Melbourne City Council Offices

Natural Lighting Opportunities

Prepared by:
Advanced Environmental Concepts Pty Ltd
ACN 075 117 243
Level 1, 41 McLaren Street
North Sydney NSW 2060

design advice

passive systems

design analysis

low energy services

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Project Team Leader	MMC	

1 INTRODUCTION

"The history of architecture is the history of the struggle for light. The struggle for windows." - Le Corbusier

There are many benefits associated with the incorporation of natural light into buildings. Natural light gives buildings a unique quality; its variability adds interest to interiors, giving contact with the outside world. Its distribution and excellent colour rendering enhance the appearance of spaces and the controlled entry of sunlight provides warmth. Natural lighting provides a connection with the outside; it allows a sense of time and knowledge of the weather.

Natural light is also an important aspect of a comfortable, productive working environment. Recent studies have shown correlation between natural light availability and academic achievement in schools and with productivity in the work place.

In addition to the qualitative aspects, natural lighting is beneficial in reducing the energy consumption attributable to artificial lighting. Artificial light is responsible for a large part of building energy consumption and is therefore an important aspect of achieving operational energy efficiency within a building.

The incorporation of natural light into the proposed new offices for Melbourne City Council provides a design challenge due to the proximity of adjacent buildings. However, there are a number of opportunities available which can harness natural light and direct it for use within the building. This report provides a brief overview of these opportunities and provides examples of buildings which use such natural lighting technologies.

2 DESCRIPTION

2.1 General

The most effective way in which daylight can be delivered to the lower floors of the building is through channelling or redirecting sunlight or daylight from the roof, distributing it through the building and diffusing or emitting it within the building's interior. This can be achieved through the use of a light pipe or similar system.

The light pipe system can operate over long distances therefore making it particularly suited for remote applications.

The daylighting system may also be suitable to meet the requirements for passive smoke ventilation, if an open shaft solution is considered. However, the fire consultant will need to assess the requirements for smoke ventilation and the shaft will require detailing to meet these requirements.

2.2 Components

Each light pipe is made up of three distinct elements; the light pipe itself; an outside collector to collect sunlight; and an emitter or diffuser that releases light into the interior space.

The following briefly explains the options for each component:

2.2.1 Light Pipe

The light pipe channels or redirects sunlight or daylight from a light collector at the roof to a diffuser or emitter at a lower level. There are many light pipe options available.

Light pipe options:

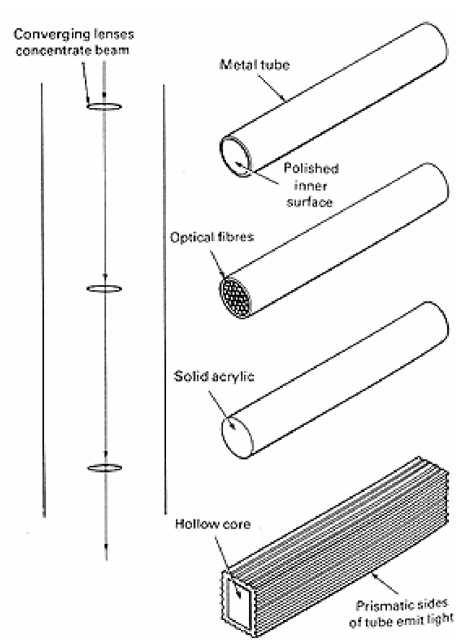


Figure 1: Various types of light pipe. On the left is a lens guide. On the right, from top: a reflective metal tube; a fibre optic bundle; an acrylic rod; and a prism light guide.

Open Shaft
This is the most basic form of light pipe, which is simply an empty shaft through which a collimated beam of light may travel. Lenses can be used to keep the beam concentrated, however, light is lost as it passes through each lens.

Reflective metal tubes are often utilised but any off-axis light has to undergo multiple reflections, so uncollimated beams will be attenuated after a few metres within the pipe.

Corrugated tubes are available, which are flexible and easy to install but have significantly lower transmission, they would generally be unsuitable for long light pipe lengths.

Fibre Optic
Fibre optic bundles, either of glass or plastic, can have good transmission characteristics. Typically between 2-15% of the light is lost per metre cable run. The use of fibre optics can also allow a flexible solution, with much smaller shaft sizes than an open tube and the ability to turn corners.

Solid Acrylic Rod
Acrylic rods rely on total internal reflections off the edges of the transmitting medium.

Prismatic Shaft
To save the weight associated with solid acrylic rods, the rod can be hollowed out and the prismatic sides of the tube guide light in the required direction.

Liquid Light Pipes
A new technology has been developed which transports light through very small diameter liquid light pipes. Such a system is similar to the fibre optic system and can offer much flexibility, as the liquid light pipe is small and can be bent.

Bomin Solar Research state that a liquid light pipe of 4cm diameter with a 1m diameter Frensel lens collecting device has the ability to transmit enough light to provide lighting to a large conference room at an illumination level of 250Lux. This performance of this system is detailed further in section 2.3.

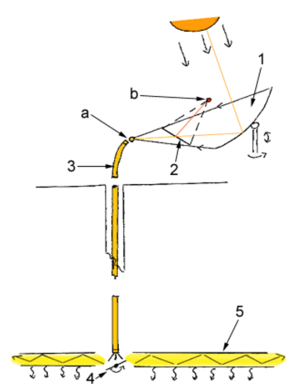
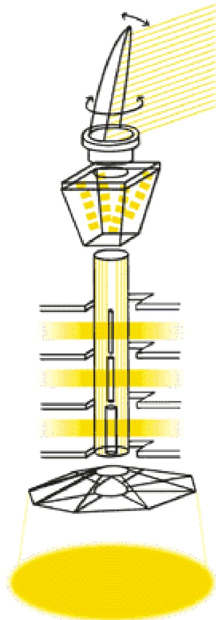


Figure 2: The operation of the liquid light pipe system.

Heliobus System
Heliobus is a new system developed in Switzerland, which encompasses all elements required for a light pipe natural lighting system. The heliobus system comprises a heliostat a light pipe and a diffusing element and has been used on projects in Europe.

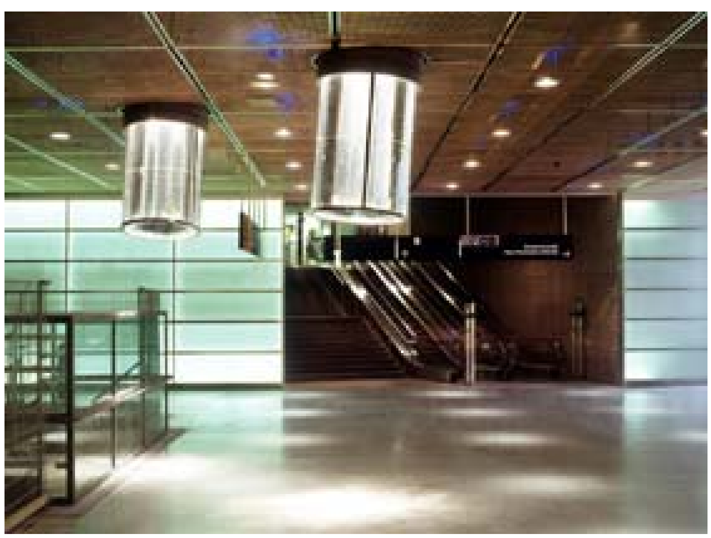


The diagram above shows the operation of the heliobus system, incorporating each of the individual elements.

The heliobus heliostat has a unique appearance and rotates to maximise the sun angle.

The following diagrams are examples of the heliobus system in operation at the Postdamer Platz in Berlin:


BAHNHOF POTSDAMER PLATZ



2.2.2 Light Collector

Due to the length of the light pipe required between the roof and the lower floors, a collecting device will be required to concentrate and collimate the sunlight before it enters the light pipe. There are a number of options available.

Heliostat
Heliostats track, collect and concentrate sunlight. Heliostats can take a number of forms, sophisticated heliostats utilise a concave tracking mirror to collect and collimate sunlight and a secondary flat mirror to redirect it downwards. Simple heliostat systems use a single tracking mirror to collect and reflect sunlight into the light pipe.

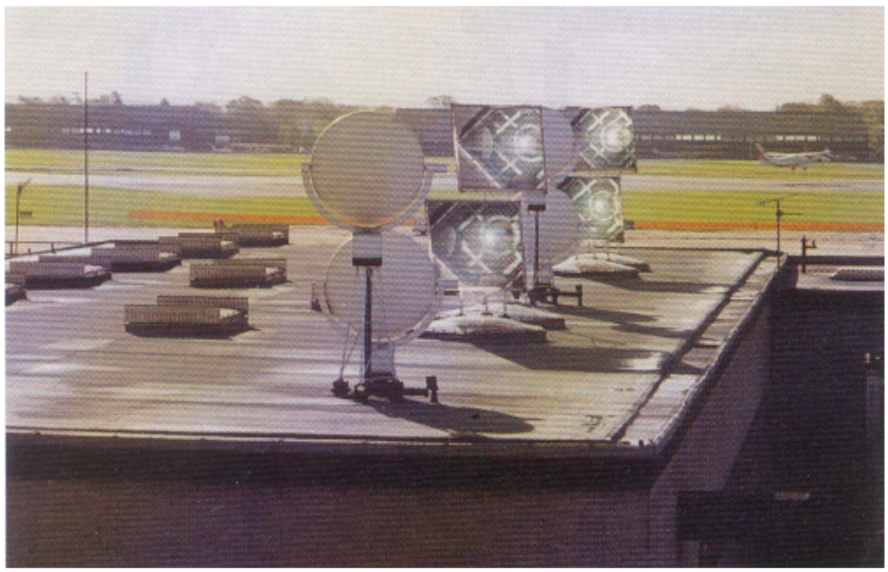


Figure 3: Heliostats in use at Manchester Airport, UK

Figure 4: Examples of heliostats in operation in Japan

The Himawari system as show in the images below consists of a sun sensor and Fresnel lens to collect and direct sunlight. A stepper motor is used and is controlled by a sensor and a microprocessor to point its lenses in the direction of the sun at all times.

When there is no direct sunlight, the system tracks the sun accurately along the computed arc of the sun

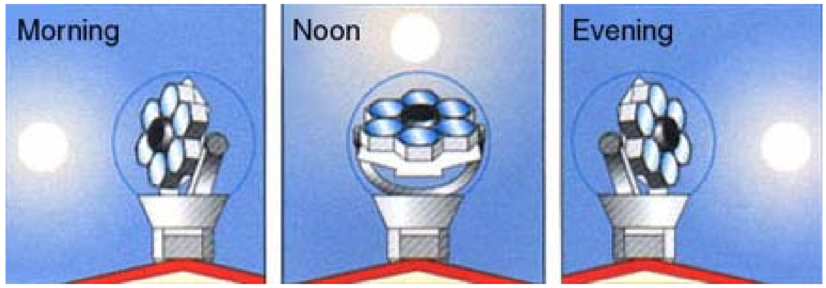


Figure 5: The operation of the Himawari System

Figures 6 and 7: The Himawari System in use in Japan.

Double Prism Collector

A double prism plate collector comprises of two circular prismatic plates that can rotate independently to refract sunlight from nearly any angle down the pipe. Such a device is compact and should be easier to maintain than a conventional heliostat, but it does not concentrate the light it merely refracts it.

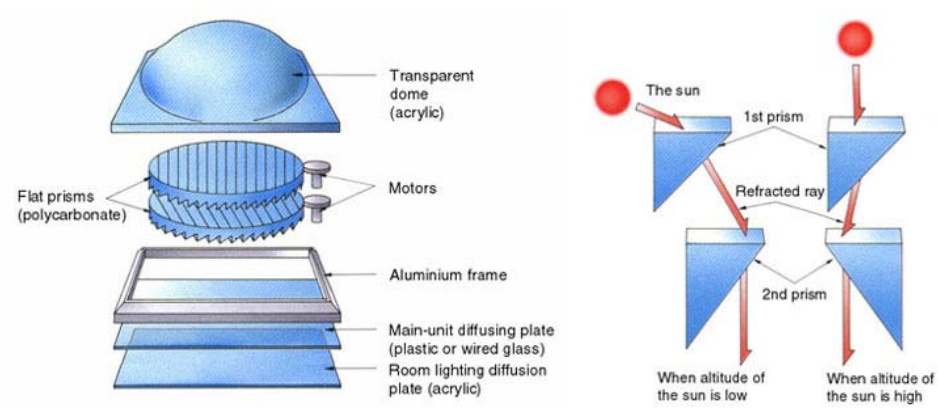


Figure 8: The operation of a double prism plate collector

Figure 9: A double prism plate collector

Fixed reflector
Fixed non-tracking redirecting devices will have lower year round performance than the systems mentioned above. They work by selectively redirecting daylight from the regions of the sky where the sun is most likely to be. A simple example is a mirror located to the south of the light pipe aperture to reflect light from the north sky.

Static Collector
Some daylighting systems utilise a simple opening or laser cut panel to focus light into the light pipe. Generally such a solution is only suitable for applications where a shallow light pipe is utilised, as sunlight will not be tracked and natural light will neither be collimated nor directed down the pipe. As such, internal reflections within the light pipe over such a long distance will result in poor light transmission at the bottom of the light pipe.

Figure 10: A tilted laser cut light-deflecting panel

2.2.3 Light Emitter/Diffuser

Light exiting the light pipe needs to be distributed in the space by using some sort of emitter or diffuser. This can be any light diffusing or reflecting device.

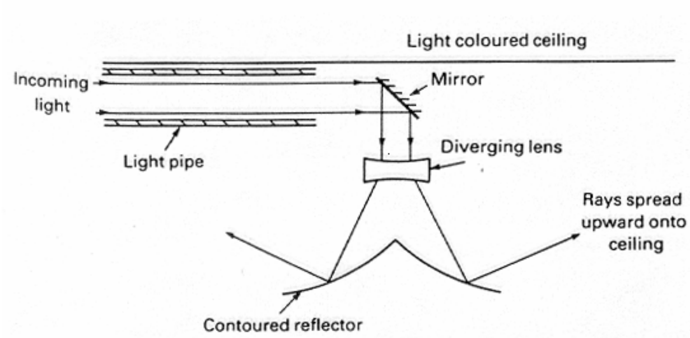


Figure 11: An uplighting emitter for beamed light. Light exiting the light pipe is directed onto the ceiling by a curved reflector.

2.3 Summary

Below is a matrix of suitability of components, each combination has been scored between 1 and 5, for its compatibility and overall effectiveness at providing daylight to the lower floors.

	Open Shaft	Fibre Optic Bundle	Solid Acrylic Rod	Prismatic Shaft	Liquid Light pipe
Heliostat	5	5	5	5	5
Double Prism	2	-	3	3	-
Fixed Reflector	2	-	3	3	-
Dome	1	-	1	1	-

The light emitter or diffuser selected can take any form to complement the architecture. Most solutions are suitable for each light pipe option selected from the table above.

3 PERFORMANCE

3.1 Open Shaft with Heliostat

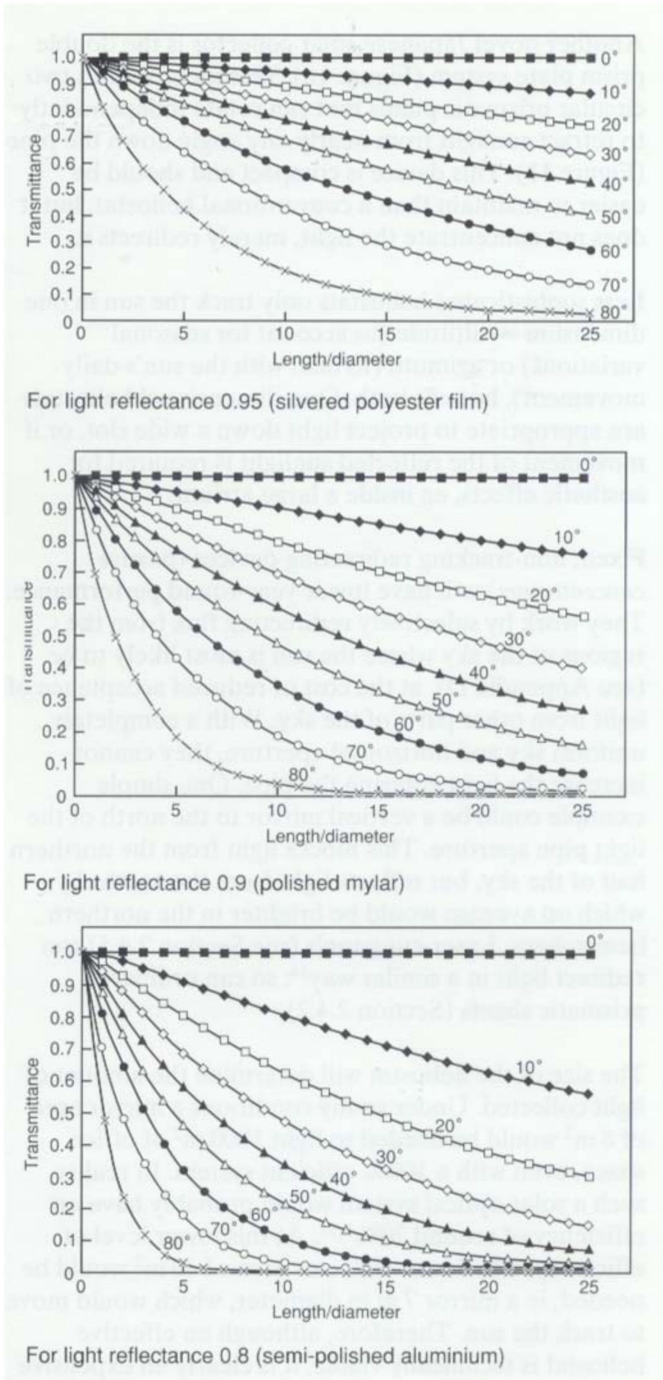


Figure 12: Open shaft light pipe performance graphs

The graphs above show the light transmittance through open shafts of different internal reflectance for varying length/diameter ratios.

In the case of the open light shaft system proposed for the Melbourne City Council Offices we estimate the light emitted within the lower floors to be 500 to 800lux on a sunny day over an area of 80m² at the base of the light shaft. Please note that a detailed assessment is still required to determine the exact light levels and the figure quoted above is an estimate based on the following parameters:

- 70,000 Lux from sun
- 80% efficiency of heliostat
- 80% efficiency within light pipe
- 90% efficiency in diffusing and distributing the light within the space.

3.2 Fibre Optic

In the case of a fibre optic solution light loss through the fibre optic bundle will be in the order of 2-15% per metre.

Assuming a 7.5% per metre inefficiency and a distance from the roof to the lower floors of 20m, a fibre optic system will provide 500 to 800 Lux over an internal area of 25m². However, this light can be provided at any point within the building and does not necessarily have to be at the base of the shaft. As with the light shaft option, detail design will enable a more accurate light prediction to be made.

3.3 Liquid Light Pipe

As stated earlier in the report, research has shown that a liquid light pipe of 4cm diameter with a 1m diameter Frensel lens collecting device has the ability to transmit enough light to provide lighting to a large conference room at an illumination level of 250Lux. We assume that this research was conducted for an installation not more than 10m from the light source, however, the system has been tested for installations up to 60m from the solar collection source. As with the fibre optic system it also has the added benefit of being able to deliver the light at any location within the building interior. Further information has been requested as to the exact performance of the system.

4 OTHER ISSUES

4.1 Maintainability

For the more sophisticated and efficient tracking systems a slight misalignment can result in a drastic loss of efficiency. Dirt on the optical surfaces is also a potential problem. It is therefore necessary that a maintenance regime must include the regular cleaning of the surfaces and maintaining the tracking motors.

4.2 Light Pipe Shafts

Shafts will be required between the roof and the lower levels. Fibre optic or liquid light pipe systems will require a smaller shaft than an open shaft system and due to their increased flexibility will be easier to install than a more rigid pipe system. However, such a system may not be used for smoke ventilation purposes.

4.3 Vandalism and damage protection

The light collector will need to be enclosed within a housing to protect from vandalism and damage. Proprietary made systems are available which incorporate a light collector and a protective enclosure.

4.4 Smoke Ventilation

Smoke Ventilation requirements will need to be confirmed with the fire engineer.

5 EXAMPLES

The following images show the operation and successful implementation of a light pipe system, at the Underground Space Centre, Minnesota University. The system incorporates a heliostat, an open shaft and a large diffusing surface. This installation is effective in providing daylight to an underground space 34metres below ground.

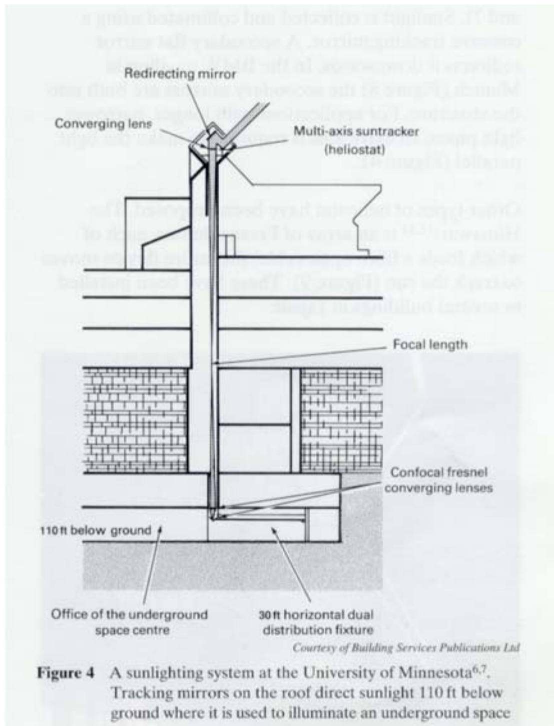
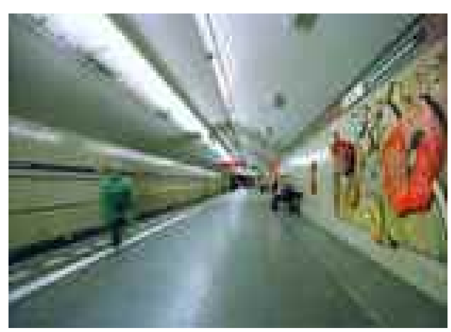


Figure 4 A sunlighting system at the University of Minnesota[6,7]. Tracking mirrors on the roof direct sunlight 110 ft below ground where it is used to illuminate an underground space

Figure 13: University of Minnesota light pipe system

The images below are examples of light pipe systems utilised in Japan.



Figures 14 to 18: Light pipe systems in use in Japan…