, choosing glazing types, the color and effect of day lighting on civic planning**.** Also, the research showed the effect of day lighting on reducing energy consumption in buildings. The research resulted that electrical consumption in building is reduced by using day lighting due to several factors such as the window to wall ratio, building facade orientation, glazing types, visible light transmittance and the window edge height.

KEYWORDS: Natural light, Day lighting design, Energy saving, Day lighting benefits

INTRODUCTION

Day lighting reduces the impact of the built environment, and it has a significant health and wellness benefits. Its purpose is to meet the requirements for good vision and healthy environment by providing good illumination. Lighting is important for human physiological because man is used to live in an environment of natural lighting.

The goal of day lighting is to collect enough daylight in the summer to turn off electric lights and collect as much as possible in the winter to help heat the building. The overall objective of day lighting is to minimize the amount of artificial light and reduce electricity costs, and lower HVAC costs

Designing for day lighting has to be considered at the initial stages of building design, and day lighting design should be applied to building design from the start and solutions should be part of the main concept, in order to meet visual, thermal and energy needs.

THE PROBLEM OF THE RESAERCH

Artificial light sources play a significant role to daily life of any human being. Electrical light sources are responsible for an energy consumption of around 1/6 to 1/5 of the worldwide electricity production [3]. Moreover, artificial lighting makes about 19% of electrical consumption worldwide and 5% of worldwide greenhouse gas emissions [4] However, not enough effort to maximize the use of natural light in building designs.

RESEARCH IMPORTANCE

Nowadays, there is wide concern of environmental pollution, rising of heat temperature and increasing of electrical energy consumption, therefore designing and planning to utilize the day lighting in buildings became a very important aim.

One of the important strategies to improve energy efficient is to reduce the use of artificial lighting. These strategies can reduce electrical consumption in buildings, improve quality of light and create comfortable and healthy internal environment.

The objective of this research is to emphasis the significant impact of day lighting design on reducing energy consumption in buildings.

METHODOLOGY

.the research followed different methods to achieve its objective:

- The theoretical part to elucidate the principles of designing day lighting and the main elements for achieving the best performance of day lighting.
- The analytical part to elucidate the effect of day lighting on reducing energy consumption in buildings.

DISCUSSION

1- DAY LIGHTING DEFENATION

Day lighting is the illumination of indoor spaces by natural light, it can be also the illumination of buildings by natural light [9].

Day lighting is the controlled admission of natural light, direct sunlight, and diffused-skylight into a building to reduce electric lighting and saving energy [6].

Day lighting is the practice of placing windows, skylights, other openings, and reflective surfaces so that sunlight (direct or indirect) can provide effective internal lighting. The source of all daylight is the Sun [10].

Daylight is the combination of direct sunlight and diffuse sky light, and it is the light source that most closely matches human visual response. That offers two advantages: a more comfortable view and a lower level of light required [13].

2- BENEFITS OF DAY LIGHTING

The main objective of day lighting is to reduce electricity HVAC costs. Day lighting is one of the ways of saving energy. Use of natural light can save up to 75 % of the energy used for lighting the buildings [4].The energy saved by using day lighting strategies can reduce building cooling energy usage by 10% to 20%. Consequently, total energy costs can be reduced by about one-third by using day lighting strategies [6].

Electrical lighting produces a lot of heat while day lighting generates very little heat, and the use of day lighting reduces greenhouse gases and slows fossil fuel depletion by reducing the need for electric consumption for lighting [7].

The benefits of day lighting also extend beyond energy savings as people need day lighting [15]. Researches had found that day lighting makes the people feel happier, more energetic, and more creative, better problem-solvers, and interact with others more effectively. Exposure to natural daylight can help facilitate these impacts [16].

Also day lighting increases worker productivity and decreases absence in day lighting commercial office buildings [15]. Researches showed that workers productivity can be increased by up to 20% when day lighting is used in offices [16].

Day lighting has positive benefits to human health, starting from better sleep to greater alertness, and a range of positive mood impacts. Exposure to natural light increases vitamin D and melatonin levels, and reduces heart disease risk. In addition, workers in offices with natural daylight suffer less eyestrain, headaches, and drowsiness than those who work on artificial light [16]. Also in day lighting hospital patients were found to require less pain medication and their recovery was accelerated and their stay were shortened in hospital patient rooms [15].

Moreover, day lighting is connected to improving to the academic performance among young people and the high test scores in day lighting classrooms [15]**.** This is consequently gave attention on schools design. A 2015 study published in the UK showed the importance of school design of different physical characteristics of classrooms as16% of variation in learning progress occurred over one year among 3,500 students. The research showed that light was the most important factor. Another study was done by the US-based Eneref Institute made the connection between exposure to natural light and the human brain. The study showed that daylight is linked with reduced melatonin production, which in turn improves cognition, with this facilitating improvement on learning-related tasks [16].

3- PRINCIPLES OF DESIGNING DAY LIGHTING

Day lighting can be gained efficiently inside buildings by designing strategies inside in order to reduce the use of electrical energy to achieve the maximum thermal, health and optical comfort as shown in figure no. (1) [1]

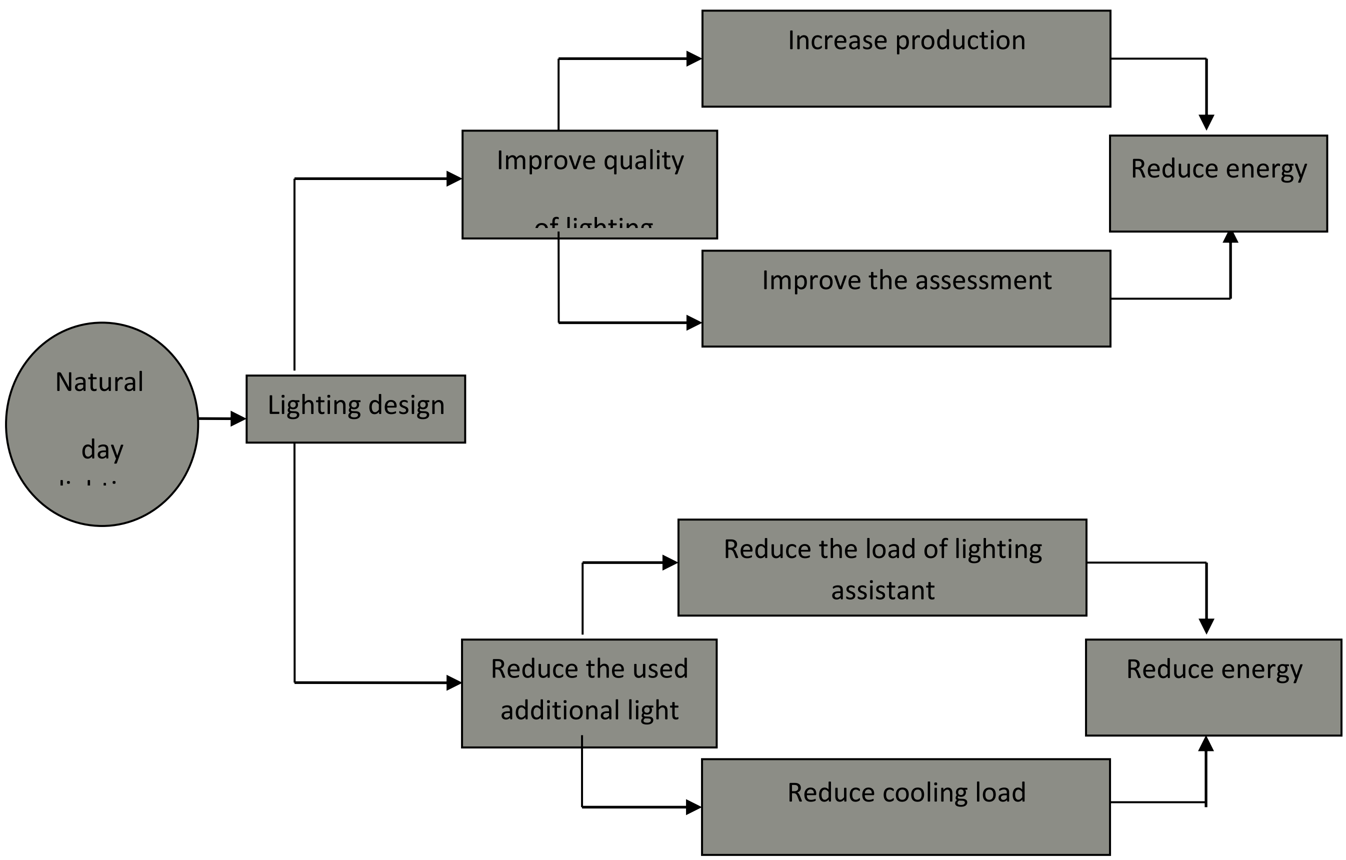

Figure no. (1): Results of strategy of day lighting design

It is important in order to recognize the levels of lighting and the required lighting is to know the light power density (LPD) for every point of the building. Good designing is to reduce about 25% of light power density (LPD) by make the sun light to be the essential and then is completed by artificial light in order to reduce electric consumption by about 50% or more. The schedule no. (1) shows the value of density of light for different spaces which the scale and light power density (LPD) is the scale of the quantity of electrical lighting which is the unit of light by (Watt) that lighten one meter square [1].

Schedule no. (1): Light density for varies spaced

Type of building	**Description of space**	**Maximum of (LPD) (watt/m2)**
offices	Corridors of the first three floors	7.5
	Corridors of the rest of floors	2.2
	Waiting rooms and reception	10.8
	Waiting areas	18.3
	Conference halls	19.4
	Entrances	8.6
	Mechanical & electrical rooms	16.2
	Reading rooms/ secretary/ communication rooms	19.4
	Rest areas	8.7
	Permanent staircase/ temporary staircase	4.3 / 6.5
Gathering places	Hearing hall	17.2
	Conference center/ educational hall	28.0
	Lecture hall/ class rooms	21.5
	Waiting hall/ beauty centers	4.3
Hospital	Emergency	24.7
	Laboratory	20.4
	Nursing rooms	22.6
	Patient rooms	15.1
	Operation rooms	75.3
Hotels	Multipurpose rooms	25.8
	reception	20.4
	Guest rooms	15.1
Stores	Storing areas	7.5
Library	Filing lockers	17.2
	Hearing library	11.8
	Reading area	20.4
	Storing area	16.2
	Maximum use area	32.3
Restaurant	Cafeteria	14.0
	Kitchen	15.1
	Sitting hall	26.9

The function of the space is what decides the possibility of varying the lighting all the day long. This helps in recognizing the suitable designing methods in designing day lighting as shown in schedule no. (2) [1].

Schedule no. (2): the suitable day lighting for buildings

Function of space	Lighting level	Acceptable variations	Comfortable day lighting
Hospitals/ health center	high	medium	high
Computer hall/ offices	medium	medium	medium
Corridors/ dining hall/ cafeteria	low	high	medium
stores	high	high	high

The day lighting has several factors must be merged in the beginning steps of designing the buildings. Achieving the following relations shows the influence of day lighting in the buildings [1]:

- The orientation, the area, the location of the building, the shape of the building and the size of the openings.
- The location and the characteristics of the internal surfaces that reflect the light and effect the light distribution.
- The location of the openings that is provided with shading means to reduce the glare.

3-1-Orientation and shape of the buildings

Studying the location and the orientation of the building is one of the most important steps of designing to achieve the maximum benefits from day lighting, reduce the lighting glare and provide thermal and optical comfort. Designing location of the openings and the means of shading depends on the studying the location and the climate, consequently the building orientation according to the path of the sun [1].

3-1-1- Orientation of the buildings

The direction of the widows in the building affects the amount of ventilation and light entering the space, as well as the amount of exposure to the sun which will affect the amount of energy consumed [12].

Light direction is important. Light that comes from the south is the best for day lighting as sunlight is consistent throughout the day and year, and it can also be used for solar heat gain. Light that comes from the north is the next best, as the sunlight is as consistent as the south, but in a lower quantity. Light that comes from the east and west should be avoided if possible because sunlight at these orientations is harsh, and only occurs during half the day, and the height of the sun changes throughout the year [5]. North-facing windows provide an even amount of light that doesn't provide glare, while south-facing windows provide a great deal of heat during the winter and limit that same amount during the summer. South-facing windows allow most winter sunlight to enter into the room, but little direct sun during the summer, especially when they are shaded. East- and west-facing windows provide good day lighting in the morning and evening, but may cause glare, admit a lot of heat during the summer when, and contribute little to solar heating during the winter [2]. Accordingly, It is best to place windows facing north and south, instead of facing east or west, and the rooms that require the most daylight to be faced north or south, while rooms that require less daylight to be faced east or west [5].

Accordingly, the southern façade is the best façade for designing the day lighting, as the changing in the lighting levels is in the acceptable rates which allows to the maximum rate of the day lighting and it is the best in controlling the sun gain in summer. Although the northern façade is less exposed to the natural sun light it can be provided by using upper roof lighting. This is better in the big buildings where the northern façade is the main façade to provide good day lighting and consequently reduces using electrical light. Also, it is difficult to provide day lighting for the western and eastern facades because the sun angle is low, exposing to the sun is at a part of the day and changing in the sun light is high. Moreover, the western façade suffers from high thermal gain in summer and light glare because of the low sun angles in the non-preferable times, and it gains negative sun light in winter [1].

3-1-2- Shape of the buildings

The best shape of buildings to achieve the maximum light of exposing to sun light is the rectangular shape because it is better than the square shape for day lighting because even that the square building has low thermal load, the internal day lighting is not available in a good way, also there is no balance between external and internal loads which requires complicated heating and cooling systems. U-shape is preferable in order to reduce the area of the used land but in the same it is better to increase the distance between the two wings of the U-shape to avoid shading on each other and to allow entering the natural light as shown in figure no. (2) [1].

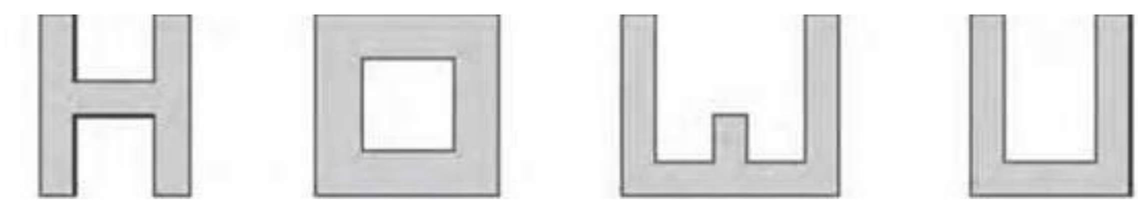

Figure no. (2): Examples of buildings shapes with high day lighting access

In multi stories buildings benefits more from the rectangular shape because the working areas can be located until 10 meters deep as shown in figure no. (3) that show the ability of using a shape of the building to achieve good lighting. For example, by taking a room its ceiling height is 3 meters and the depth of the room is 1.5 times of the height of the main window that provides the room with balanced distribution of day lighting, it was found that 51% of the room area has complete lighting, 33% of the room area has partial lighting and 16% of room area has no light. So, if the lighted area of the room floor is about 4.5 m2, starting from the window, the width of the façade is 12 meters to allow the room to be benefited sun light [1].

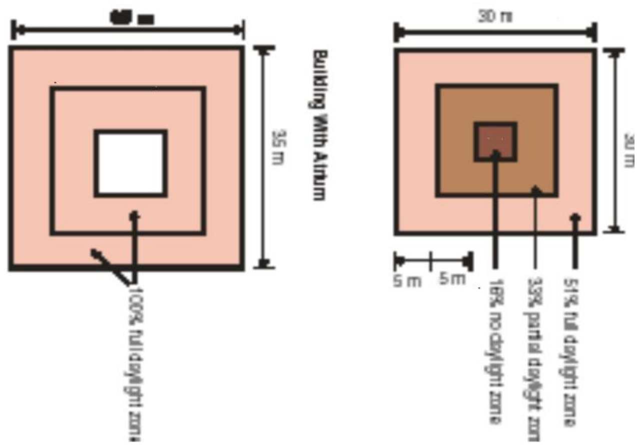

Figure no. (3): the ability of using a shape of the building to achieve good lighting

3-2- Design of windows

It is important to determine the optical range of day lighting to choose the ratio between the area of window and the volume of the room in order to provide enough day lighting to the perimeter of the building. For calculating the required window to wall ratio (WWR), the following percentages are assumed [1]:

- Ceiling reflection factor is 70%.
- Floor reflection factor is 30%.
- Height of the room is 3 meters
- Medium factor of sunlight is 3% because this percentage is more suitable for public lighting.

The best distribution of lighting can be achieved in the areas that have two windows on two different walls which mean it has double lighting. This will improve the distribution of lighting and reduce the glare, also the window will lighten the adjacent walls which results in reducing the contrast between the window and the opposite wall. Also, it is better to use linear windows for day lighting instead of single widows because it provide the room with better enough light, but glare must be controlled [1].

To increase the widow height, a sloping smooth with light color ceiling to the back of the room can be used over the window as shown in figure no. (4) to make the light homogeneous, direct it to the ceiling then to the depth of the room and to improve reflectance [7].

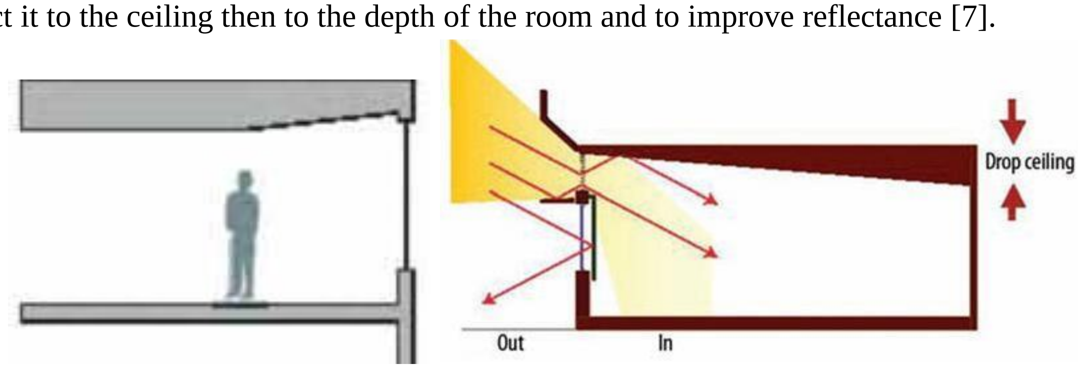

Figure no. (4): Sloping ceiling to increase the day lighting

The day lighting covers 1.5 times of the window height, this percentage can be increased by using light shelves under the widow lintel which helps in entering the natural light to the of the room because light shelves can be used for multistory buildings as they can enter sunlight deep into rooms through high glazing areas on the south side of buildings as shown in figure no. (5) [7].

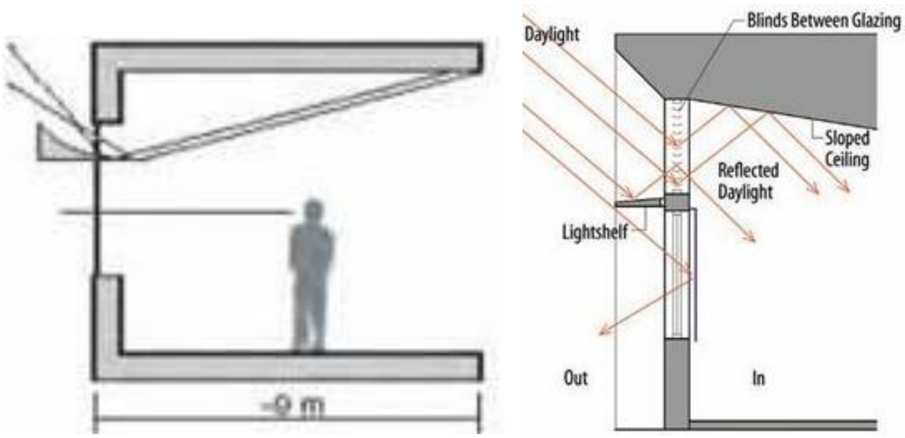

Figure no. (5): Lighting distribution by light shelves

If the light shelves are located in a correct way reflects day lighting deep into the space, shades the lower view window and improve the distribution of day lighting in the room by reducing the glare and distributing the light in good way which shows that the light shelves can be used to provide ideal day lighting all over the year, especially if they have bright colors [1]. An interior light shelf usually cannot stop direct sun light from entering the top section of glazing when the sun has a low altitude, so an extended interior light shelf is used, but this requires a deep shelf. The performance of the light shelves can be increased by using a sloped ceiling above the light shelf downward to the back of the space as shown in figure no. (6) [7].

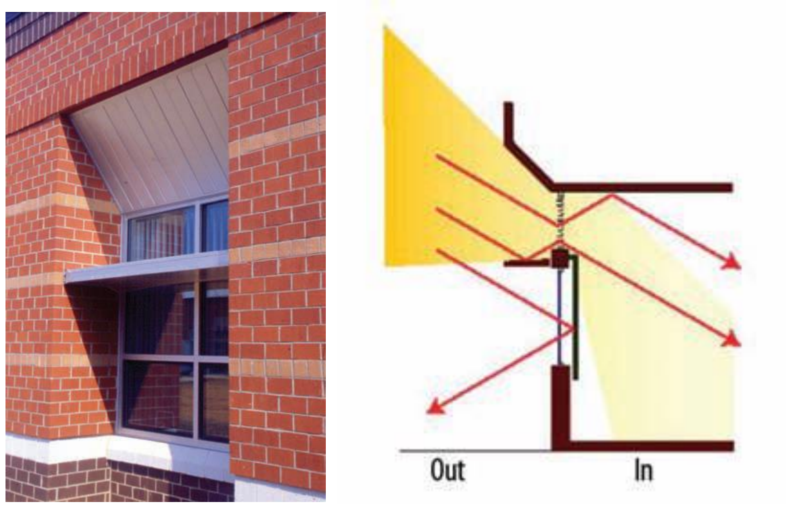

Figure no. (6): A sloped ceiling above the light shelf

3-2-1- Lighting the center of the building

The roof monitors and skylights allow daylight to enter from above, as they useful in spaces at the center of the building where light from windows can't reach [5]. They can be used to achieve the maximum limit of sun light and to provide the whole internal areas with natural sun light increase the day lighting in the deeper rooms inside the areas which are far from the building façade and require better lighting. Roof monitors receive a lot of direct natural light especially in summer and there are many types of roof monitors to collect light as shown in figure no. (7) [1].

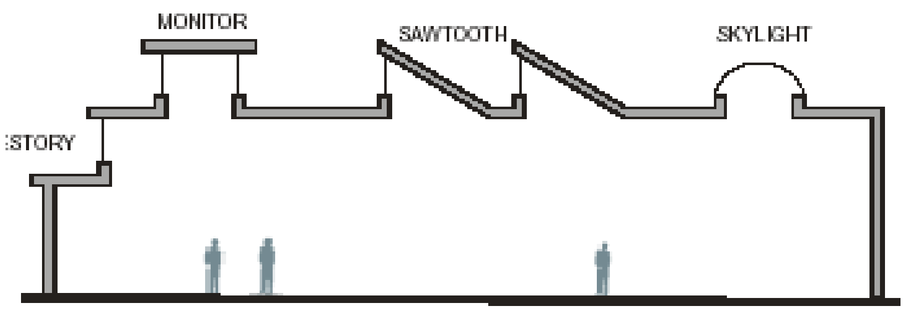

Figure no. (7): types of roof monitors

Roof monitors can be vertical or inclined towards south or north direction. South-Facing Roof Monitors can provide uniform lighting with less contrast by using with it light-color ceiling to reflect sunlight into the glazing [7]. Roof monitors that is inclined towards south must be located above latitude 23.5 will collect more sunlight in winter and has to be inclined with an angle to the direction of the maximum angle of the sun height to increase sunlight without glare and must have means of shading from direct sun light, while north-facing monitors, require at least 25% more glazing than south-facing monitors to achieve the same amount of day lighting [7]. Roof monitors that is inclined towards north that is located above latitude 23.5 receive less level of lighting but the light enters the room constantly with little glare [1].

The area and dimensions of roof monitors can be calculated according to the ceiling height, as distance between the roof monitors must be equal to the ceiling height measured from the floor, also the location of the roof monitors depends on the existence of side windows as they can be moved to the inside as shown in figure no. (8) if there are side widows. The volume of the space determines the number of roof monitors [1].

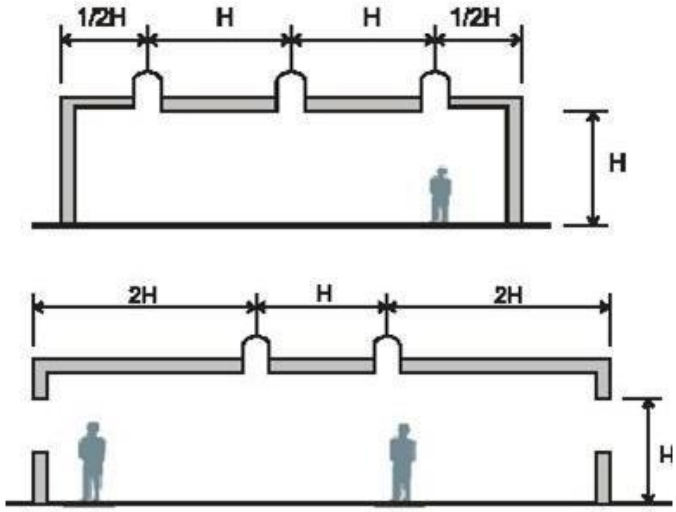

Figure no. (8): Location of roof monitors

3-3- Choosing glazing types

The types of glazing play a significant role in controlling the transmitted day lighting into space. Choosing glazing characteristics aims to reduce energy consumption and to achieve the maximum limit of light by using special types of glazing have characteristics of reducing thermal radiation transfer and increase the reflectivity to prevent the undesirable heat and at the same time to keep a clear vision range for the windows that is difficult to be shaded [1].

The first step of choosing the glazing type is to know the glass characteristics [6]:

- U-value: represents the rate of heat transfer due to temperature difference through a particular glazing material.
- Shading coefficient: a ratio of solar heat gain of a given glazing assembly compared to double-strength, single glazing.
- Visible transmittance: a measure of how much visible light is transmitted through a given glazing material

Accordingly windows with low U-value are used to reduce the thermal load of the building and low U-value factor will reduce the thermal load so will reduce or illuminate the need of cooling the building. To get U-value less than 1.5 watt / m2 require designing treated widow in order to achieve a window with high performance. This means that the window has to be painted with reducing thermal paint, double glazing has to be used, non-metal material frames are used with high performance such as fiber glass frames or any multi layer glazing has to be used [1]. Also, the type of glazing with a high visible transmittance value allows a high amount of light to be admitted into space, which will decrease the usage of electric lighting. Consequently, will result low lighting energy consumption [14].

3-4- Effect of the Color on day lighting

The Color affects the visual adaptation in the room; the sky may be very glaring if the rooms have dark color, but by painting the walls with light color, the glare will be reduced. Moreover, light reflective paint helps light to make the space brighter [5].

Also, the light affects the internal color design. Usually, north walls have much color, while the south walls may be almost colorless. A high tinted ceiling tempers any glare and distributes an opalescent bloom on the walls even if the walls are white [8].

Also, it is better to choose the light colors for the external surfaces because most of the sun light is reflected to the inside by the light colors more than the dark colors. The surfaces with light colors will reduce cooling loads [1].

Maximum contrast between the window and the wall is when the color of the adjacent walls is brighter than the window, this cause glare. So, the window has to be deeper inside the external wall with chamfering its edges as shown in figure no. (9) [1].

Figure no. (9): Chamfering window edges

3-5- Effect of day lighting on civic planning

Planning for daylight needs to take consideration of the effects of neighboring obstructions. There are areas that light and air are being shut off and the streets are becoming entirely inadequate. The standards of day lighting on the lower floors of buildings in urban area are governed by building codes which limit the heights of buildings, angles of setback, etc….

It is important to limit the loss of the light caused by high buildings on the opposite buildings on the other side of the street, and compensate light from a low altitude sun to allow it enter to the opposite buildings, the distance to which the light would go inside the building depends on the height and width of the window openings [8].

4- THE EFFECT OF DAY LIGHTING ON ENERGY CONSUMPTION

Day lighting strategies promote the quantity and distribution of day light by collecting natural light and reflecting it into the darker areas of the building by using elements such as windows, skylights, clear doors, light shelves and other reflective surfaces to collect and direct and reflect light throughout the building

.

4-1- Window orientation

A study was done to show the effect of window orientation on total energy consumption the, and it resulted that the minimum total energy consumption is when the building is oriented to the southwest and north, and the maximum total energy consumption is when the building is facing south, followed by of building which facing. When building is facing the southwest, lighting energy consumption is the lowest; when the building is facing the south, the heating energy consumption is the lowest; when the building is facing the north, the cooling energy consumption is also the lowest as shown in figure no.(10) [11].

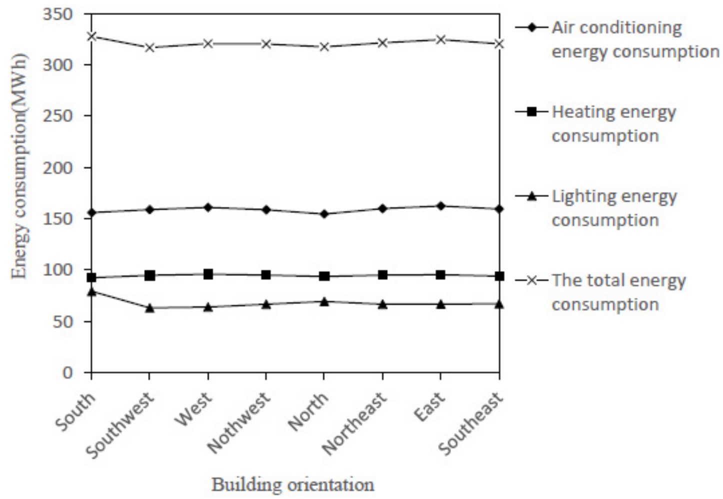

Figure no. (10): The effect of building orientation on total energy consumption

Another study was done in The Energy Center of Wisconsin that aimed to prove that, the results of the study showed lighting savings of 32 % and cooling savings of 25 % by using natural light. The end result was 22 % total savings [2].

4-2- Window to wall ratio

The window to wall ratio (WWR) plays a significant role in transmitting daylight into space, as increasing in window to wall ratio (WWR) for the external wall of the building will result in reducing the dependence on artificial lighting, as by studying the relationship between window to wall ratio (WWR) and the amount of energy consumed, it is found that 30% to 40% window to wall ratio that result in reduced energy consumption and provide enough day lighting. [12].

A study showed the effect of window to wall ratio (WWR) on the lighting energy consumption is determined when it is compared with using illumination system all day, the energy consumption is reduced, and by increasing of window to wall ratio, lighting energy consumption is reduced, and when the window to wall ratio (WWR) is 40%, the total energy consumption is the lowest as shown oh figure no. (11) [11].

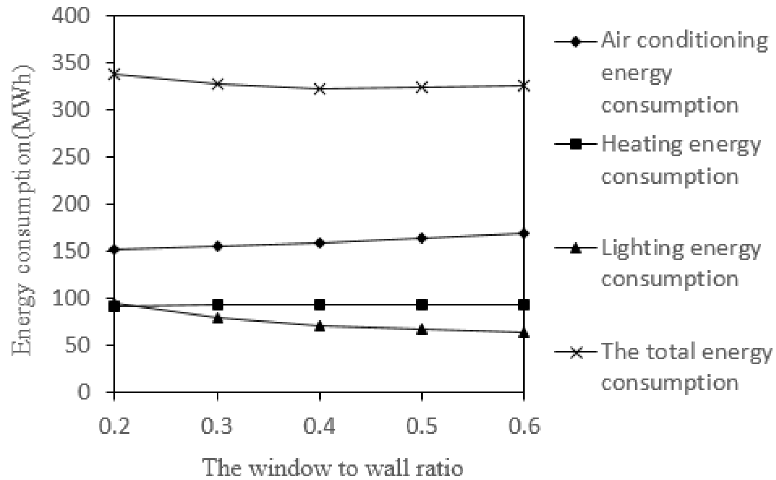

Figure no.(11):The effect of window to wall ratio on total energy consumption

In another study it was found that all the favorite windows are the large ones with 40% of window to wall ratio as it was satisfying 85% of the people, and the small widows with.10% of window to wall ratio is extremely unsatisfactory [13].

The position of the window in the external wall of the building affects the amount of lighting, according to its direction, proportion and dimensions. Studies measured the effect of the different positions of the widow on the amount of natural lighting inside the room showed that the windows, whose center are placed on the vertical wall axis with window to wall ratio of 10-20%, resulted in almost the same amount of natural lighting in the room, while windows, whose center are placed on the wall's horizontal axis, produced more consistent lighting and more efficient than other window positions, especially with the increase of the window ratio. Some studies show that when the opening in the wall has a window to wall ratio of about 20%, the effect of the opening becomes more clear [12].

4-3-Visible light transmittance

Visible Transmittance is the amount of light in the visible range of the solar spectrum that passes through a glazing material. Visible transmittance is influenced by the glazing type, the number of panes and coatings [13] and it has greater impact on total energy consumption than other factors, epically on the lighting energy consumption [11].

Visible light transmittance has a significant influence on energy consumption of lighting. The change of lighting energy consumption affects the cooling and heating load and energy consumption. The higher the visible light transmittance is, the more the visible light comes into the room, and lower the lighting energy consumption is. A high visible transmittance means that there is more day lighting in the area with reduced electric lighting and its associated cooling loads [13].

A study showed that when the visible light transmittance increases by 1.0, energy consumption of cooling is reduced, and energy consumption of lighting is reduced, and the total energy consumption is reduced by. And when the visible light transmittance is decreased to 0.2, energy consumption of cooling is increased, energy consumption of heating is reduced, energy consumption of lighting is increased, and the total energy consumption is increased. This means that visible light transmittance has greater impact on total energy consumption as shown on figure no. (12) [11].

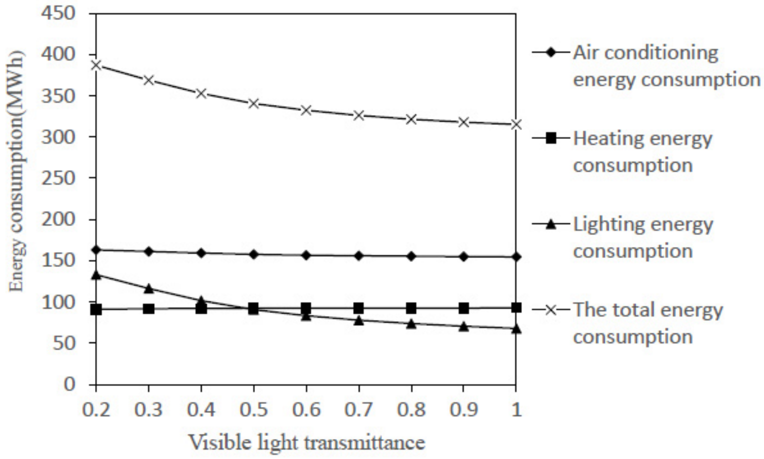

Figure no. (12): The effect of visible light transmittance on total energy consumption

Visible Transmittance plays a role in the choice of glazing systems that maximize the visual and the thermal comfort. For example, Low-emissive (low-E) glasses select specific areas of the solar spectrum, so the desirable wavelengths of energy are transmitted and the rest are reflected. A glazing material can optimize the energy transmission to solar heating and day lighting by modifying the solar reflectance of low-E coatings to include specific parts of the visible and infrared spectrum [13].

4-4- Heights of the window and window sill

Windows play a significant role as they largely influence the energy load, as windows have a significant impact on the energy consumption The height of the window affects the position of visible light into the room, so it affects the energy consumption of lighting. The illumination intensity of the internal room that is located away from the window increases with the increase of the window height [11].

A study was done to show the effect of window height on total energy consumption, and it resulted that when the height of the window is reduced from 2.1m to 1.4 m, the energy consumption of cooling is increased, heating energy consumption is increased, lighting energy consumption is increased, and the total energy consumption is increased. So the height of the window has a great effect on lighting energy consumption as shown on figure no. (13) [11].

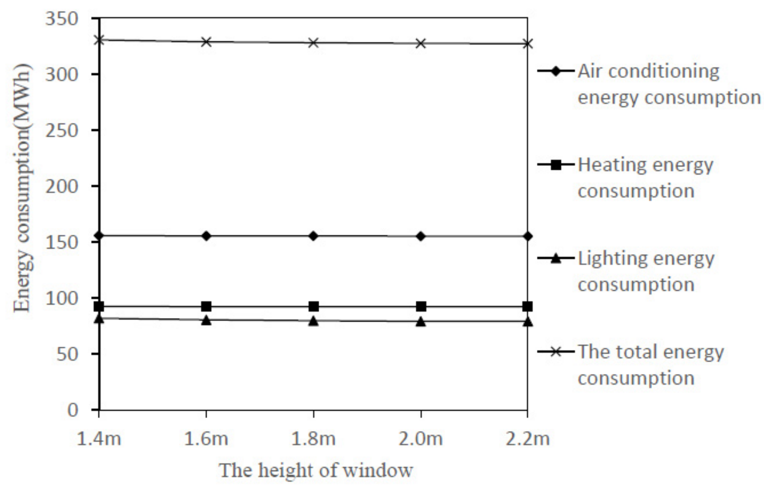

Figure no.(13): The effect of window height on total energy consumption

Also the window sill height has an impact on lighting energy consumption. A study was done to show the effect of height of window still on total energy consumption, and it resulted that when the height of the window sill is increased from 1.0 m to 1.2 m, lighting energy consumption is reduced, cooling energy consumption also is reduced, but heating energy consumption increased, and total energy consumption is reduced. And when the height of the window is reduced from 1.o m to 0.4 m, lighting energy consumption is increased; cooling energy consumption is increased, heating energy consumption is reduced, and total energy consumption is increased as shown on figure no. (14) [11].

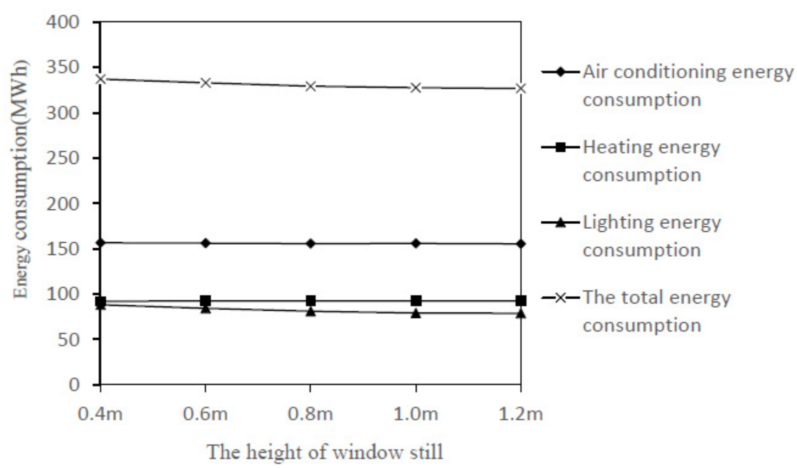

Figure no. (14): The effect of height of window still on total energy consumption.

Another study has done to show the effect of height of window still on total energy consumption, when the height of window edge keep certain. The study was done when the sill height along with window height was kept on 3.3m, case (a) sill height is1.2m and window height is 2.1m, case (b), sill height is 0.8m and window height is 2.5m, and case (c), sill height is 0.4m and window height is 2.9m. The results showed that the energy performance for different combination of window height and window sill is that the three total annual energy consumptions have little difference; but case (a) is the lowest, this means that when the height of window edge and the window area were kept constant, the lower the total annual energy consumption occurs when the sill is higher. So increasing the sill height has larger effect on reduction of total energy consumption than increasing window height as sown in figure no. (15) [11].

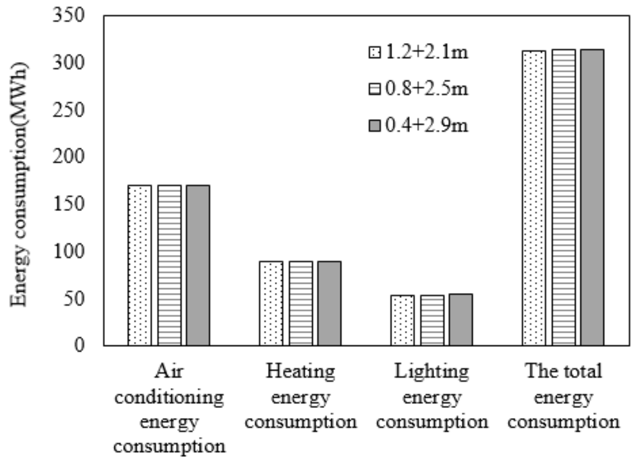

Figure no. (15): The window edge height impact on the total energy consumption.

Accordingly a window on the higher part of the wall is better than one on the lower part of it, and this because the daylight penetration is more effective if the glazing surface covers the upper part of the wall. The reason is that the upper part of the sky is brighter therefore; the windows facing it spread a brighter light in the room [13].

4-5- glazing type

The selection of the glazing type and the size of the windows are important during the building design process as it directly effects the energy consumption of a building [14].

A study was done to show the impact of various types of glazing with different window to wall ratio (WWR) on the energy consumption when artificial lighting is integrated with daylight, this when the area of the window was increased up to 5%, and with larger window to wall ratio (WWR) up to 40%. The results showed that there is a significant reduction in lighting energy consumption for all types of glazing and all possible window to wall ratio (WWR) when artificial lighting and daylight were integrated, which was found that about 40% to 54% reduction in energy consumed almost for all window to wall ratio (WWR) and glazing types, also the results showed that the energy consumed for lighting is reduced for all types of glazing when the area of the window is increased. This is due to the increase of the amount of daylight transmitted into space as shown in figure no. (17) [14].

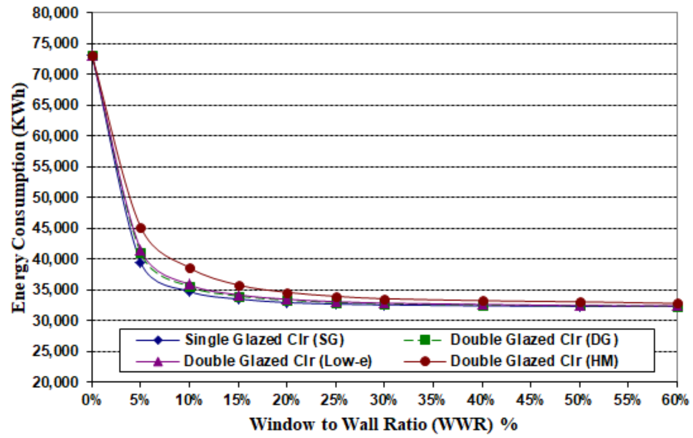

Figure no. (17): Lighting energy consumption for glazing types and window to wall ratio

Another study showed that the main factor that determines the energy performance of a window is the glazing type along with the value of shading coefficient. The results showed that the lower amount of total energy used was when a type of glazing with low shading coefficient value is used. The total energy consumption for all types of glazing is reduced as a result of using natural lighting. The results also showed that the total energy consumption is lower in the north zone compared to the south, west, and east orientations as it is found that the variation in the total energy consumption is not much with the change of glazing type in the north zone and is clear in other orientations as shown in figure no.(18) [14].

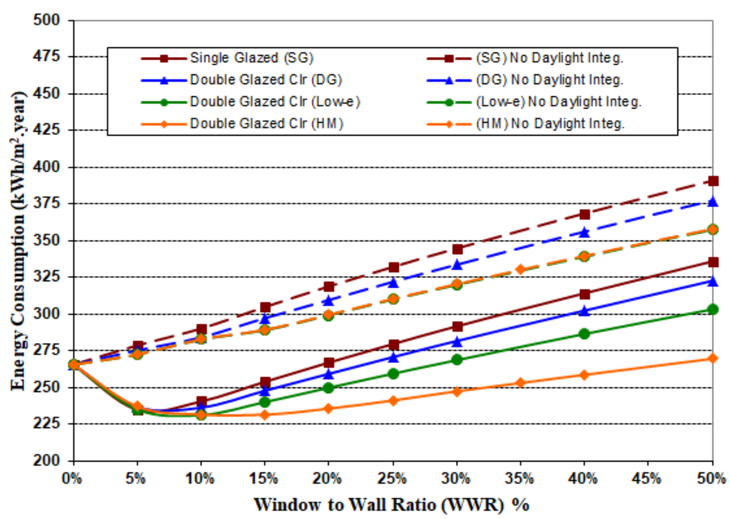

Figure no. (18): Lighting energy consumption for various glazing types

CONCLUSION

Day lighting represents the use of natural lighting to provide a suitable environment with adequate and comfortable lighting and healthy living conditions.

Good day lighting can provide a pleasant and comfortable working environment and enjoyable living to human beings. Eliminating glare and providing diffused light are the two most important objectives in providing high quality day lighting.

Visible light transmittance has greater impact on total energy consumption than other factors, epically on the lighting energy consumption and the window wall ratio is 40%, building facade heads for the south.

The effects of window to wall ratio (WWR) on lighting energy consumption are great, with the increase of window to wall ratio, lighting energy consumption is reduced because the intensity of interior day lighting increases, also the lighting energy consumption decreases significantly; with the increase of window area.

The heights of the window and window still, also, have great effect on lighting energy consumption. With the height of window increase and the height of the window sill increase, the total energy consumption is reduced.

The glazing with low shading coefficient and high visible light transmittance leads to lower annual energy consumption, and Due to the lower heat transfer coefficient, lower shading coefficient and higher visible light transmittance, low-e is the best glazing in various kinds of windows.

During the design process of day lighting, the following design strategies, the following points must be considered:

- Day lighting is to be provided as possible without glare.
- Glare has to be controlled by using the proper type of glass, curtains, blinds or louvers and interior color rendering;
- Provide the suitable orientation has to be provided to improve the day lighting conditions of a building.
- Windows to be located at high level in the wall or in roof monitors to allow deeper light penetration and reduce the excessive brightness.
- Day light is to be reflected inside the room to increase its brightness. A light shelf can be used to increase room brightness and decrease window brightness.
- Ceilings to be sloped to direct more light into the room. Sloping the ceiling away from the windows will help increase the surface brightness of the ceiling further into the room.
- .Select light colors for interior finishes. Finishes should be white or light colored with good reflectance.

RECOMMENDATIONS

- Arrange windows to provide day lighting to all rooms.
- Enter daylight from two directions to provide balanced lighting in order to avoid glare.
- Place windows so that the sunlight is reflected from internal walls and floors to provide diffused light.
- Use reflective floor surfaces or walls to increase daylight distribution into south- and north-facing windows.
- Avoid reflective floor surfaces that will increase glare from low sun entering east- and west-facing windows.
- Use translucent glazing on skylights to diffuse direct sunlight.
- Use landscape elements to block low direct sun into east- and west-facing windows
- Use light from the north-facing windows to provide less variable, more diffuse light.
- Minimize contrast between bright surfaces and dark surfaces.

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