PIERCING SKIN: Significance-Light-Tectonics

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Skin piercing may be defined as the artful creation of openings in the body. This metaphor is used as a means to appreciate the cultural relationship between building design and body art as a preoccupation of the 1990s.

BACKGROUND

The burning of fossil fuels to heat, cool and light buildings is a major environmental concern as it continues to deplete non renewable resources and cause environmental damage. Since the 1970s, the thermal performance of the non vision portion of the building envelope has been maximized and has succeeded in creating more energy efficient buildings—decreasing fuel consumption and resultant CO_2 emissions. Engineers continue to develop new glazing coatings and window systems which have increased the thermal performance of windows. High performance windows, however, do not provide the total solution to environmental envelope problems. For the architect, ground remains to be gained in handling the broader issue of piercing of the skin of the building. Students and practitioners continue develop projects which fail to treat sunlight as a valuable commodity. The cause of this is a failure to understand or take advantage of the environmental aspects of building openings.

Where the body is a building, the piercing of the skin has a profound effect on the act of design. Likewise, the critical attitude taken towards environmentally conscious design can have a tremendous impact on the successful articulation of openings in the building envelope. Apertures effectively puncture the building skin, resulting in a discontinuity of the integrity of the envelope. Piercing creates a thermal hiatus. Environmental concerns arise out of the loss of heat through these openings as well as the control of solar gain and daylighting.

> "...a fundamental weakness in most discussions of architectural aesthetics is a failure to relate it to its matrix of experiential reality ... this leads immediately to serious misconceptions as to the actual relationship between the building and its human occupants." [1]

The creation of apertures requires the concurrent resolution of often conflicting design criteria-formal pedagogy based on concerns of pure form and pattern versus experiential and thermal/environmental concerns. The making of openings addresses, as well as connects, themes of design, culture, technology and the environment. The act invokes the coordination of a complex set of issues including, significance (proportion/style), light (experiential) and tectonics (material resolution of envelope and thermal performance). From a technical viewpoint architects must learn to manipulate and manage the sun's effects on buildings to control heat and light.

> "And the cloud that passes over gives the room a feeling of association with the person that is in it, knowing that there is life outside of the room, and it reflects the life-giving that a painting does because I think a work of art is a giver of life. So light, this great maker of presences, can never be ... brought forth by the single moment in light which the electric bulb has. And natural light has all the moods of the time of the day, the seasons of the year, [which] year for year and day for day are different from the day preceding."
>
> - Louis Kahn.[2]

> Light is the double edged sword. It is simultaneously a design and a technical issue!! It is the essential thread which connects / mediates / arbitrates formal design criteria and tectonic / environmental concerns. Light is an architectural element akin to structure and materials.[3]

The manipulation of light has always been a concern of vernacular architecture—i.e., direct sunlight penetration equals heat gain. Daylighting can reduce the need for artificial source lighting, thereby effecting environmental gains through a reduction in the use of electricity. Cold climate architecture developed to increase light penetration into buildings. Light renews the spirit during the short winter days and simultaneously creates heat. Mediterranean and arid regional architecture traditionally developed building styles which excluded large quantities of direct sunlight, often in deference to capturing reflected light. This allowed for brightness without heat (UV). Perhaps this is why museums and galleries tend to take a more Mediterranean approach to naturally lighting interior spaces through the use of reflected daylight? There are no truly great pieces of architecture that do not take full advantage of the interactive dynamic potential of daylight.

> "The interaction between light and climate is multidimensional. It has to do with the spirit of the place, with thermal comfort, and also with culture, since climate affects people, their habitats, and their rituals. The character of light, its colors and rhythms, is one of the great contributors to genius loci. ... Light can convey a visual message that transforms the uncomfortable realities of a particular climate condition. For example, the admission of even a small beam of sunlight into a building in a northern climate on a cold winter day can add a sense of vitality and sparkle to the interior. This fact may seem obvious, but there are many buildings in northern climates that exclude sunlight, or conversely, admit it unrestrained so that it presents a visual burden due to its intensity

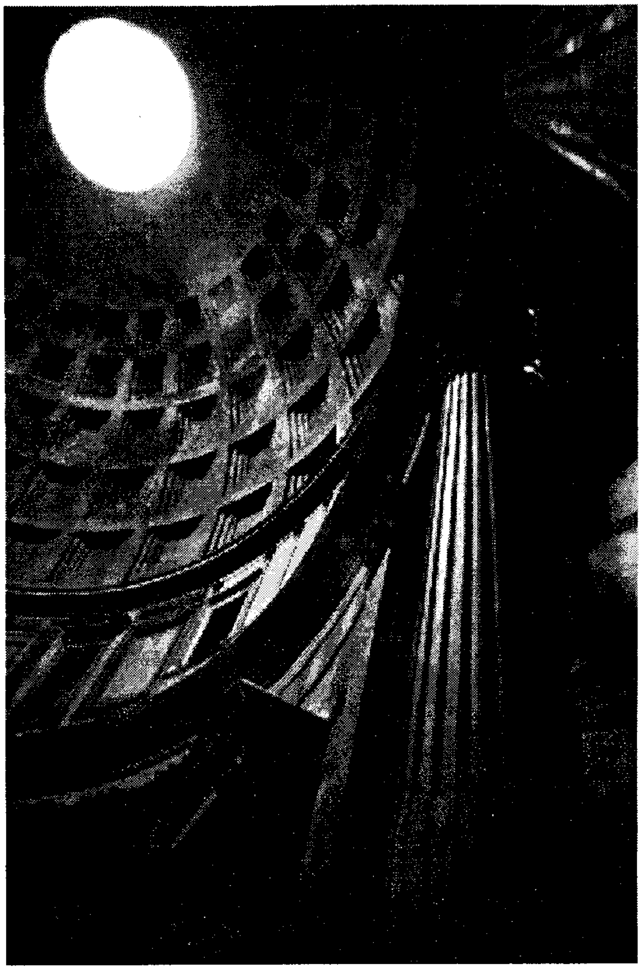

Figure 1: Light from the oculus of the Roman Pantheon.

and the glare conditions it creates as well as a thermal burden through the heat that accompanies it."[4]

The sun's radiation, if properly controlled, is capable of supplying cold climate buildings with free heat energy. If improperly managed, the sun can overheat a building and necessitate excessive cooling expenses. Apertures must be geometrically designed, according to winter and summer solstice sun angles, to maximize the entry of the sun in the winter and shade the interior from the sun during the summer. During the winter months, in cold climate buildings, solar energy must be able to be stored within thermal mass on the interior of the building. This allows for the storage of excess heat during the day and slow release during non daylight hours. If thermal mass is not available (as is the norm in wood frame buildings with batt insulation), heat builds up in the air and comfort cannot be achieved. Venting is required and the free energy is lost. External shading devices are required during the summer months to prevent heat gain from entering the building. Light shelves can both enhance the penetration of daylight and provide external shading.

It is not possible to consider the effect of the sun on the openings in a building without constructing a three dimensional model and testing the model in either real or simulated light conditions. Physical (versus computer) models when tested on a heliodon provide a quick and fairly accurate impression as to the general effectiveness of the method of fenestration, penetration of light into the building at varying times of the year, and the geometrical correctness of solar shading devices and light shelves.

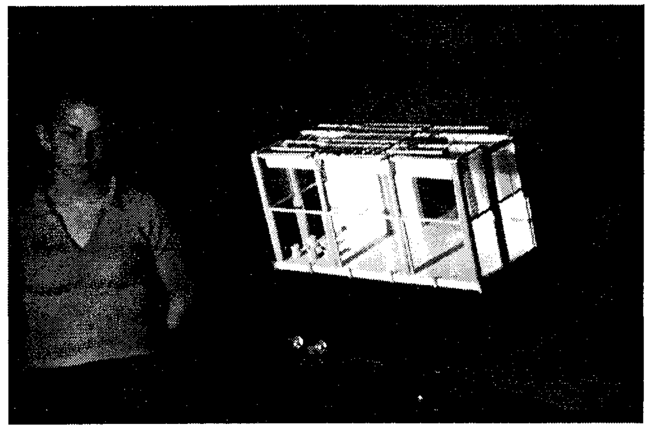

Figure 2: Illustrated is a 1:10 scale lightbox from the second year design studio under the direction of Professor Marie-Paule Macdonald. Winter solstice lighting conditions at noon are simulated.

THE FORMULATION OF THE STUDIO PROJECT

There typically comes a point in the design process where the early design student is somewhat satisfied with the plan of the building and commences to create elevations. It is often an awkward move and can tend to result in graceless diagrams symbolizing facades. Where the initial locations for windows and doors were attached to the plan, dissatisfaction with the facade seems to necessitate an absolute detachment of these elements and their subjugation to a pattern. Windows are added or deleted, enlarged or reduced, raised or lowered— without regard to orientation and the functional or experiential requirements of the plan or cross section—in order to satisfy the aesthetic quality of the facade.

The program of study in the second year design studio at the School of Architecture at the University of Waterloo created a new project to highlight the specific issues associated with piercing the building envelope. The aspiration of the project arose from the desire to eradicate thoughtless rectangles... spots and dots on the elevation. Although the official title of the project was "The Environmental Envelope," the project was soon affectionately called "The Lightbox" by the students, a title which perhaps more aptly identified the critical issues of the problem.

Figure 3: Critic Darlene Remus looks at a second year model under summer solstice lighting conditions. The students could easily see the need to add external shading devices to prevent the apparent entry of sunlight into the interior at noon conditions.

The "Piercing Skin" project formed a detailed lead-in to a larger multi-family residential design project in the first half of the second year Design Studio. Initially the students were assigned one of three building elements to study—window, balcony and threshold. They first created a small scale (1:20) rough "light box" out of foamcore to examine (with the aid of a heliodon) the issues of orientation, solar shading and aperture size. Subsequently, they developed a detailed model (1:10) which showed the material nature and specific tectonic aspects of their proposal. Students were asked to incorporate a selection of these detailed building envelope elements (window, balcony and threshold) into the appropriate rooms of their final project. They were also encouraged to incorporate the designs of others in their projects. The process was intended to reverse the normal design process — that of working from the plan to the elevation — in order to ask that the students think more deeply about apertures and orientation.

The students were asked to look at the piercing of the skin of a building as a significant event with respect to architectural design, program and the experiential quality of the space, both interior and exterior. The project addressed as well as connected issues of design, culture, technology and the environment. The students were to develop prototypical building elements of threshold, balcony and window, while examining conditions of "significance," "light," and "tectonics." Significance was suggested to include such issues as architectural meaning, cultural importance, function/purpose, proportions/composition, architectural precedent and initiative. Issues of light were to include control, manipulation of the experiential aspects of the interior as it related to the desired use of the interior space, quality of light, orientation, passive solar gain and solar shading. Tectonics was suggested to include the implications of cutting the envelope, the construction of the envelope, the materiality of the opening(s), the material nature and construction of the elements, the detailing of shading devices and light shelves, the use of the heliodon and representational model building.

The architectural significance of threshold, window and balcony lead to a study in environmental contrasts: daylight and thermal. The design of these elements had direct ramifications on the experiential quality of the space, daylighting, the condition of comfort and the condition of human occupation. The creation of apertures effected by piercing the environmental envelope characterized the transition and passage from interior to exterior as well as from exterior to interior—entrance versus exit—beginning versus end. They also addressed the very specific nature of materials as related to texture, construction, reflectance and design detail.

The elements all shared the condition of "aperture," and could be seen as a penetrable "screen." The aperture framed a view and modified the environment. The disposition of these elements addressed formal issues of composition in the facade. In order to be effective, the design of these elements required a cognitive manipulation of: scale, material, light, and view.

Central to the exercise was the development of physical models of a series of prototypical rooms whose primary study facade was one of "threshold," "balcony," or "window." Programmatically, the rooms were to be a detailed part of a much larger multi-family residential project under simultaneous development. The rooms were tested using a pair of heliodons set at winter (December 21) and summer (June 21) solstices. This allowed for a live demonstration of the changing effects of the time of day and time of year. The ability to manipulate orientation and see its the direct ramification was paramount to appropriate design development. The models were designed to be easily modified in order to enrich the ease of the hands-on design process. The models were constructed of 1/4" white foamcore although it is translucent and not completely impermeable to unwanted light. It was felt that for the first stage of the project, the workability of the material would offset its inaccuracy in correctly representing the actual nature of the lighting conditions. This material is structurally simple to work with as it is rigid and can be quickly pinned together which avoids the time consuming use of glue. The preference was for "quick and dirty" over "painstaking and finished."

Given the location of the University of Waterloo, cold climate concerns were of central importance to the design issues of the "lightboxes." The objective in designing the south facing openings and shading devices was to maximize solar penetration (heat, light) during the winter months and eliminate solar penetration (but not quality of light) during the summer months. Because these were working models, the students were able to modify the construction, orientation and geometry of shading devices during the reviews to achieve these goals. Materials of varying reflectivity were available during the working reviews which could be used to either bounce or absorb solar radiation. It was possible to see the effectiveness of light shelves and their ability to reflect light more deeply into the interior, while at the same time shading from direct solar gain. Comparative modeling at both solstices allowed the students to test the same devices at opposite solar conditions as a means to optimize their designs. Conversation at the reviews not only addressed the more technical solar penetration issues, but as well issues of quality of light, human comfort, and glare. As these were prototypical room studies which were to be adapted to a larger final term project, students also addressed the suitability of the daylighting strategy to the specific function of the room. There was experimentation with varying types of glazing (clear, opaque and bubbled) as one means to alter the light quality of the interior environment. Although all of these technical issues are able to be modeled using computer simulations, this type of physical modeling proved superior as it was very accessible to all of the students, providing them with an immediate look at experiential as well as technical aspects of their projects.

The studio project recognized the predisposed "design" position of elevational studies and expanded it to address daylighting and solar geometry (insolation and shading). Current issues relating to environmental concerns, building science and daylighting demand the development of a critical pedagogy to inform the articulation of the facade and building envelope. This pedagogy must connect the technical/environmental issues to design. This was done by examining the experiential qualities associated with light and the material and thermal aspects of the interior environment. As you manipulate light you create dynamic space, you play with textures and the reading of materials, you control solar gain, you manipulate shading devices, you control glare and visual comfort, you alter thermal comfort.

Specifically, arising from my experience of teaching both Building Construction and Design Studio to second year students for several years, the "Piercing Skin" studio project was designed to address some of the following concerns:

- to create a project which made a pointed connection between what is taught in a technical class and the process of design as examined in the Design Studio
- to highlight the point in the students' design process when windows appear as a silly pattern of rectangles (and other shapes) on an elevation— a geometry and patterning game—extruding upwards from plans and then adding spots and dots...
- to recognize that light and its manipulation has the potential to create fabulous versus mediocre, space, remembering fondly the Pantheon, Chartres, Kimbell, Carpenter Center ... experiential architecture
- to illustrate the importance of sections and of drawing a section of the window in the room with people in it: Why are the head and sill height where they are? Can I see out of it? Is it suitable to the function of the room? Will the experience of the space be better because of the manipulation of light and the view that results from the design of this window?
- to point out that students (and practitioners, for that matter) must not continue to ignore orientation; south, east, west and north

light are all very different in terms of heat, color of light, angle of penetration, character, time of day as connected to the function of the room;

- to stress that windows are a major cause of energy expense in a building,but can be designed for solar gain and controlled with shading devices (shading devices and light shelves need to be modeled in order for students to appreciate their effectiveness in varying circumstances);
- to realize that apertures can provide ventilation. The way in which a window opens alters the breeze and feeling of connection to the exterior. You can leave certain windows open when it is raining but not others —who needs all the windows shut on a rainy hot summer day?
- the project is about getting students deeply involved with three- and four-dimensional studies of these issues to get them off the drawing board and away from their computer screens.

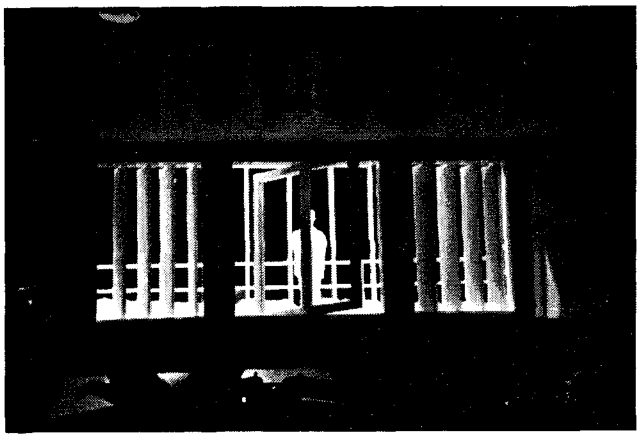

Figure 4: A view of the interior of the lightbox from the rear.

OUTCOMES

The Piercing Skin project exposed the students to a "fourth dimension of architecture"—that of the experiential. Although there are aspects of the project that could be strengthened, its overall impact was successful. The students (and the guest critics) were visibly excited when they could see how their building elements performed (or not) when tested on the heliodons for summer and winter conditions. Many of the students had performed sun angle calculations to design their openings and shading devices and were eager to be able to verify the effectiveness and accuracy of these aspects of their building elements.

Introducing this project at an early point in the curriculum provided the students with a working tool with which to develop projects in subsequent design studios and during their professional career. Students in a parallel third year studio with "light" as its central theme carried out independent tests of their models for light quality on the heliodons. Another group of students involved in conducting detailed building performance case studies in conjunction with our entries into the University of California at Berkeley's "1998 Vital Signs Student Case Study Competition" constructed building models to conduct year round lighting and shading device studies to support data collection and provide images for their web documents.[5]

One such study was carried out in some detail for the Green on the Grand, C-2000 Office Building, in Waterloo, Ontario.[6] The main focus of the building designed by Snider, Reichard and March Architects was to achieve an even level of daylighting throughout all office spaces, regardless of building orientation. The designers of that building also chose to use a highly energy efficient window which was capable of selective transmission of light, instead of a more conventional window coupled with sun shading devices. The actual physical study by the students took place during a short time frame during the month of March. Situated at the equinox, March is neither representative of the severity of winter sun penetration nor summer angles. This was not ideal as most apertures that are designed with passive solar strategies and daylighting in mind make use of solstice geometry, whose effectiveness could not be seen at this gray time of year.

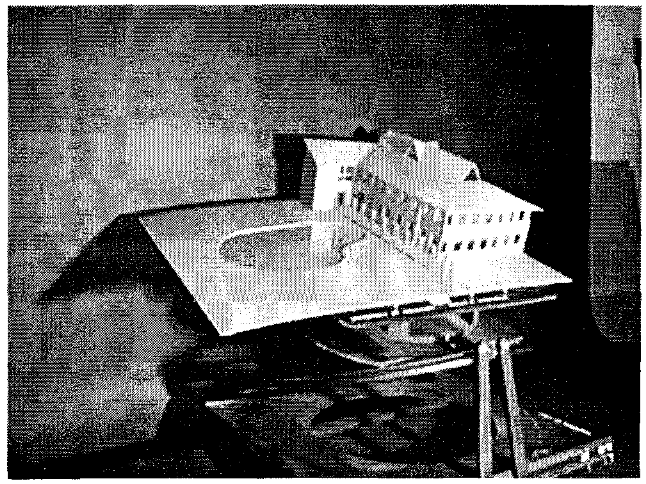

Figure 5: Green on the Grand: Daylighting case study model showing mount on heliodon.

Through the heliodon models, the students were able to quickly simulate conditions at all times of the year and commence a more accurate assessment of the successes and failures of the project from the point of view of solar access, lighting levels, glare and human comfort. The lighting models were able to be compared with actual data collected from the building site through the use of light meters and light dataloggers, and with information generated through the use of lighting simulation computer programs such as Energy-10.

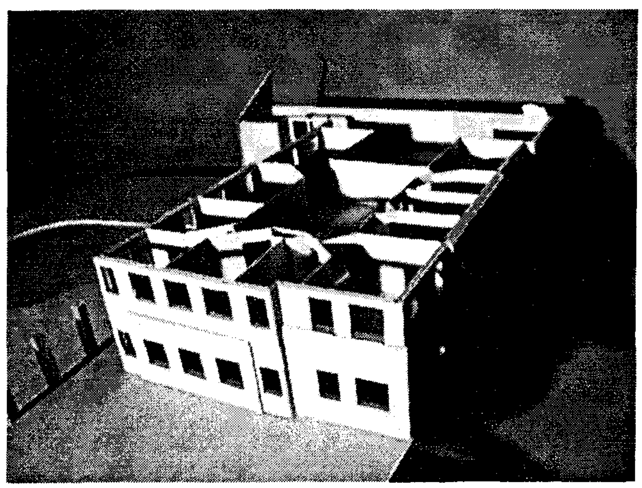

Figure 6: Green on the Grand: interior view (roof removed) of daylighting, on a heliodon.

ENVIRONMENTALLY SPEAKING

Sunlight is free and entirely renewable. It is irresponsible to continue to design buildings without regard to the potential benefit of solar energy and daylight. Numerous studies have been carried out which outline the health benefits and energy savings of daylit buildings. Computer programs are available to assist architects in applying basic principles to design passive solar buildings. The Piercing Skin Project is designed to initiate the education of the architect with regard to the design of apertures and to introduce a pedagogical stand in regard to the relationship between the building and the environment. Students and practitioners are constantly building models. It is not a great leap to suppose that these should be examined under realistic lighting conditions. Current issues relating to environmental concerns, building science and daylighting demand the development of a critical pedagogy to inform the articulation of the facade and building envelope. The basis for this pedagogy is light.

NOTES

[1] Fitch, James Marston, "Experiential Context of the Aesthetic Process," *Journal Of Architectural Education*, (Winter 1988).

[2] Kahn, Louis. Light is the Theme. (Kimbell Art Museum, 1975): 18.

[3] Millett, Marietta. *Light Revealing Architecture*. (New York: Van Nostrand Reinhold, 1996): 59.

[4] Millett, Marietta. *Light Revealing Architecture*. (New York: Van Nostrand Reinhold, 1996): 17.

[5] Details of these case studies can be found at the University of Waterloo Website located at <http://www.fes.uwaterloo.ca/Departments/Arch/>

[6] C-2000 is a program sponsored by the Canadian government to develop small commercial buildings which exhibit high energy efficiency.