Day and Light. Natural Light in Architecture

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Synopsis

There are many reasons for the renewed interest in daylighting, the high cost of fossil fuels and the realization that sources of electricity have a finite life, being quoted as most cogent; but perhaps even more important are the less tangible aspects of daylighting which relate more to the human spirit, and the quality of life….Change and variety….modelling….orientation….sunlight effect….colour….and view out. The introduction of natural light into today's buildings is an area where British architects lead the way.

History

The history of daylighting dates of course from the beginning of time starting with natural light entering the mouths of caves. Perhaps the first civilized use was the Roman Patio house. After 1900 daylight was in competition with the various forms of artificial light, up to the point when it appeared to be irrelevant, having as its nadir the development of "Burolandschaft" when buildings could be of infinite depth, and when even some schools and factories were built without any windows at all.

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Environment

What are these less tangible aspects of daylighting? Whilst none on their own might be thought to be of primary importance; it is when they are added together and a holistic view taken of the interior environment which they create that their importance becomes paramount. Taken in no order of priority they can be listed as the following;

1. Change and Variety
The human desire for change wrought by the changes in the seasons, the weather and the time of day. Artificial means have sometimes been adopted to replicate this variety by means of electric sources, but with little success.

2. Modelling
The direction of natural light providing the shadow patterns which inform the appearance of objects and surfaces, and give them the appearance that we associate with the natural world.

3. Orientation
Orientation is of importance not only in the external siting of buildings to maximize the influence of diurnal change, but to enable those within a building to establish themselves in relation to the world outside.

4. Sunlight effect

When it is available sunlight has a therapeutic effect and the importance of access to a degree of sunlight during the day is most noticeable when it is denied.

5. Colour
Natural colour may vary throughout the day, but it is the standard by which all colour is judged, and there is no artificial source which can match it.

6. View out
Access to a view out may not have been paramount in the minds of the early building designers, but it is not only in the 20th century that the view from buildings has been conceived to be of some importance.

Windows

The design of windows is in constant development, both in the form of the aperture through which the daylight comes and in the nature of glass or transparent material permitting the light to enter. Windows do more than let in light and are often associated with solar shielding and ventilation.

Forgetting about the early architecture, such as the Pantheon or the Roman patio house, where holes were left in the roof admitting rain as well as light; it was left to the 18th century and the introduction of the glazed skylight, to introduce daylight deep into the interior of a building. This development had the important effect of increasing the “daylight effective depth” and has its modern equivalent in the atriums we see today, the word atrium being devised from the original Roman patio house.

There are many window forms which have been developed over the centuries, some for military reasons, and others designed to introduce light into the interior in such a manner as to reduce the difference in brightness between the window brightness, and its surroundings to reduce glare; to the point where the wall became the window and some form of control is required to protect the occupant from excessive brightness.

The control of sunlight is sometimes necessary and many ingenious devices have been designed to cope with this, some of which are at odds with the less tangible benefits of daylighting enumerated above and pay attention more to architectural fashion than functional design.

The importance of the introduction of daylight to modern building interiors can be measured by the innovative methods often employed; these include the use of “Light pipes” where glazed apertures are left in the roof with daylight being directed to parts of the building by means of reflective ducts, sometimes associated with heliostats placed on the roof to track the sunpath.

Energy

The energy used by artificial lighting in buildings is a major part of the energy use in buildings and it is recognized that if this can be reduced and consequently the emissions of carbon dioxide, this will assist in the reduction of greenhouse gasses and have an important effect in reducing global warming. The greater use of daylight can lead to a reduction in the use of electrical energy and assist significantly in the battle to solve the energy crisis.

Whilst there are climates in the world where the use of methods of air conditioning are considered to be mandatory, there is some ambivalence among building owners as to whether the climate in our country demands its use. A passive response building in which the maximum use is made of daylighting can be both comfortable and cost effective having undoubted savings in the use of running costs and energy. More buildings are being built in the UK, where the use of air conditioning has been omitted.

It is not suggested that daylight can in all circumstances replace artificial light entirely during the day; but by the use of "daylight linking controls" the use of electrical energy can be significantly reduced. Special "intelligent" light fittings are now available which react directly to the light level of a space, adding or subtracting light in relation to the available daylight.

There are some areas in buildings where daylight can never reach and electric light will always be required; just as there are some buildings, such as homes, where electric light will rarely be necessary during daylight hours. A careful study of the plans related to energy efficient daylighting design will indicate where sufficient daylight is available, and where it will need to be supplemented.

The new science of Photovoltaics where the glass skin of the building is used for solar collection is in its infancy; but the possibilities for energy savings are obvious, and this is where architects have a role to play, as important as the established needs for the introduction of alternative sources of energy from wave or wind.

Human Factors

Daylight is inextricably linked with windows, and windows let in more than light, they have associations with the admission of heat and of heat loss, solar gain and with the admission of noise; they are closely related to air movement and the needs for ventilation.

But it is impossible to judge the need for daylight and sunlight in engineering terms alone, the human factor is at least of equal importance. People like daylight, and in some countries such as the Netherlands and Germany, there are regulations determining that in a work situation, the staff must not be located further than six metres from a window. Daylight is believed to be essential in providing a pleasant visual environment, contributing to a feeling of wellbeing.

During daylight hours in a work situation where people are in a fixed position most of the time the method of lighting is clearly crucial and those situations where people work in entirely artificial conditions are liable to lead to ill health and absenteeism.

Some of the most successful installations are where the control system leads to a system of "daylight linking", where daylight penetration is combined with artificial sources, in such a way that the space appears to be daylit during the day, but where some areas are supplemented by artificial light for some or all of the day; it is the appearance of being daylit coupled with a relationship to view outside the window which is of importance. Together with the engineering solutions to the problems of heat loss in winter and heat gain in summer, the window is at the leading edge of solutions to the human needs it must satisfy.

Daylight Calculation

The first and most obvious thing to understand is that daylight is variable: it varies with the season of the year, the time of day, and the weather; for this reason the means of calculation are based on relative rather than absolute values, and this is usually defined in terms of the relationship between the light available outside, and that available at different positions inside, a proportion known as the daylight factor. By calculating the DF at a number of points throughout a space, an average DF can be assessed.

The simplest situations are those where the windows are placed in the vertical elevations of a building, and simple calculation methods are available to work out the Daylight Factors in the rooms adjacent to the windows; where it is usually agreed that for average conditions, as represented by an overcast sky in the British climate, then the daylight inside will be a given % of the daylight available outside.

The following values are correct where the unobstructed overcast sky provides an illuminance of 5000 lux…..the British condition!

For example a 1% DF will give a light level of 50 lux, a 2% DF will give a light level of 100 lux, the latter being a figure considered to be sufficient to provide some sense of the room being daylit, but not sufficient to carry out normal office tasks.

A 2% DF would therefore be a space requiring artificial light for a large part of the year. Normally an average DF of 5% is necessary in a work situation to provide a daylit space for a large part of daylight hours. Due to the variable nature of daylight a diffuse sky produces 5000 lux or more for 85% of the day, or lower for the remaining 15%.

Lighting design offices will no doubt have the necessary computer software to calculate the amount of daylight in rooms lit by side windows; but where an architectural programme demands complicated building sections, there are computational methods available to assess the likely daylight penetration; these will demand the use of computers, and at the end of the day the cost involved is heavy, and the outcome uncertain bearing in mind the variable nature of the source.

The use of simple architectural models is useful here, since they are relatively simple to construct, can be altered easily to permit experimentation with change. These measurements may be made in daylight conditions outside, or in special cases such as art galleries, where illuminance levels are critical, by the use of an artificial sky designed to represent the exterior condition at any time of the year in different weather conditions.

But perhaps the greatest advantage to the architect will be in the visual appearance of the interior spaces of the model under different conditions, something which the architect can understand more readily than a series of numbers.

There are two main design considerations concerned with the orientation of the building. Firstly there are the new buildings placed on a green field site, where the architect has control of its location and orientation and where the needs of daylighting should inform the initial building strategy; then there are those buildings on restricted sites where the neighbouring buildings must be considered as obstructions, affecting the amount of daylight penetration, and likewise that your building does not obstruct that of your neighbour.

Where there are adjacent buildings these may enjoy certain rights of light, and these must be taken into account; in much the same way that the architects own building when complete, will have its own "right to light". It is important therefore for the architect to ensure that the profile of the building to be constructed complies in all respects with the planning laws, and observes the right of his neighbours light. This can be something of a minefield, and specialist consultants are available to assist.

Case Studies

Finally some ten buildings have been selected in the following fields:

Transport/Offices/Education/Leisure/Religion/Display/Industrial

Examples of buildings in these fields have been selected to show how the needs of daylighting have informed the architect's design strategy, and how this has been translated into the built form. The examples are designed to show how daylight may have a greater or lesser effect in the different architectural programmes, and will identify where one or more of the intangible factors have had a disproportionate influence on the design. The aim is to illustrate that there are virtually no buildings where daylighting will not have a part to play.

Transport

The extension to the Jubilee Line Underground in London, which runs from Westminster Eastwards as far as Stratford was completed in 1999, and is a fine example of engineering in the field of transport; and in most cases daylight has been introduced to the lower areas of the stations, by various means, such a s domes, drums, canopies and light shafts.

Roland Paoletti, the architect in overall charge was, as Frank Pick before him, conscious of the opportunity to create buildings of quality; but rather than imposing some form of grand design on his project architects he relied first on choosing those architects with particular engineering skills, and then allowing them to work within the framework of the local community to express the grain of an individual neighbourhood.

In selecting four underground stations to feature in this Case Study of the Jubilee Line, the purpose was not to provide a "beauty contest", since the architectural quality of all the new stations along the line is significant, but to choose stations in which the solutions to the problems posed by daylighting stations on the Jubilee Line are noted for their differences of approach.

The examples chosen are as follows:

Southwark

Arriving at Southwark Station you are fed by daylit escalators to the "intermediate concourse" which leads you either down to the main Jubilee Line train level, or upwards to Waterloo East; The intermediate concourse being a key element of circulation.

The concourse is daylit from overhead by means of a cone clad in blue glass patterned in triangles, the daylight through the cone being controlled by "piranese" like deep louvers. This is an enormously impressive space, and a dignified entrance to the "world of the train".

Canada Water

A glazed cylindrical ticket hall at ground level allows light to filter gently down to the escalators below, with dynamic patterns of sunlight and shadow.

Canary Wharf

Three wide glazed canopies located above the vertical circulation at the escalator locations, provides ample daylight in the spaces below for orientation and daylight impression.

Stratford

Here the situation is entirely different. First it is an “above ground underground” station, in which the passenger enters the trains which run inside the building at the same level as the ticket office.

Offices

One of the latest office buildings to be completed in London, by Sir Michael Hopkins is the new Parliamentary building, where daylighting was a part of the brief, built without air conditioning. Located in a world heritage site, placed between Pugin’s Houses of Parliament and Norman Shaw’s Scotland Yard the site posed many problems which required a unique solution to provide 210 individual offices for members of parliament, with all the associated ancillary accommodation; together with a pedestrian connection under Bridge Street to “the House” to enable members of parliament to react swiftly to the division bell.

The daylighting strategy is determined by the plan, in which the MPs offices are arranged around a hollow rectangular courtyard, with rooms on four floors for the MPs, which look outwards or inwards to the courtyard; rooms have balconies and French windows with rooms to the outside having their own bay window.

At ground level the courtyard has an enclosed area with a vaulted glazed roof, where MPs can congregate, and meet their constituents. Two rows of trees create an avenue with a central water feature, all enlivened by excellent daylighting.

Education

The Faculty of Education at the main University of the West of England in Bristol (UWE) represents an example of the new look in educational buildings in the UK, planned to provide an excellent environment.

The lighting strategy agreed was as follows:

1. To provide appropriate levels of lighting for a range of teaching, administration and social spaces.
2. To make the most effective use of natural light to reduce running costs and Co2 emissions, and to enjoy the varying qualities of the natural source.
3. To relate the building to its external environment and landscaping.

As can be gained from the diagrams, the large amount of space required by a University Faculty is broken down into four wings connected by a double height social and communication space. By breaking up the accommodation into a series of parallel wings the architect met the brief to provide naturally lit teaching spaces, whilst the interconnecting “street” was unified by the overhead daylighting.

The plan clearly indicates its daylight credentials with a careful relationship to landscaping between the blocks.

Leisure

The Chelsea Club provides private sports facilities for its members, including a 25 metre level deck swimming pool, 200 metre running track, at high level around the perimeter, sports injury clinic, cardiovascular and aerobic studios, Jacuzzi, steam room and sauna; associated with the Chelsea football ground at Stamford Bridge.

The lighting brief was unusual in that due to the paramount need for privacy, views “out from” and “into” the facility were to be excluded, but the impression of a daylit space was desired. High level brise soleil protect the south elevation from the sun. Escape stairs, lifts and main plant are concealed in louvered enclosures at either end of the building.

The exterior impression of the building is of white wall cladding, whilst the interior reminds one of the effect of Japanese shoji screens, as a simple background to the working areas.

The exterior appearance is gained from the use of vandal-resistant, light-diffusing fiberglass panels. This material, called “Kalwall”, which spans from floor to ceiling around the perimeter of the space allows daylight through to all the major spaces of the interior during the day, whilst at night it allows the artificial light from the interior, to spill out a glow to the exterior façade, obviating the need for any exterior floodlighting to register the form of the building.

The solution to the interior lighting is a method of daylight linking, providing a light level which can be varied from low for exercises such as yoga, to high levels where this is required. The combination of daylight received through the “Kalwall panels” and variable artificial light from the stretched ceiling panels provides a calm soft light with no hard shadows, ideal for the sporting activities below.

Churches

The Methodist Church built in Milwaukee, by Architects William Wenzler Assoc. was completed in 1982. The Church is partly submerged into a hillside, with the roof being formed by the hillside itself and covered in wild flowers. The climate in the area is cold and by forming the church sheltered by earth on three sides it is protected to minimize operating costs.

The Nave is surrounded by ancillary spaces, but the architect resisted the temptation to incorporate perimeter skylights in his design, as this would have prejudiced the simplicity of the effect of the wild flowers on the hillside, so that another solution had to be found. This solution consists of a tall tower with sunlight entering from the South, with a blank wall to the North.

The lighting designer was the American Bill Lam, noted for his daylighting design and author of the Seminole book “Sunlight as formgiver for architecture”.

The tall tower is designed to collect both light and solar energy, but also registers the presence of the church in the neighbourhood; it bears a resemblance to Utzon’s Bagsvaerd Church in Denmark, although for somewhat different reasons.

The tower contains an electrically operated high-tech thermal shutter which can track the sun, offering an inexpensive opportunity for redirecting low angle winter sunlight towards the floor of the Chancel, whilst at the same time directing some light to the roof of the Nave, by means of a secondary system of mirrors below. During the summer the shutter is in its closed position to reject high angle summer sunlight and heat.

In order to test the system, model studies were carried out to convince the architect that the idea was practical. This is an excellent use of model studies which can be carried out quite simply using actual sunlight conditions; they are both quicker and cheaper than to try to use the various methods of calculation or by means of computers. The model studies showed the architect the dramatic sunlight patterns that would be achieved.

Display

The Sainsbury Superstore in Greenwich had a particular brief, to reduce the amount of energy used, by the maximization of the use of daylighting. Artificial and natural light were to be closely integrated, and this resulted in a strict energy use of as little as 25 watts/m2. It is the supermarket with lowest energy use.

This was achieved by means of a special roof contour allowing natural light in to the building, whilst at the same time controlling sunlight and glare.

The roof with eight high angled north facing roof lights, basically of a sawtooth pattern, occupies some 20% of the roof area. Each window is equipped with motorized aluminium louvers operated by Photo-sensor control.

The daylight design has achieved a Daylight factor of between 5% to 9%. At the same time the goods are well lit at all times by carefully designed artificial lighting to the gondolas; leaving the environmental lighting of the store to the natural source. The store has retained a light airy and attractive ambience.

Industrial

The “Gridshell” is essentially an Industrial building, built for the Weald and Downland Museum in Sussex. It is a no-frills solution to the problem posed by the Museum, for a large tall open space where the timbers and frames of historic buildings can be laid out for conservation and repair, before being erected on the site of the Museum.

The design objectives for the project were for sustainable construction, and energy efficiency: an early decision was made that daylighting should provide the means of illumination. Artificial light was seen as a necessary supplementary provision for extended hours usage, or in extreme winter conditions.

The primary use for the building required a large tall open space free of obstruction for the conservation work, with a smaller area for use as a museum and storing of the Museum’s artifacts. Whilst the former required a high level of energy efficient lighting (interpreted as daylighting during the day), the artifacts store would have intermittent use and might therefore be met by artificial light at all times.

The architect, Edward Cullinan’s, sketch design illustrates the concept for the building, showing the tall “conservation space” above ground level, well daylit from roof lighting, whilst the “artifacts store” is placed at a lower level cut into the chalk hillside, artificially lit when in use.

Three important considerations were apparent;

1. The roof should contain a high degree of transparency.
2. The internal finishes should be light in colour to improve contrast rendering.
3. A balance was to be found between the need for a high level of daylight, and the need to control solar gain.

The Daylighting consists of continuous rows of Polycarbonate sheeting at high level, which on the North side is “clear”, letting in maximum daylight, and on the South side it has a “bronze tint” to reduce possible sun glare. Looking up from inside the building the effect of this change is visible but not disturbing, and the impression at floor level is of an even light, ideal for the needs of conservation work. The final result is an enclosed space with a high level of daylight provision, estimated to provide a Daylight Factor (DF) of 10%.

For work after dark a sufficient level of artificial light is available from a pattern of downlights, visible in the photographs; whilst during the day they have been little used.

Summary

This paper has tried to illustrate the importance of daylighting in terms of the past history of architecture and in its relevance in terms of todays energy problems; but most of all in the less tangible aspects of daylighting in informing the quality of life…..by the introduction of natural light into our modern buildings…..this is an area where British architects lead the way.