Improvement of Thermal Efficiency Through Natural Lighting: Energy Saving

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***Abstract* —** Roughly a third of Europe's energy consumption accounts for the housing market. This usage, like that of other homes, mostly in the tertiary sector, contributes for 40% of total energy consumption and 36% of CO2 emissions. Artificial lighting accounts for 14% of the European Union's power use and 19% of the world's energy usage. By using well-designed natural lighting, controlled when technology and systems which guarantee the usability of all areas inside buildings, it is possible to reduce the energy consumption of lighting or air conditioning. The essay would address the development of technologies and equipment for controlling natural light in buildings, focusing on control methods that not only protect inhabitants from direct sun exposure, but also regulate the absorption of natural light into buildings in compliance with the wishes of occupants, while at the same time allowing for a reduction of natural light. All systems and/or tracking and/or control methods for natural light insure that daylight is consumed and that electrical energy is used to heat and cool.

***Keywords* —** Lighting, Daylighting, Thermal, improvement, Natural lighting, Technology, Energy consumption, simulation, Solar shading, electrical energy, Artificial lighting.

I. INTRODUCTION

Natural light is a free and necessary resource. It is also variable, in its intensity and inclination. Using it is therefore an imperative and requires a lot of thought. The good design of a building combined with adjusted management must ensure comfort and energy savings. Several experiments have shown the value of natural light in buildings. Natural light significantly affects buildings ' energy balance as well as actual human behavior. Given that it plays a significant biological function in regulating the phycological cycles of living beings, it gives the inhabitants warmth and health benefits. Nonetheless, owing to its changing nature, it is necessary to control and to substitute natural light. Unless controlled, natural light can have a net environmental impact as excessive solar gains lead to an increase in cooling energy consumption. On the other side, many natural light control systems rely at reducing natural light's negative impact. Thus dismissing the positive effects. By reducing the external heat load caused by solar radiation in a building, the amount of natural light is often insufficient and the energy used for electrical lighting in- creases. Therefore, a well-designed, controlled use of natural light, the use of technologies or systems that ensure light penetration throughout the building, energy consumption for lighting and air conditioning can be kept to a minimum. Daylight harvesting is the term used for a control system that, when natural daylight is available, reduces the use of artificial lighting with electrical lamps in building interiors to reduce energy consumption. In open-loop or closed-loop systems, all daylight harvesting systems use a light level sensor, a photo sensor to detect the prevailing level of light, luminance or brightness. Image detectors are used to connect an electronic lighting system with a day lighting system so that lights can work when there is inadequate sunlight. About half of the total energy produced in the developed world is inefficiently used for heating, cooling, ventilating, and moisture control in buildings to satisfy the increasingly high standards of thermal comfort required by occupants. Using advanced materials and passive technologies in buildings would significantly reduce energy demand and improve the impact of building stock worldwide on the environment and carbon footprint. Energy efficiency and thermal comfort technologies for buildings study the innovative building materials used to enhance the built environment objectively. Thermal comfort is the state of mind that communicates satisfaction with the thermal climate. There are large variations from person to person, both physiologically and mentally, making it difficult to please everyone in a room. For everyone, the environmental conditions necessary for comfort are not the same. There are six main factors that need to be addressed in the definition of thermal comfort conditions. In some circumstances, a number of other secondary factors affect comfort. There are the six primary factors as regards, clothing insulation, air temperature, radiant temperature, air speed, humidity.

II. LITERATURE REVIEW

Daylighting is the relationship between architecture and how natural light is optimized for health and well-being benefits in a space or place. By understanding how daylight flows throughout the day and at different times of the year into a specific space, we can then influence

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how light is incorporated into the design of the building to benefit the end user. However, effective daylight use is not just about light. The sun can be a source of heat within a building and it is also aesthetically pleasing to have the sun shining through your window creating a positive sense of visual comfort for building users. Second, daylighting also affects energy performance, as light is radiation in essence. This means that in winter it can contribute to thermal comfort and in turn reduce the heating needs of a building. However, by the same token, too much light in the summer may require additional cooling. A good daylighting strategy should consider how a building varies over the seasons to avoid too cold or overheating, but also how the light flow works alongside windows and roof lights, as well as dynamic shading protection. Architects and designers are currently using daylight as a tool to create very complex and impressive buildings-an example is the Koch Center for Science, Math and Technology in Massachusetts, USA, where designers built the building with an all-day light effect More broadly, however, the design community could better understand the natural course of the sun and its effects depending on the building's orientation and location. Used effectively, daylighting techniques in terms of performance and comfort can have a positive effect on building design.
Fortunately, there are several emerging technologies and products that help designers take advantage of natural light's power and benefits. One such example is products that redirect or diffuse light such as complex fenestration systems. Such devices have advanced mirrors and louvers that, depending on the season, may alter. Redirecting these items, as well as other solutions such as micro shades, helps with glare issues when optimizing the light available. People often use artificial lighting or inner illumination to change and enhance their luminous indoor environment. Nevertheless, different activities require different kinds of lighting, so different color temperatures are given by different lamps. Human behavior, including the use of artificial lighting, should therefore be included in luminous comfort tests. From the information obtained, as shown in Fig. 4, 30,9% of the respondents felt more comfortable with their whole luminous world than they were happy with the sunlight. Only 8.5% of respondents thought their satisfaction level fell when noticing their own light-related behavior. Approximately 60.6% of the respondents registered the same level of satisfaction with their total luminous ease as with their daytime condition. For further study of how behavior factors affect luminous comfort, they picked the group of people who rated their degree of comfort as "about wrong" with daylighting and viewed their degree of luminous comfort as the dependent variable. The Kruskal-Wallis experiment was introduced to research how multiple behavior increased the performance of the respondents. 149 respondents were classified in each cognitive experiment according to their own survey question responses, and the outcome was the degree of overall satisfaction they showed. If
their P-values were above 0.05, the range of happiness rates was the same across behavior patterns. The lower the P-value for a certain type of behavior, the greater the role played by the type of behavior. Table 6 shows the results of these measures in the third column (where the degree of happiness with daylighting is 3).

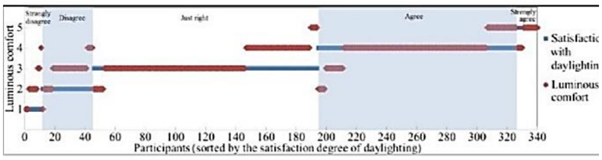

Fig. 4. Comparison of satisfaction with daylighting and level of luminous comfort

As shown by the third column in Table 6, the proportions of living room operation types, inner shading region and level of artificial lighting are the same across the luminous comfort classes. Such behaviors, in other words, added little to the total luminous warmth. Nevertheless, artificial lighting hours had a major influence on the degree of luminous comfort. A Kruskal Wallis experiment was used to analyze how such activities affected luminous comfort and the degree of happiness with daylighting in order to provide a comprehensive analysis. Table 6 provides the description of the test results for the theory.

Degree of satisfaction with daylighting	1	2	3	4	5
Kinds of living room activity	0.713	0.025	0.351	0.019	0.539
Internal shading area	0.382	0.155	0.099	0.055	0.833
Artificial lighting hours	0.655	0.021	0.000	0.702	0.736
Artificial lighting types	0.141	0.234	0.245	0.025	0.219

Table 6. Hypothesis test summary with different degrees of satisfaction with daylighting.

As can be seen from Table 6, psychological influences had great influence on the respondents who rated their level of satisfaction this medium with daylighting. Nevertheless, no specific behavioral influences tended to have a significant influence in cases where respondents were strongly frustrated or highly pleased with their daylighting efficiency. Lateral analysis found that the most important P-values among the four behavioral variables are artificial lighting hours and forms of operation. In average, the most important and effective activity impacting the luminous atmosphere and the luminous health of citizens was the enhanced use of artificial lighting.

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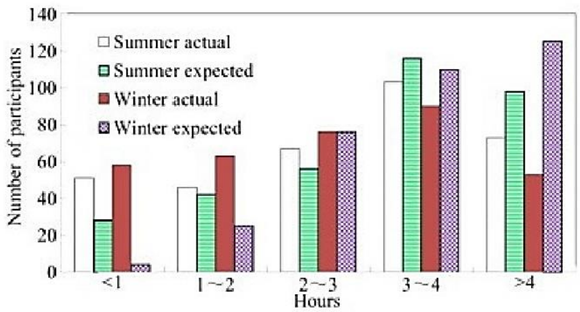
III. METHODOLOGY

This paper discusses recent research on natural light technology and control systems in buildings. The main objective of such devices and control system is not only to shield inhabitants from overt sun exposure, but also to optimize sunlight absorption into buildings depending on the needs of residents, thus allowing for a decrease in lighting and heating electrical usage. The results were collected for this work by checking archives in different disciplines (e.g. reports on the atmosphere and daylighting, and public health). The search engines used were those on the pages of the Web, the weather and sunlight. Daylighting, sustainable construction, healthy buildings and the environmental impact of daylight and daylight control systems were the key words for the searches. In line with the characteristics of the research, the inclusion requirements for publications are explicitly defined. The article had to be a thorough study of daylighting, its characteristics, influential factors, consequences, technology or control systems, effects on human health and environment, etc. to be included in the review. This review's structure reflects the inventory of possible daylighting control systems in buildings.

IV. FINDS AND DISSCUSSIONS

When researching daytime efficiency, the concept of uniformity has always been a major issue. It consideration is also one of the four key values in campaigning for lighting schemes, and it is considered highly important to increase the uniformity of light. Galasiu and Reinhart have raised a relevant question as to what metric we should use to measure the efficiency of daylight value. More than 60 percent of 28 qualified researchers reacted to the expectation of uniformity, with this quality ranked third behind energy conservation and glare avoidance. Amazingly. Galasiu and Veitch find that the real glare of discomfort from windows in an office environment is less troublesome than that expected by daytime glare index models, and the perceived degree of glare of discomfort is mostly linked to the activity being done. People may be more forgiving of glare in urban environments than in office settings, where glare can hinder the quality of the mission. People at home has more freedom of movement than at school, and there are also certain ways of controlling light that may not be possible at work Because energy saving is not a variable in luminous comfort, it is reasonable that our respondents in the survey found the sense of light uniformity more important than other factors affecting luminous comfort. The important factor is sunshine duration, as this has a great effect on daylight satisfaction. The real summer sunshine hours and the predicted winter hours were key factors in forecasting daylight quality. The amount of sunlight hours actually decreases from summer to winter, and the participants would have had less winter sunlight hours (see Fig. 6). However, the quantitative results of this study support the findings of an earlier survey conducted by Lau et al. showing exactly the same pattern in planned living room hours in the fall. Many people expected on a summer day to have three or four hours of sunlight. The rates of daylight period we wished for in fall, though, was significantly different. We believe our participants in the winter wanted as much sunshine time as possible. This may be due to the way in which winter sunshine acts as an effective means of warmth for living rooms.



It is essential for our well-being to ensure that we get out and expose ourselves sufficiently to the sunlight, but it is only a part of the guarantee that we will reap all the benefits that natural light can offer us. Like our parents, most of us don't stay outdoors, so we spend a lot of time in our homes. While "wellbeing architecture" continues to become an industry trend, it becomes clear that natural light is not only good for us, it is also good for our buildings. Natural light can enhance energy efficiency: In the typical house, particularly commercial buildings, lighting is a significant part of the total energy expenditure / use and can amount to about one-third of your total energy bill. Electricity is not inexpensive and the continuous illumination of an indoor space may produce an important bill in an incredibly short period of time-especially if the lighting solution of your choosing is not energy-efficient. Enter the light of day. Although the cost of installing windows, glass sliding doors or other glazing solutions may initially be higher than the average monthly electricity bill, once installed, they do not cost anything (unless you opt for a motorized or electrical option) of course), and they light up your interior spaces even more efficiently than lighting It is not only lighting that can be optimized by using daylight in your indoor spaces, but also heating. This does not seem apparent at first, but by choosing the right thermal glazing materials, the "solar gain" (the thermal impact of solar radiation on an indoor space) can be regulated and controlled. Thanks to intelligent design, you can not only illuminate your home, but also heat it with natural light, while adequate insulation allows you to maintain this indoor climate. It is essential for our well-being to ensure that we get out and expose ourselves sufficiently to the sunlight, but it is only a part of the guarantee that we will reap all the benefits that natural light can offer us. Like our parents, most of us don't stay outdoors, so we spend a lot of time in our homes. While "well-being architecture" continues to become an industry trend, it becomes clear that natural light is not only good for us, it is also good for our buildings. Natural light can enhance energy efficiency: In the typical house, particularly commercial buildings, lighting is a significant part of the total energy expenditure / use and can amount to about one-third of your total energy bill. Electricity is not inexpensive and the continuous illumination of an indoor space may produce an important bill in an incredibly short period of time-especially if the lighting solution of your choosing is not energy-efficient. Enter the light of day. Although the cost of installing windows, glass sliding doors or other glazing solutions may initially be higher than the average monthly electricity bill, once installed, they do not cost anything (unless you opt for a motorized or electrical option) of course), and they light up your interior spaces even more efficiently than lighting. It is not only lighting that can be optimized by using daylight in your indoor spaces, but also heating. This does not seem apparent at first, but by choosing the right thermal glazing materials, the "solar gain" (the thermal impact of solar radiation on an indoor space) can be regulated and controlled. Thanks to intelligent design, you can not only illuminate your home, but also heat it with natural light, while adequate insulation allows you to maintain this indoor climate. The use of windows and skylights to bring sunlight to your building is daylighting. very energy-efficient windows today, as well as advancements in lighting design, minimize the need for artificial lighting during daylight hours without causing problems with heating or cooling. The best way to incorporate daylight in your home depends on the design of your climate and

home. Windows sizes and locations should be based on cardinal directions rather than their impact on the house's street-side appearance. For example, for example:

- South-facing windows allow most winter sunlight into the home but little direct sun during the summer, especially when properly shaded
- North-facing windows admit relatively even, natural light, producing little glare and almost no unwanted summer heat gain
- East- and west-facing windows provide good daylight penetration in the morning and evening, respectively, but may cause glare, admit a lot of heat during the summer when it is usually not wanted, and contribute little to solar heating during the winter.

Artificial lighting accounts for 14 percent of energy use in the European Union and 19 percent globally, according to the International Energy Agency (IEA). There are a wide variety of mechanisms for monitoring and/or directing the natural light that penetrates a building's interior, set up to reduce energy consumption. These commands and/or direction mechanisms or methods for natural light can be classified into two groups:

- Side-lighting systems
- Top-lighting systems

The first group includes lateral illumination systems in which natural light passes through the sides into the interior of a building. A window is this group of systems or strategies simplest ex- ample. Zain-Ahmed et al. conducted a report on energy savings created by using sunlight in the layout of passive solar buildings. They demonstrated that a minimum saving of 10 percent in electrical energy consumption is achieved by modifying the size of the windows. Natural light from the top enters the interior of a building in the second group. A skylight would be this group's simplest example. The main objective of these systems and/or control and/or guidance strategies for natural light is not only to maximize natural light levels within a building, but also to optimize the light quality in the environment for its occupants (an excess of natural light can be uncomfortable). The key to well-designed natural lighting lies not only in the control of light levels, but also in the direction and light distribution. This will guarantee both the safety of the inhabitants and the decrease in the use of electrical energy for heating and cooling. Side lighting systems are designed to prevent an unequal distribution of natural light that can oc- cur by using traditional lateral windows. These systems achieve a more homogeneous, balanced distribution of natural light within a building by reducing excessive light levels near the windows and increasing the light in areas far from the windows. In this report, the examined side lighting systems.

- Light shelves
- prismatic glazing
- Mirrors and holograms
- Anidolic ceiling
- Louvres and blinds

Light shelves are items mounted in a window above the stage of the eye horizontally. These systems protect the lower areas near a window from direct solar radiation, as Ochoa and Capeluto show. They also reduce the contrast between the light levels generated at the

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window's vicinity and those at the room's back. Edmonds and Greenup have shown that light shelves are a good shading and natural lighting device. Light shelves are split into higher and lower parts. Their job is to reflect the light that shines on them towards the ceiling surface in order to achieve better penetration and more uniform light distribution while at the same time reducing the consumption of electrical energy for lighting. Sanati and Utzinger thus revealed that spaces where the doors were installed with light shelves required fewer illumination power than those with traditional windows.

The geometry of both the ceiling and the light shelves plays a very important role in their performance as these systems operate by reflecting the light that falls on them towards the ceiling sur- face. Freewan etal, proved the best ceiling in both the front and rear of the room is one that is curved. In a subsequent study, the authors analyse the interaction between the various geometries of the light shelves when combined with a curved roof. Al-Sallal revealed that a 5 ° roof pitch helps reduce the brightness difference between the ceiling and the back wall. Light shelves affect a building's architectural and structural design and must be considered at the start of the design phase as they require a specific type of roof to function effectively. Light shelves must be specifically designed for each window orientation, room configuration or latitude. While light shelves are effective only during the seasons of the year when light falls directly on them, they help to reduce glare. They are not always suitable for rooms with north exposure as they reduce illumination levels.

For many years, devices similar to prismatic glazing have been used to adapt daylight so that the diffused solar radiation enters a building while the direct radiation is reflected. Critten showed that prismatic glass could be used in greenhouses to enhance winter sunlight, while Kurata showed the effects of a Fresnel prism on a greenhouse cover, concluding that light transmission increased in winter while it decreased in summer. Prismatic glazing observes the fundamental laws of daylight reflection and refraction to change the direction of light inbound and redistribute it. Part of the incidental sunlight will be reflected on the ceiling while the rest will remain close to the window (Fig. 1). In this way, it is possible to achieve better penetration and more uniform sunlight distribution. Lorenz showed that this improved penetration and light uniformity decreases the use of electrical energy for cooling as it provides a significant improvement in consumer thermal comfort during the summer months.

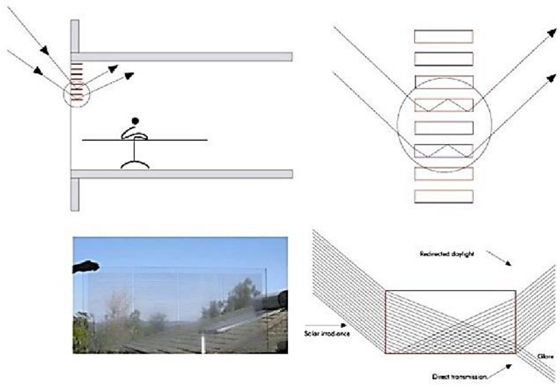

Fig. 1 Light Deflection Using Prismatic Glazing

Different studies have concentrated on various aspects of prismatic glazing with the goal of optimizing the delivery of sunlight in the spaces. Some of the factors studied include size, density, angle of divergence, amount of light deviated. However, when the sky is overcast, the effect of prismatic glazing is negligible. In this case, be- tween two transparent glass panes, the prismatic plates are placed at the top of the window. A material of similar thickness to conventional glass windows was analyse along these lines by Ed monds with a prismatic glazed laminate placed between two panes. The resulting material pro- vided a more efficient sunlight distribution.

Mirrors and holographic sheets or holographic optical elements (HOEs) allow natural light to be redirected, improving the penetration and distribution of light within buildings. Both systems of for significant energy savings and improved user comfort. Breitenbach and Rosenfeld studied the optical properties of holograms, finding that since they isolate most of the visible light from the infrared portion of the solar spectrum, they are an effective means of controlling natural light as well as maximizing sunlight gain. The environmental benefits of holograms have been studied by various authors. Müller showed that electrical illumination use could be decreased by more than 50 percent by using holograms if complemented with an integrated lighting control unit. James and Bahaj showed that if holograms were added to 62% of the glass, the temperature in a greenhouse could be reduced by as much as 6.1 degrees. According to Tholl et al., however, holograms offer the disadvantage of reducing transparency in an environment while Klammt etal. state that it is difficult to use them on a large scale because of the high cost of holograms. In fact, Koster argues that glass mirror windows reduce energy transfer through the glazed layer. It ensures that the energy consumption of electrical lighting is enhanced by increasing the external heat load arising from solar irradiation into the building

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being mirrored and/or consumed in the outer skin (Fig. 2)

Fig. 2. Mirror facades darken the interior, making it necessary to switch on the lights during the day

The anidolic ceiling is a system that improves not only the levels of natural light within a building, but also energy efficiency. Wittkopf et al. showed that this device could save more than 20 percent of electrical energy usage for illumination. This energy saving for lighting is 30% for Courret etal. Using a comparative study, these authors also proved that personal appreciation of the luminous atmosphere is higher in a room with an anidolic ceiling, leading to a significant reduction in both paper and screen reading errors. Scartezzini and Courret showed that the daylight factor, measured at the back of a room, in- creased by 1.7 on a cloudy day; this allows for a 3rd lighting reduction in electrical energy consumption. In addition, visual comfort measurements recorded that the anidolic ceiling provides better illumination than conventional glazing with a cloudy sky. Linhart and Scartezzini have shown that lighting densities can be reduced by at least 4 W / m2 with no significant impact on visual comfort and efficiency with anidolic lighting systems; even a reduction of 3 W / m2 is a re- alistic possibility. Vázquez-Moliní et al. describe in detail as part of the systematic daylighting process the anidolic collection system. The day lighting system is based on a Truncated Compound Parabolic Concentrator (T-CPC) collection system that minimizes system dependence on solar incidence, meaning a suitable behavior during working hours for virtually any time of year. In addition, the con- trolled aperture angle, limited by the array of the collector, reduces the loss of reflection. Other researchers including Ochoa and Capeluto have shown that the anidolic ceiling offers quantitatively high levels of lighting. Nevertheless, care must be taken qualitatively about solar angles where glare can be induced by the reflective core. Errors in the hub's size or orientation may cause unwanted reflections, even if the performance of the system is good.

Louvres and blinds are two systems designed to capture and redirect the sunlight entering the front of a room. This increases the light levels at the back of the room while at the front it decreases.

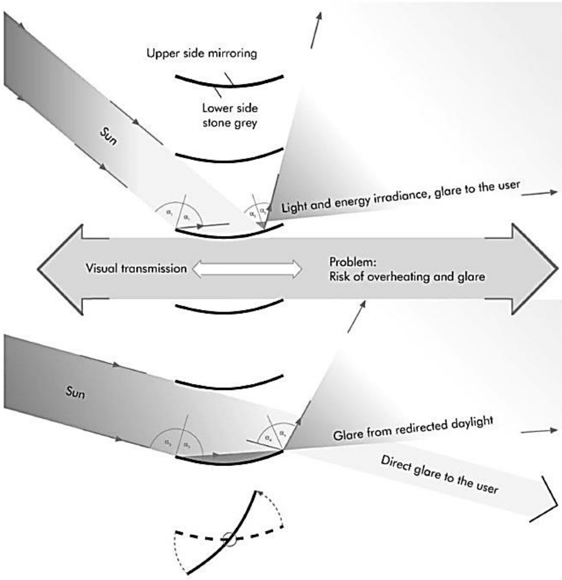

Fig. 3 Blinds open

There are several horizontal, longitudinal and sloping slats in the louvres or blinds. The optical (and thermal) properties of the device are complex due to the discreet nature of the device and depend on several parameters including louvre characteristics, tilt angle and solar incidence angle. The angle of rotation, shape, size, configuration and color of the slats all affect the glare and visibility, but also the efficient transmission, absorption and reflection of a window-blind system.

The effect of louvres and blinds on electrical energy use in buildings has been documented by various researchers. Hammad and Abu-Hijleh[93] investigated the improvements in electricity consumption in an office block in Abu Dhabi, United Arab Emirates, along these lines. They contrasted this device to another, easier way of using a sensor-controlled light dimmer. The results showed that in the south, east and west façades, the potential energy savings were only 24.4 percent, 24.45 percent and 25.19 percent when using the dimmers. Together with the progressive light control approach, the proposed system of adaptive blinds culminated in energy savings of 34.02%, 28.57% and 30.31% respectively in a southern, eastern and western direction. Saelens et al. assessed the influence of a south-facing office on cooling demands and peak cooling potential when various models and perspectives were applied to

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simulate the performance of external Louvre shading devices.

Oh etal. configured slat-type blind control strategies over two levels. Double-sided blinds are proposed in the first stage by applying different reflection between the front and back of the slat and by rotating the slat entirely when the device function was changed between heating and cooling.

When the double-sided blind was used with the operated light dimmers, it was possible to achieve an energy saving of 24.6 percent relative to the reference case to prevent glare at the same time. The control techniques of the slat angle and up / down control theory were built in the second stage to completely remove glare and improve energy efficiency.

As a consequence, it was possible to achieve an energy saving of 29.2% while glare was limited to just 0.1%. Shen and others. The illumination, heating and cooling use of power, electrical de- mand and visual comfort of various control strategies are analyzed and contrasted.

The results showed that in all cases, integrated controls achieve the lowest total energy. Strategy (Fully inte- grated lighting and daylight control with blind tilt angle control without blind height control) generates the lowest total energy in most cases. Strategy (Fully integrated lighting and daylight control with blind tilt angle and height control) achieves the lowest total energy level in mixed humid climates and buildings with interior blinds.

One disadvantage of louvres and blinds is that they often fail to meet the thermal, lighting and visual efficiency requirements if they are manually controlled by the occupants of a building ac- cording to personal preferences. If the blinds require adjustment, the occupants may be out of the room.

However, in order to avoid overheating or haze, the inhabitants frequently cover the louvres and blinds entirely, thereby reducing the amount of light. If this occurs, the electricity consumption would rise for both heating and cooling. The inhabitants may also change the position of the blinds to shield the room from direct sunlight, but in the absence of direct sunlight they do not often alter the position of the blinds

The solution to this problem is the use of automatic blinds with an appropriate electronic control system, which allows to achieve the correct amount of natural light and maximum protection against overheating.

- They provide higher levels of natural light and better protection against overheating and glare inside a building.
- Better thermal efficiency and higher natural light penetration leading to savings in both cooling loads and lighting energy Galasiu et al. presented the field-measured performance of two commercial photo controlled lighting systems, continuous dimming and automatic on/off, as a function of various configurations of manual and photo controlled automated venetian blinds. The results showed that under clear sky and without blinds both lighting control systems reduced the energy consumption for lighting on average by 50-60% when compared to lights fully on from 6 am to 6 pm.
- These savings, however, dropped by 5-45% for the dimming system, and by 5-80% for the automatic on/off system with the introduction of various static window blind configurations. The savings in lighting energy were more significant when the lighting control systems were used together with photo controlled blinds. This was due to the capability of the blinds to adjust their position automatically in direct response to the variable daylight levels. Lee etal. , designed a dynamic venetian blind and dimmable electric lighting system to optimize daylight admission and solar heat gain rejection in real-time, while accommodating other occupants' considerations. The authors showed a significant energy saving (22-86%) and a reduction in peak demands (18-32%) using the automated venetian blind/lighting system instead of static venetian blinds with the same dimmable electric lighting system.
- They close automatically when the temperature inside a building or the levels of light become too high, and they reopen when the temperature and light decrease, to allow penetration of day- light.
- The control system adjusts automated blinds to block direct sunlight, avoiding in this way glare, and offering total daylight illumination and electrical illumination on the illumination level range.

A skylight system consists of a horizontal or sloping opening in the roof of a building. It is de- signed to capture sunlight when the sun is at its zenith, allowing daylight to penetrate into buildings. This system of natural illumination can only be used on the top floor of a multi store building or in single store buildings.

To quantify the efficiency of these skylights, some studies employ scale models or computer simulators . In this way, Henriques et al. developed a skylight system which responded to the environ- mental demands of a building’s exterior as well as its interior. Parametric and environmental software analysis was used to generate and assess solutions. Acosta et al. conducted an analysis

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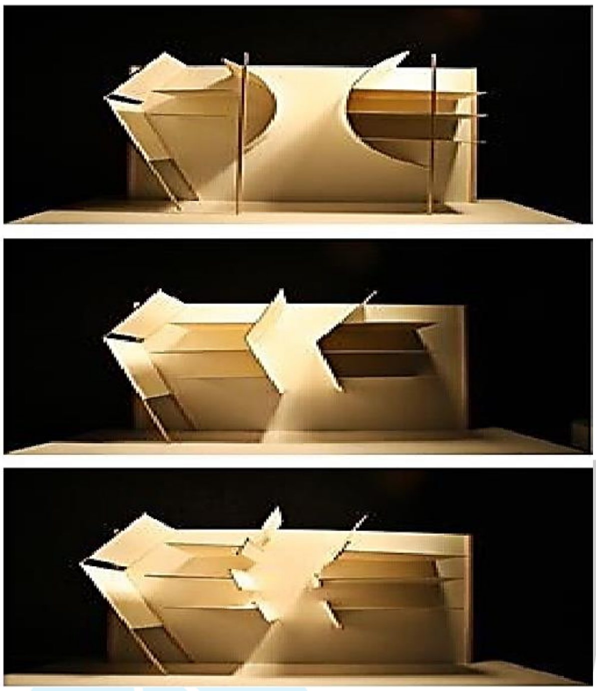
in order to determine the most suitable set up for a skylight system, in order to ensure maximum working plane illuminance within a room. Treado et al. concluded that skylights are the most efficient option for minimizing total energy use in a building for heating, cooling and lighting. They are furthermore the most effective source of natural lighting, achieving a reduction of 77% in electrical energy consumption. Although, for Al-Obaidi et al. the use of this system is limited to specific climatic regions because of its considerable effect on the indoor environment.



(Image .1) Natural illumination system

Other researchers have based their studies on the classic treatises dealing with daylight. In this way Tsangrassoulis and Santamouris offer a practical methodology to estimate the efficiency of this system and determine the quantity of light reaching the interior of a building where these devices have been installed. This methodology is based on the flux transfer approach, used to model the distribution of light energy in round skylights of different proportions of height and width, wall reflectance and transmittance of the glass. Chel et al. through the study and validation of a model used to estimate daylight factors, showed a potential yearly saving in electrical energy for lighting of 973 kWh/year. This saving is equivalent to 1526 kg/year of CO_2 emissions. Roof monitors and saw tooth are lighting systems which differ mainly in form. They consist of vertical or sloping openings in the roof used to capture light. These openings can be designed to reflect sunlight at certain moments of the day or the year, depending on the requirements of a building. The roof monitor system allows sunlight to penetrate a room in winter when the sun is low in the sky, but not during the summer months. Heras et al. present the experimental results and the specific analysis of thermal energy savings carried out to analyse energy efficiency in a building with a saw tooth system installed. The light pipe system consists of a dome skylight (to capture sunlight), a reflective tube (to reflect the sunlight to interior spaces) and a diffuser assembly (placed inside the room to be lit). The dome must be ultraviolet and impact resistant, to protect the tube from dust and rain. Commonly two types of light pipe system are used straight and elbow bends. The light pipe system is an energy-saving technology offering the possibility of illuminating even the farthest depths of an interior space. Darula et al. feel that straight light tubes offer a unique opportunity for carrying natural light to the farthest corners of a room even in spaces with no windows. However, for Kocifaj et al. the light tube must be pointing directly at the sun to reach its full efficiency potential. Wong and Yang demonstrated that light pipe system can work in both clear and overcast sky conditions. However, there are limiting factors that affect the performance of it such as orientation, solar azimuth angle and angle of incident light. Görgülü and Ekren lighted a windowless room with a light tube and dimmable electronic ballasts. A saving of around 30% was made using the proposed controller. In the summer months, the energy saved on illumination would be greater. Jenkins and Muneer, discussed numerous design models/methods to use in predicting light levels in light tubes, in other words, a tool to quantify the best configuration for light tubes in any given situation. A year later, Jenkins et al. [141] developed a model which employed the cosine law of illumination to trace the distribution of the light diffusing light tube, taking into consideration pipe elbow pieces or bends. Canziani etal. proved that the light pipe system offers an energy saving potential for both electrical energy (used in artificial illumination) and thermal (heating and cooling) energy. They are furthermore capable of avoiding unwanted phenomenon such as direct irradiation, glare, and overheating. They uniformly distribute sunlight to assure adequate luminous comfort.

V. CASE STUDY

The selected as a case study was Paulo de Tarso Montenegro building, the present headquarters of the Brazilian Institute of Public Opinion and Statistics (IBOPE). This building is characterized by being an open plan office building situated in the center of São Paulo (SP), which latitude is 23 ° 37 'and longitude is 46 ° 39 '. The Figure 1 shows the edification and enables to verify the existence of significant dimensions of the nearby buildings capable of influencing the availability of shading and daylighting in the building under study.

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Figure 1: front view of the Paulo de Tarso Montenegro Building

The developed computational model considered the effect of louvers, ceilings, walls and light shelves on the availability of natural light inside the rooms, to create routines representing the integration of systems of daylight and artificial lighting. The building of study, used in addition to these strategies to optimize the use of daylight, automation devices that allow intervention in the artificial lighting system. This is only activated to supplement the light levels provided by daylight when necessary. Through these simulations, systems with dimmers and switching control were compared. The simulation model will be further detailed below.

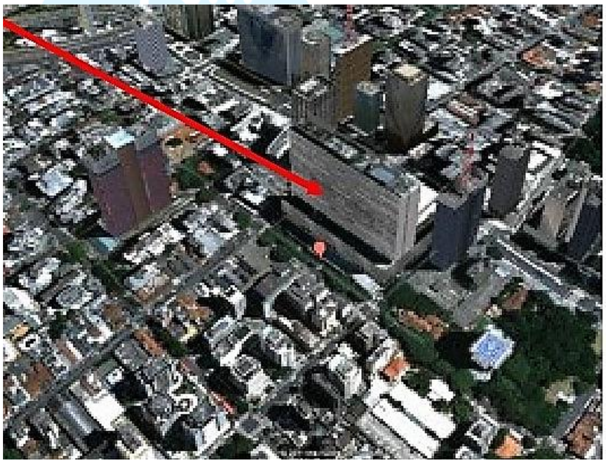

Figure 2 ; 3D map view of the building

SOLAR SHADING: The building has solar shading in its glass facade, which contribute also to reduce heat gain to the building and for a better distribution of diffused daylight inside the rooms. Such devices are com- posed of horizontal and vertical plates fixed, both made of reflective materials, in order to reflect the most of daylight for the interior. The horizontal louvers (10 pieces with 18 cm distance) take place on all facades, and, in the south- east and northwest facades, these were combined with vertical devices. The horizontal plates pre- vent the incoming of sunlight through the opening, when the sun is at high altitude and the vertical plates, when it is present at low altitudes and focuses laterally. The assembly protects the fa- cade of sunlight during periods with high temperatures and elevated solar radiation gain, especially in the summer months, as seen in Figure 4 Image of the louvers in the model simulation.

Figure 4 Image of the louvers in the model

DAY LIGHT: Aiming to maximize the use of daylight in indoor environments, were considered the use of light shelves, in order to uniform and improve the distribution of light in internal spaces through the redirection of direct light by reflection to the deeper parts of environments, since the building under study consists of open plan offices. Moreover, the device is designed to shade the part near the opening, avoiding high levels of illumination and glare. Furthermore, the model has considered a sloping ceiling to help in the reflection of light to the deeper regions. Along, in the same lines, the surface of the ceiling was painted of white, the interior surfaces prioritized clear colour (absorb maximum 0.4) and the divisions had the upper glass.

V. CONCLUSION

Traditional strategies of sun protection reduce the energy transmission through glazed building components using darkened solar shadings and/or mirror glass. The aim here is to reduce the external heat load resulting from solar irradiation into the building being reflected and/or absorbed in the outer skin. This fails to provide the buildings with sufficient natural daylight. The result is an increased use of energy for electric lighting, so that in terms of total energy consumption in these buildings, the mirror glazing often results in a negative energy balance.

Through a well-designed, controlled use of natural light, employing technologies or systems which ensure the penetration of light throughout the whole building, energy consumption designated to lighting and air conditioning can be kept at a minimum.

In accordance with the research analysed, all of the systems and/or strategies of control and/or guidance of natural light guarantees the penetration of natural light

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into the building, thus reduc- ing the electrical energy consumption for lighting and cooling. They simultaneously improve the thermal and visual comfort of the users of a building. However numerous studies have also brought to light various disadvantages presented by these systems:

- Skylight systems are inappropriate for direct application in the tropics to balance the thermal and lighting loads. Therefore, these systems should be integrated by using shading, glare protec- tion, proper use of reflective surfaces, reflectors, prisms and multi-pane, using splaying and wells for skylight, as well as double-layered roof system, and taking advantage of different geometries, roof angles, orientations, and complicated roof profiles.
- Light shelves affect the architectural and structural design of a building and must be considered at the start of the design phase as they require a relatively high roof in order to function efficient- ly. These systems must be specifically designed to fit every window orientation, room configura- tion and latitude. The performance of light shelves is reduced with Eastern or western orienta- tions and in climates where the conditions are predominantly overcast.Prismatic glazing has a negligible effect when the sky is overcast. In such conditions the prismatic plates are placed between two transparent panes of glass at the top of the window.
- The disadvantages of using holograms are twofold. Firstly, holograms reduce transparency in an environment and secondly their excessive cost mean that they cannot often be used on a large scale. The disadvantage of mirror glass windows is that they reduce the transmission of energy through the glazed surface. This means that, by reducing the external heat load resulting from solar irradiation into the building being reflected and/or absorbed in the outer skin, energy use for electric lighting is increased.
- The Anidolic ceiling offers high levels of illumination in quantitative terms. However, qualita- tively, care must be taken over solar angles where the reflection hub may cause glare. Errors in the size or orientation of the hub may cause undesired reflections, even when the system's performance is good. One disadvantage of louvres and blinds is that, if they are controlled manually by the occupants of a building, according to personal preferences, they often do not comply with the thermal, light- ing and visual efficiency requirements. The solution to this problem is automated blinds. These are fitted with an appropriate automated control which helps achieve a balance between the cor- rect amount of natural light and maximum protection from overheating.
- The light pipe system is an energy-saving technology offering the possibility of illuminating even the farthest depths of an interior space. However, the light tube must be pointing directly at the sun to reach its full efficiency potential. Prismatic light pipe can work in both clear and overcast sky conditions. However, there are limiting factors that affect the performance of it such as orien- tation, solar azimuth angle and angle of incident light.

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