The Tectonics of Sustainability

“Truth emerges more readily from error than from confusion” [1]

Francis Bacon

Introduction

Exponential growth and development of 20th century industrialization has had a profound impact on cultures around the world. This century alone has seen a paradigmatic shift in how we manufacture and distribute goods, how we inter-relate as human beings and more fundamentally, how we think and perceive the world and ourselves within it.

To the degree that industrialization has enriched our lives, it has also overwhelmed us and for every advancement in science and technology we experience the extent of repercussions that challenge our values and demand resolution.

Modern history is a proliferation of human error that has inadvertently created a culture of opportunity for learning. Critical issues of environmental degradation, urban decline, and depletion of non-renewable resources have taught us lessons that perhaps, only crisis can teach.

> "Green design is not only about energy efficiency, and it is not purely a technical matter. Instead it involves a whole nexus of interrelated issues, the social, cultural, psychological and economic dimensions of which are as important as the technical and ecological."[2]
>
> Peter Buchanan

Introduction

In hindsight the Modern industrial age can be interpreted as a retrospective text that articulates the limitations of 'leading edge' scientific and technological expertise. If we examine the nature of its 'errors' we may find that the specific knowledge and information of this era was not so much wrong as incomplete.

In many respects, Modern architecture epitomises the emphasis of science and technology employed in the development of mass production processes and products.[3] This is not to say that Modern architecture was remiss in its application; other pertinent design issues were simply absorbed within the syntax of specific production processes.

A preoccupation with specific products over relative knowledge is evidenced in the transferal of Modernist designs from one culture to another. Building technologies that have been regionally developed and applied can yield enormous public benefit. However, the same application transported to another culture and climate may have costly and destructive consequences.

The failure of new technologies to adapt to other environments reflects a limited understanding of conditions that are relative to the specific technology. It stands to reason that the Architect's specific technological expertise must be balanced by an equal understanding of those relative issues.

Shades of green: ten key issues that need to be considered to create a fully green architecture

- Low energy/high performance
- Replenishable sources
- Recycling
- Embodied energy
- Long life, loose fit
- Total life cycle costing
- Embedded in place
- Access and urban context
- Health and happiness
- Community and connection[4]

Introduction

Those issues begin to emerge when we look at countries like Canada that endure a substantial share of the kind of International Style buildings that function well in moderate climates but perform poorly in colder regions. Thus far, we have compensated for design improprieties with enhanced heating and cooling measures and building maintenance with a subsequent increase in overall life-cycle cost.

Reference Case Projections

Table A1. World Total Energy Consumption by Region, Reference Case, 1990-2020
(Quadrillion Btu)

Region/Country	History 1990	History 1998	History 1999	Projections 2005	Projections 2010	Projections 2015	Projections 2020	Average Annual Percent Change, 1999-2020
Industrialized Countries								
North America	**99.9**	**113.1**	**115.7**	**128.8**	**138.2**	**146.9**	**155.6**	**1.4**
United States[a]	84.5	94.7	96.7	107.9	114.1	120.7	127.0	1.3
Canada	10.9	12.4	12.8	14.3	15.4	16.0	16.6	1.2
Mexico	5.0	6.0	6.1	7.5	8.7	10.1	11.9	3.2
Western Europe	**59.9**	**65.7**	**65.9**	**71.5**	**74.5**	**77.3**	**80.7**	**1.0**
United Kingdom	9.2	9.8	9.8	10.6	11.1	11.7	12.1	1.0
France	9.3	10.9	10.9	12.0	12.6	13.1	13.7	1.1
Germany	14.9	14.2	14.0	15.3	15.9	16.3	16.9	0.9
Italy	6.6	7.6	7.6	8.4	8.8	9.2	9.5	1.1
Netherlands	3.3	3.7	3.7	3.9	4.1	4.2	4.4	0.8
Other Western Europe	16.6	19.7	20.0	21.3	22.1	22.9	24.1	0.9
Industrialized Asia	**22.8**	**27.6**	**27.9**	**29.6**	**30.7**	**32.7**	**34.0**	**0.9**
Japan	17.9	21.5	21.7	22.8	23.5	25.1	26.0	0.9
Australasia	4.9	6.1	6.2	6.8	7.2	7.6	8.1	1.2
Total Industrialized	**182.4**	**206.4**	**209.6**	**229.9**	**243.4**	**256.9**	**270.4**	**1.2**
EE/FSU								
Former Soviet Union	61.0	38.8	39.3	43.2	46.4	51.8	55.8	1.7
Eastern Europe	15.3	11.9	11.3	12.7	13.9	15.3	16.5	1.8
Total EE/FSU	**76.3**	**50.7**	**50.5**	**56.0**	**60.3**	**67.2**	**72.3**	**1.7**
Developing Countries								
Developing Asia	**51.0**	**72.9**	**70.9**	**92.4**	**113.4**	**137.0**	**162.2**	**4.0**
China	27.0	35.4	32.0	43.2	55.3	69.1	84.1	4.7
India	7.8	11.6	12.2	15.5	18.4	22.2	26.1	3.7
South Korea	3.7	6.9	7.3	9.2	10.3	11.6	13.2	2.8
Other Asia	12.6	19.0	19.5	24.6	29.3	34.0	38.8	3.3
Middle East	**13.1**	**19.1**	**19.3**	**22.5**	**26.9**	**31.7**	**37.2**	**3.2**
Turkey	2.0	3.0	2.9	3.5	4.1	4.7	5.4	3.0
Other Middle East	11.1	16.1	16.4	19.0	22.9	27.0	31.8	3.2
Africa	**9.3**	**11.6**	**11.8**	**14.3**	**16.1**	**18.6**	**20.8**	**2.7**
Central and South America	**13.7**	**19.4**	**19.8**	**24.3**	**29.6**	**36.2**	**44.1**	**3.9**
Brazil	5.4	7.8	8.1	9.6	11.5	13.5	16.0	3.3
Other Central/South America	8.3	11.6	11.7	14.7	18.1	22.7	28.1	4.3
Total Developing	**87.2**	**123.0**	**121.8**	**153.5**	**186.1**	**223.4**	**264.4**	**3.8**
Total World	**346.0**	**380.0**	**381.8**	**439.3**	**489.7**	**547.4**	**607.1**	**2.2**
Annex I								
Industrialized	177.4	200.3	203.4	222.4	234.7	246.7	258.5	1.1
EE/FSU	64.9	43.7	43.6	48.0	51.5	57.5	61.9	1.7
Total Annex I	**242.3**	**244.0**	**247.0**	**270.5**	**286.1**	**304.2**	**320.3**	**1.2**

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in Australasia.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Energy totals include net imports of coal coke and electricity generated from biomass in the United States. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.

Sources: **History:** Energy Information Administration (EIA), International Energy Annual 1999, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001) (Washington, DC, December 2000), Table A1; and World Energy Projection System (2001).

Energy Information Administration / International Energy Outlook 2001 175

Fig. 1

Relative Issues

Volatile world markets and dwindling fossil fuel resources in the latter half of the twentieth century have increased energy costs to the point that compensatory heating and cooling measures are no longer economically viable in Canada. Climatologically inappropriate building design alone has created an artificial need for energy in Canada that distinguishes our country as being one of highest per capita consumers of energy in the world today.

Canada is not alone in this regard but we do face a unique dilemma. Countries in Europe have a long, living history of building traditions as a reference towards the advancement of sustainable building practice. Not surprisingly, these countries are not only getting back on track but according to Peter Buchanan are well ahead of North America not just in using known sustainable building strategies but in innovation as well.[5]

Fig. 2. Modern multi-unit dwellings, Calgary, Canada

Fig. 3. Modern 4-plex, Calgary, Canada

Relative issues

Much of North America's urban growth (western Canada in particular) took place during the height of Modernism's International Style. Given the limited variety of building stock in many of our Canadian cities, it is difficult for us imagine that the quality of built environment for most Canadians could be substantially improved upon in a more cost effective manner than we currently support.

Fig. 4

Fig. 5

Relative issues

This problem is critical in the Canadian North where building technologies designed for moderate climates perform abysmally in extreme cold. The average life span for a typical CMHC approved low cost bungalow in the Canadian North is 6 to10 years. If that isn't bad enough, basic shelter that malfunctions compromises health in children and adults, leading to chronic illness, learning and working disabilities that inhibit productivity, independence and life-span, not to mention quality of life.[6]

Ironically, solutions lie in specific, technical issues that are well within our grasp. It's our incomplete understanding of relative issues and perhaps our inability to fathom the extent of their repercussions that overwhelms us.

Fig. 4. & 5. Climatologically inappropriate house designs in western Canada. Large, west facing windows unprotected from solar gain; north/east basements exposed to prevailing winter winds.

Fig. 6. Anticoli Corrado, near Rome, a history of sustainable building practices

Communal enterprise

Not to trivialize the success of our distant relatives but Europe could be seen as simply experiencing a ‘renaissance’ in sustainable building design. If the predominant architectural paradigm in Canada is no longer working, what do we replace it with? Bernard Rudofsky describes the difference between orthodox architecture, as exemplified by the international style to vernacular idioms. “In orthodox architectural history, the emphasis is on the work of the individual architect; [in vernacular architecture] the accent is on communal enterprise”[7]

The holistic notion of communal enterprise as a condition of sustainable building and urban design is not a new idea. Sustainable building practices are based on principles founded in architectural traditions that sometimes predate recorded history.[8] The fact that some of the oldest buildings in the world stand to out live much of their modernist progeny suggests a reexamination of vernacular building practice is in order.

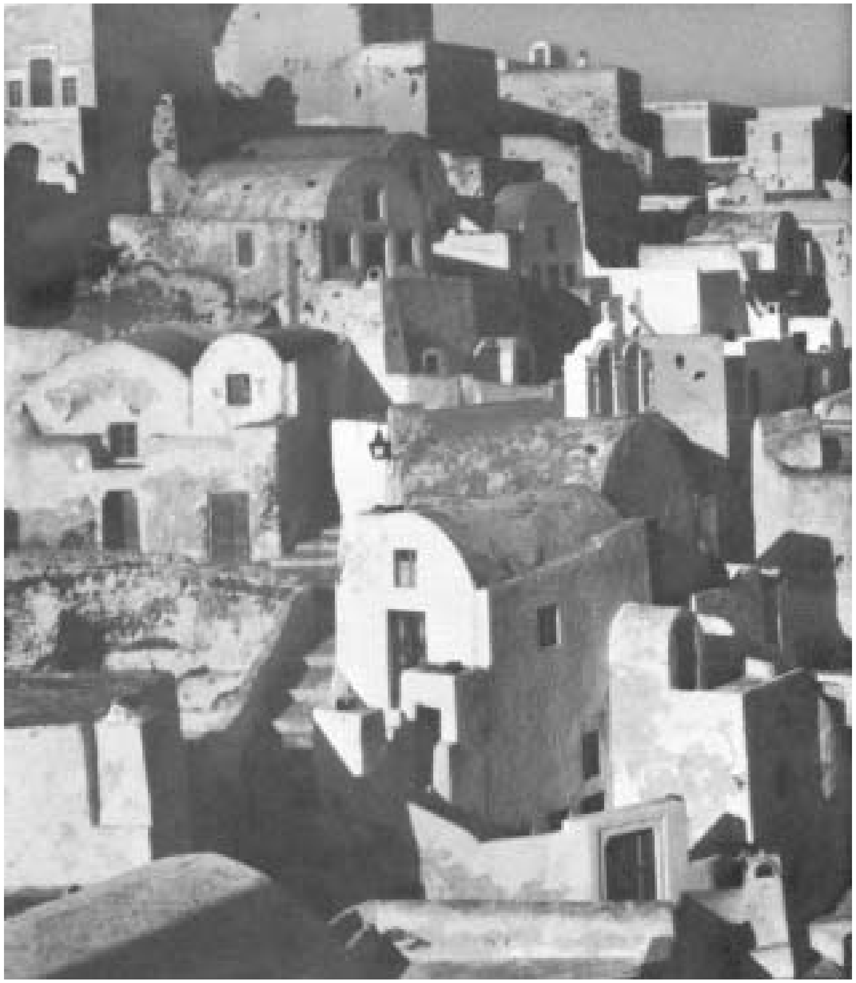


Fig. 7. Continuity in communal enterprise

Communal enterprise

Vernacular architecture is characteristic of every existing culture in the world. What distinguishes vernacular from the predictability of stylistic convention is attitude. Unfettered by 'orthodox' architectures obligation to do things the 'right way', the vernacular is free to do things the best way. The appearance of tradition is not essential to Vernacular architecture. It relies on the empirical strength of traditional methods and materials as a point of departure and progresses through consideration of functional efficiency in interior program and as an integrated component of existing site conditions and the extended community.

Fig. 8. Progressive vernacular in contemporary design

> "An architect is in a unique position to revive people's faith in their own culture."[9]
>
> Hasan Fathy

Communal enterprise

Many of the sustainability concepts we consider in design are technologically specific and rightly so. "Buildings account for nearly half the energy consumption in developed countries"[10]. We consider issues of embodied energy, capital vs. life cycle cost, the impact of a building footprint on the environment, alternative energies and the strain on natural resources, animal habitat and water supplies when we build. We've come to appreciate the fragility of our world and the responsibility we have, as designers, to treat the natural environment with reverence. But as humans, we tend to ideologically separate our selves from our collective concept of 'the natural world' to the detriment of nature and humanity.

Architects who employ vernacular methods in sustainable design may understand that concepts like the fragility of nature, our ethical imperative to preserve it, and the methods we employ to manifest our ideals are incomplete unless we expand our concept of the natural world to include our own fragile and imperfect species. We do well to remind ourselves that given the current state of our environment, it is not the well being of our planet that is in peril but our own existence.[11]

Hassan Fathy

Figure 1 Gouache of Abd al-Razik house. The image observes the ancient Pharaonic convention of flattened perspectives.

Introduction

The architecture of Egyptian architect, Hassan Fathy, is ultimately guided with a conviction toward the harmonious coexistence between man, the environment and architecture. Fathy's efforts toward this reconciliation involve the use of traditional methods that rely on natural energy from the sun and wind. Responding to the challenge of designing for hot, arid and warm humid climates Fathy used the following design strategies:

1. Structural form and orientation to take advantage of the natural elements
2. Use of natural and locally available materials
3. Use of traditional architectural elements such as lattice wood shutters (Mashrabiya), wind traps (malqaf), domes and vaults as roofing elements and the courtyard house prototype and;
4. Traditional construction methods.

Hassan Fathy believed that an architect has a responsibility to develop an intimate awareness of the particular habitat and the culture of which he is designing. Only in this way can an appropriate design strategy be devised that takes advantage of the natural energies of the sun and wind.

Materials

Building materials are of integral importance for the protection against heat or cold. The material's physical properties, such as thermal conductivity, resistance and transmission and optical reflectivity must be carefully considered.

Thermal transmittance, from one side of a wall to the other, is reduced by increasing the thickness of a wall or, by using materials of lower thermal conductivity and therefore of higher resistance.

Experiments done in Cairo, Egypt have proven that mud brick is most appropriate for achieving thermal comfort in addition to being locally available to all segments of the population. **(Figures 2 and 3)** The graphs show a comparison of indoor and outdoor air temperature fluctuations within a 24 hour period.

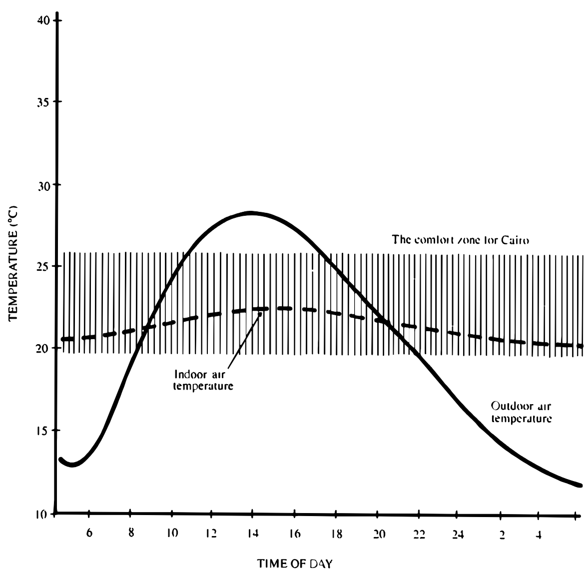


Figure 2 Comparison of indoor and outdoor air-temperature fluctuations within a 24 hour period for the mud brick test model.

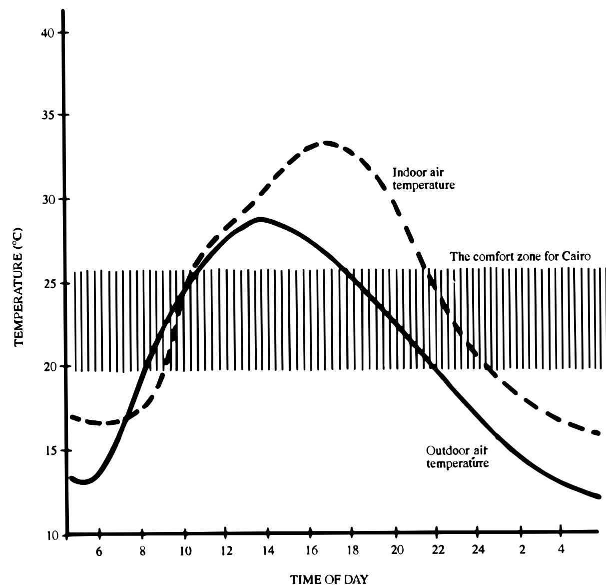


Figure 3 Comparison of indoor and outdoor air temperature fluctuations within a 24 hour period for the prefabricated concrete test model.

Orientation

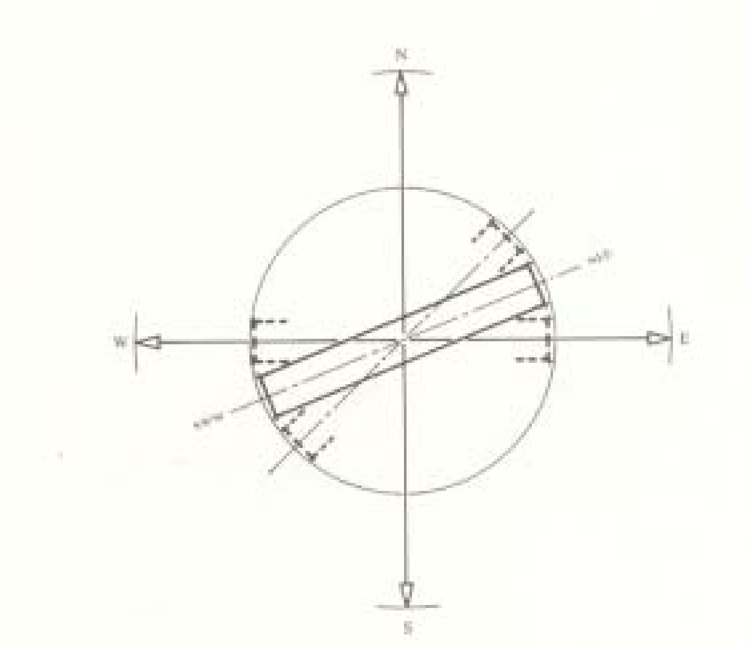


Figure 4 Optimal orientation of a row of houses with regard to both sun and wind.

The main objective in planning a site, where the sun is the major source of heat, is to establish the optimum orientation with regard to the sun and the prevailing wind.

For example, in considering a block consisting of a single row of buildings in Cairo, the optimum orientation with regard to the sun factor is east west. However the optimum orientation with regard to the wind is a northeast to southwest alignment so the wind will be exposed as much as possible to the long surface, as the cool wind blows from the northwest. The obvious solution would be to orient the row from north-northeast to south-southwest, bisecting the angle between the two optimal orientations. **(figure 4)** This would be correct if the windows served as inlets and outlets to ensure air movement.

Hassan Fathy

Orientation

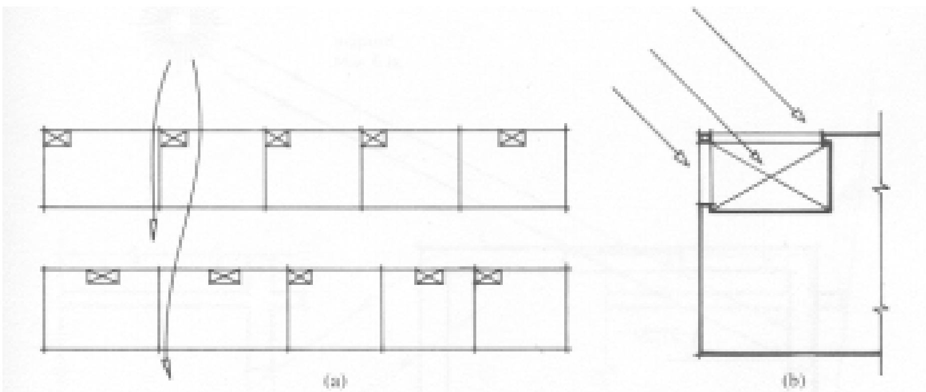


Figure 5 Plan for two rows of houses showing the malqaf or wind catch of each arranged to bring wind to the dwelling (a), and details of a malqaf(b).

However, the **malqaf** or windcatch was devised whereby air high above a building can be captured and forced through the interior. The use of the malqaf solves the wind problem allowing the row to be aligned eastwest, which is optimal for the sun. **(figure 5)** The malqaf is an innovation that allows for flexibility in design with regard to the wind factor and allows for the orientation of buildings with respect to the sun factor.

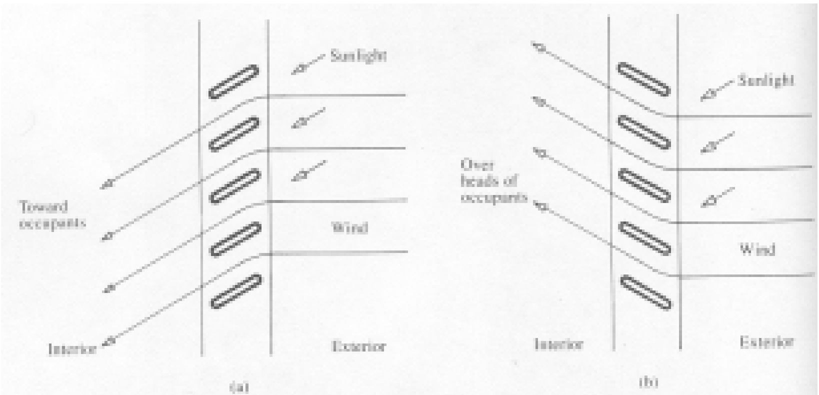


Figure 6 Difficulty in adjusting Venetian blinds in summer: (a) the position for the optimal direction of the air movement in undesirable with regard to sunshine: (b) the optimal position for blocking sunlight is undesirable with regard to the wind direction.

Sun

For those sites where the optimal orientation is not feasible, an appropriate means of shading, depending on its orientation, is required.

Window openings serve to let in sunlight and air and to provide a view. The size, form and location of windows are determined by the local climatic conditions. In hot arid climates it is unlikely that the three functions can be combined in a single architectural solution. Several solutions were developed:

The **Venetian Blind** – the adjustability is useful in regulating solar radiation and wind flow. The suns rays can be blocked out while allowing the breeze in. **(figure 6)**

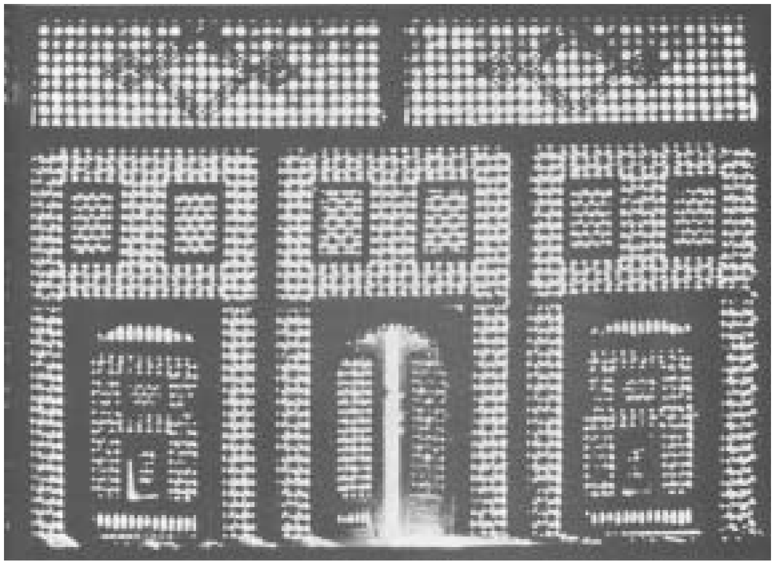


Figure 7 Brise-soleil in Boike, Ivory Coast.

Sun

The **Brise-soleil** – Generally used to shield entire facades of buildings. A properly designed brise-soleil reduces heat gain to at most one third. The brise-soleil is a transposition of the venetian blind, with the slat width increased to suit the scale of the entire façade. The result is a view slashed by large dark stripes which can be interspersed by offensive glare.**(figure 7)** However, it may be used advantageously, exercising due regard toward reduction of glare.

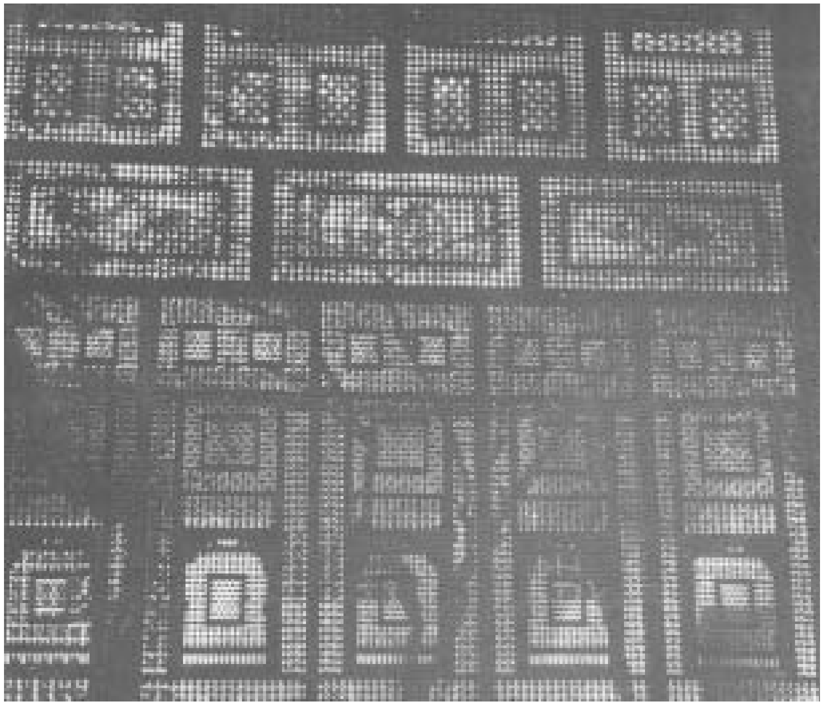


Figure 8 Mashrabiya in the As-Suhaymi house, Cairo.

Sun

The **Mashrabiya** - An opening with a wooden lattice screen comprised of small wooden balusters that are circular in section and arranged at regular intervals, often in a decorative geometric pattern. **(Figure 8)**

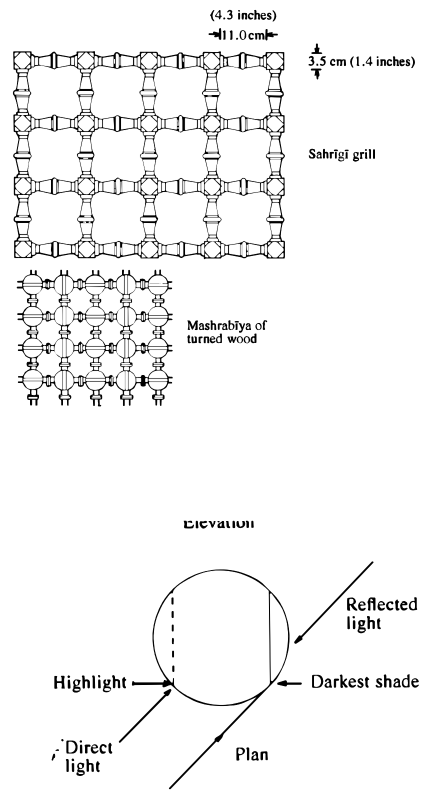
The mashrabiya serves five functions:

1. controls solar rediation
2. controls the air flow
3. reduces the air temperature
4. increases the humidity and
5. Allows for privacy

Each Mashrabiya is designed to fulfill several or all of these functions. It is the sizes of the interstices and the diameter of the balusters that are adjusted.

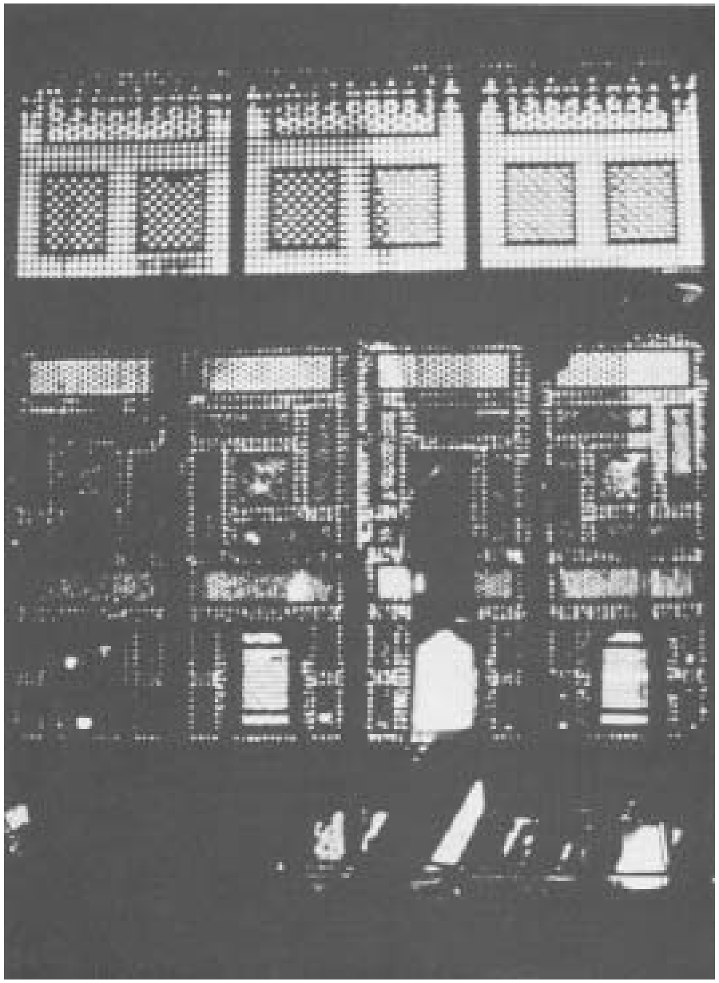
Hassan Fathy

Sun



The baluster, which are round in section, graduate the light falling on surfaces, softening the contrast between the darkness of the balusters and the brightness of the glare entering through the interstices. The eye is not dazzled by glare. **(figure 9)**

Figure 9 Analysis of light falling in a mashrabiya: (a) example of lattice arrangements; and (b) the effect of light falling on a cylinder. The graduated light and shade of the cylinder subdue the dazzling effect of contrast which occurs when looking from the inside toward the light outside.



Sun

Larger interstitial spacing of the upper part of the mashrabiya permits light to brighten the room above eye level, compensating for the dimming effect. **(figure 10)**

It's cooling and humidifying functions are closely related. All organic fibers, such as the wood of a mashrabiya, readily absorb, retain, and release considerable quantities of water. Wind passing through the interstices of the porous-wooden mashrabiya will give up some of its humidity to the wooden baluster when the balusters are cool during the night. When the mahrabiya is directly heated by sunlight, this humidity is released to any air that may be flowing through the interstices. In addition, the mahrabiya ensures privacy from the outside while at the same time allows the inhabitant to view the outside through the screen.

Figure 10 View of mashrabiya, showing it's effectiveness in reducing glare at eye level. Note the large interstitial spacing of the upper part of the mashrabiya, which permits reflected light to brighten the room above eye level, thus compensating for the dimming effect.

Sun

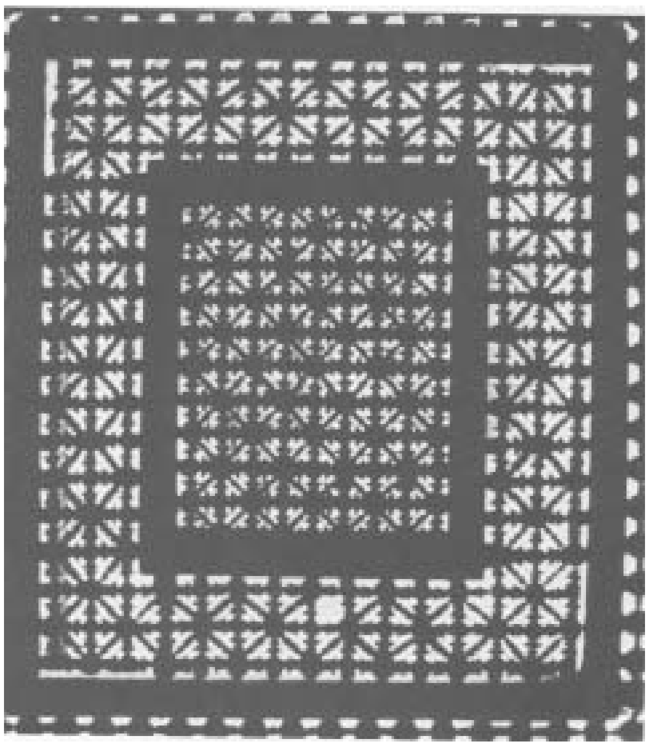


Figure 11 Mashraiya of the As-Suhaymi house, Cairo , photographed from inside with the camera focused on the lattice.

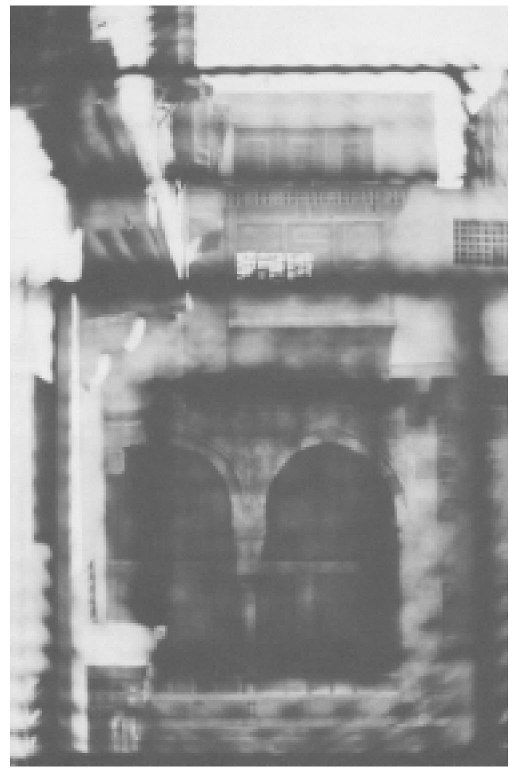
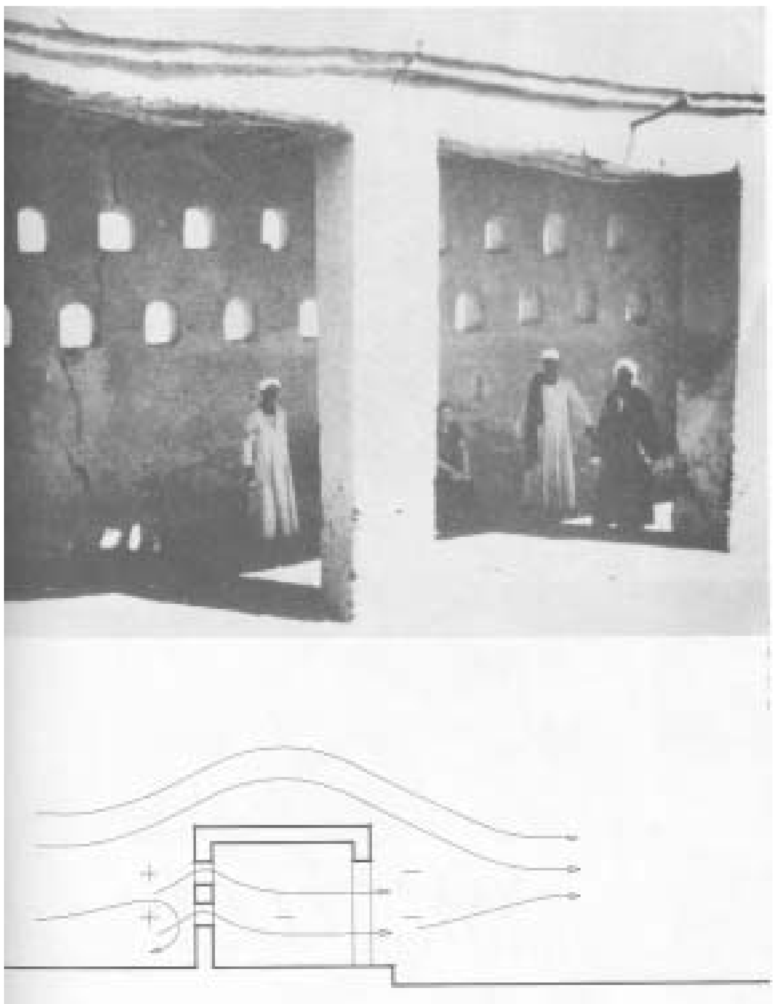


Figure 12 View through the mashrabiya shown in figure 11, with the camera in the same position but focused on the building across the courtyard.

Hassan Fathy



Wind Orientation

Natural air movement is can be achieved in architectural design through the following principle:

Differences in wind velocity produce a pressure differential, resulting in air flowing from the higher to the lower air pressure zones .

This principle, coined “Venturi action”,is based on the Bernoulli effect. According to Bernoulli’s theorem, the pressure of a moving fluid decreases as its velocity increases.

Indoor airflow is steadier in circumstances that depend more on the suction resulting from low air pressure than on the high air pressure caused by the force of wind. A window or opening will not create the desired air movement in a room unless an air outlet of some sort is also provided. Air movement is faster and steadier when the area of the openings on the leeward side of a structure is larger than the openings on the windward side. **Figure 13** shows schematically the airflow and pressure changes for this loggia.

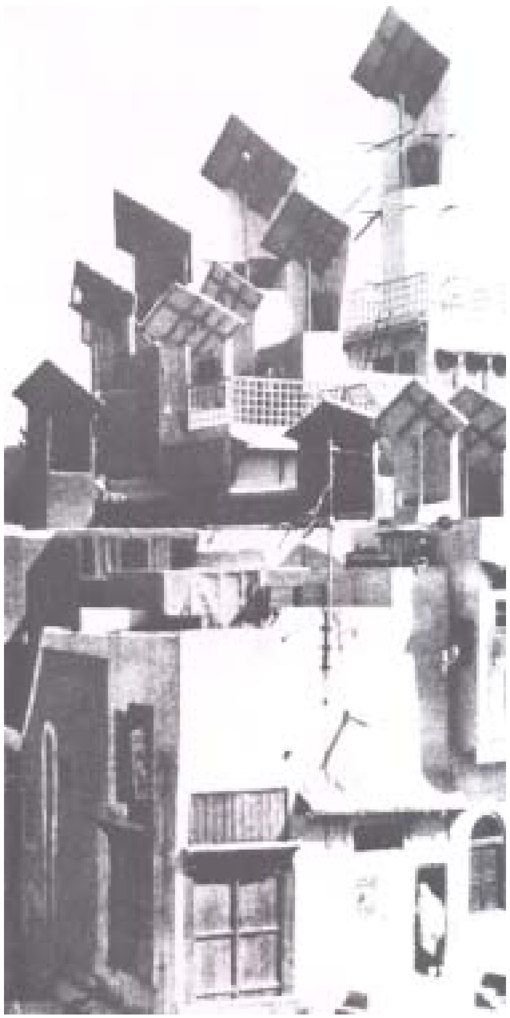
Figure 13 The top image shows a pierced wall in the windward side of the loggia of a guesthouse, Gourna, Egypt.

The lower image is a schematic drawing, showing the aerodynamic principles that provide a comfortable breeze in a loggia of the type shown in the upper image. The positive and negative signs indicate the regions of pressure buildup and deficiency, respectively.

Wind Orientation

Larger opening than those typically used in the mashrabiya can be used for ventilation and lighting. They are set at specific places in the building and are made up of lattice work. These lattices, called claustrum, were first used at high levels in the Roman baths. They are made in different decorative patterns of carved plaster plates, unlike the wooden mashrabiya. Claustra are used to evacuate the hot air that tends to collect in the higher areas of the room. They also serve to produce drafts over people. **(figure 14)**

Figure 14 Claustra in Dubai, United Arab Emirates.



Wind Orientation

The Malqaf – A shaft rising up above the building with an opening facing the prevailing wind. This shaft traps the wind where it is cooler and stronger and channels it downward into the interior of the building. There is no dependency on windows to ensure ventilation and air movement. The malqaf is also useful in reducing sand and dust which is prevalent in the winds of hot arid regions.

The malqaf is valuable in dense cities of warm humid climates where comfort depends on air movement within the building. **(figure 15)**

Figure 15 Use of the Malqaf in a village in the Sind province of Pakistan.

Hassan Fathy

Wind Orientation

The Wind-Escape –The suction caused by low air pressure zones to generate steady air movement indoors is used in the design of the wind escape. The funnel and side tube used to illustrate the Bernoulli effect are transposed into the structural elements of an architectural design in order to accelerate air movement and to create drafts in places where there is no exposure to the outside, such as in basements. **(figures 16 and 17)**

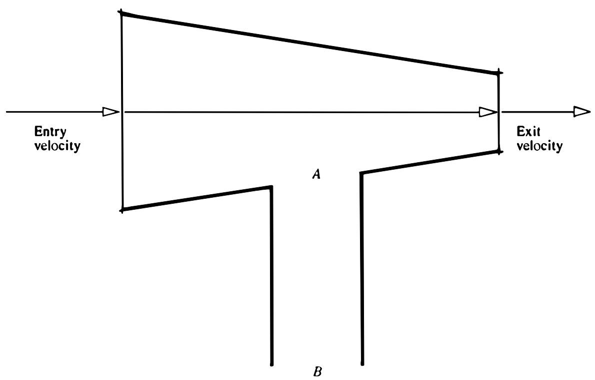


Figure 16 Funnel with a side tube to illustrate the Bernoulli effect.

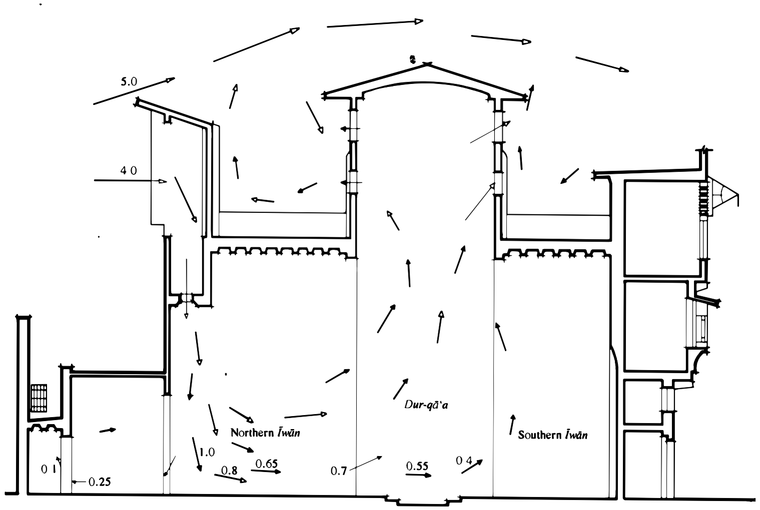


Figure 17 Section through the Qa'a of Muhb Ad-Din Ash-Shaf'I Al-Muwaqqi, showing how the malqaf and wind-escape produce internal air movement. Arrows indicate the direction airflow; arrow length corresponds to airspeed. All wind and air speeds are given in meters per second.

Roof

In hot arid countries, because the temperature drops considerably during the night, loggias or open galleries and lightweight roof covers are use. The loggias and roof covers shade the roof during the day and serve as a comfortable sleeping space at night. **(figures 18 and 19)**

Figure 18 Roof-terrace loggia in Iraq.

Figure 19 Roof-terrace loggia of a house in Rosetta, Egypt. The railing encloses an opening in the main roof through which hot air can escape from the lower floors during the day and cool air descends during the night.

Courtyard House

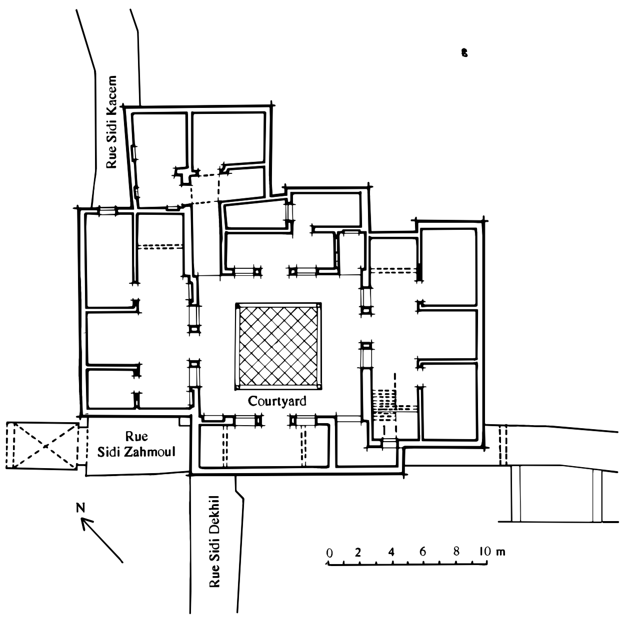
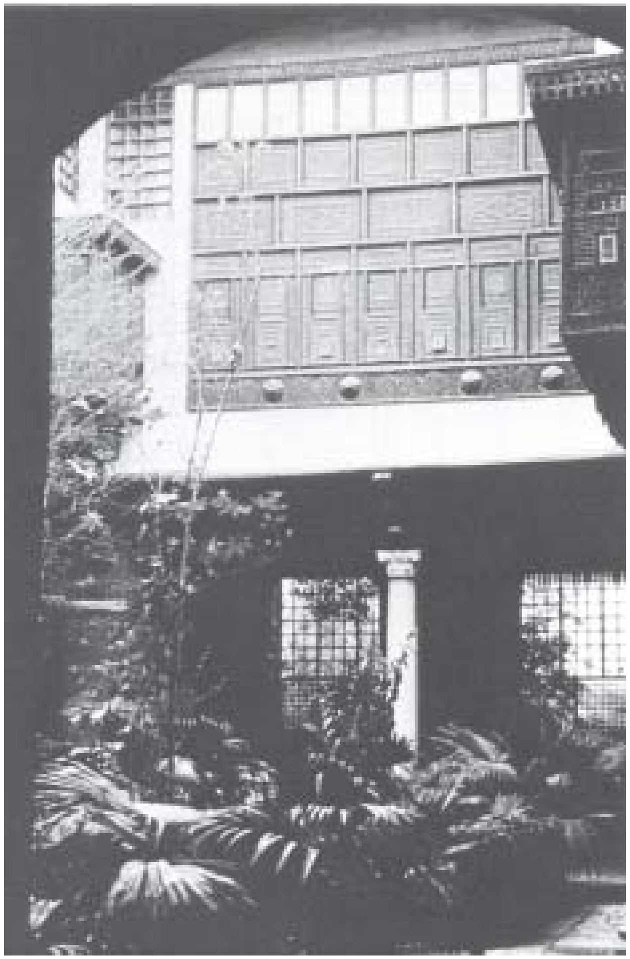


Figure 20 The plan of Dar Lajimi, a courtyard house, Tunis.

The Courtyard House – Because of hot arid temperatures, people learned to open their houses inwardly onto internal courtyards which are open to the sky. The courtyard is heated directly, by the sun and indirectly by the warm building. The warm air rises and is gradually replaced by the cooled night air from above. The cool air distributes into the surrounding rooms, cooling them. In the morning, the air of the courtyard, which is usually shaded by four walls, and the surrounding rooms heat slowly and remain cool until later in the day when the solar radiation begins to penetrate. The warm air during the day does not enter the courtyard but merely creates eddies inside. The courtyard is able to serve as a reservoir of coolness. **(figure 20)**



Takhtabush

The Takhtabush – A covered outdoor sitting area, situated between the courtyard and the back garden, opening onto the courtyard and through a mashrabiya onto the back garden. The heated air rising from the garden draws cool air from the courtyard through the takhtabush, creating a cool draft. **(figure 21)**

Figure 21 View of the As-Suhaymi house, Cairo, showing the courtyard and surrounding spaces with mashrabiya-filled openings. The recesses space behind the pillar is a takhtabush.

Hassan Fathy

Conclusion

Through his architecture, Fathy demonstrates the intelligent utilization of the sun and wind's natural energies toward providing a comfortable microclimate for the inhabitants of his buildings. This is based on the scientific understanding of the principles upon which they are based including an intimate knowledge of the building site's particular habitat and of the region's culture.

In this epoch of the search for renewal in the face of increasing environmental degradation, Hathy's effective harnessing of natural energies serves to prevent further degradation to the earth and its resources.

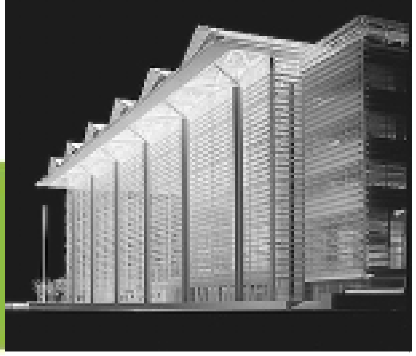
Regardless of world region, it would be beneficial for architects to appraise the conditions under which traditional solutions are valid. Traditional techniques may be improved using new technologies and knowledge and this is of course all dependent on a particular site and its particular circumstances.

With regard to the validity of the use of Hathy's principles within our own context here in Alberta we do have a lot to learn from Hathy as he would not use these particular principles here in Alberta. However, I believe Hathy would advocate a site specific strategy that would serve to optimize microclimate conditions particular to our region.

For example, the use of the mashrabiya is suited to hot arid climates. The wooden mashrabiya would deteriorate due to the moisture of the rain and snow we experience here in Alberta.

The use of the malqaf would probably function well in some form here in Alberta as a substitute for mechanical cooling in the summertime and it would also serve as ventilation.

Federal Building & United States Courthouse
Richard Meier Architect



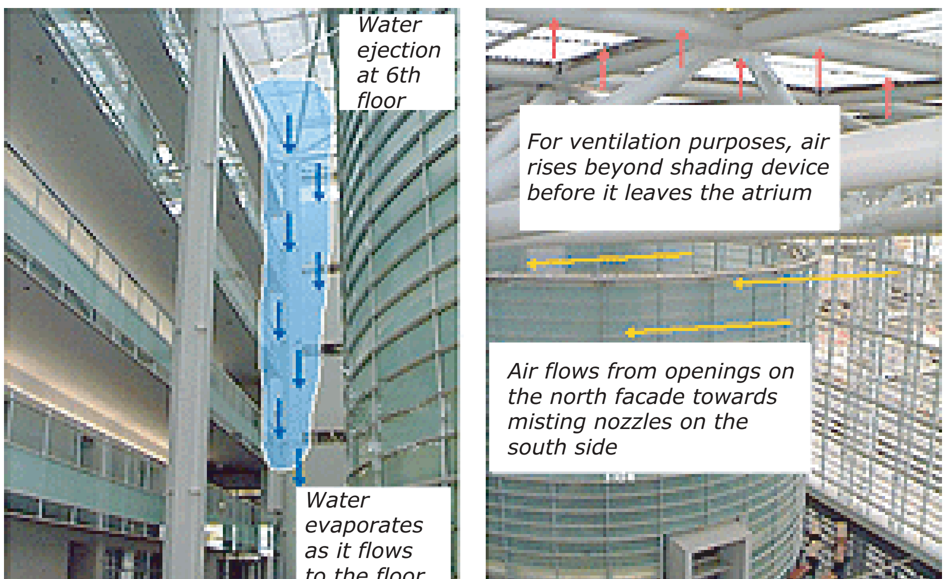
Building Overview

The Federal Building and United States Courthouse, also known as the Sandra Day O'connor Courthouse, is in Phoenix, Arizona. It was built between 1995-2000. It has the distinction of being the largest civic building in the U.S. thus far to be cooled by a system of evaporation[1].

The courthouse is essentially an enormous glass box in the desert, where temperatures can reach a summer day time high of 50 degrees celsius. The building is six stories tall and has a total area of 571,000 square feet. The structure is composed of an L-shaped concrete-frame block containing 18 courtrooms wrapping around a steel-frame glass atrium 120 feet tall. Within the atrium space are free-standing 'objects' such as the security checkpoint, glass elevator, L-shaped bank of balconies and courtrooms[2] and the spectacular 60 foot tall special proceedings court room glass drum that sits on a concrete base at the far end of the atrium.

The atrium is designed as an intermediate experiential space between the extreme temperatures outdoors and the fully air-conditioned courtrooms. The huge atrium would not be economically feasible without the passive cooling system[3] and careful attention paid to the building's orientation and fenestration.

View of the atrium with special proceedures courtroom at the back.



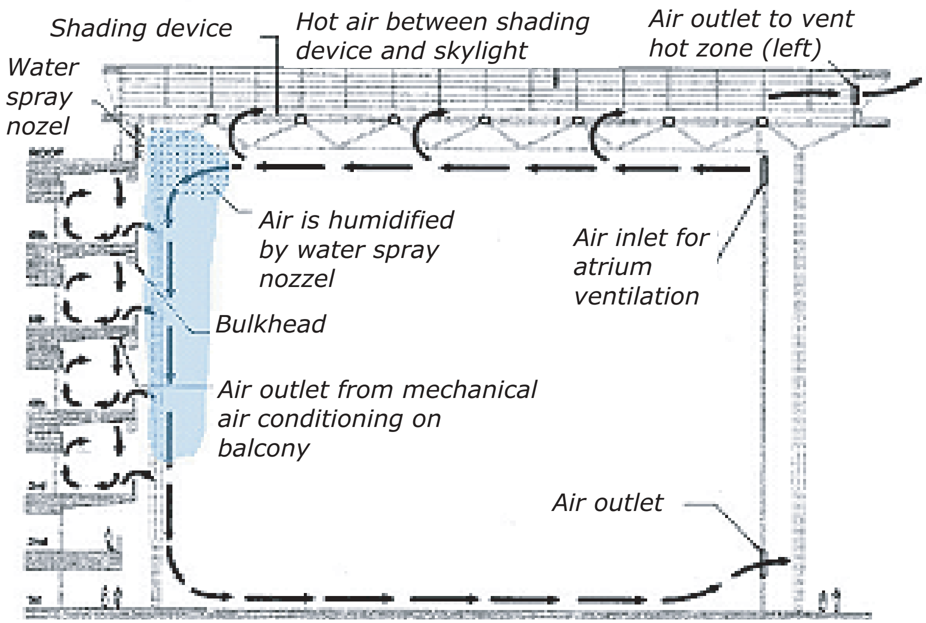
Air flow diagrams of adiabatic cooling system.

Optimize Energy Performance

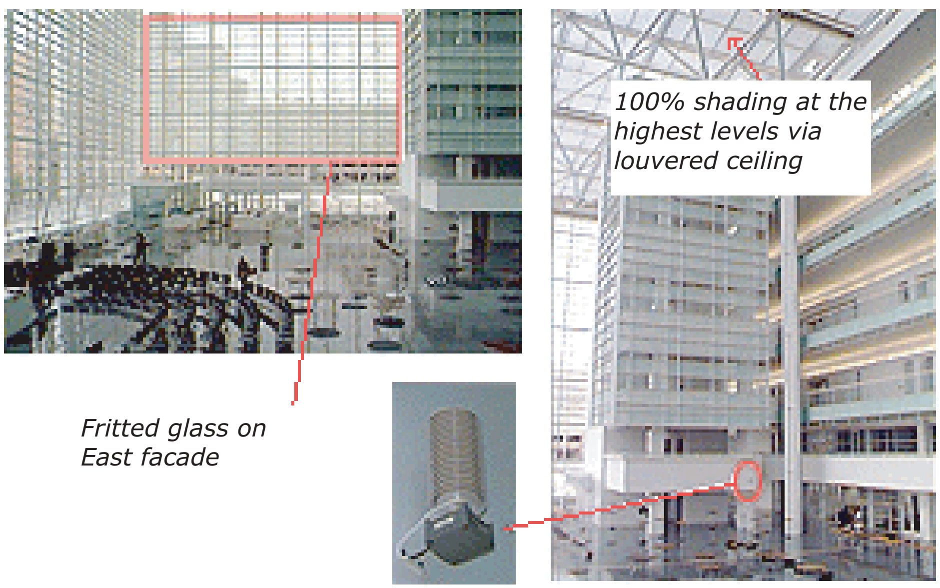
Adiabatic Cooling

The atrium is a transitional place and does not need to be fully air conditioned. "Inspired by the misting cooling systems that bring down the temperature of outdoor cafes in warmer climates, Richard Meier brought in the firm Ove Arup to design a similar system for the Phoenix courthouse. Ove Arup's evaporative cooling system brings outside air into the atrium just under the roof of the courthouse, where it moves across the space to the courthouse block. Here, air is sprayed with water from nozzles located along the sixth floor south corridor. As it absorbs the moisture, the air cools down and drops to the atrium floor, where it joins overflow air from the air-conditioned balconies and exhaust air from the enclosed portions of the building . The air then returns to the outside through slots about ten feet above the atrium floor on the east facade. By using this method, Ove Arup contends the temperature will drop at least 20 degrees on hot summer days."[4]

Adiabatic, or evaporative cooling, increases moisture evaporation and lowers sensible air temperature. Adiabatic cooling 'works' without changing the total heat content of the air. Increased moisture content of the air produces a rise in the latent temperature, this is similar to the difference between a 'wet' bulb thermometer temperature and a 'dry'bulb thermometer temperature. From the standpoint of human comfort, very hot, very dry air is improved by becoming less hot and more humid.[5] Evaporative cooling works very well in the desert climate of Arizona.



Sectional diagram of airflow in the courtyard of the building.

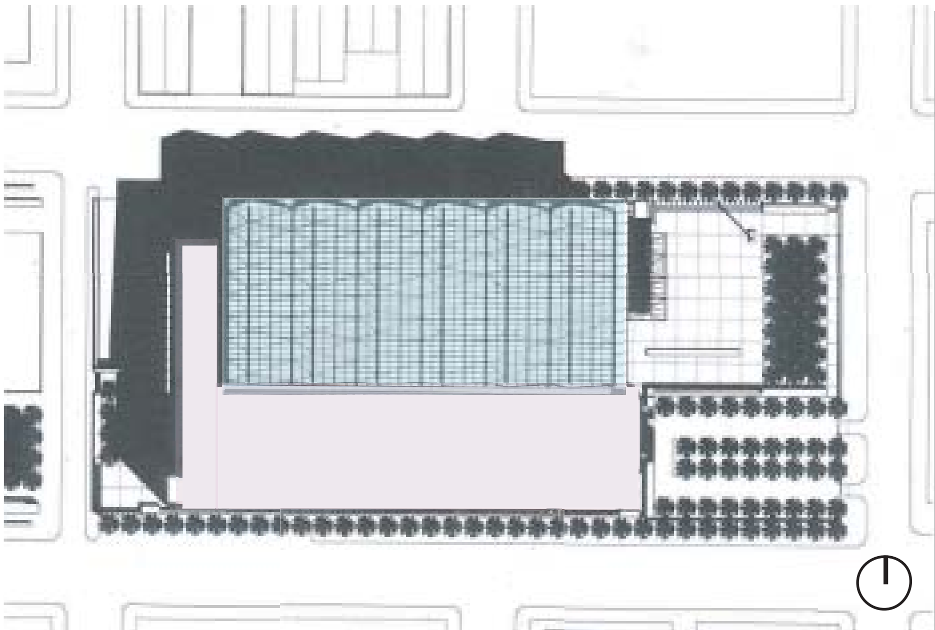


The atrium looking east, and location of one of three temperature/ humidity sensors.

Optimize Energy Performance

Solar Shading

Other passive cooling devices, such as louvers in the atrium's ceiling, foster a "temperate" (not air conditioned) climate.[6] Two walls of translucent ceramic-frit-and-transparent glass are held within a white lattice like frame and the filigree of trusses and skylights above give a sense of scale to the monumental atrium. The fritted glass and skylights shield the atrium from the hottest and most intense light and sun from above and the East and West. The special glass was selected for insulating and reflective properties that block 40-60% of the sunlight.[7] The largest glass facade is oriented towards the North, thereby preventing solar gains and allowing maximum ventilation.



Courthouse site map showing the orientation of the building, the glazed atrium is on the North side of the site and the concrete courthouse block is shown on the South and West.

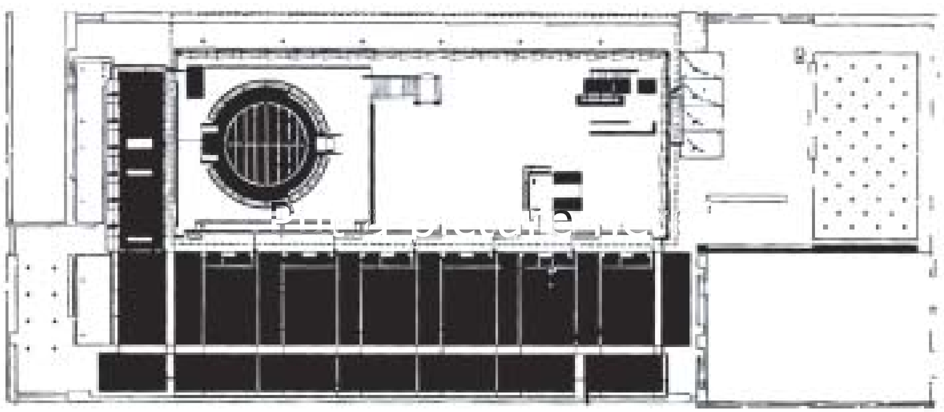


Figure ground diagram showing the concrete courthouse block on the South side of the site. The dark areas are solid, concrete parts of the building and the white areas indicate the glazed atrium, exterior plazas and interior hallways.

Optimize Energy Performance

Building Orientation and Solar Reflection

Two walls of translucent ceramic-frit-and-transparent glass are held within a white lattice like frame and the filigree of trusses and skylights above give a sense of scale to the monumental atrium. The fritted low-e glass and skylights shield the atrium from the hottest and most intense light and sun from above and the East and West.[7]

The concrete, L-shaped courtroom block has been positioned on the South side of the site to shield the atrium from excessive solar gains. White elements used to construct the building reflect sunlight and also help to defer cooling needs. The South elevation, as well as the rest of the building, acts as a double skin for the building. In effect the glazed exterior is a large container for the discrete building elements contained within its volume. This allows all the circulation spaces to act as buffer zones for the cooled courtrooms and office spaces, The double-skin strategy saves energy by allowing for a greater variety of temperatures within the building envelope.

For more temperate climates a strategy, opposite from that of Phoenix could work by closing the North side of the building and allowing the South side to act as a solar collector

Tribunal de Grande Instance
Richard Rogers Partnership

Picture illustrating architectonic elements of the courthouse.

Building Overview

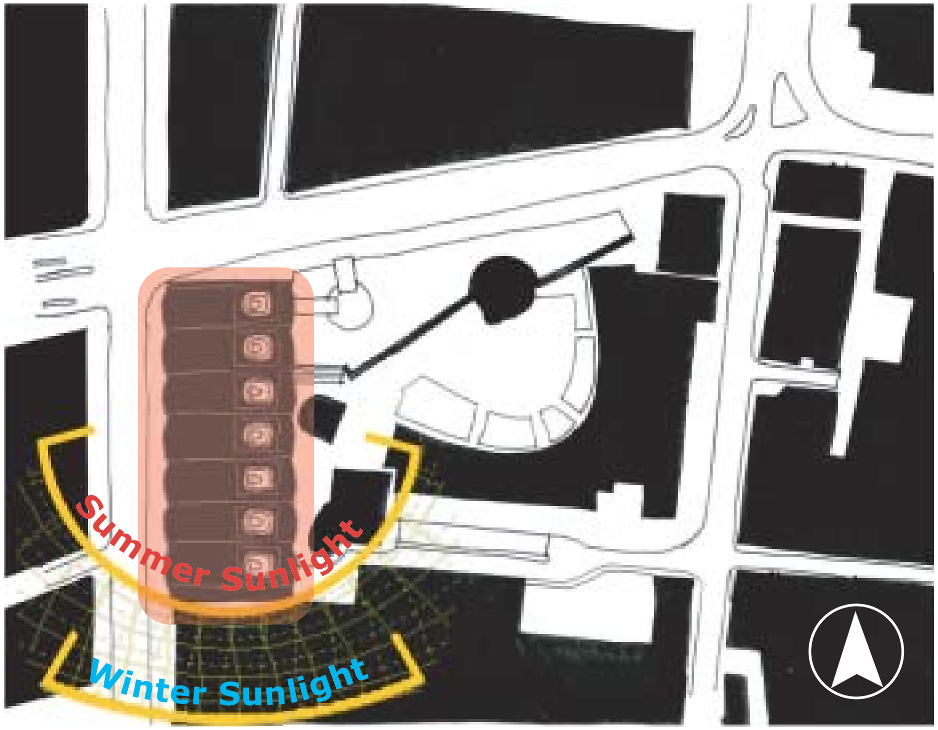
In 1992 the local municipality of Bordeaux, France held an invited competition for the design of a new law court, the main goal of which would be to demystify the stereotypically closed nature of the French judicial system. The winning concept, by The Richard Rogers Partnership, addresses this concern to demystify the judicial process by creating a building as a sequence of free-standing objects sited within a light weight, transparent envelope.[1]

The building positions itself ambitiously between the nineteenth century neoclassical Palais de Justice and the medieval walls of Fort Duha. A large stair crosses the reflecting pool to the east, providing public access to the courtrooms.

The courthouse is composed of four distinct architectonic elements. The first is a row of seven capsule-like volumes clad in western red cedar, these house the various courtrooms. The second, a narrow atrium spanned by steel gangways, links the courts to a five-storey administrative block (the third element). The fourth is the light weight, undulating copper roof.

Sustainable Characteristics Examined:

Siting & orientation strategies
Ventilation & cooling via the stack effect
Thermal massing & storage
Embodied energy



Siting Strategy & Seasonal Solar Gain

Siting Strategy

1) Urban redevelopment

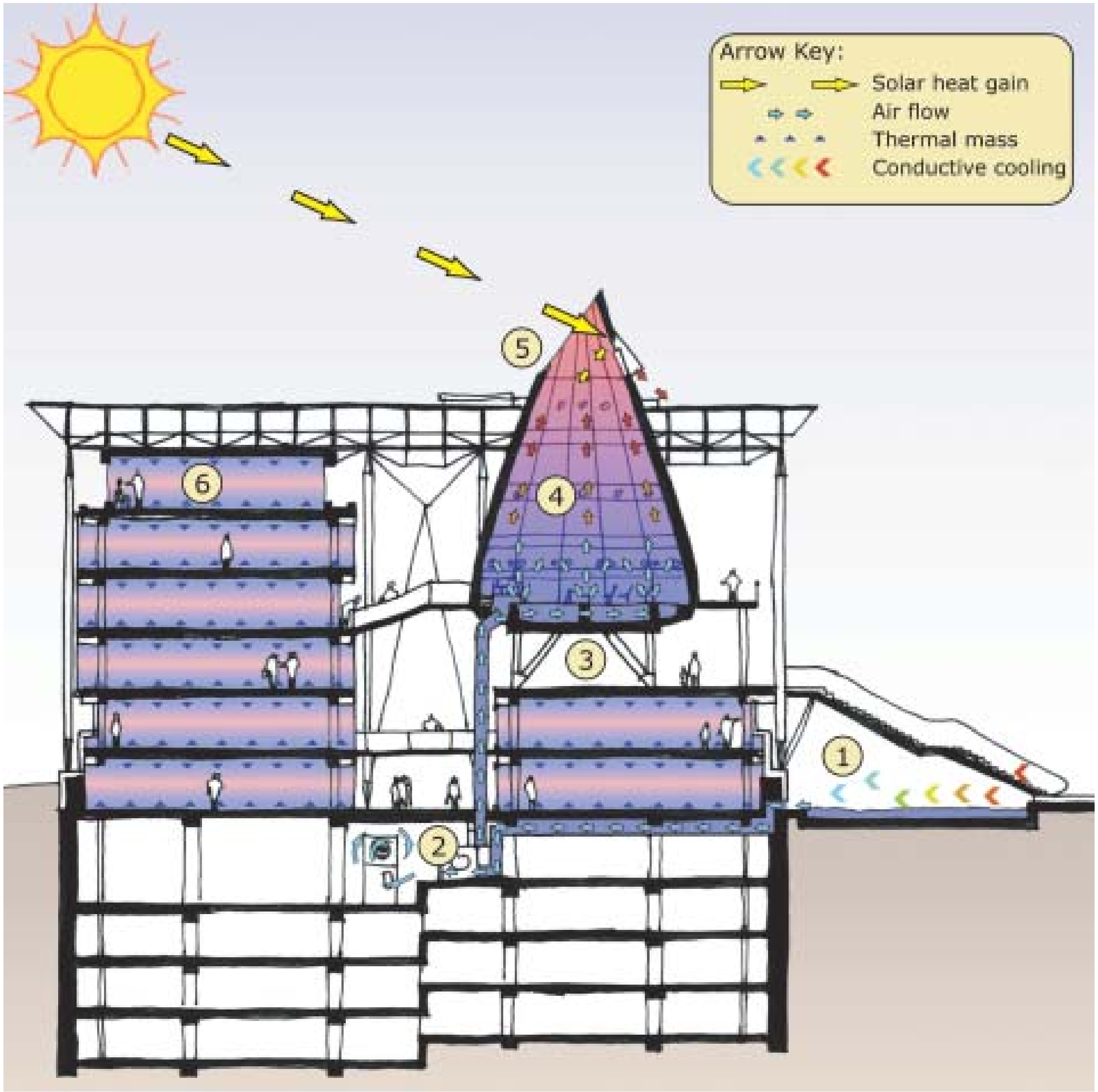
The building is constructed within the dense urban core of the old city taking advantage of both the proximity to the existing Palais de Justice and existing urban infrastructures. This reduces infrastructure costs and decreases the transportation load for the City of Bordeaux.

2) Building Orientation

The building is sited with its longitudinal axis oriented north-south. This orientation provides maximum daylight exposure by reducing the amount of the building perimeter with northern exposure, while minimizing the thermal gain from the southern sunlight. The conscious decision to allow for maximum daylight penetration, increases ambient light levels, therefore drastically reducing the electrical lighting loads and improving occupant comfort.

3) Plan

The Tribunal de Grande Instance utilizes a narrow floor plate. This not only facilitates daylight penetration, but also allows for natural ventilation in lieu of air-conditioning.



*Cross section illustrating ventilation and cooling *

Ventilation & Cooling

1. The reflecting pool acts as a giant heat-sink. Air intakes draw the warm air across the surface of the water. As the air contacts the cooler surface of the water it looses heat and is gradually cooled. This process is called conductive heat loss.

2. Air is drawn into the building, passing through a heat-exchanger, providing additional cooling.

3. Air at low velocity is provided at the occupied zone of the courtrooms via a raised-floor and in-floor diffusers.

4. As the air is warmed by occupants, equipment, and lighting. The stack-effect causes the air to rise.

5. Additional heat is provided at the top of the courtroom pods via solar gain. The extra heat, in conjunction with a small horsepower motor, serve to promote the evacuation of warm exhaust air through openings in the lee of the top of the court.

6. Cool air is drawn into the office accommodation through the hollow ribs in the floor structure, making maximum use the thermal mass of the concrete to provide cooling.

Ventilation & Cooling

Convective Ventilation by Stack Effect

The Tribunal de Grande Instance utilizes an energy efficient method to ventilate the building called the stack effect. This is a naturally occurring phenomenon that is induced when temperature differences between the warm air inside a building and cool air outside cause the air in the building to rise and exit at the ceiling or roof. As the warmer air is pulled out the top it is replaced by cool air that is drawn in via lower openings in the building. The rate at which air is drawn through the building depends on several factors, the inside and outside air temperatures, the area of the openings, and the height difference between the top and bottom openings. A common use for stack effect is to provide night time flushing of a building's interior, to cool it for the next day (refer to diagram).

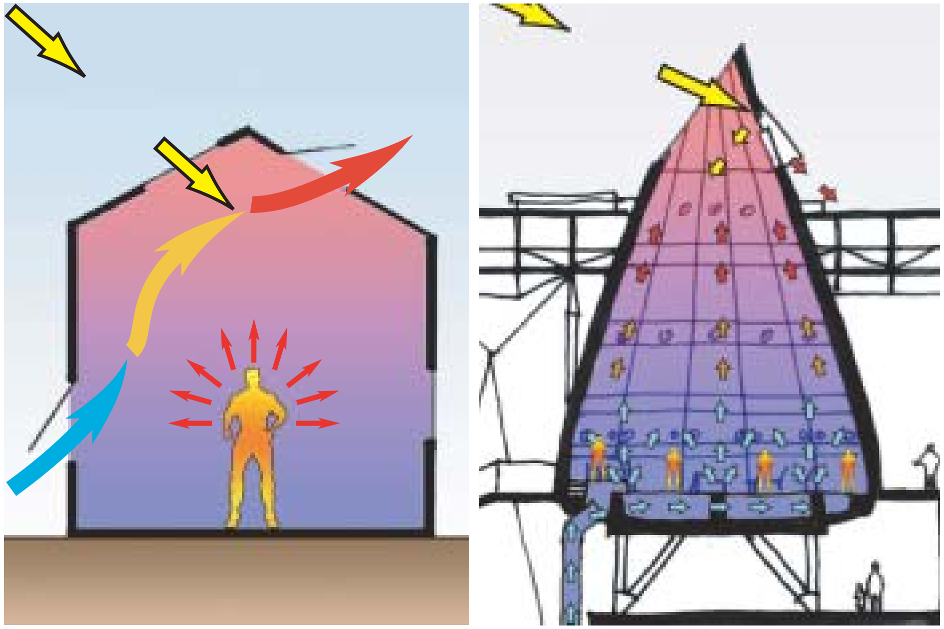


Diagram Illustrating the Principle of Stack Effect

Heating & Cooling by Thermal Storage

An alternative method to reduce indoor air temperatures and cooling load, is to store heat in the structural materials of the building. The storage material is the construction mass of the building itself, which is referred to as a thermal mass. It is typically contained in walls, partitions, ceilings and floors, constructed of material with high heat capacity such as poured concrete, bricks and tiles.

The thermal mass of the building has a positive effect on indoor conditions during summer and winter periods. The energy available from southern solar gains during the day is absorbed and then slowly radiated back into the building at a later time. In winter, the stored heat is transferred back into the room in late afternoon and evening hours, when it is most needed, satisfying part of the heating load and avoiding overheating and discomfort during high solar radiation periods of the day. In summer, heat is stored in the thermal mass, thus reducing the cooling load peaks and is progressively released into the interior of the room at a later time (refer to diagram).

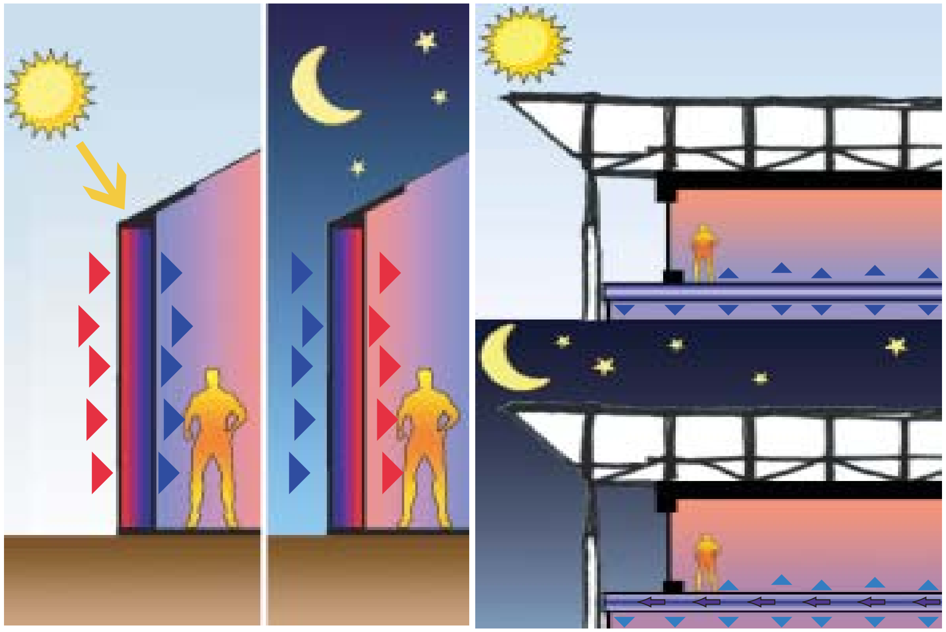


Diagram Illustrating the Principle of Thermal Massing

Tribubal de Grande Instance - Richard Rogers Partnership

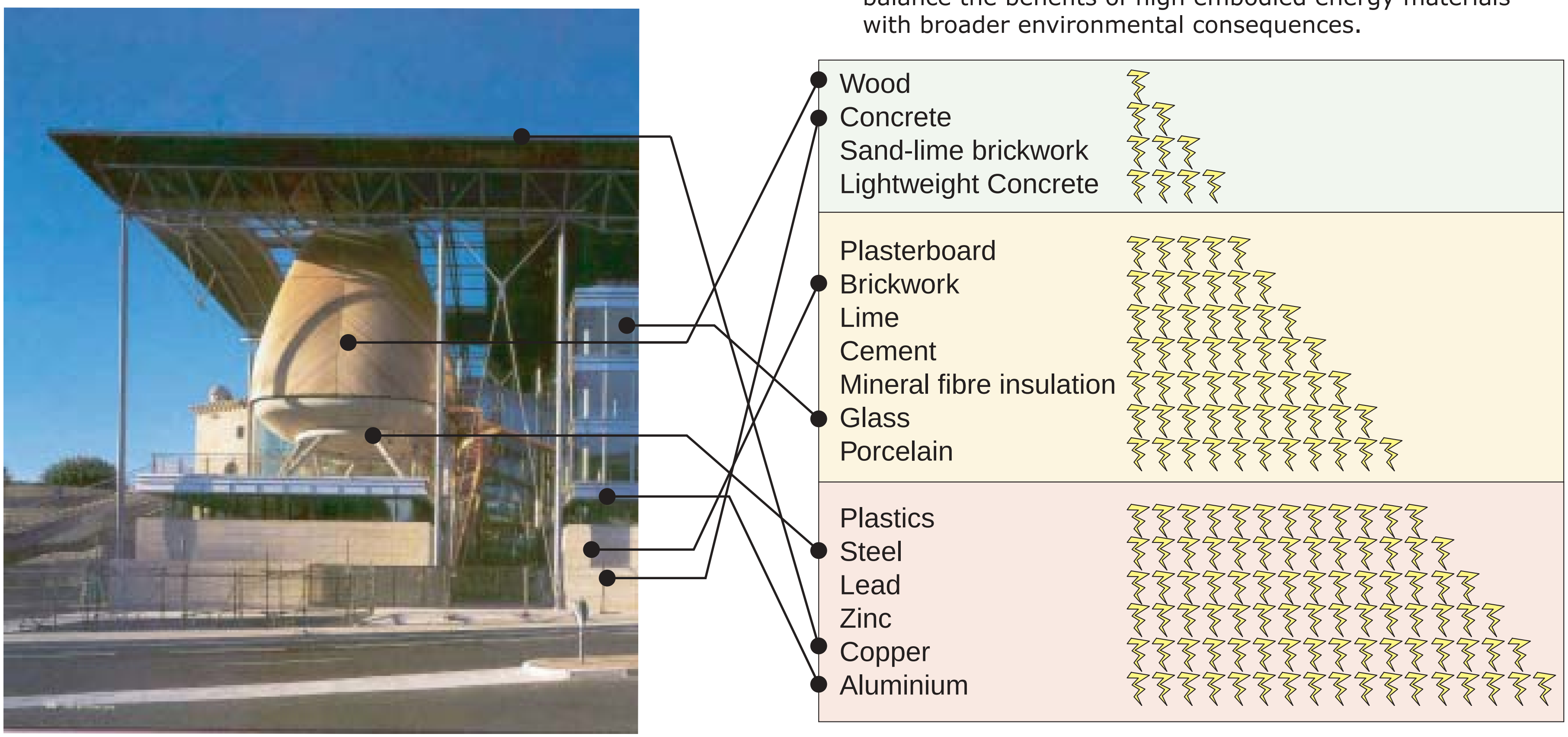
Embodied Energy

Traditionally, when asked to tally how much energy a building consumes, we add up the energy that is used every day to keep it running - heating, cooling, ventilation and lighting. However, it also takes energy to make a building. This energy of production - or *embodied energy* - accounts for all the energy required to extract raw materials, process them into building supplies, and to finally transport and install them on site.

The Tribunal de Grande Instance serves to illustrate this concept due to its apparent complexity: it uses a wide variety of materials, each with their own embodied energy values.

The structure crosses the entire spectrum of embodied energy - from the low index wooden courtooms to the high index aluminium office windows.

If adopting a sustainable building approach necessitates the use of low embodied energy materials, this courthouse would seem unsustainable due to its liberal use of copper and aluminium. However, aluminium is a primary component of super-efficient windows, which contribute to significantly lower energy consumption during a building's life. This points to a dilemma: energy efficient materials (sustainable) are often very high in embodied energy due to intensive manufacturing processes (unsustainable). A sustainable building approach is therefore one that seeks to balance the benefits of high embodied energy materials with broader environmental consequences.

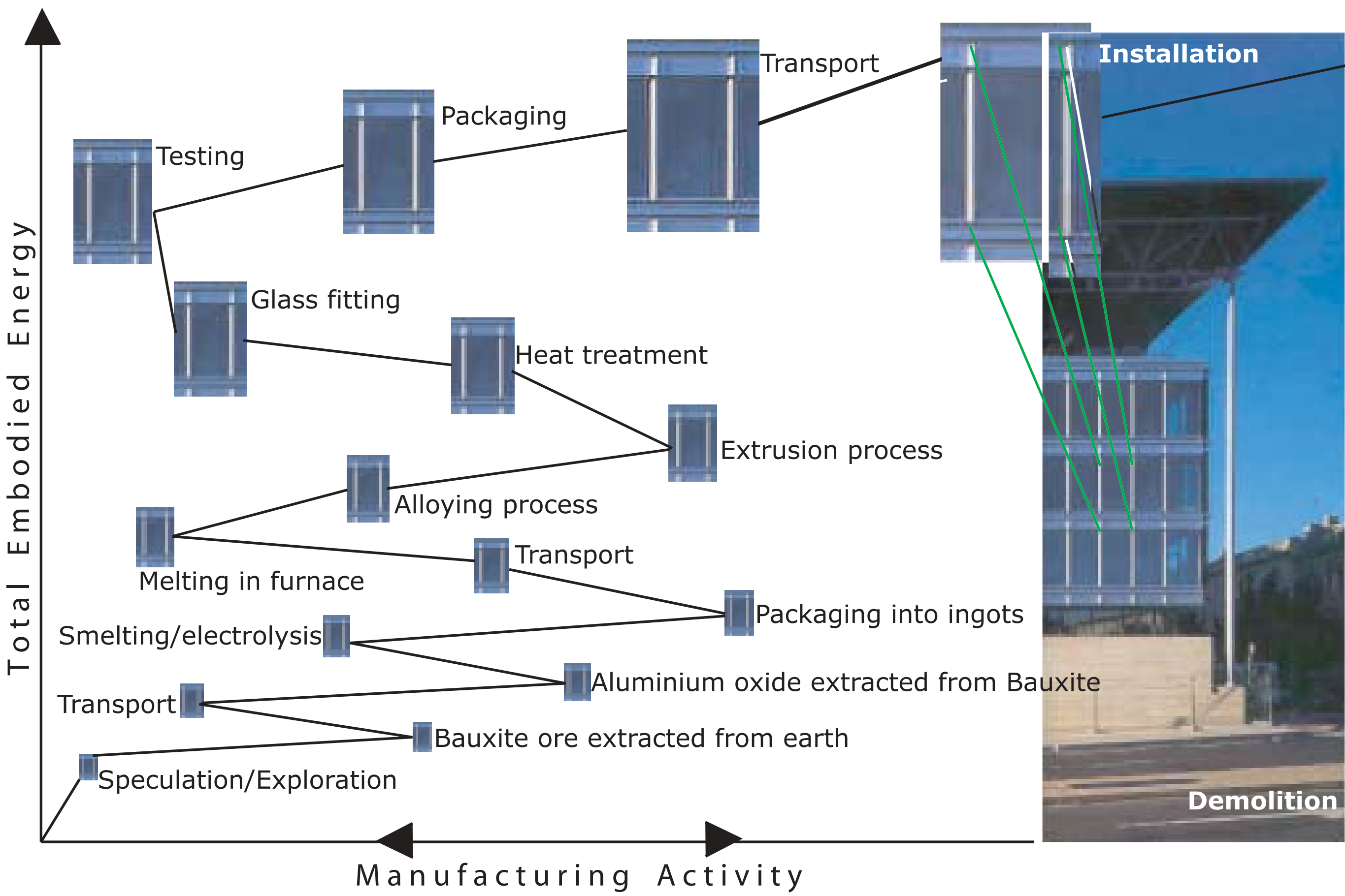


Embodied Energy - Strategies for Reduction

The graphic below illustrates the embodied energy in the courthouse's aluminium windows. From the time raw material is sought out, to the final moment of installation, the energy consumed by the window continually grows. If the building is eventually demolished, all of the energy invested is rendered useless. However, if the building uses recyclable windows - as the courthouse does - the energy in the window is passed on to the next project at marginal gains in embodied energy. That is, the window in the new project undergoes a small number of embodied energy gains in a recycling effort compared to the manufacturing process.

Another strategy for reducing the embodied energy in the lifecycle of a project is to design it as a 'loose fit' structure. This implies flexibility in design that lends the building well to unforeseen uses in the future. This loose fit to current program means less chance of demolition, and therefore a longer lifespan.

Finally, using local materials and supplies reduces transportation costs and ultimately lessens embodied energy consumption. As an additional benefit, local material selection helps satisfy the need in sustainable design to ground the building to its place. This reveals embodied energy reduction as a universally applicable strategy, one where benefits are as easily reaped in the prairies as in Bordeaux.



Recycle

- Recycled materials
- Recyclable materials
- Demonstrated in the courthouse's recyclable aluminium windows.

Loose fit

- Flexible design
- Increased longevity
- Not clearly demonstrated in the courthouse

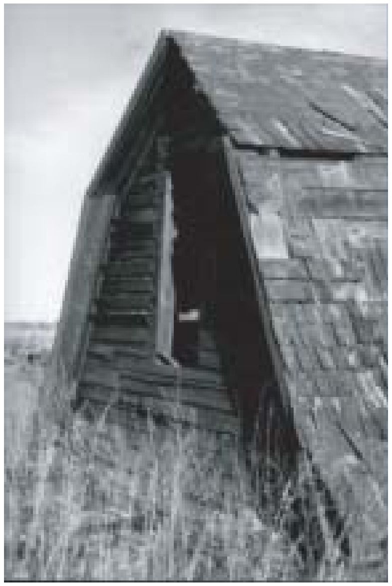
Local materials

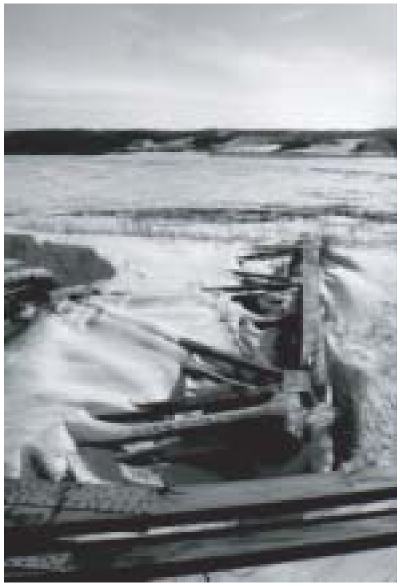
- Less transportation
- Links building to its region - Bordeaux or Canadian prairies.
- Demonstrated in the courthouse (the wood in the courtroom pods).

Applicability to Prairie Climates

The siting strategies of urban redevelopment, building orientation, and floor plan are rudimentary principles that can be considered on any site, making them universally applicable tools for placing a building within an urban prairie context. In addition to basic siting strategies the stack effect is also an appropriate sustainable measure. Stack effects are more pronounced when the difference between a buildings interior and exterior temperatures are more extreme, thus making the prairie climate an even more appropriate climate for this solution. The technique of thermal massing, when employed in walls with sunny southern exposures, is also directly applicable to our prairie climate. Finally, the reduction of embodied energy is a universally applicable principle of sustainability, one which can easily be applied to the prairie context.

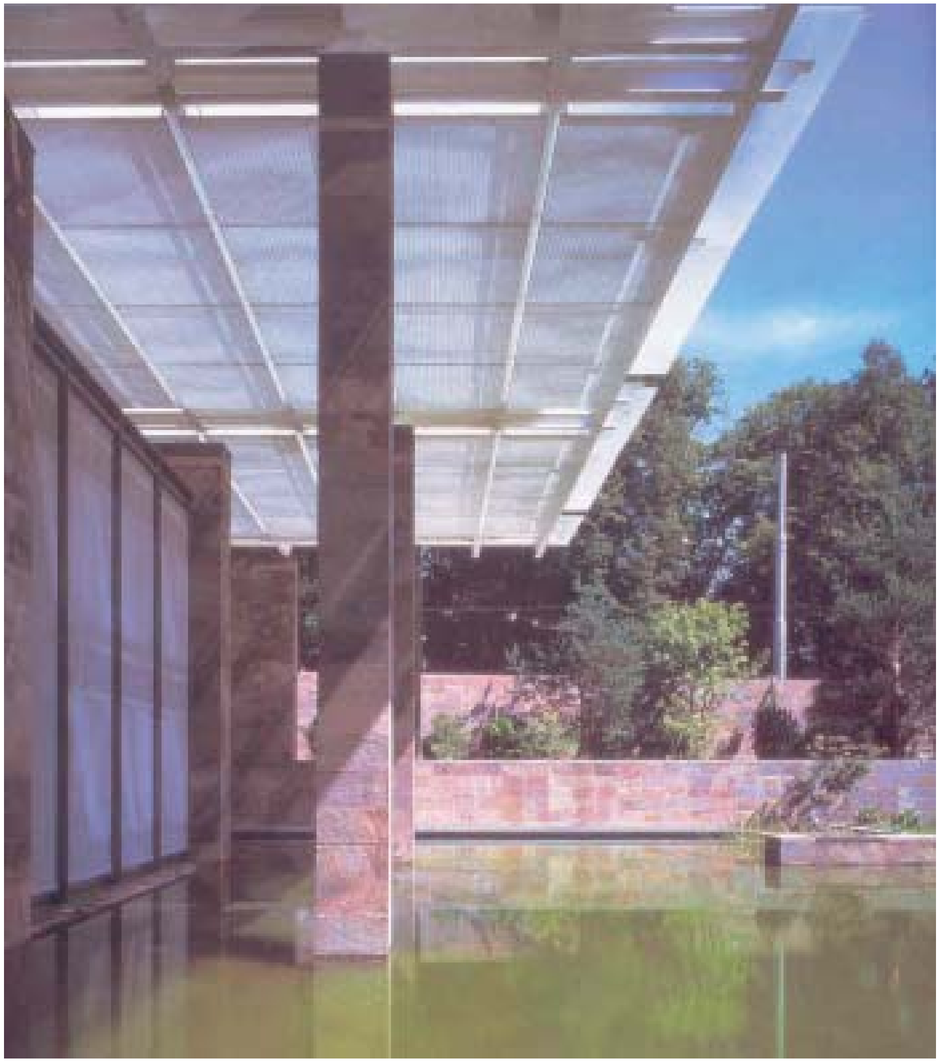
Picture of prairie





Picture of prairie

Beyeler Foundation Museum
Renzo Piano Building Workshop



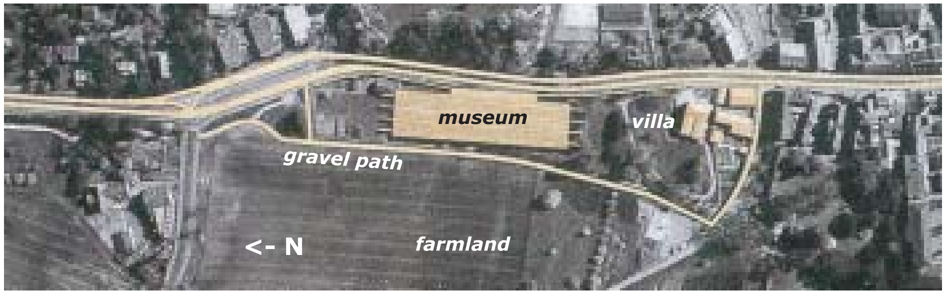
Pool at south end of museum facing east.

Building Overview

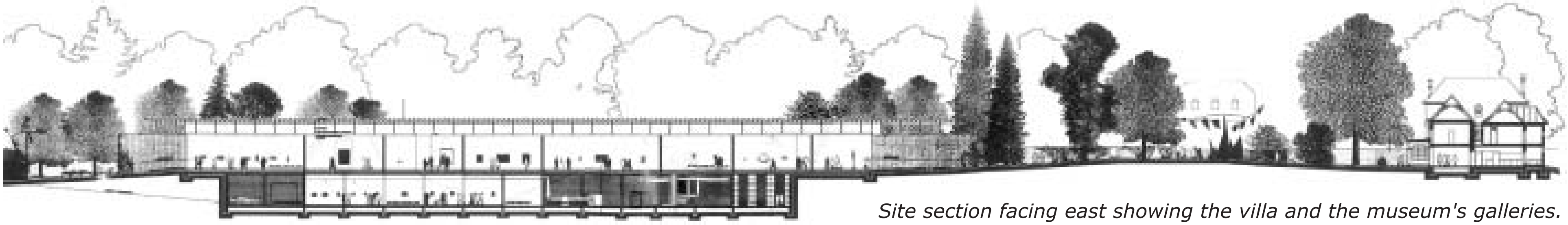
The Beyeler Foundation Museum (1992-97) is exceptional in the way it meets the stringent climatic requirements a museum demands and does it in a way that is both energy-efficient and architecturally expressive.

Site Selection & Concept

A significant portion of the museum's architecture is in its sensitivity to its location. The building is situated on a long narrow site known as Berower Park in Basel, Switzerland. It is flanked by an agricultural field on one side and a residential district of the town on the other. Along the side of the farmer's field runs a stone wall and a gravel road that existed before the museum. The museum continues the visual language of this wall with a basic structure consisting of four parallel walls clad in a red Patagonian porphyry similar in colour and texture to the stones of the pre-existing wall. The roof is entirely sheathed in glass and windows seal the ends

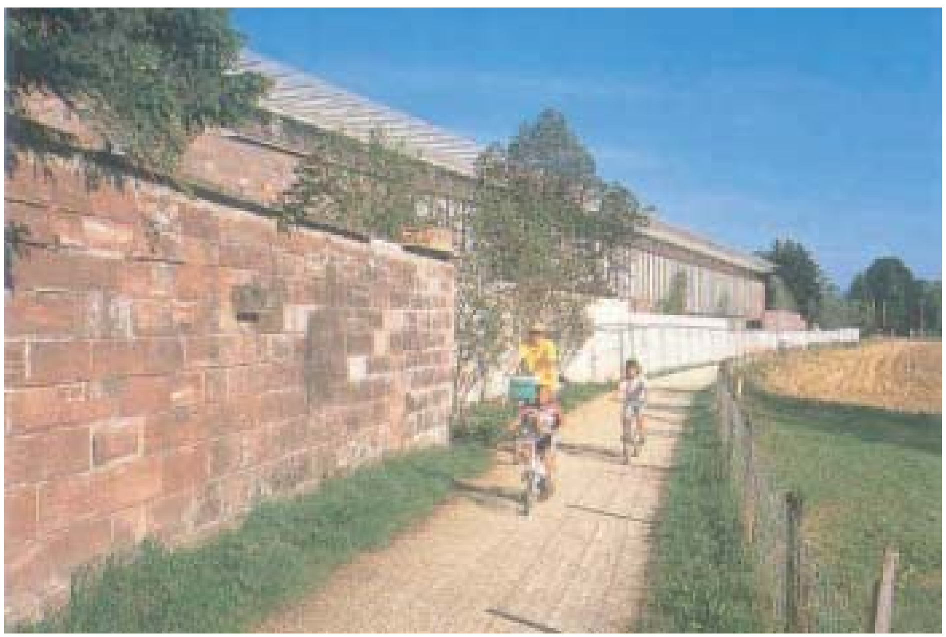


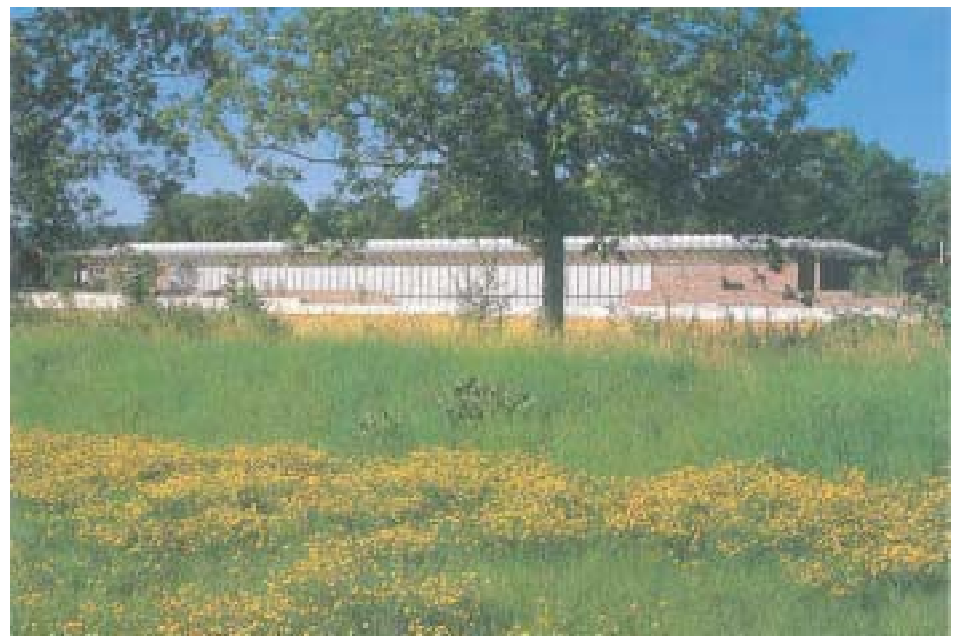
Aerial photograph of Berower Park, Basel Switzerland.


Site section facing east showing the villa and the museum's galleries.

of the spaces between the walls and run along the length of the building. The history of the park dates back to the 18th century when it was first conceived as a garden. It is said that the concept of a garden inspired Piano to adopt a structure that would embody the simple elegance of a greenhouse, in order to further tie the building into its physical and historic setting.

The program of the museum is distributed between the main building described here, and the historic 18th century Berower Villa. The villa houses the administrative offices of the museum along with a restaurant, while the building by Piano contains the galleries which house a collection that boasts works by Monet, Giacometti, Kandinsky, Klee, Braque and Picasso. The value of the collection demands particular attention to the climatic conditions of the building in order to suspend the deterioration of the artwork. These demands include a strict uniformity in temperature, humidity and a requirement to limit the infiltration of excessive light. The more delicate items, such as watercolours are displayed in a basement gallery with low intensity artificial lighting, while the more hardy artifacts inhabit the day-lit ground floor galleries.


Old stone wall along the west elevation.


West elevation.

Energy Efficient Day-Lighting

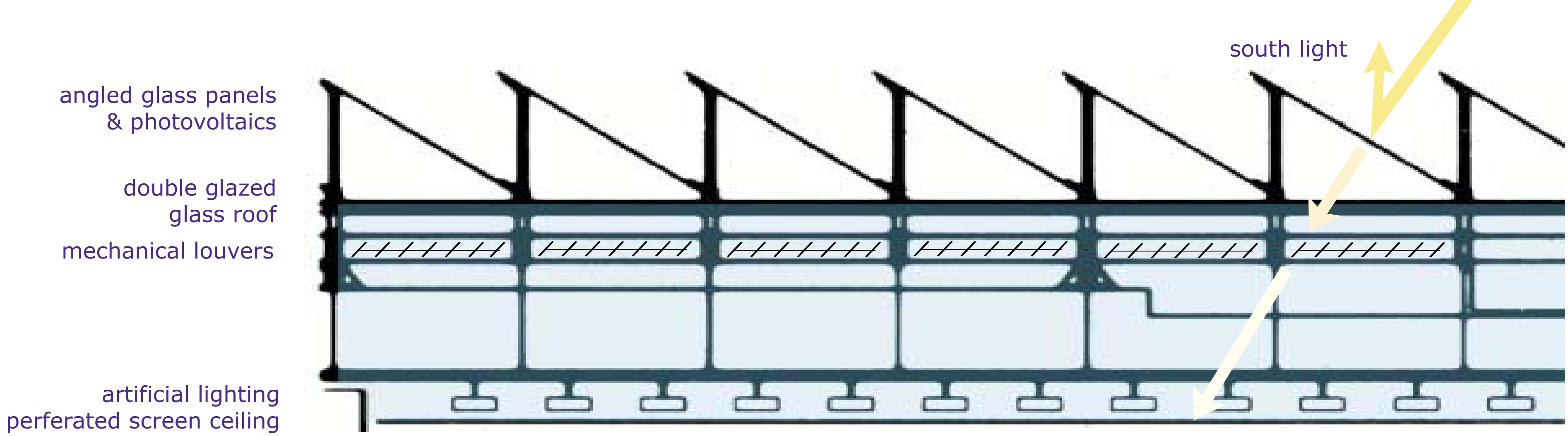
Lighting Concept

The glass roof and the museum's use of day-lighting are the more prominent design features of the building which meet the demands and ideals of all aspects from energy conservation, climate control to gallery atmosphere. The concept of capitalizing on day light is one which Piano has developed over numerous projects. In traditional museum design, daylight is often dismissed for its irregularities, but it is this dynamic nature that a previous client of Piano, Dominique Menil, venerated it for. The Menil Gallery in Houston, Texas (1981-86) was designed with the idea that

Monet's 40 foot 'waterlily' painting overlooking the pool.

the collection it housed required the nuances in the change of light over time, seasons and weather conditions for the experience of the artifacts to be complete. An awareness of the exterior environment facilitates a richer interaction with the artwork not unlike the atmospheric experiences a landscape painter like Monet captured in his work.

Beyeler Foundation Museum - Renzo Piano Building Workshop



Moderated Day-Light

The inherent dangers of using daylight are primarily the bleaching effects of excessive exposure and the acceleration of deterioration from heat gain. To mitigate the intensity of the sun, the roof is composed of a layering of various components. The topmost element of the building is a series of angled, sunscreens positioned to deflect the harshest light from the south, while giving the underlying glass roof more direct exposure to the ambient light from the north.

Below the sunscreens is a five foot high loft space enclosed by glass and perforated steel panels that form the visible surface of the ceiling. Concealed within this space is the roof structure, artificial lighting (for night illumination), and louvers that provides the ability for precision in adjusting the intensity of light penetrating the ceiling. These mechanical louvers are solar powered by photo-voltaic cells incorporated with the sunscreens, not making the introduction of these mechanical components anymore energy consumptive than a building without them. The successive moderation of the light through the various layers in the roof, diffuses the sunlight into a soft uniform glow that gives the entire ceiling a celestial lightness in a compelling contrast to the earthbound heaviness of the stone walls.

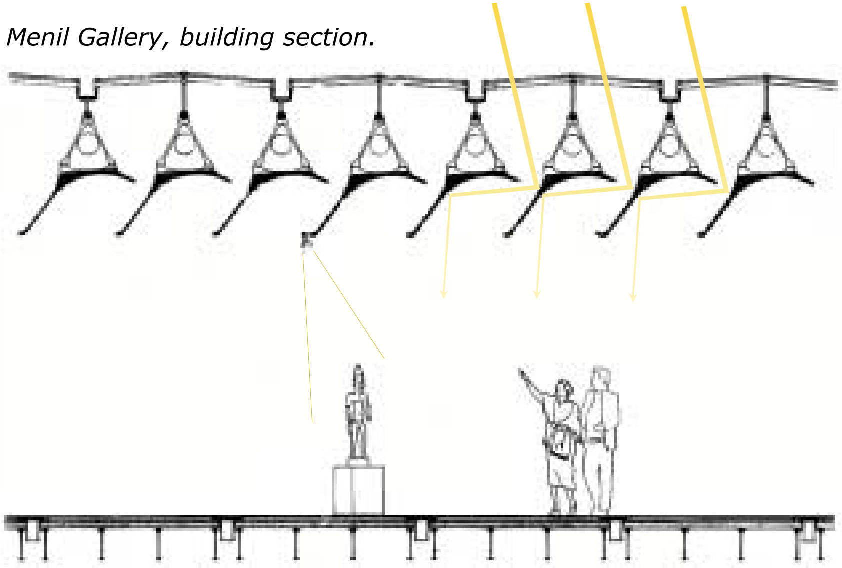
Standard glass and steel components at the Beyeler museum (above) allow for simpler construction, maintenance, replacement, and recycling.

At the Menil Gallery (right), complex, custom formed shading devicesmade of unordinary materials make their repair and replacement costlyand labour intensive operations.

Life-Cycle Cost Reduction

The strategy used to diffuse the sunlight in the Beyeler museum differs slightly from that of the Menil Gallery in its appearance, but more apparently in its complexity of construction and life-cycle costing. Instead of sunshades on top of the roof, complex curved light shelves or leaves are suspended below a glass roof similar to that of the Beyeler. These leaves are specially designed to reflect direct sunlight, and allow more ambient light to reflect off the surfaces of the leaves into the galleries below. The lighting effect is similar to the Beyeler, but the Beyeler goes further in encompassing a design that is simpler in construction and is therefore initially less expensive and more conducive to its long term maintenance. The complexity of the leaves in the Menil gallery required custom construction of ferro-cement involving a specialized casting process to derive the curvature required. The suspension of these leaves also required the use of ductile iron trusses specially designed for the leaves to hang from. Piano omits these complexities in the design of the Beyeler and uses standard steel construction and uniform sheets of glass that are both common products that are readily manufactured and recycled.

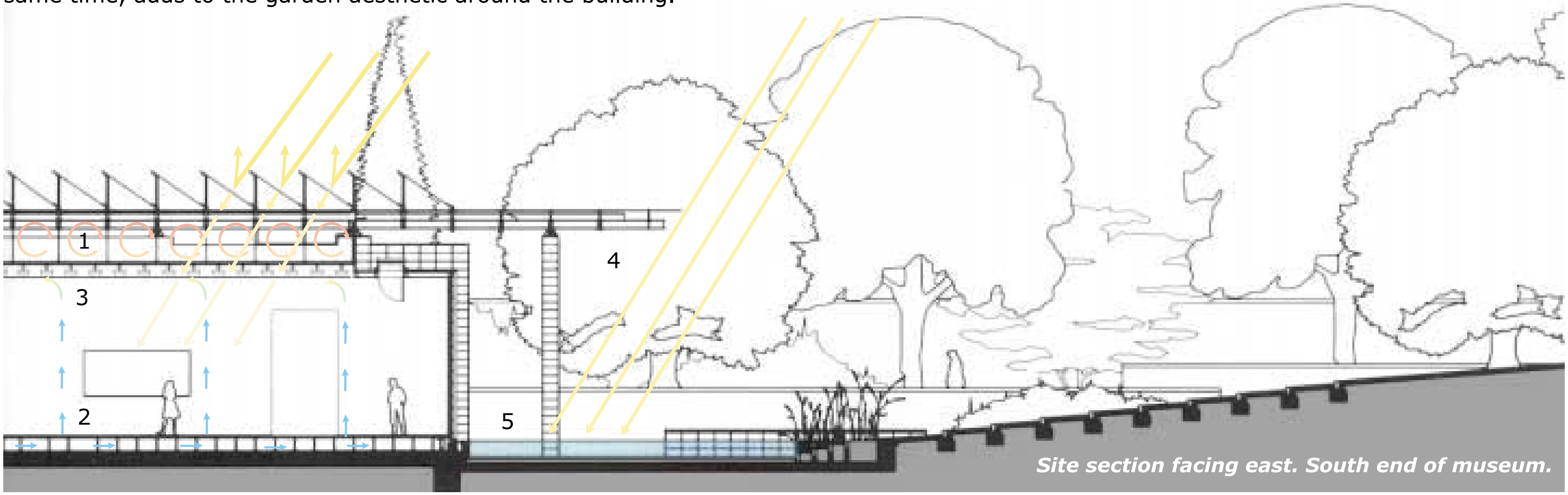
Menil Gallery, building section.



Temperature Control Design

The problem of heat gain from the use of glass roofs is addressed by several means. The most significant of these is the dual purpose of the loft space (1) in the ceiling as a thermal buffer. As the hottest part of the building during the day, its enclosure restricts the transfer of heat into the galleries below. To further ensure the hot air is kept away from the artwork below, cool air is introduced into the galleries through grilles that line the floor of the gallery (2). As cool air enters from below, warm air is removed from the galleries at the ceiling level (3) which coincides with its natural tendency for warm air to rise.

On the outer sides of the building a number of other design decisions contribute to thermal buffering. Deep eaves created by extensive cantilevering of the roof over the north and particularly the south ends of the building (4) are critical in shading the glass enclosing the gallery spaces at the ends of four walls. A pool (5) at the south end of the building assists thermally by contributing humidity to the air while at the same time, adds to the garden aesthetic around the building.

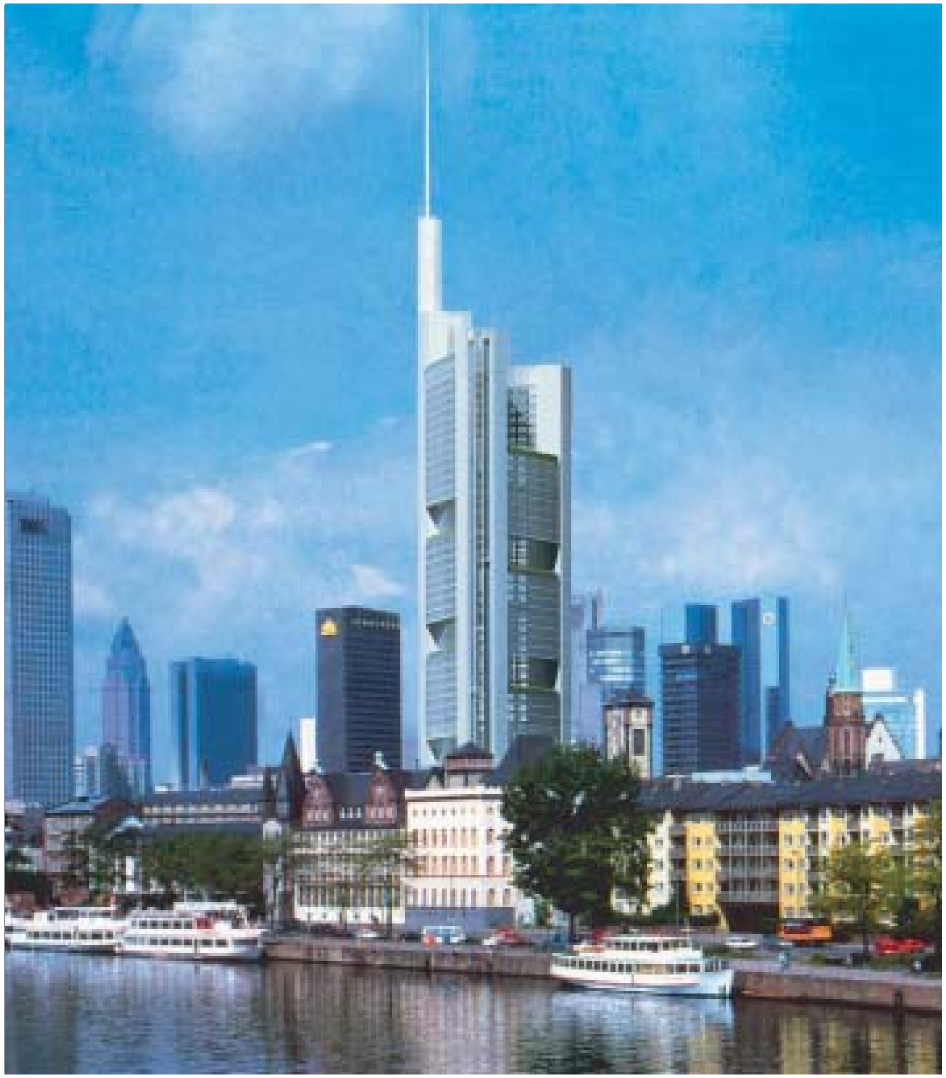


Site section facing east. South end of museum.

Solutions for the Canadian Prairies

Many of the solutions found in the Beyeler museum are applicable to building in a Canadian prairie context. Basel experiences a similar temperate climate to southern Canada, making the temperature control and day-lighting concepts fully transferable. The conceptual strength of the Beyeler in reflecting the historical and cultural context of Berower Park and the surrounding community is a matter of sensitivity to and the surrounding community is a matter of sensitivity to the context the building exists in. The Beyeler museum is a relatively subdued building in keeping with the provincial nature of it's setting. Similarly, the strategies in linking buildings in the prairies to their context would require attention to the nature of the surrounding community and any cultural and historical characteristics of value.

Commerzbank Headquarters
Foster + Partners



Building Overview

Legislation and attitudes towards sustainable design are more progressive in Germany than in most other countries. This is clearly demonstrated in Foster + Partners Commerzbank Headqaurters building. The Green Party in Germany initially urged Commerzbank to build their new banking headquarters as an environmentally sensitive, 'green' skyscraper. Commerzbank embraced the idea due to the promise of savings in energy costs and building operations, and a healthier, more productive work environment. In 1991 Commerzbank held a competition for the design of their new bank headquarters in Frankfurt, Germany. The competition called for a building that:

- was ecologically oriented
- energy efficient
- economical to operate
- offered flexible office space
- presents a positive corporate image

Through an analysis of the Commerzbank building it was apparent that the design had many elements and ideas contributing to the success of the building to become the world's first ecological office tower. The building not only functions as a sustainable building, but is sensitive to specific contexts of the city. It attempts to respond to surrounding buildings as well as the street life and the sense of activity and social vibrancy of Frankfurt.

Two main sustainable systems found within the building that will be examined in terms of their sustainable functions and appropriateness are: daylighting and natural ventilation.

Interior image of daylighting in interior atrium space

Views: daylight in the office areas

Daylighting

The use of the sun's natural light was incorporated into the design of Commerzbank to reduce energy consumption in the building and create a connection to the outdoors. Daylight is considered all direct, diffuse, and reflected light from the sun in the daytime. Daylighting uses daylight as the primary daytime light source in a room or building. Devices such as light shelves, skylights, light tubes, louvers, mirrors, and windows are the primary devices of daylighting.

Daylighting has been used in buildings for almost as long as buildings have existed as it was the only source of light. Over the past fifty years daylighting strategies have declined due to the reliance on electrical lighting. However, with artificial lighting now the largest consumer of energy in a building there is again the need to recognise daylight as a viable means of lighting.

The amount of daylight available at any time is dependent on the atmospheric conditions and the position of the sun. Cloudy conditions will decrease direct sunlight but increase daylighting levels. A clear sky will result in increased direct light and less difuse light. Daylighting systems, if incorporated effectively within the design and keep within the principles of sustainability can:

- save energy by allowing electric lights to be turned off.
- maximise colour perception as daylight has a colour rendition index of 100% where as coolwhite flourescent has an index of 67%.
- be cooler as daylight contains half as much heat per units of illumination as other light sources, thereby requiring less air conditioning services. With proper architecture over 99% of the sun's heat can be rejected, while still being able to use 100% of the light inside of a building.

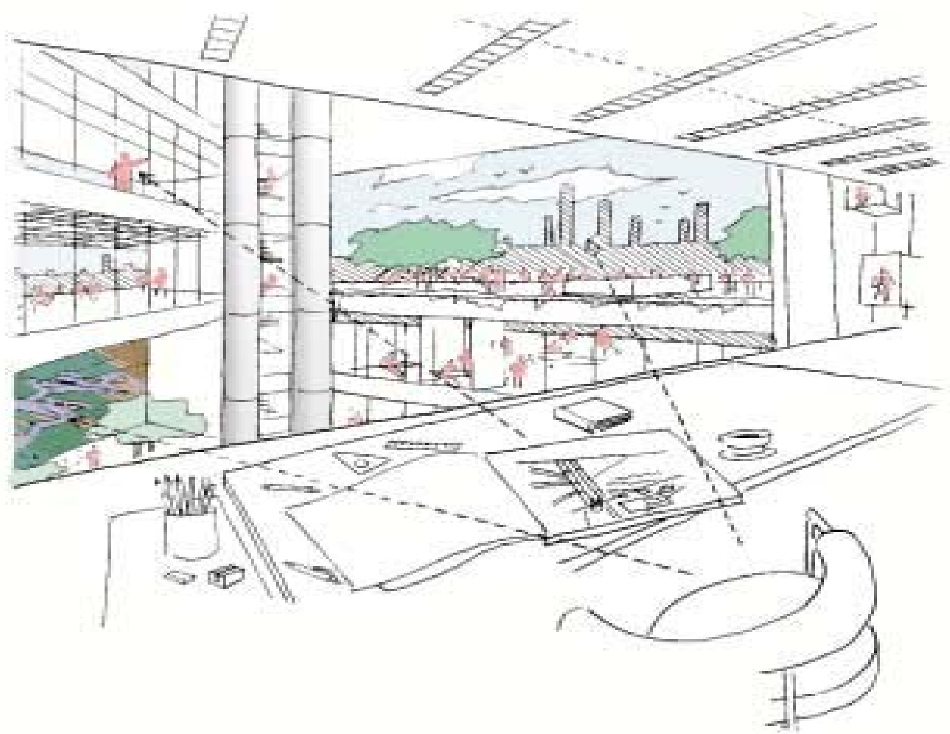
Daylighting Strategies

In the design of Commerznbank, Foster and Partners used five methods to align the building to the ideas of sustainable design as well as challenging high-rise typology.

1. Moving the typical core of an office tower, which generally contains the building services, to the corners of the building. This creates a hollow centre around which 13 four-story atriums spiral around. The atriums are arranged so that on every floor two sides are occupied by offices and one by a garden, giving every inward facing office natural daylight, which is a German building code requirement, and garden views.

2. The building has a Building Management System (BMS) that monitors the external conditions, in order to help regulate the interior building atmosphere. When necessary, the BMS can override the manual controls of the blinds or the cavities of the double-skin exterior. Lighting in offices is monitored automatically and can turn off unneccesary lights.

3.Venetian blinds with five centimeter wide blades can be moved by the BMS in order to compensate for seasonal characteristics of the sun. In the summer the blinds incline to reduce excessive sunlight penetration, and in the winter reflect the sun up onto the ceiling.

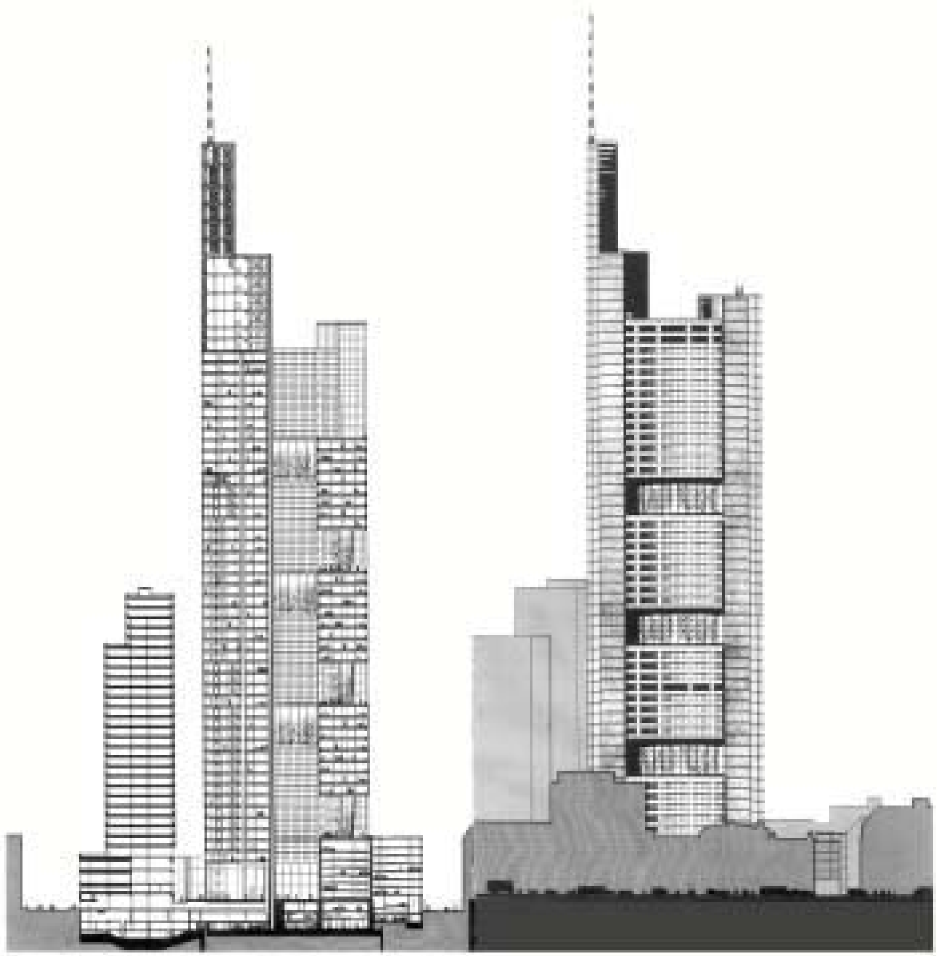


interior office view/concept sketch of central atrium

Actual interior office view with daylighting

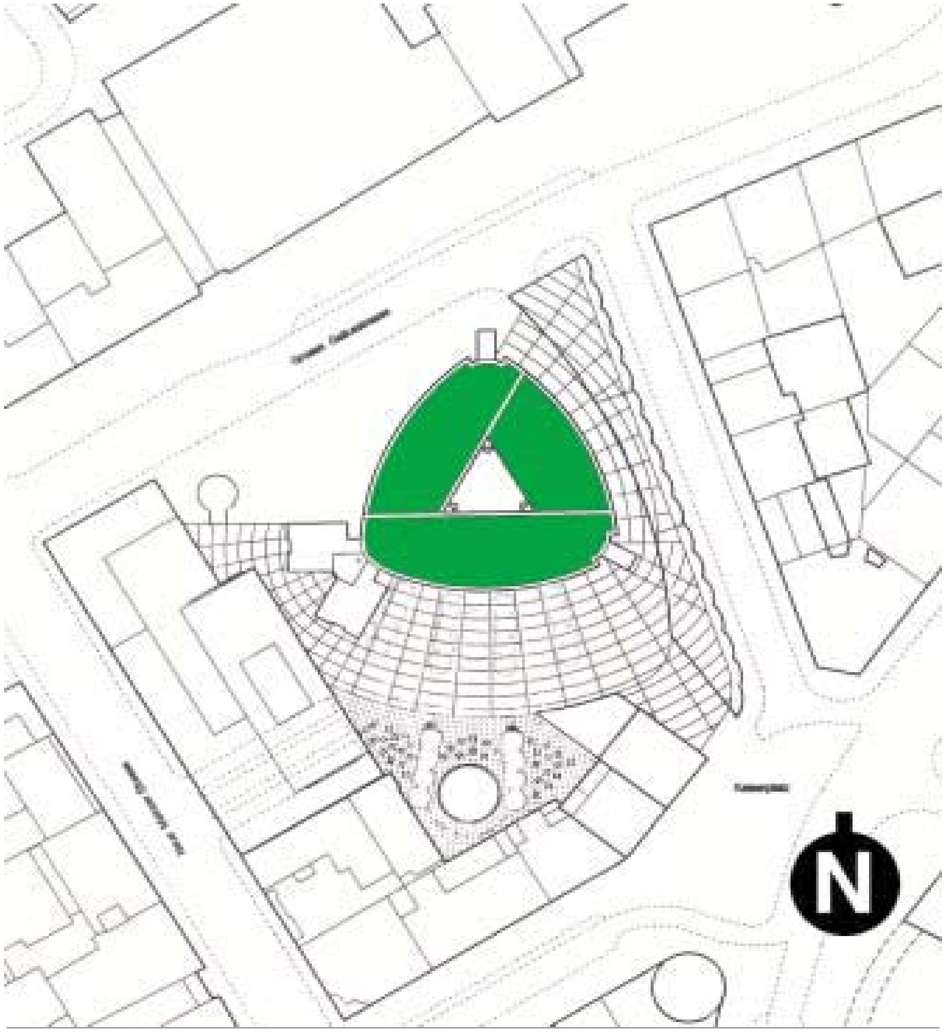
Daylighting Strategies

4. The building is in the shape of a equilateral triangle, ensuring the buildings' three faces all receive direct daylight throughout some part of the day. There is no true north face of the building. In Frankfurt the amount of northen ambient light may not be as significant as found in the Alberta prairie region which makes this a logical design choice. However, this strategy should be considered when looking at daylighting options for a prarie condition.



Building section and elevation

5. The orientation of the building also ensures that the shadow cast by the higher Commerzbank Headquarters does not affect the daylighting potential of the smaller, original Commerzbank building.



Site plan of Commerzbank Headquarters

Relevance of Daylighting to the Prairies

In the Canadian prairies we enjoy incredible sunlight throughout much of the year. During the winter months the sun may only be useful for as little as eight hours but in the summer, daylight can be enjoyed up to 14 hours in one day.

The Commerzbank design changed the typical office tower typology, opening the building up to daylight at the south, east, and west sides. This strategy would have great potential in the prairie environment allowing daylighting to benefit our buildings.

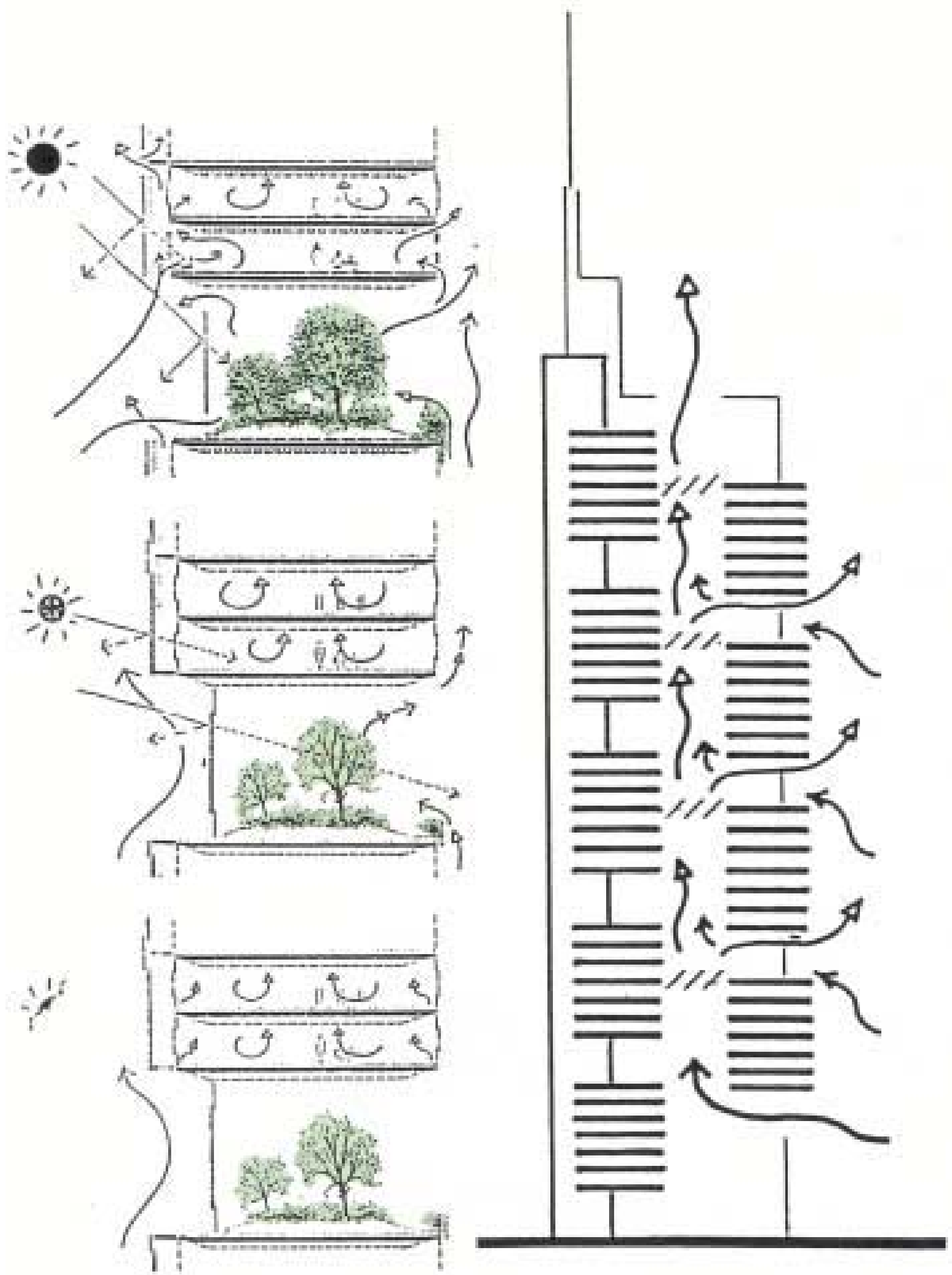
A concern with such a system in Canada could be the effects of condensation and frost on the windows. The cold winter air against the outside of the atrium glazing and the warm, humid atrium air on the inside could cause moisture to condense against the glass. Double glazed, high efficiency glazing systems would mitigate this problem.

The atrium relies on a skylight roof system in order to allow light in to the hollow core of the building. This type of daylighting device could experience snow coverage problems and lose some of its effect during the winter unless dealt with in the design of the building.

Operable window in garden space

View: from above into garden space

View: looking up central atrium space



Conceptual air flow diagrams of garden spaces and main atrium

Indoor Air Quality

Natural Ventalation

Statistics demonstrate that society spends more time at our place of work than we do at home, in addition we spend upwards of 80-90% of our waking lives indoors. It is obvious that the the design of our workplace directly affects the quality of our lives. Indoor air quality plays a direct role in the health and well-being of building occupants. Accompanied by natural light, proper indoor air quality can contribute to better health, greater comfort and higher productivity caused by a decline in employee sick days. These benefits are in addition to energy cost savings achieved through the use of passive solar heating and cooling.

The Commerzbank headquarters is a radical reappraisal of the very nature of an office building. Instead of a solid core the heart of the building there is a vertical shaft of open space which expands at intervals up to the height of the building into nine large indoor gardens. Each of these green spaces is four stories high; they spiral around the edge of the building to become a dramatic feature, visible from the outside as well as the inside.

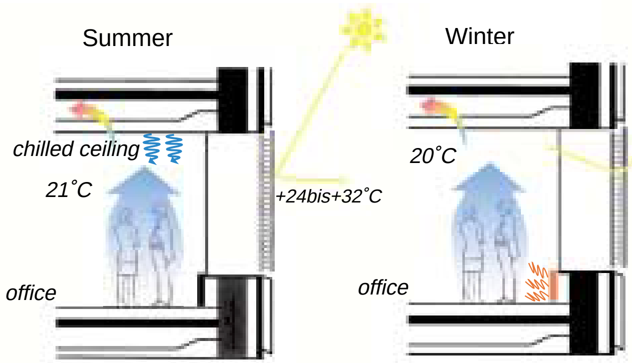
These green spaces,or gardens, offer technical benefits beyond their aesthetic beauty. As the diagram to the left demonstrates, the air flows introduced into the building from the exterior and circulated throughout the interior spaces are modified by the presence of the greenery. The plants aid in the creation of fresh air and help to modify the amount of sunlight entering to the large atrium spaces creating a fresh and relaxing atmosphere for the buildings' inhabitants unlike that of the traditional office building.

Indoor Environmental Quality

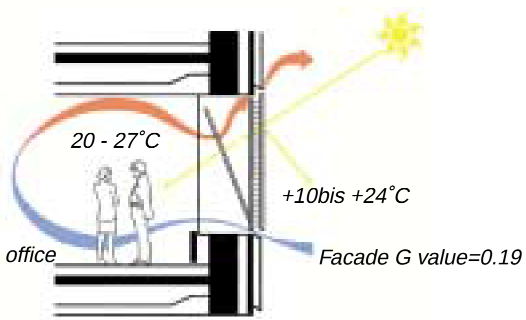
The primary objective of the Commerzbank internal environmental systems is to reduce the use of energy while giving the inhabitants a healthy office environment with a degree of personal control with operable windows. Utilizing a heating and cooling strategy that includes natural ventilation, stack effect, radiant cooling in the ceilngs, conventional convectors under the exterior windows and daylighting will allow the Commerzbank to save between a half and two-thirds of purchased energy costs. The diagrams below demonstrate the fundamentals as they relate to natural ventilation an indoor environment.

Stack Effect

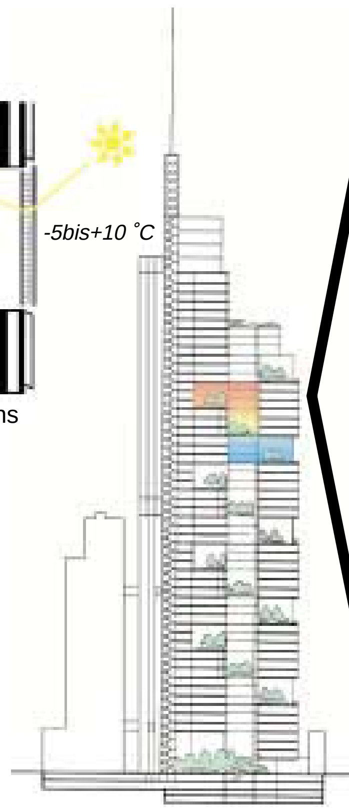
Stack effect in buildings is the same as stack effect in a chimney. The total pressure difference acting on a building as a result of stack action depends on building height and the difference between inside and outside temperatures. Openings occur in the walls of buildings at various levels. The air in the building is typically warmer, and lighter which allows it to rise up inside and escape through the upper openings. The warm air is replaced by the cooler, denser outside air coming in through the lower openings. The pressure difference required to cause the flow of air through the openings is the stack effect.

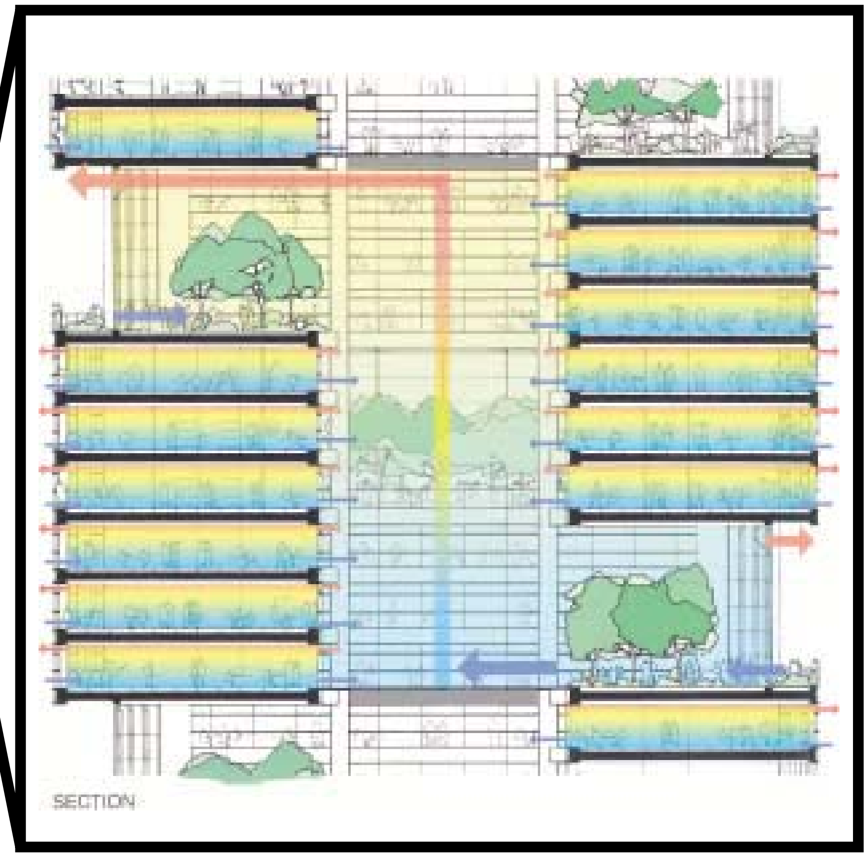


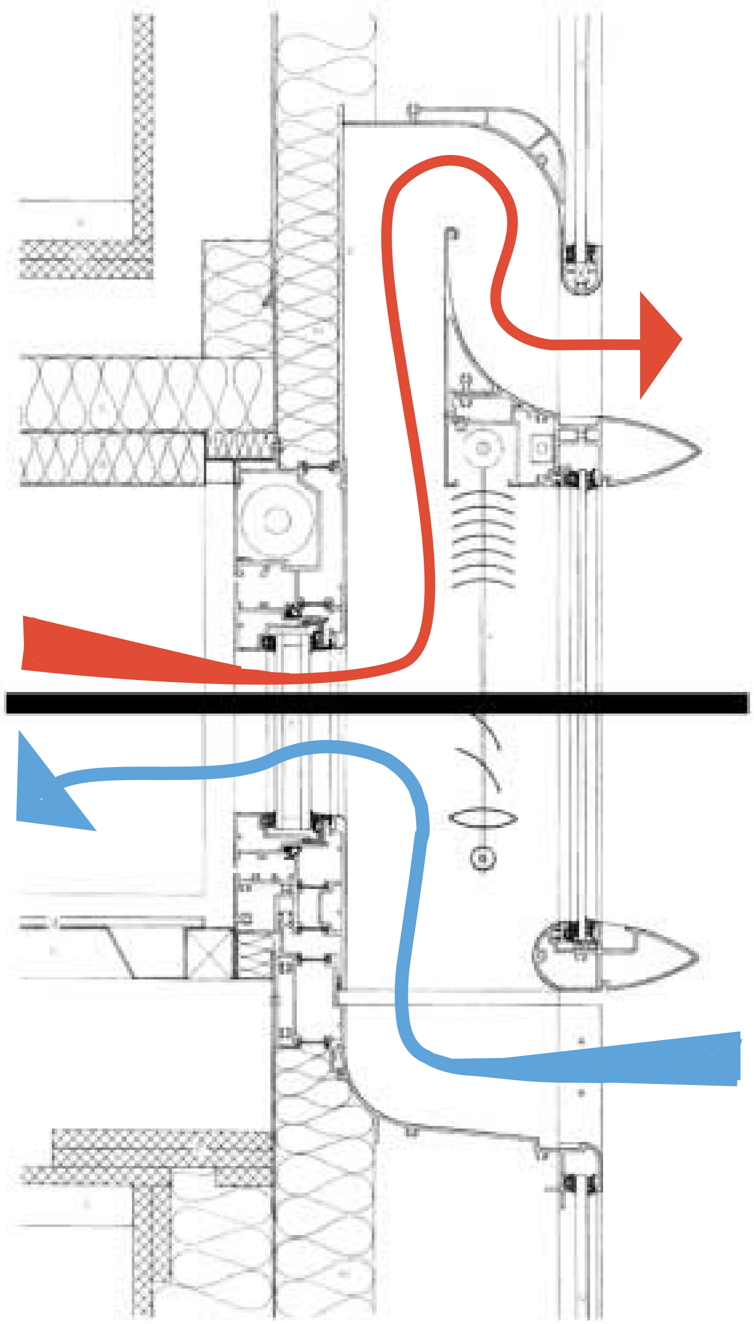
principles of climate control in unfavorable conditions



general operating condition 60% of year





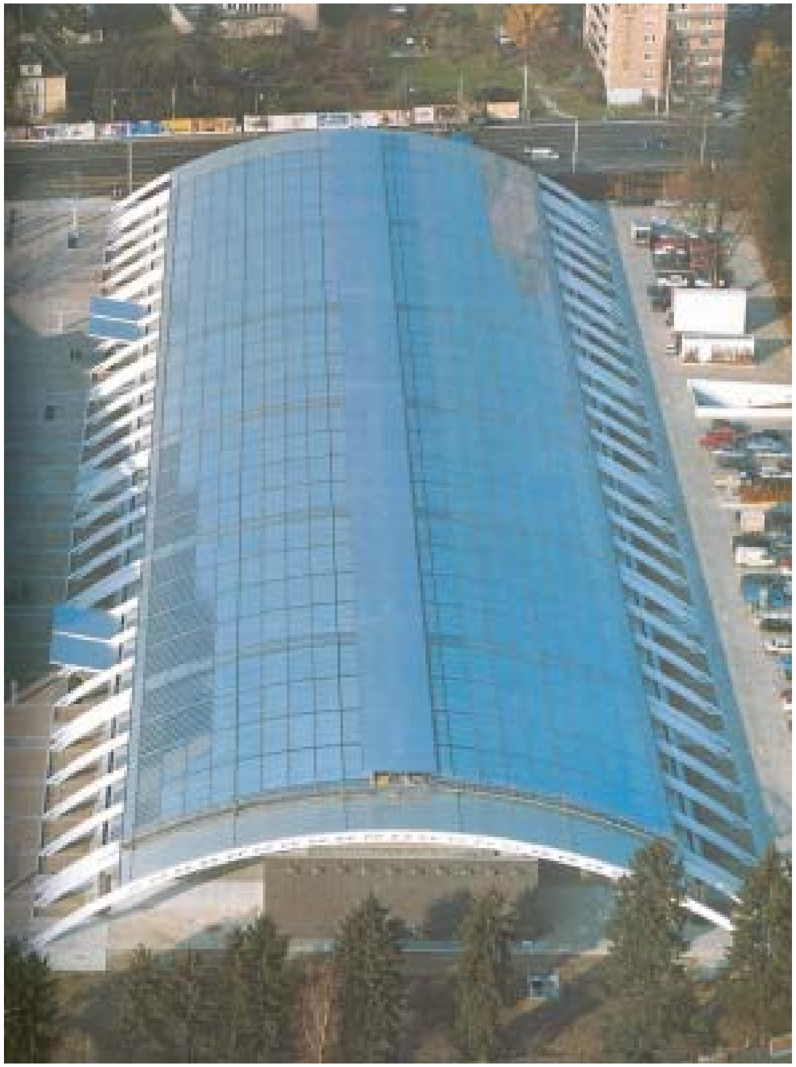


Design Relevance to the Praries

Natural Ventilation

The building management system, as shown in the Commerzbank Headquarters split-wall section to the left, demonstrates how the basic principles and forces of natural ventilation are shaped and harnesed in the design of the buildings' double-wall construction. This self drying, interstitial wall cavity plays several roles in the energy management of the building. First, the exterior, glazed, skin acts as a self-drying rain screen, mitigating wind forces and rain penetration into the inner, sealed office wall. Secondly, a series of louvers operated by the BMS in the interstital cavity regulates the buildings' solar loads. This double-skin strategy allows the outer wall to deal directly with the exterior elements while the interior wall is concerned with air-circulation/ventilation and heating/cooling. With the inner wall sheltered from the elements, employees control operable windows which open into the office spaces. The employees contribute to the overall success of natural air circulation in the tower, as fresh air enters lower in the office spaces, flushing the warmer, used air out near the ceiling plane. The process brings in fresh oxygen while effectivly balancing the room temperature in conjunction with other building systems. As seen in the case of natural ventilation, the use of passive solar heating to provide air-flow throughout a building represents the best of cutting edge building technology. This demonstrates the importance of complex, composite and flexible systems that can adjust to changing needs and adapt to different environments.
Although climactic factors differ between the province of Alberta and Frankfurt, Germany, the implementation of innovative green buliding strategies, like natural ventilation, can be successfully integrated into prairie architecture and design around the world. What this represents is a pro-gressive world view that turns to the wisdom and knowledge of the past, to direct and manage the technologies of today while creating a sense of personal control with inhabitants of the building.

Design Center Linz
Thomas Herzog + Partners



Building Overview

Linz is the capital city in the "Oberoesterreich" region of Austria which only has a population of 600,000. The Design Center Linz has help make the city of Linz a new hub and inter regional centre of employment and services. The project is located in the south part of the city center, close to an industrial area. It is characterized by wide streets and chaotically arranged residential buildings. The complex intentionally ignored integration into the existing condition and instead tried to calm and clarify the area.

The Design Center Linz is a multi-functional complex suitable for exhibitions, trade fairs, conferences, festive occasions and public events. The complex also includes a four star hotel. In 1988 an Austrian-wide competition was held with international participation. It was won by the architect Thomas Herzog, together with the designers Sailer & Stepan from Munich, Germany. The project was completed in 1993 and the complex opened in 1994.

The design for the Design Center Linz was inspired by the 'Crystal Palace'. As in the design from engineer Paxton for the world exhibition of 1851 the concept of Design Center Linz is a fully covering glass roof. 1 Under this glass roof Herzog has designed a large exhibition area that allows for a multitude of usage and layout variants. 2

Flexibility of Building

A Glass Roof

The concept envisioned by Herzog was a climatically regulating outer skin which would permit a high degree of flexibility in the layout the whole of the interior.[3]

To ensure a maximum degree of flexibility, all congress and exhibition spaces are laid out under a single glass barrel roof. A total of 34 steel arches span an area the size of two football fields. The arches span 74m and a have a radius of 59.20 m, reaching a maximum height at the crest of 13 m and encloses a space 225,000 m3 in volume.[4] The sturdy steel arches consists of four prefabricated welded steel-plate segments. Between the arches are very delicately designed secondary plate beams which are bolted together to provide a very strong skeleton for the glass installation. The main sections of the building are of reinforced concrete and brick. The entire structure was built on flat pad and strip foundations in compacted gravel.

A southern view of the complex

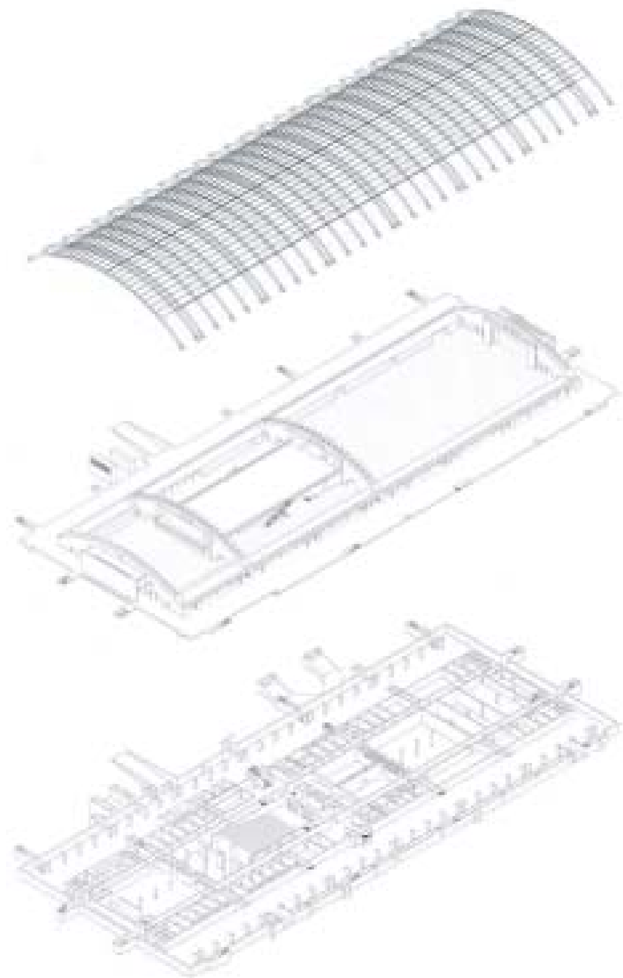


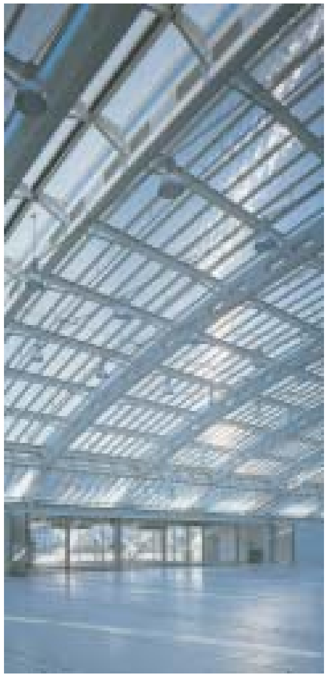
Diagram of construction layers

Design Centre Linz - Architect Thomas Herzog + Partners

Half of the building consist of a single large space, where trade fairs and exhibitions can be held. The other side of the space contains flexible meeting rooms and auditoriums. Service areas and offices are situated around the perimeter of the building in a one story volume. Accessible cable ducts are located throughout the floor of the building.5

The building is cited to maximize size and sun exposure.6 The arch-shaped insulated glass roof allows for both reflection and refraction of direct sunlight. The passage of daylight diffuses from above providing a pleasantly bright atmosphere for exhibits.

A view showing inner space.



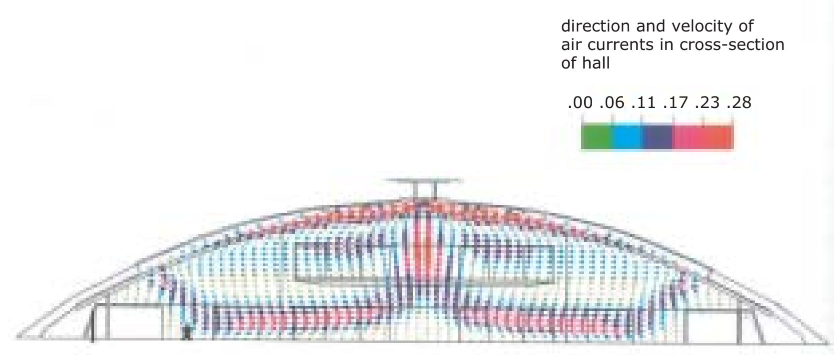
View of steel structure and entry to hall

Individual drawings showing possible variations of possible uses

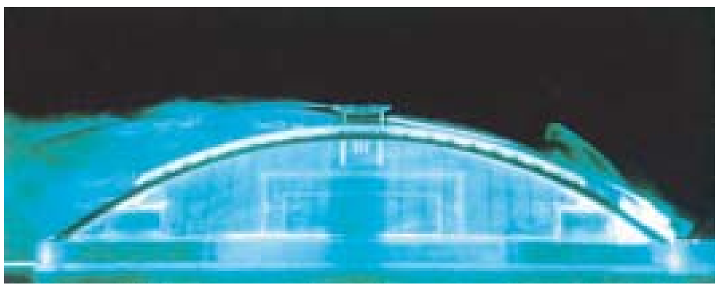
Indoor Environment Quality

Ventilation

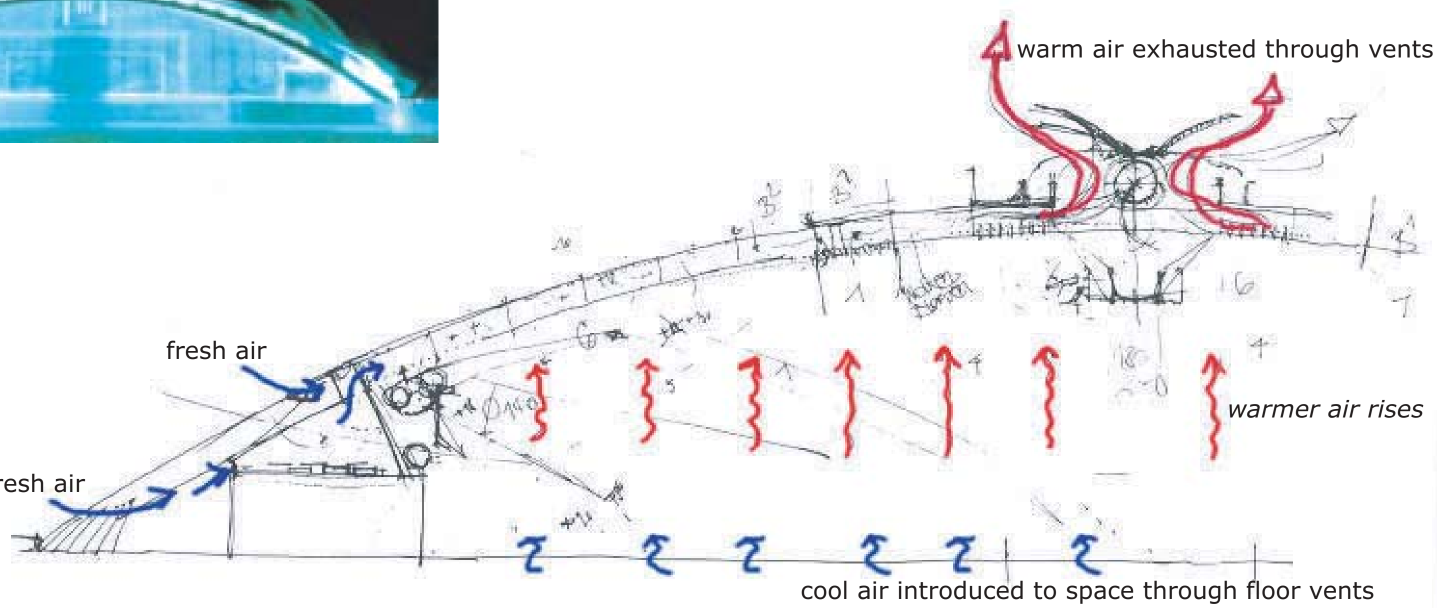
A knowledge of the thermal process in large spaces with high internal and external heat loads is essential if an economical ventilation system is to be installed.7 Room temperature, humidity and hygienic requirements for the air exchange were established and analysised to optimize venting efficiency. Computer simulations for various situations, and wind tunnel tests provided information for the basis for the ventilation and air-conditioning plant.8 The roof is purposely kept low to minimize the building's volume.



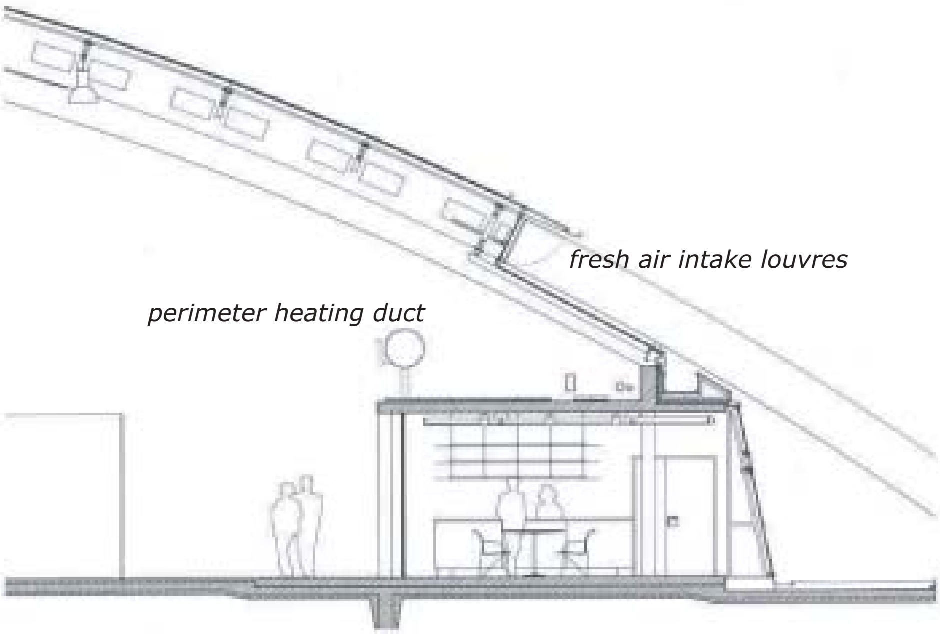
Velocity diagram



Wind tunnel tests



Schematic diagram displaying the design of air movements during SUMMER months



Cross-section of hall showing perimeter heating and air intake louvres

To keep the energy consumption to a minimum, the use of "free ventilation" and "supported ventilation" is considered. Free ventilation is provided using fresh air supplied via inlets in the floor of the hall and window strips which occur at the point where the plane of the roof changes. Along the crown of the roof are continuous openings with louvres to regulate the extraction of air in summer. The form of the large spoiler over this opening reinforces the suction effect along the entire length of the building. Support ventilation is provided by a system of operable ventilation flaps combined with the complex ventilation plant.9

The division of the building into individual zones with its own plant reduces to a minimum the operating time of the plant as well as the number of spaces to be ventilated at any one time.10

Intelligent Skin

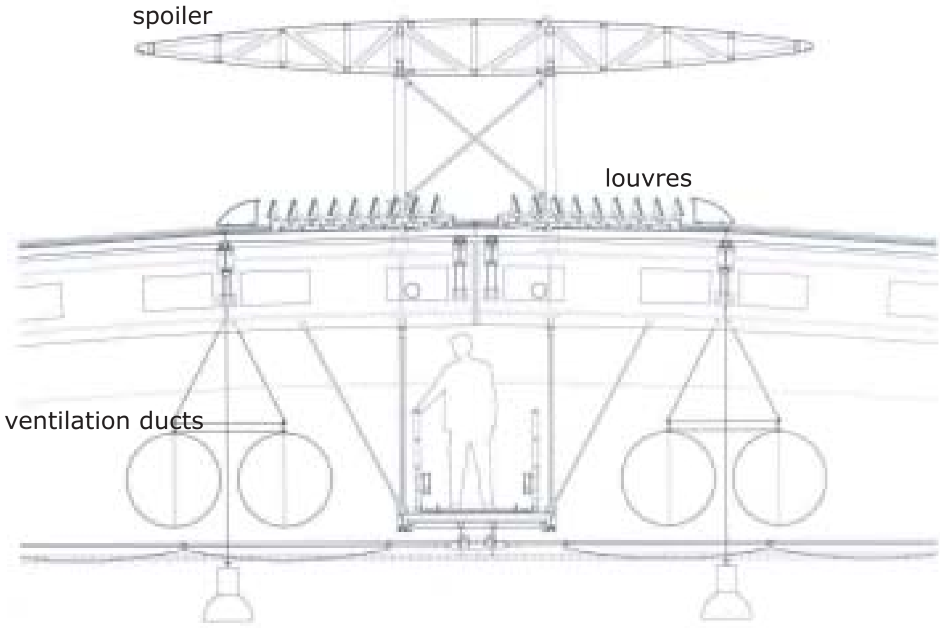
A feedback system helps the facade adapt to different circumstances to ensure optimal conditions. Over 2500 sensors make up a extensive nervous system that register the conditions at several places in and around the building. With the information collected and the experiences of the users of the building, a central computer adapts the facade. Over time the building begins to understand its environment and adjusted to it automatically.

View of hall and office showing floor vents and perimeter heating

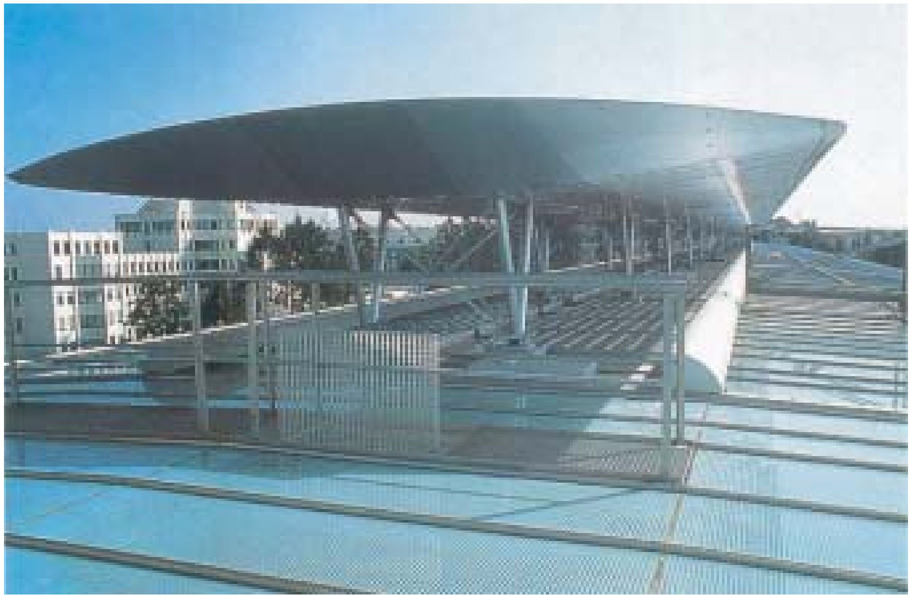
Design Center Linz - Architect Thomas Herzog + Partners

A wind 'spoiler' is also placed at the top of the roof arch to create ventilation for the building. The roof directs wind under the spoiler causing turbulance and an upward movement of inner air. Flaps under the spoiler are opened by computer to regulate the airflow.

The exhibition hall, foyer, auditorium, conference hall and seminar rooms are heated exclusively via their respective air-conditioning plant. Heating surfaces are installed along the two long edges of the auditorium to prevent cold-air down draughts.[11]



Cross-section showing upper vents, mechanical louvres and spoiler



External view of spoiler and louvres

"The single most efficient use of solar energy is the use of daylight for lighting. The best light bulb needs far more watts per m2 and produces far more heat then the sun does for the same amount of light." *Thomas Herzog*

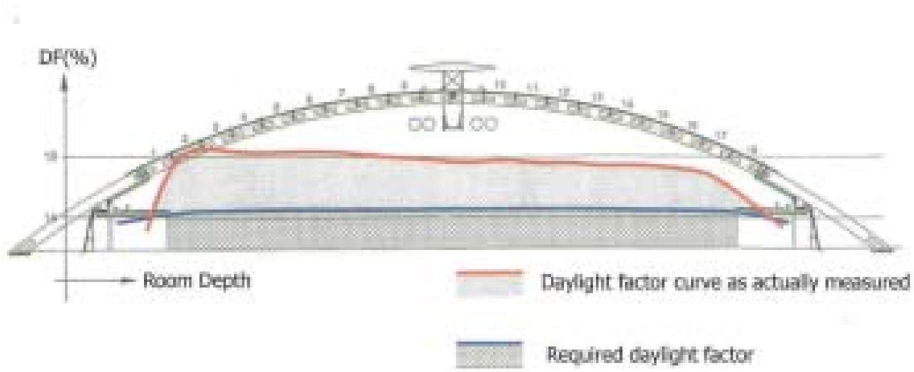
Daylighting in the building

The Glazing System

A major feature of the new glass roof is the prevention of solar heat gain in the building during the summer months, even with changing angles of inclinations of the sun and different roof slopes.

A new system consisting of extremely thin louvre grids between the panels of double glazing provide quality daylight for the interior of the building. The plastic grid consist of narrow plastic strips or bars with flat and parabolically curved surfaces. These bars are laid out in parallel, linear rows and reflect direct high inclination sunlight away from the building.[12] The louvres reflect the solar radiation allow only diffused light to enter the building preventing overheating in summer.

A grid is inserted between the thick sheets of double glazing. The grid is only 16 mm and is coated with a fine layer of pure aluminium.[13] This system allows light to enter indirectly via what might be described as minute "light shafts" set next to each other in tight rows. At the same time, direct sunlight is excluded.



The cross section with daylight factor curve

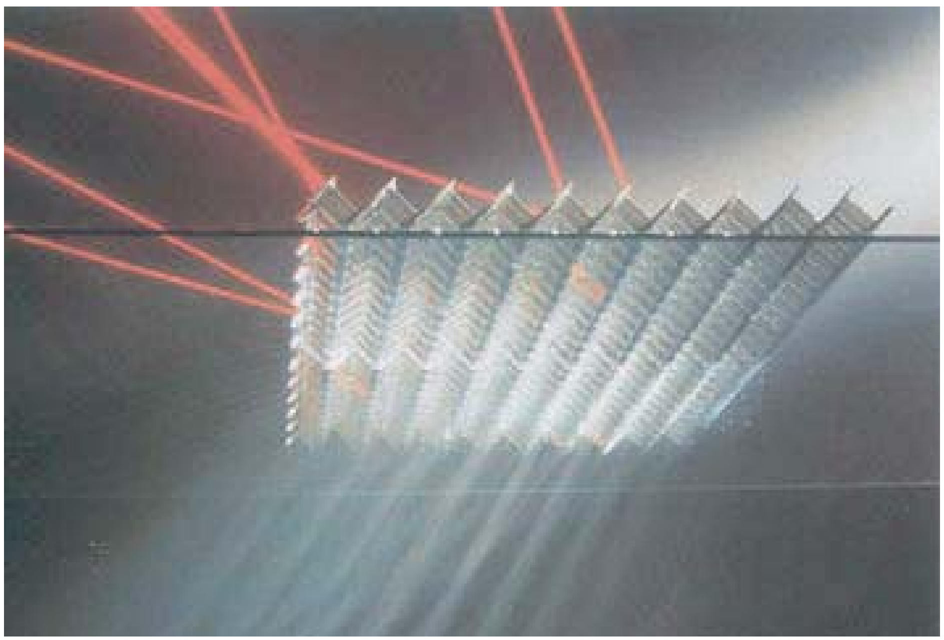
View showing internal daylighting in the buiding.

Reflection and Refraction

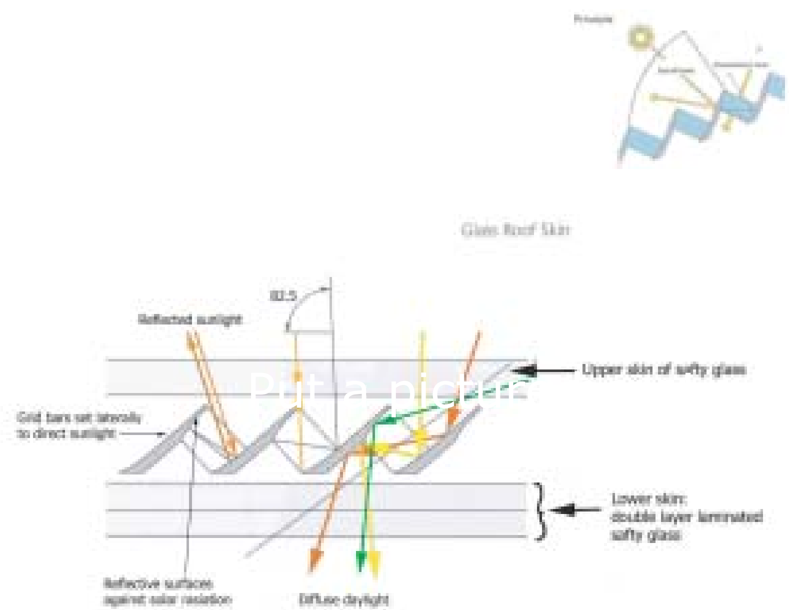
All the 2.70 metre wide panels in any one horizontal row of grid elements have different geometries.14 The units of reflecting/lighting grid were cut in different ways as a response to different roof angles. This system provides as much as a threefold reflection of the individual ray of light.

Modern heat absorbing plate glass was used to achieve a considerable reduction in the heat transmission value of the glazing. The reflecting grid panels inserted in the roof help to improve thermal conductivity values and fire protection.15

Solar measurements made at the same time to determine the thermal conductivity (u value), the overall energy transmission (g-value) and the transmission in relation to different angles of inclination of the sun were carried out.16 The overall transmission value of the plastic grid is roughly 42 per cent. The finished panel, with the grid inserted between the two layers of glass, has an overall daylight transmission value of 33 per cent.17



Model of grid showing reflective action of south-facing grid bars with different positions of sun.



Section showing main elements of solar shading screen.

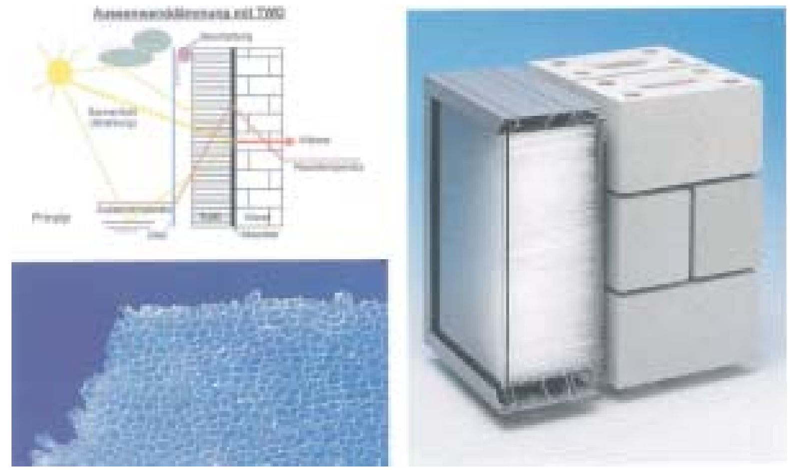
Design Centre Linz - Architect Thomas Herzog + Partners

Summary

Glass Technology in Relationship to Alberta

The Linz design center uses a micro-sun shielding louvre system similar to the one produced by Siemens AG. The micro-sunscreen grid, integrated in a double glazing unit, helps to create a bright, transparent internal space with pleasantly cool temperature conditions even at the height of summer.[18] This technology works best in glass roofs where diffused daylight is required and direct solar radiation is to be avoided.[19] The Design Centre Linz uses this glass technology in a intellegent system which controls heat gains.

This technology would work very well during Alberta's summers, because we get high sun angles. This system could prove very inefficient in the winter however do to Alberta's, comparatively low sun angles.



Solar Facade Element SolFas

Glass Louvered Sunscreening System

Translucent Heat Insulation made from Glass

GAP Corporate Offices, 901 Cherry
William McDonough + Partners

Building Overview

The corporate offices for the Gap in San Bruno California are best characterized by the qualities embodied in the roof. What makes this building an interesting case study is the use of a vegetated roofscape. The undulating line of the roof at 901 Cherry Ave. has come to characterize the building.

Set in San Bruno California, the corporate offices for the Gap find themselves somewhere between suburban development, an industrial landscape, and the rolling hills to the west.

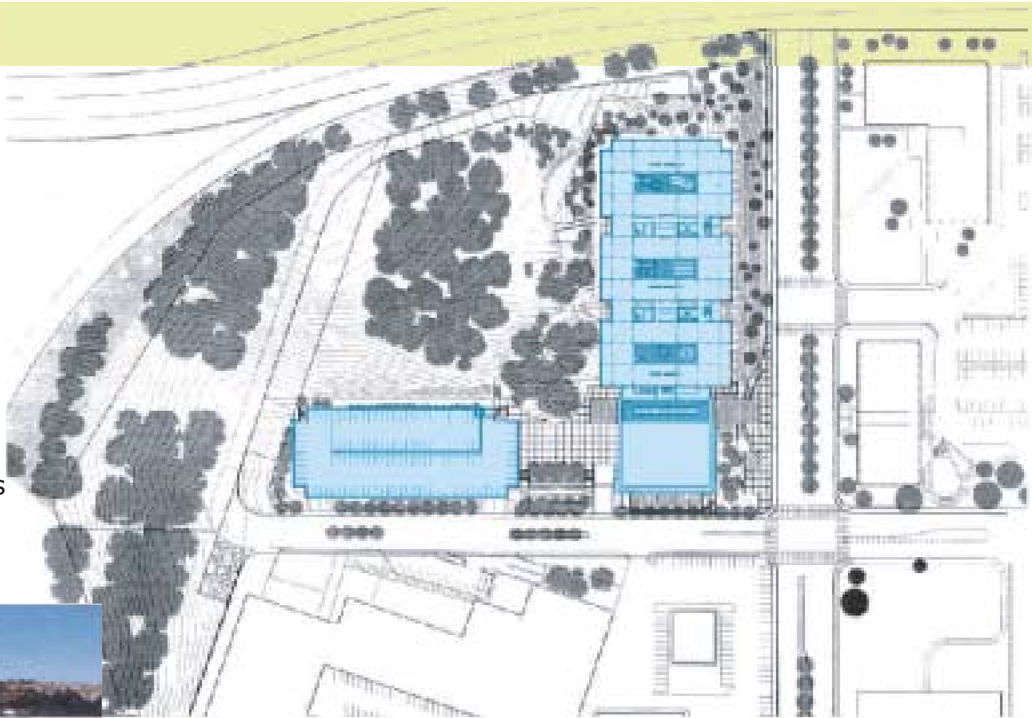
The building, designed by William McDonough + Partners, is 195,000 sq. ft. in floor area and completes the "campus" of buildings which comprise the corporate headquarters of the Gap. The building itself is of three distinct office bays. Each bay is organized around an atrium space that admits copious amounts daylight deep within the building. This strategy in combination with an electronically controlled lighting system has contributed to tremendous energy savings since completion of the project.

The firm of William McDonough + Partners has been recognized as a leader in the field of sustainable design. This report will examine the ecological features of the building which include the grass roof, the daylighting system, the cooling system, as well as a sensitivity to building placement on the site. This study will examine these features of the building and will attempt to demistify the ideas encompassed in the term "Green Architecture".

Site Selection

The building is oriented in a North - South fashion, with the largely glazed facades to the East and West. This orientation ensures that the building will not overheat during the hotest hours of the day. In addition, the building was sited in such a way as to preserve a grove of large oak trees.

The site for the Gap building is located directly across the street from two other Gap offices. As far as selection of the site, the architect was limited. Despite the site plan, which gives the impression that the building is located in a densely vegetated natural environment, the reality is that the site is surronded by roads, and flanked by a major highway overpass. Despite this proximity to major tranportation corridors, McDonough + Partners have managed to create what appears to be an oasis.



Site Plan

This raises the question of context. How does the building deal with the reality of it surrounding environment? The rolling roof line is supposed to conjure images of the rolling hills of San Bruno. This image seems slightly romantic given the proximity to the nearby rolling interstate.

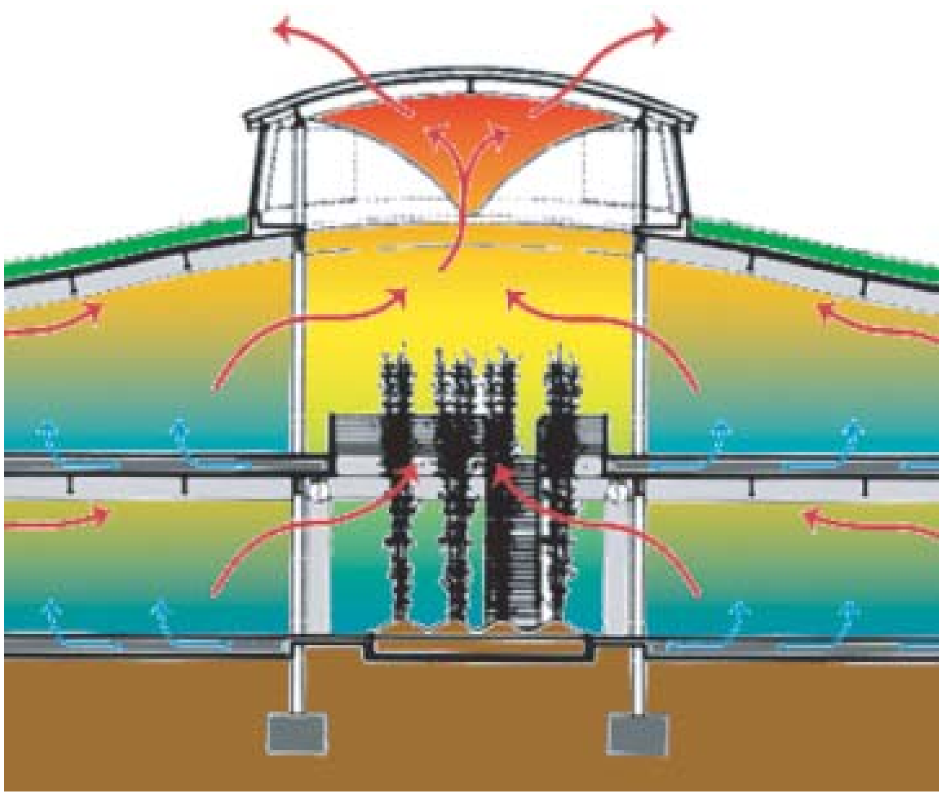
view toward the main entry

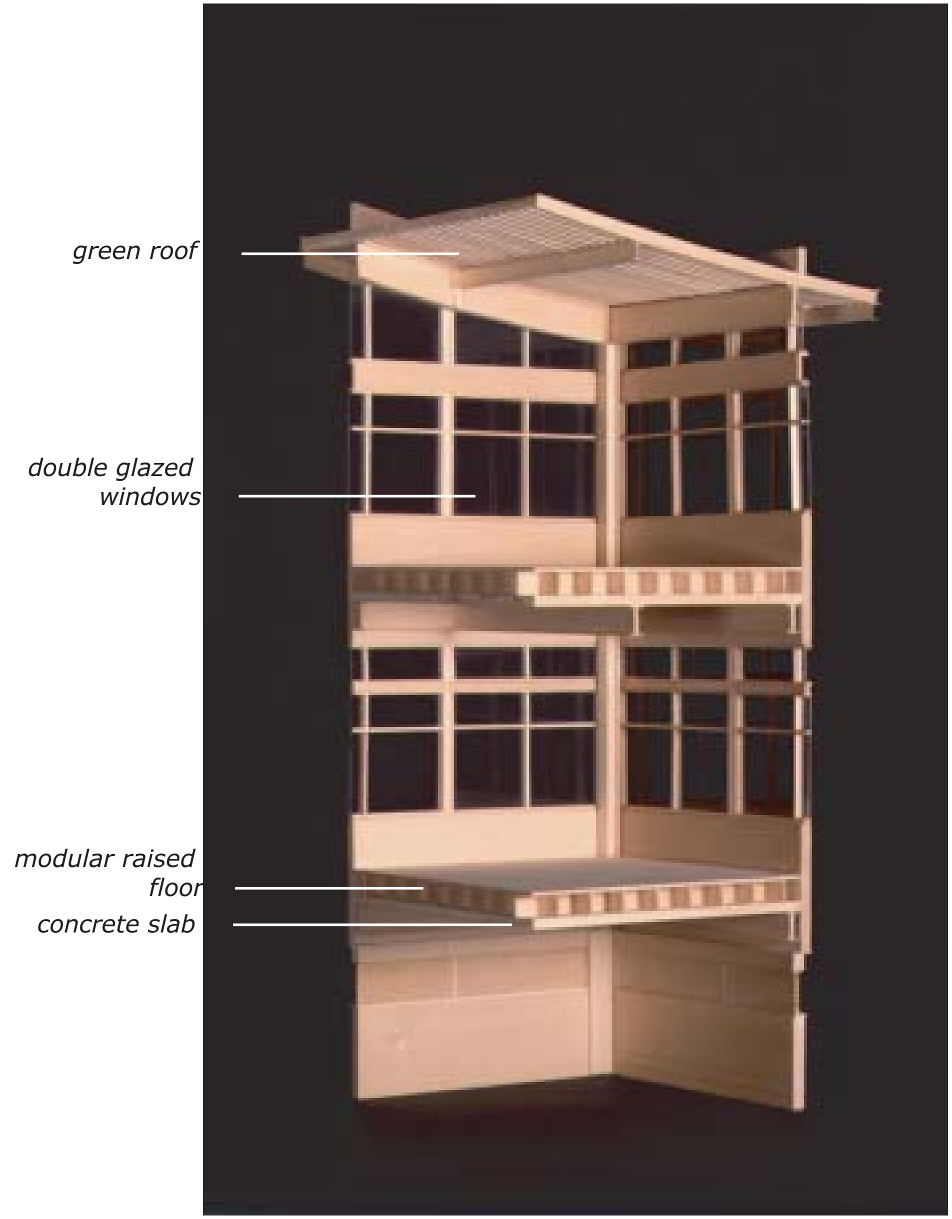
East Elevation

Cooling Strategy

Free Cooling Through Common Sense

These two diagrams show how the cooling system functions. The system at work relys heavily on passive heat transfer and convection forces. Cool night air is passed over the concrete slab, cooling it to a low temperature. The slab retains this temperature until the daytime, when it is released into the office to compenste for heating due to solar gain, computers, and people in the office. The modular floor system allows for flexibility of ventilation across the office. This system eliminates the need for any extensive air handing machinery.

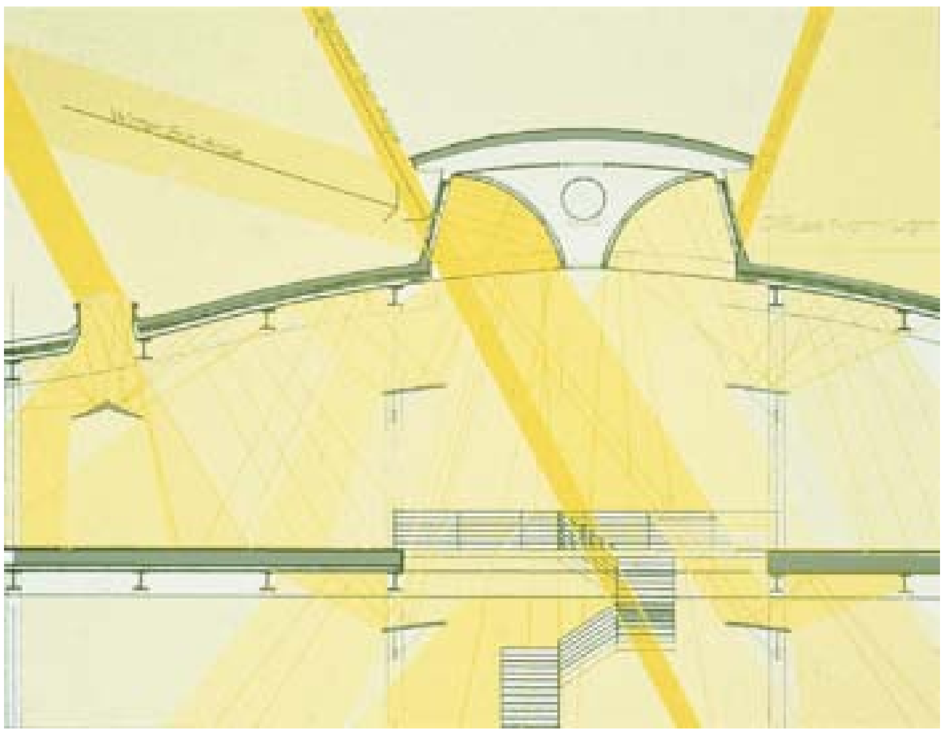




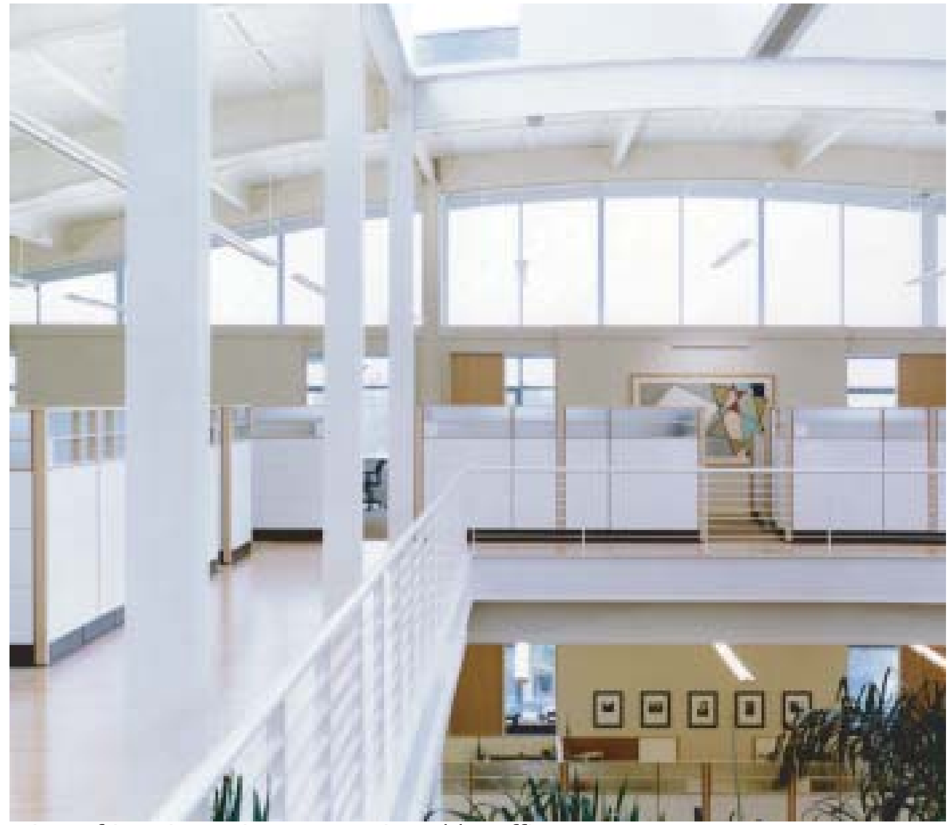
Lighting System

Daylighting = Energy Savings

The lighting design concept for the GAP building was simple according to William McDonough. "People would rather spend their days outdoors than indoors." The outdoors is brought indoors at 901 Cherry through three atrium spaces that are ringed by offices. This design ensures that offices are no further than 30 feet from a window throughout the building. Natural Light is supplemented by electronically controlled artificial lights that are dimmed according to a series of sensors. This lighting configuration allows the GAP headqurters to be 30% more efficient than the current stringent California guidelines.



Section illustrating light penetration into the building

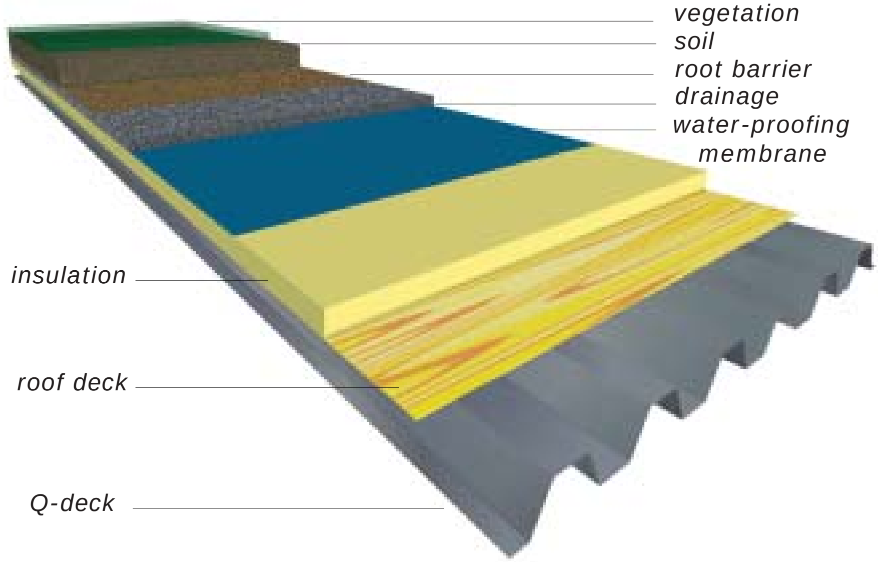


View of interior atrium space ringed by offices

Not only is the building more energy efficient, but the extensive fenestration provides an environment of varying light conditions throughout the day. This fulfills a psychological need for employees, enabling them to be more productive during their workday.

The Green Roof

901 Cherry, entry



What is a Green Roof?

Modern green roofs have a layer of soil covering them and plant matter growing in this soil. They can be installed on roofs that are inclined from 2º-50º. Green roofs are divided into two categories, extensive (thin) roofs and intensive (thick) roofs.

Extensive roofs have a very thin layer of soil ranging from 2-6 inches thick and are very low maintenance. These roofs are not meant to be habitable and must be planted with shallow rooting, drought resistant ground cover such as sedums, mosses, wildflowers, and prairie grasses. No extra structural support is required for their installation due to the light weight of the thin growing medium. Despite their thin growing medium they still provide all the benefits of green roofs (with the exception of providing habitable amenity space).

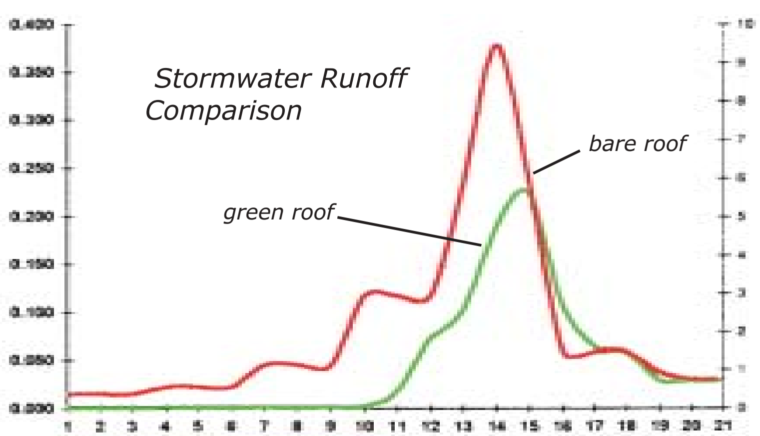
Intensive green roofs typically have soil depths of 18-60 inches and must be maintained in the same way as any conventional landscape. These roofs can sustain plant matter of all kinds, including many types of trees and shrubs. These roofs are habitable, potentially including terraces and water features, but require additional structural support.

The Composition of a Green Roof

Green roofs consist of all the normal elements of a BUR (roof deck, insulation, water-proofing membrane) as well as several additional elements. These include a root barrier, a drainage system, a soil filter, the growing medium, and the plant matter. Manufacturers have developed different products that fulfill these basic functions in a variety of ways(including the growing medium and the plant matter) all of which have their advantages.

Green Roofs

View out a second floor office onto the roof



Benefits

Storm Water Management

The growing material of a green roof holds a substantial amount of rainfall which can then be used during dry spells by the plant matter on the rooof. As a result a green roof can reduce by up to 60% the amount of rainfall on a roof that reaches the storm water systems

Improved Aesthetics and Usefullness

A green roof reduces glare, provides a meadow-like landscape for those above or beside it, and potentially outdoor amenity space for the building occupants.

Enhanced Durability

European studies and experience suggests that living roof systems last 2 to 3 times as long as standard flat roofing systems due to the protection that the soil provides for the water proofing membrane (the most critical aspect of the assembly).

Soprema, one of the leading suppliers of living roofs in North America, recently provided the Chicago City hall living roof with a 15 year guarantee, up from the usual 10 for a standard BUR.

Green roofs

The Alberta Context

Reduced Heating Loads and Heat-Island Effect

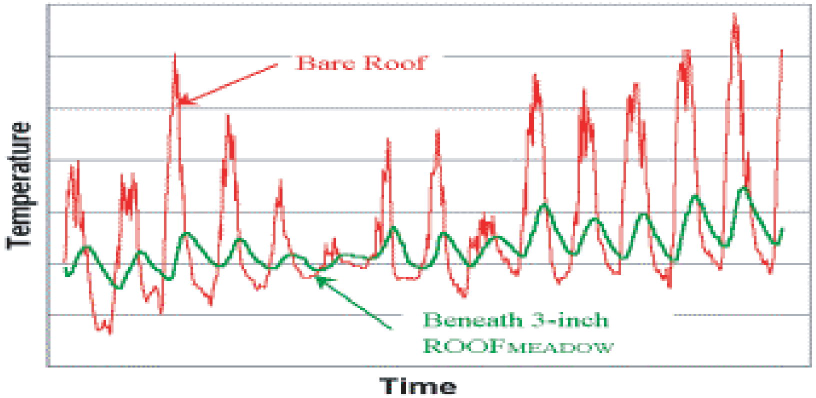
A living roof can reduce the cooling costs by 20-30% by lowering and moderating the surface temperature of the roof itself. The reduction of black roof surfaces in urban environments greatly reduces the creation of 'heat pockets' which surround North American cities. In Chicago it is estimated that covering all the existing flat roofs in the city would result in a 100 million dollar annual savings of energy costs, due to both the moderating effect of the roof and the lowering of the air temperature of the city.

Noise Insulation

The mass and density of a living roof provides extremely effective noise insulation, especially against low frequency sound that standard insulation does little to mitigate.

Pollutant Filtration

The vegetation and soil of the living roof system both filters and holds various air-borne particulates, hydrocarbons, pesticides, and volatile organic compounds. Many of these 'caught' pollutants are then used and disposed of by the natural systems of the vegetation on the roof and the microorganisms that are present.



Conclusions

The Gap Building at 901 Cherry Ave. by William McDonough + Partners exibits many "green " characteristics. These concepts could and would be transferable to any number of regions and climates. This of course would require certain modifications to secondary and tertiary systems such as the building envelope, and structural detaling. Also, an increased system of heat delivery would be required in order to adequately controll temperatures within the building in colder climates.

Conceptually the building develops the idea of an architecture of landscape. In particular the undulating roof plane suggests rolling hills similar to those found across the prairies and into Alberta. This would imply that the architecture, depending on its immediate setting could be appropriate to the Alberta situation.

The concept of the green roof is one that is applicable across the globe, and particularly in Alberta, where native grassland ecosystems have been exacerbated. The introduction of this type of roof could re-establish this ecosystem in a new and interesting way.

View from the oak grove

Minnaert Building, Utrecht
Willem Jan Neutelings & Michiel Riedijk Architecture

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Building Overview

The Minnaert Building acts as a collection point linking the existing network of the northwestern node of the Uithof University campus an extension of the University of Utrecht. Developed in the mid nineteen-nineties the programme consists of three primary elements consisting of: classrooms, laboratories, a restaurant and pleasant workspace for three departments.

The functional programme of the building is set around a central hall derived from a culmination of all "tare spaces" which are the circulation and service spaces condensed, creating something out of what would normally utilitarian service space. The conceptual idea is to create a meeting place for the varied groups using this multi-purpose building. This central space is a transit area, meeting place and the service core all within this dynamic grand hall. The architects have crafted a well-placed position for each of the main programatic elements that tie back into or spill out onto this central hall.[1]
The prime feature of this hall is a clever integration of a pond (10m x 50m), which collects rain water, an integral role in the environmental agenda that these Dutch architects have fostered as a natural progression in their practise. The building acts as a device to manage stormwater. This collected water cools the building as it is pumped through a circulation system. During rainy periods the water falls noisily into the hall, creating an interactive feast for the senses.

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Site and Context

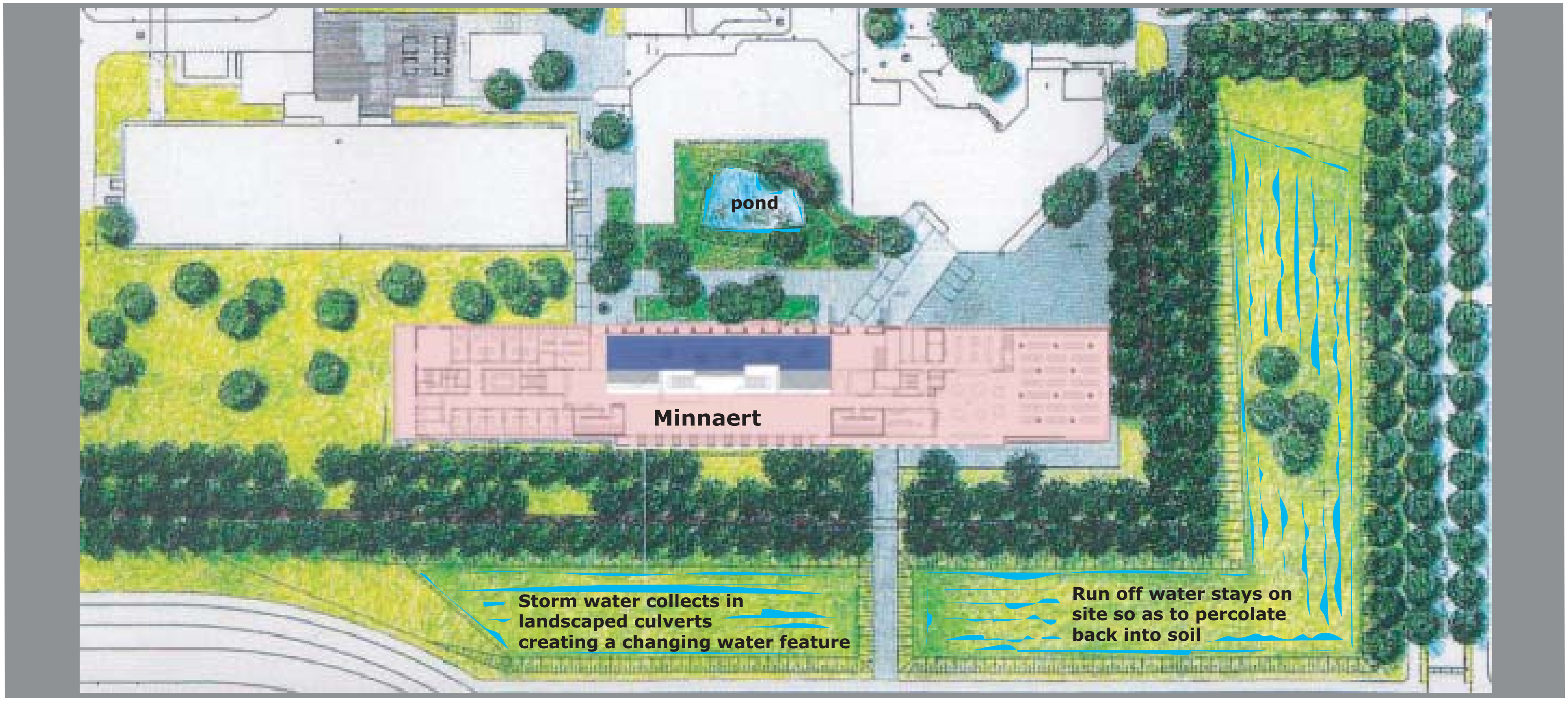
The site of the Minnaert Building is the northwest corner of the main university in Utrecht, Netherlands. The conditions of this cooler climate call for a strict insulation standard that often creates overheating in buildings. This creates a condition where the buildings consume vast amounts of energy to cool them. The concept of sustainable site water management helps to solve this problem.[2]

Site Sustainability

Integration into Site and Context

The green strategy utilized in this building carefully examines the geographic, climatic, and cultural context. It examines natural cycles that characterise this part of the planet and devises a strategy which works with this natural balance. This green strategy works well within this particular northern climate.

Water is an everyday concern for the people of the Netherlands as most the country sits below sea level. Culturally water has a strong tie to the national identity. The sophisticated integration of water as a dynamic and responsive element in the operation of this building shows a vision of cultural relavance in their design.



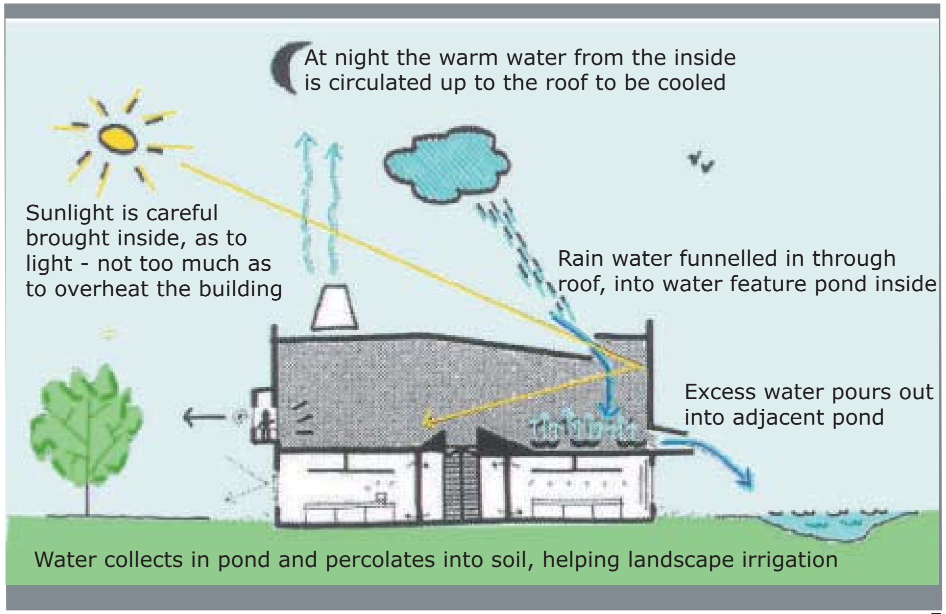
The Minnaert Building sitting at the northwest corner of the campus, completing the circuit - connecting the university network

Sustainable Water Management

Site Water Management

Neutelings and Riedijk have taken a clever appoach to dealing with the issue of on-site water management. They have incorporated water as an intergral element of the design. Water plays an important role in the overall air conditioning strategy, but also acts as a dynamic element that help activate the central hall making the connection between the inside and the outside that much stronger.

The water in the 150ft. X 30ft. pool feeds a circulation system, by which the micro-climate within the building is controlled. The water collected in this pool acts as a heat sink drawing out the heat that collects in the building over the course of the day. At night this water is pumped up to roof the roof, carrying away with it the day's heat.[3] Even in the cold days of the Northern European winter, the building collects heat from computers and machines, people and sunlight. Due to the tight construction of these buildings, this heat is trapped inside and usually requires energy consuming air conditioning units to cool this indoor environment. The architects through a keen sense of space management have created a natural air conditioning / ventilation system. The ingenious system they developed resolves several issues regarding the indoor air quality, while promoting their environmental agenda.



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The building acts as rain collector, using the water to create a micro-climate

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Looking east across the great central hall - 2nd floor

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The computers in the labs and the library serve to heat the building.

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The water circulates acting to cool the building through panels below ceiling.

The Water Cycle - A Green Strategy

Natural Ventilation - Low Energy/High Performance

Due to the large number of computers in the library and adjacent labs the building requires very little heating. The building managers are more concerned with cooling the building. The unique cooling system devised to facilitate this consists of a large panels suspended below the ceiling through which cool water is passed. The water is drawn from the pool of collected rain water on the second floor. The cooling panels absorb the rising heat that collects in the building and draws it away. The warm water is circulated to the roof where the heat escapes into the night air. After being cooled the water is returned to the pool continuing the cycle.

This cooling system uses the whole building to moderate and control the internal environment for a more comfortable and energy efficient building. The water level of the pool in the central hall rises and falls as the circulation system requires, this is easily seen as it is marked along the sloped edge of the pool defining the perimeter of the large pool.[4]

The building's cooling system also relies on natural ventilation. This once again helps to minimize the overall energy consumption. The pumps that circulate the water are the only energy consumers in this system. The great saving afforded by this creative solution to air conditioning makes this buiding a model for others to consider.

The architects have taken a strong influence from the workings of the human body in devising the cooling system. Utilizing a simple system the architects have achieved great results. Rather than relying on complex air handling units they have used the natural rhythm of the natural world to achieve a comfortable indoor living environment. Inspiration derived from nature will lead us to solutions which will help us live and work within the natural order rather than dominate it.

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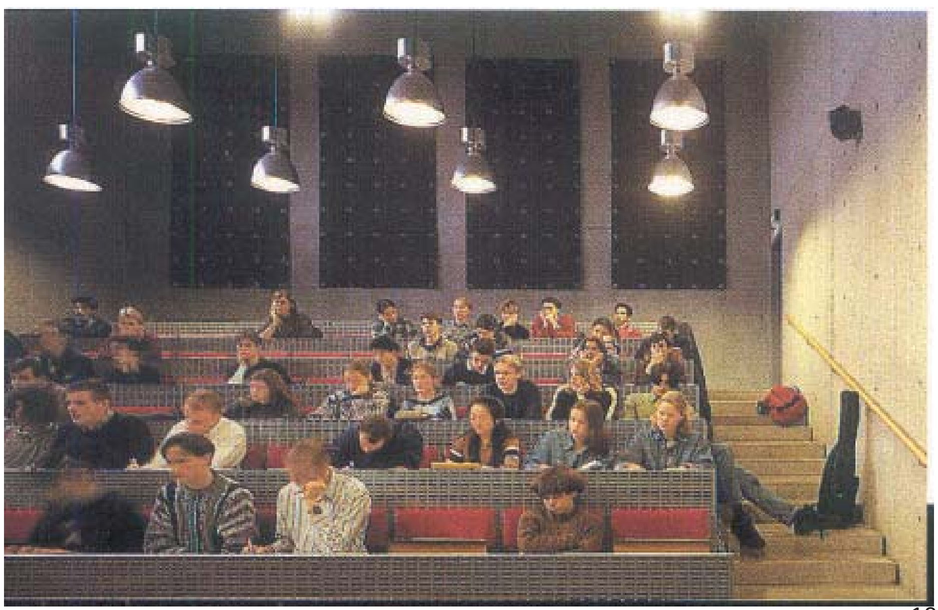
The evaporating water from the pool helps to circulate and cool the air.



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Keeping a building cool and comfortable is the key to a successful building

Total Life Cycle Costing - A Green Strategy

The creative strategy used to make this building unique incorporates an attitude of environmental responsibility towards the problem of cooling buildings.

Total life cycle costing is the type of holistic thinking that needs to take place in order for us to fully realize the great impact our built creations have upon this earth. We have to realize that the initial capital required to build is only a fraction of the cost that will be required to operate and maintain that building. The savings that can be accumulated over the life of a building will far exceed the initial cost of the building, if the first critical design steps are well thought out. The benefits of creating a green building result from the fact that the building is set to work within the balance of the natural cycle. In seeking this balance through proper design it is possible to achieve a healthy built environment, while sustaining our home - the earth.

The the green strategy highlighted in this building is based on a simple principle of proper water management. In allowing the building to operate much like the natural environment around it, the benefits that can be found rewarded the users and managers of this building with a comfortable and inviting work place, that does not tax the resources of the earth.

To get a better understanding of this strategy we must put it into our local context. To try to apply this same strategy into the context of our cold dry prairie the result would be very different. Due to the extreme temperature shift from hot to cold and the severe dry conditions of this landscape this particular architectural strategy could not work. Aside from the strict building code mandating a tight building envelope so as to exclude water infiltration into the building, the problems that would result such as water freezing into the roof funnels and causing a collapse, greatly exceed the benefits of using this strategy. The lesson we can learn is to more carefully consider the basic principle of the strategy and use the storm water that falls on our site to the advantage of the site and perhaps in the water requirements of the building.