Implications

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Daylight in Buildings

Introduction

Throughout history, daylight has been a primary source of lighting in buildings, supplemented originally with burned fuels and more recently with electrical energy. Before daylight was supplemented or replaced with electric light in the late 19th-century, consideration of good daylight strategies was essential. As we entered the mid-20th-century, electric light supplanted daylight in buildings in many cases. Fortunately, during the last quarter of the 20th-century and early years of this century, architects and designers have recognized the importance and value of introducing natural light into buildings.

Daylight can provide a welcome and dynamic contribution to the human experience in buildings and, as demonstrated in recent studies on schools and retail sales environments, can impact human performance (Heshong Mahone Group, 1999a & b). Most people appreciate daylight and also enjoy the outside view that windows provide. Good daylighting design can result in energy savings and can shift peak electrical demand during afternoon hours when daylight availability levels and utility rates are high.

Le Corbusier so clearly identified the importance of light in architecture when he expressed the point that, "Architecture is the masterly, correct and magnificent play of volumes brought together in light ..." emphasizing that "...the history of architecture is the history of the struggle for light." (Le Corbusier, 1989).

This article summarizes the use of daylight in buildings with focus on goals, climate and weather, sky conditions, design criteria, and strategies for daylighting design. Useful reference sources are also cited.

Aalto's Academic Bookstore

Goals for Daylighting

In general, design professionals should try to get as much daylight as possible deep into a building while controlling the brightness of surfaces within the users' fields of vision. Review and understand lighting requirements for critical and non-critical task areas. A building's critical load must also be considered as human comfort and energy performance are crucial.

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Climate and Weather

Building types and site conditions vary widely for different geographic locations and from one climate type to another. For design guidelines, consider four specific climate types, as discussed below.

New Orleans, LA is an example of a **hot-humid** climate. In locations similar to this, reduction of heat gain is important, therefore solar gain should be controlled. The designer should also control or minimize direct sunlight. Extensive roof overhangs or external shading strategies are desirable. Windows should be sized and located to admit indirect daylight. Buildings should generally be elongated on the east-west axis to minimize east-west exposure.

Hot-arid climate locations like Phoenix, AZ require design strategies that provide relief and protection from intense sunlight. Solar gain and glare, therefore, must be minimized. Strategies that admit indirect light are appropriate on south elevations while larger glass areas may face north. Solar controls should dominate on the east and west. Enclosed courtyard spaces are frequently used in hot-arid locations, especially in the Southwestern US and Northern Mexico.

The **temperate** climate of locations like Eugene, OR benefit from building forms elongated on the east-west axis to maximize south-facing walls. Larger glass areas may be considered, however glare conditions should be carefully studied. Often, solar heat gain needs to be balanced with shading on a seasonal basis. Temperate climates allow greater flexibility in design due to modest temperature and seasonal changes. Greater connections between indoors and outdoors should be considered. Exterior horizontal louvers are effective for creating deep penetration of sunlight on south facades.

Madison, WI is often referenced as an example of a **cool/cold** climate. This climate type experiences tremendous seasonal changes in temperature, precipitation, and sky conditions. Sensible design combines daylight and passive solar light. Daylight openings should be on the east, south, and west while glass on the north should be minimized. Special effort may be required to control glare and contrast from direct solar gain and bounced daylight, especially in snowy winter conditions. Architects generally attempt to minimize building surface areas due to the temperature extremes. Wind protection is often essential.

Sky Conditions

Season of the year, weather, and time of day combine with predictable movement patterns of the sun to create highly variable and dynamic daylighting conditions. Atmospheric and pollution conditions vary depending on season, weather, and time of day. Densely populated urban cities, like Phoenix, have more pollutants than rural cities. Daylighting design is usually based on the dominant sky condition and the micro-climate for the building site. There are three common sky conditions: clear sky, overcast sky, and partly cloudy sky.

Stockman's Department Store, Helsinki, Finland (skylight detail)

The **clear sky** includes sunshine and is intense and brighter at the horizon than at the zenith, except in the area around the sun. Daylight received within a building is directly dependent upon the sun's position and the atmospheric conditions. Easily used charts, diagrams, and software programs allow study of solar geometry for any geographic location and time of day.

The **overcast sky** is characterized by diffuse and variable levels of light and has dense cloud cover over 90% of the sky. It is generally three times brighter overhead (zenith) than at the horizon. Because direct sun is not present, the brightness of this type of sky depends on sun position. Generally, higher daylight illuminance occurs at higher solar altitudes.

The **partly cloudy sky** may have cloud cover that ranges from heavy to light and is similar to the clear sky at one moment and the partly cloudy sky the next. Most designers do not base decisions on the partly cloudy sky because it is constantly changing and therefore, too variable.

Design Criteria

The following criteria generally apply to most daylighted buildings. In all cases, specific issues about climate, geographic location, building type, and client preferences may influence the importance of each item. Since LEED certification is of increasing importance (http://www.usgbc.org/), architects and designers should review the credits allowed for daylight and view and for optimizing energy performance for additional items of value during schematic design. TMY2 solar radiation data, available from the National Renewable Energy Laboratory (NREL) (http://www.nrel.gov.publications/) and other sources based on geographic location, should be used during analysis of performance (see references). This list is a good place to start at the schematic design phase with appropriate refinements during the design development and construction documents phases.

Unidentified church in Helsinki, Finland (sidelight detail; splayed)

—Avoid direct sunlight and skylight unless needed for thermal comfort.
—Bounce daylight to create indirect daylight.
—Bring daylight in from above to obtain deeper penetration.
—Filter daylight into buildings.
—Use sustainable design principles.
—Maximize ceiling height to gain better light distribution.
—When appropriate, separate view glass from daylight glass.
—Determine whether daylight is primary or supplementary in lighting design.
—External control strategies offer best light and heat control. Combined strategies of external and internal controls are also practical and are becoming more common.
—Building geometry and interior space planning should promote, rather than preclude, distribution of daylight.
—Locate the maximum number of spaces near daylight through building massing and configuration.
—Create low contrast between window frame and adjacent walls to reduce glare and improve the vision experience. Splaying openings inward can increase distribution of daylight into rooms.
—Integrate building systems, including artificial lighting with daylighting through control systems.

Design Strategies Using Daylight

Conceptually, daylighting can be distributed to interior space through openings from the side, from the top, or a combination of the two. Building type, height, aspect ratio and massing, dominant climatic conditions, site obstructions, adjacent buildings, and other issues most often drives choice of strategy.

Throughout history **side lighting** has been a primary way of introducing daylight into buildings. Besides supplying light, side lighting can provide view, create orientation, allow connectivity to out-of-doors, and allow ventilation during less harsh times of the year.

Will Bruder's Burton Bar Library, Phoenix, AZ (sidelighting and external shading detail)

Daylight openings and external controls should vary by compass direction since each façade of a building, based on orientation, receives differing amounts of daylight throughout the day and across seasons. Location of openings in walls can be low, middle, or high depending on desired distribution and structural and wall system restrictions. Common strategies are:

—**Single side lighting** from one direction provides a strong directional quality of light with rapid depreciation of light quantity away from the window.

—**Bilateral lighting** occurs when light enters rooms from two side directions, thus improving uniformity of distribution depending on width of room, height, and location of glass.

—**Multilateral lighting** enters from several directions and can reduce contrast and glare, improve uniformity of light on horizontal and vertical surfaces, and provide more than one primary daylighting zone.

—**Clerestories** are high windows with sill heights greater than seven feet above the floor and are excellent strategies for task illumination on horizontal and vertical surfaces. Glass higher on a wall generally provides deeper penetration into a room.

—**Light shelves** provide shading for middle window positions and re-direct sunlight from high position windows. Light shelves, which separate view glass from daylight glass, are most effective on a building's southern exposure and under clear skies. Light shelves may be external, internal, or a combination of external and internal. Depth of shelves depends on visual needs, orientation, latitude, and window height.

—**Borrowed light** as a concept allows sharing of light to adjacent spaces when the geometry and depth of perimeter spaces permit. Corridor lighting gained through translucent partitions, glass block, or glass transoms represents a viable concept. Usually borrowed light will supplement or replace electric light during daylight hours when illuminance requirements are low. Security and fire safety influence feasibility of borrowed light.

When daylight penetrates a building from above the ceiling plane or is concentrated in the roof, it is referred to as **top lighting**. Top lighting can provide greater freedom of source placement to achieve more uniform illumination, takes advantage of high wall surfaces and other architectural elements to distribute light where needed, and increases security and privacy.

Splayed openings, for example, can spread the horizontal distribution of daylight over a wider area and reduce contrast associated with glare. The major restrictions for top lighting are the structural design, mechanical system, electrical system, and fire safety layouts. Top lighting is of limited use in tall buildings because it can only illuminate upper floors, unless

Aalto's Academic Bookstore, Helsinki, Finland (skylighting from top floor)

combined with other strategies. Common top lighting strategies include:

—**Skylights** placed horizontally in flat or sloped roofs can provide a uniform level of illumination throughout a space when skylights are spaced on a ratio of 1.5 times ceiling height. Skylights are generally effective for lighting horizontal tasks and function best for one-story buildings. The performance of skylights differs under clear versus overcast skies. Thermal gain is an issue in hotter climates.

—**Roof monitors** are in raised or elevated roof planes. The higher plane contains the monitor which illuminates task areas under each monitor bay. Glazing may be vertical or sloped. North facing monitors perform differently from south facing monitors. Monitors should be avoided on east and west orientations.

—**Sawtooths** are apertures with vertical or angled glazing installed in a slopped roof plane. Sawtooths are most effective when used in series of three and were historically used in industrial and manufacturing buildings as the primary light source. Sawtooth slope is generally at a 45 degree angle.

—**Courtyards** are outdoor areas open to the sky and are partially or totally enclosed by the building. In partly enclosed courtyards, the north orientation should be the open segment to reduce glare and to reduce the need for sun control. Façade and ground materials should reflect daylight and sunlight without increasing glare for building users.

—**Lightwells** are openings in the ceiling or floor of a room that allow daylight penetration to the floor, or floors, below. Lightwells are generally utilitarian shafts for daylight and ventilation and are not occupied space. Performance of lightwells depends on depth and the aspect ratio of the shaft. It is best to consider a lightwell as a source of supplementary light.

—**Atria** are central areas of multi-storied buildings open to the sky. Atria can be glazed to create a controlled environment. Short and wide atria perform better than tall and narrow atria. Performance of atria, like lightwells, is dependent on aspect ratio.

Summary

Throughout history, daylight in buildings has impacted human behavior and human factors and has reduced the stress and discomfort of users (IEA SHC Task 21, 2000), along with directly influencing the design of buildings including layout of space. With today's renewed interest in sustainability, daylight should be a requisite consideration.

New developments in design strategies are

Dayspring United Methodist Church, Tempe, AZ (roof monitor over chancel); daylighting design by the author and architecture by G. Christensen, FAIA gaining attention (Heshong Mahone Group, 1999b; Köster, 2004) just as the ageless experience of light expressed through paintings, demonstrated by masters like Vermeer and others, have captured our imagination through the play of light on space, color, and human interaction. Daylight is a constantly changing and variable phenomenon requiring the use of good lighting design process based on sound architectural and interior design principles. Ultimately, users of built environments can report on the success of our design efforts.

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About the Author:

Michael D. Kroelinger, Ph.D., AIA, FIIDA, LC, is the Director of and a Professor in the School of Architecture at the University of Nevada, Las Vegas. He teaches architectural lighting, daylighting, and graduate research methods at UNLV and lectures internationally on these topics. Kroelinger is also a Professor Emeritus at Arizona State University. A partner in MK Design

Associates in Tempe, Arizona, the firm provides daylighting, energy, and architectural lighting consultation and research to architecture, engineering, and design firms and to governmental agencies on a referral basis. Kroelinger received a Ph.D. from the University of Tennessee; a M.Arch. in desert architecture from the University of Arizona; an M.S. from the University of Tennessee; and a B.S. from the University of Alabama.

Related Research Summaries

InformeDesign has many Research Summaries about daylighting, lighting design, energy use, and related, pertinent topics. This knowledge will be valuable to you as you consider your next design solution and worth sharing with your clients and collaborators.

"Evaluating a Passive Daylighting System"
—*Lighting Research and Technology*

"Increasing Daylight Penetration"
—*Architectural Science Review*

"Daylighting in Athens"
—*Lighting Research and Technology*

"Illuminating the Worksurface"
—*Building and Environment*

"Energy Efficient Office Buildings"
—*Energy and Buildings*

"Bringing Daylight into Underground Spaces"
—*Lighting Research and Technology*

"Reduction of Natural Light From Dust"
—*Lighting Research and Technology*

"Designing for Summer Heat in India"
—*Traditional Dwellings and Settlements Review*

"Shading Devices for Daylighting in Offices"
—*Lighting Research and Technology*

"Housing Site Influences Daylighting"
—*Lighting Research and Technology*

"Textile Properties Affect Window Shade Performance"
—*Textile Research Journal*

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