ACSA Annual Meeting, Technology Conference Montreal, June 1999:

Terri Meyer Boake B.E.S. B.Arch. M.Arch.
Associate Professor
School of Architecture
University of Waterloo

PIERCING SKIN: Significance~*Light*~Tectonic

The year 2000 is the beginning of the future of architecture. If architecture is to have a future, it must begin to more seriously consider its impact on the environment. Environmental considerations must begin to impact the teaching of the beginning design student.

Daylighting is an aspect of architectural design that calls into play concerns that are environmental/technological as well as aesthetic. As a result of its dynamic nature, the issue of daylighting can be readily integrated into early design teaching. In order to give substance to the implementation of daylighting in formative design projects, it is imperative that students also be given a degree of grounding in the more scientific aspects of solar geometry, climate and the environment.

skin piercing -- the creation of openings in the body...

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 1970's, 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 emissions. Engineers continue to develop new glazing coatings and window systems that 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 piercing of the skin of the building. Students and practitioners 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 heat through these openings as well as the control of solar gain and daylighting.

The creation of apertures requires the concurrent resolution of often conflicting design criteria -- formal pedagogy 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 manage the sun to control heat and light.

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.


The Roman Pantheon: the impact of light from the oculus

Manipulation of light has always been a concern of vernacular architecture -- i.e. light = heat. Daylighting also reduces the need for artificial source lighting, thereby effecting environmental gains through a reduction in the use of electricity. Northern architecture developed to increase light penetration into buildings. Light renews the spirit during the short winter days and simultaneously creates heat. Mediterranean and arid 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 natural 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. ... 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 and the glare conditions it creates as well as a thermal burden through the heat that accompanies it."
Marietta S. Millett. LIGHT REVEALING ARCHITECTURE. 1996

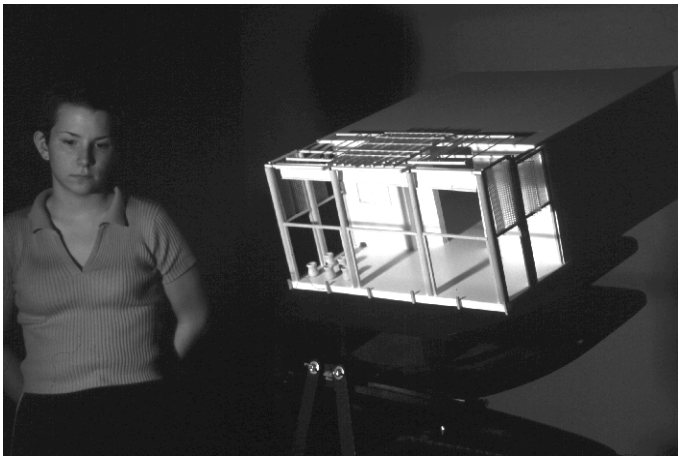
The sun, if properly controlled, is capable of supplying buildings with free heat energy. If improperly managed, the sun can overheat a building and necessitate excessive cooling expenses. Apertures must be geometrically designed, according to winter and summer solstice sun angles, to maximize the entry of the sun in the winter and shade the interior from the sun during the summer. During the winter months, 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), 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.

the aspiration lies in the desire to eradicate thoughtless rectangles...
spots and dots on the elevation...

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 geometrical correctness of solar shading devices and light shelves.

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 often tends 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 -- to satisfy the aesthetic quality of the facade.



model on heliodon under winter conditions

model on heliodon under summer conditions

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. 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. Central to the exercise was the development of physical models which 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 design process.

Cold climate concerns were of central importance to the design issues of the “lightboxes”. The objectives in designing the south facing openings and shading devices were 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 to achieve these goals. Materials of varying reflectivity were available during the live reviews that 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 to be 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.

The "Piercing Skin" studio project was designed to address some of the following concerns:

- 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 plans and adding spots and dots...
- recognition that light and its manipulation has the potential to create fabulous, versus, mediocre, space -- remembering fondly the Pantheon, Chartres, Kimbell, Carpenter Center... experiential architecture
- sections!!! draw 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 view that results from the design of this window?
- 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 function of the room
- 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)

- apertures can provide ventilation, breezes -- 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 3 and 4 dimensional studies of these issues -- get them off the drawing board


view of interior of model on heliodon

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 into their final project. 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 architectural significance of *threshold, window* and *balcony* can allow for a discussion of environmental contrasts: daylight and thermal. The design of these elements has direct ramifications on the experiential quality of the space, the condition of comfort and the condition of human occupation.

Outcomes...

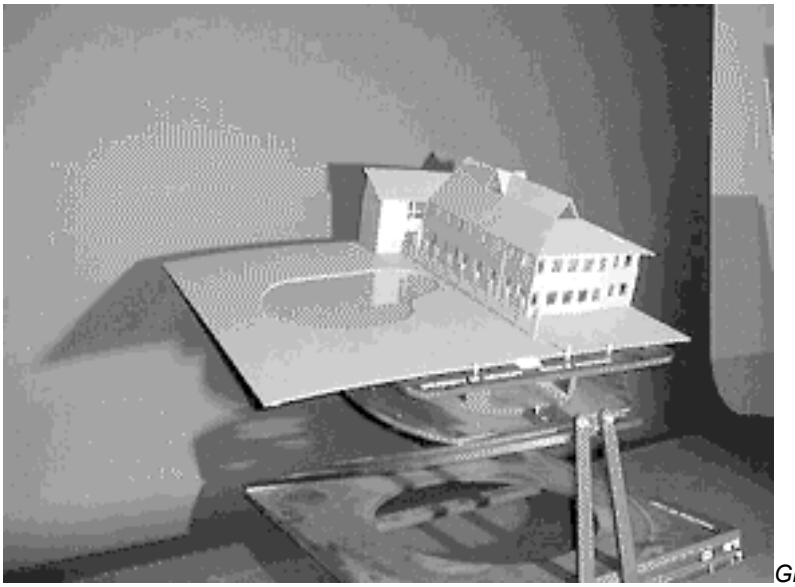
The Piercing Skin project exposed the students to a "fourth dimension of architecture" -- that of the experiential. Although there are aspects of the project that could be strengthened, its overall impact was successful. The students (and the guest critics) were visibly excited when they could see how 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 of these aspects of their building elements.

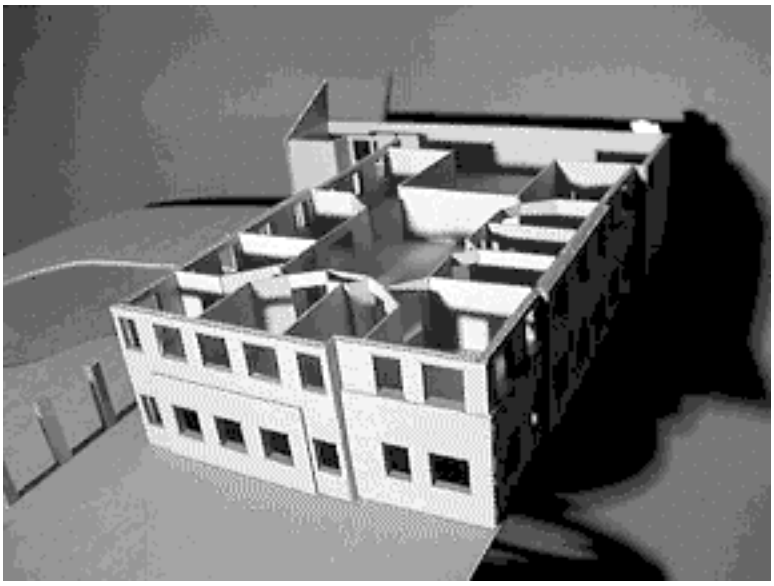
Introducing this project at an early point in the curriculum provides the students with a working tool with which to develop projects in subsequent design studios and during their professional career. Students in a parallel third year studio with “light” as its central theme carried out independent tests 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 “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.

One such study was carried out in some detail for the Green on the Grand, C-2000 Office Building, in Waterloo, Ontario. The main focus of the design was to achieve an even level of daylighting throughout all office spaces, regardless of building orientation. The designers 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 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.

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 Hobo Light Dataloggers, and with information generated through the use of lighting simulation computer programs.



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



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.