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MEASURING A BUILDING'S VITAL SIGNS:
Cold Climate Case Studies:
The YMCA Environmental Learning Center, Paradise Lake, Ontario

Background:

The Vital Signs Curriculum Materials Project examines the physical performance of buildings, their energy use and their impact on occupant well being. The goal of Vital Signs is to encourage the next generation of architects to create energy efficient and environmentally responsible buildings. The U.S. based project is supported by The Energy Foundation, Pacific Gas & Electric, The National Science Foundation, The Nathan Cummings Foundation, The Educational Foundation of America, The U.S. Department of Energy and the Society of Building Science Educators. It is operated from of the Center for Environmental Design at the University of California at Berkeley.

The Vital Signs Project feels that architects must be targeted for education about energy and environmental issues. Energy issues ought to be considered and balanced with other aspects of the architectural design process at the earliest point of the project.

The Vital Signs Method for Building Performance Evaluation:

The main challenge of the Vital Signs Project is to restore an appreciation and understanding of the physical environment. Consideration of appropriate building design according to bioclimatic concerns should become one of the basic notions that governs the design process. Building performance, both from energy and occupant comfort points of view, needs to be brought to the forefront of architectural concerns. Understanding energy issues must be a key part of architectural education.

Such studies cannot be accomplished without adequate fieldwork. Data must be collected to verify assumptions and hypothesized performance criteria. The Vital Signs Project requires that students engage the building to assess its performance. This approach integrates abstract conceptualization with reflective learning, concrete experience and experimentation.

As part of the Vital Signs Project, twelve teaching "Resource Packages" have been developed by architecture faculty in the U.S. and Canada. These units address physical building performance issues such as energy use, the experiential quality of buildings and occupant well being. The specific topics include: whole building energy use, the dynamics of solar shading devices, natural ventilation, occupant thermal comfort, thermal mass, health in the built environment, indoor illuminance, and glazing performance.

The protocols for field evaluation fall into three levels. The first level is based on document based research, occupant interviews and observation. It does not require any equipment. The second level involves minimal equipment for data collection and uses simple site experiments to understand building processes and performance. The third level requires a significant equipment component and involves data collection and analysis over a period of time.

Building the Case Study Library:

A series of retreats held by the Society of Building Science Educators during the late 1980's concluded that there existed a rarity of good building case studies for students to study. A substantial amount of information is published about buildings when they are first constructed, and often unoccupied. Documentation is based design intent rather than "post occupancy evaluation". Buildings are seldom "followed up" to assess their ability to perform as predicted.

In addition to providing a general environmentally based teaching benefit, the protocols are intended to assist students and faculty in documenting "case study buildings". Vital Signs has granted a series of faculty awards towards the development of case studies and has run two Student Case Study Competitions. A library of building case studies, available for public use, is growing at the Vital Signs Web Site. In addition to the web publication of these peer-reviewed examples, non peer-reviewed case studies from other University sites are also linked to the Vital Signs Case Study page.

Cold Climate Performance: University of Waterloo Student Case Studies:

The School of Architecture at the University of Waterloo, through the course Arch 366: Energy in Design, worked with the Vital Signs Project during the Winter 1998 term. As the result of a Request for Proposals in the Spring of 1997, the school was one of 9 in the United States and Canada to be awarded the loan of a "Toolkit". The toolkit included approximately $US35,000 of data collection equipment. The equipment sets include small microprocessor data acquisition systems that can measure temperature, humidity and light levels over time (Hobos); an infrared thermometer to measure surface temperature: photometers to determine luminance and illuminance levels; a sling psychrometer to measure humidity; an anemometer to calculate wind speed; carbon dioxide, ozone and VOC monitors to make preliminary evaluations of indoor air quality; a digital camera for web documentation; and a laptop computer for field use.

Students at the University of Waterloo used Vital Signs protocol and equipment/testing devices to carry out a series of four detailed building case studies that were entered into the 1998 Student Cast Study Competition. Students employed all three levels of evaluation protocols. Their building performance evaluations fell under 3 primary categories: thermal performance, lighting and air quality. Specific areas of focus were dependent upon the building type and its design intentions.

Within the confines of equipment sharing, course work and the curriculum, data collection was limited to a one month period. In spite of time limitations, this did provide a relevant discrete picture of building performance during a certain time of year. In this case, data was collected during the month of March which allowed for an assessment of cold climate building performance. In order to create a more complete picture, the students created daylighting models to allow for visualization of the year round solar and lighting characteristics. These models were tested through the use of a heliodon.

Four buildings were selected by the students to be evaluated. Case studies were specifically chosen which had shown initiatives in cold climate passive and sustainable design principles. As little or no post occupancy information was available for these buildings, the students were interested in finding out whether the applied principles were working as planned and whether or not the buildings were able to achieve a comfort level comparable to buildings which did not use passive heating and daylighting.

Two buildings will be included within this paper: The Burrows Residence and the Solarium Building at the YMCA Environmental Camp in Paradise Lake Ontario, designed by Charles Simon Architect.

YMCA Environmental Camp, Paradise Lake, Ontario. Charles Simon, Architect

Study #1: The Burrows Residence:

The primary method of data collection used in this case study was through the use of Hobo Dataloggers. The students used heat profile as well as light profile loggers to assess heating conditions throughout the subject building and to study the correlation between sunlight levels and heating levels on cloudy versus sunny days. A Raytek Ranger infrared heat sensing "gun" was employed to take spot heating levels. Various light meters were tried to check and compare daylighting levels in the building.

This camp building was designed to be entirely energy and systems independent. It has sleeping accommodation to house 40 campers. The building is organized with a main gathering room on the south glazed side of the building adjacent to a large masonry heater. Behind this space, on the north side of the building, which is earth-bermed and lit by clerestory windows, are 8 sleeping bedrooms. The building is heated via passive solar in combination with a large wood burning custom designed masonry heater. There are no other supplementary sources of heat. Students investigated heating patterns during the winter for both sunny and cloudy days; the effectiveness of the masonry heater; and daylighting for both the large common room and clerestory lit sleeping quarters. The primary structural, floor and finish material used in the Burrows is reclaimed wood. This is an excellent material choice when sustainability is a central concern, but fails to provide thermal mass for passive solar storage. Key questions that the students studied included: the distribution of thermal mass, the ability of the masonry heater to warm the building, daylighting levels, and the effectiveness of earth berming in reducing energy requirements. In investigating heating levels, the concern was to see if there was a level of uniformity in various parts of the building and, if not, if the deviation was acceptable in terms of occupant comfort.

To test the hypotheses this investigation employed analytical study involving site visits and environmental testing. The primary purpose was to analyze the heating performance of the building. Both quantitative and qualitative methods of gathering data were used. These included:

1. Recording the building's thermal performance for a period of one week during the month of March between the 9th and 16th. (Note that this limitation was due to the availability of testing equipment). This was achieved by programming a set of temperature, relative humidity and light HOBO data loggers located inside and outside the building in different indoor spaces.
2. Interviews, which were usually informal in nature were carried out with the Architect and Camp Director Callum McKee who were involved in the design and/or supervision of the building.
3. Photography and field notes were employed to support the data collected and played a positive role in documenting the building situation. Both of these instruments were critical since they added to documentation of investigative process.

View of Burrows Residence showing south facing exposure

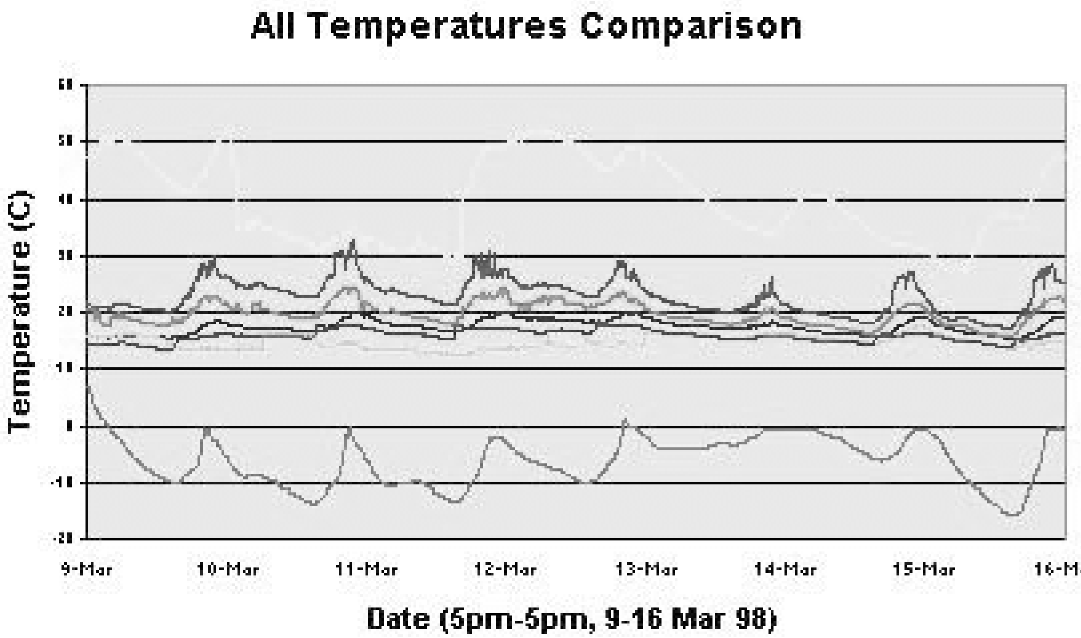
There were limitations to the accuracy of the investigation. Since this building does not have full time occupants, occupant surveys could not be performed. Also, due to the nature of the camp program the building was in use by different occupants on a daily basis. This factor made it impossible to shut down the wood firings in order to selectively test the building's passive qualities.

The testing devices were placed in carefully chosen locations in order to accurately test the hypotheses. Temperature Hobo's were positioned in order to get a full range of the building's heat profile. Typical locations were immediately outside the south wall, inside the wall adjacent to the south facing glazing, near the interior thermal mass masonry wall and in the sleeping quarters. There was concern that some of the bedroom areas, being quite distant from the masonry heater would be cold. These were looked at separately. Profile outputs, such as that illustrated below, were constructed from the data and analyzed.

The week in which the data was collected had varying weather conditions, which impacted the readings and provided an interesting range of output. The outdoor temperature varied from a high of 8C to a low of -20C, averaging -7C. There were days of sun as well as cloud. The average indoor temperature varied between 16C and 24C. Through comparison of the temperature and lighting data the students were able to find that the temperature profile of the indoor environment was more closely connected to the impact of solar radiation on sunny days than with the outdoor temperature. The indoor temperature was at its lowest on cloudy days even though this coincided with the warmest outdoor temperatures of the week. There was a strong correlation between the temperature at the main room window and the temperature at the back wall of the main room. This suggested that the building effectively transfers the heat from the heat from the solar gain at the glazing to the ambient air temperature near the back wall where there was no direct sunlight. The window temperature was also never below the temperature at the wall in the center of the building. This suggests that the windows are quite efficient and that the thermal massing of the thick internal masonry wall is fairly effective at releasing heat throughout the colder hours. This would also support the use of this masonry wall for its thermal capacity and the use of carpet covered reclaimed wood flooring for the main space -- selected for reasons of residential foot comfort.

Interior view of common room and masonry heater

It would appear from the collected data that the heater was not fired in the evening of March 10 and in the evening and morning of March 11. However, during this time the temperature of the main room stayed relatively steady. This steady temperature is likely due to a combination of large solar gain during these days and the effectiveness of the thermal mass of the heater. As well, during March 14 and 15 the temperature at the surface of the furnace dropped even though it was still being fired. With a few hours lag-time, this time of lower heater temperatures also correlated with the period of low solar gain. This would suggest that the masonry may also be acting as an effective thermal mass which is strongly effected by the amount of solar radiation. According to employees at the Environmental Center if the wood furnace isn't fired at all, it takes several days for the building to get down to 3C to 4C where it stabilizes. The indoor temperature usually falls at an average rate of 2C per day. Likewise, when the furnace is fired again, apart from large solar gains the indoor temperature rises at the same rate. This would support the suggestion that the building makes effective use of thermal massing.



From discussions with the Architect, the only quantitative objective of the Burrow's Residence was to keep the farthest bedroom within 2C of the temperature of the main room. From the collected data this objective was met when there was little solar gain as was the case on March 13, 14, and 15. There was a much larger differential of around 4C on sunny days. The average temperature for the week in the bathroom was 14.7C, in the far bedroom was 15.8C, in the middle bedroom was 17.3C, and in the main room in the center of the building was 19.7C. During both overcast and sunny days, the most steady temperatures were in the far bedroom and in the bathroom. The back rooms (bedrooms and bathroom), laid against the earth berm on the north of the building, are much colder but also have much more stable temperatures. The building, likely due to the fact that it is well insulated, effectively mediates the indoor temperature despite drastic swings of the heater and outdoor temperature.

Finally, by comparing all the temperature measurements several observations come to light. The sunlight enters the bedrooms every morning (especially the farthest and coldest bedroom) warming it up quickly. All interior temperatures fluctuate with extreme regularity with daily solar gain.

The students felt that their conducted investigation should assist to overcome existing beliefs that passive solar building design in a cold northern climate is not sustainable and its spaces are of limited comfort. This investigation proved that, through the combined effort of passive solar techniques, such as thermal massing, south facing glazing, berming of north wall, and coniferous tree plantings to protect the building from the cold northern winds, and the wood-burning furnace could all work together to create a comfortable living environment.

Study #2: The Solarium Building

The study of the Solarium building was conducted between the 24th of March and the 4th of April 1998. The weather was unusually warm and sunny, while there was still about a foot of snow on the ground throughout the tests. Outside temperatures ranged from -10 Celsius to about +20 Celsius.

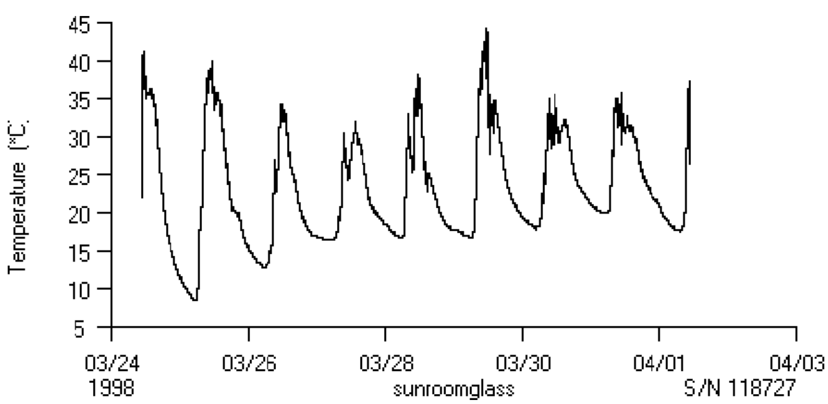
The building is a conference room/greenhouse for the camp and serves as a starting and ending place for the various events programmed for the campers. The building consists of four basic rooms. The first is the sloped glass roofed south facing greenhouse, the second is the south facing lounge, the third is the bermed north facing conference room, and the fourth is the south facing bermed washroom.

The building's program is centered around the south facing greenhouse, which acts as both a source of heat for the rest of the building and a greenhouse within which food producing plants are grown. The roof of the greenhouse slopes from south to north, starting at 2 feet off the ground an rising two stories to form a mezzanine at the north end of the space. The room contains a ventilation system which automatically opens and closes to allow the room to cool naturally by the physics of air flow (heat rises and exits through the vents at the top north side of the greenhouse, thereby sucking cooler fresh air through the bottom south vents).

The success of this building hinges on the effectiveness of the greenhouse due to the fact that this area is designed to provide both food and heat for the occupants. The first site visit involved a preliminary investigation of the building, documented with a digital camera. At this time the students were loaned plans and sections of the building produced by the architect. The second site visit involved placing the Hobo dataloggers from Onset Computers. The students used 12 Hobos in all, recording Relative Humidity, Light Levels, and Temperature Levels throughout the building, but focusing especially on the greenhouse area.

South elevation of solarium building

The first site visit revealed that there were no plants in the greenhouse. This would effect the interior temperatures of the space, and was kept in consideration when regarding the data as the plants would normally absorb much of the solar energy. The floor of the greenhouse was simple 3/4 inch plywood. Upon discussion with the architect it was revealed that the intent was to fill the space under the floor with water that would cool the space in the summer and retain heat for the winter, acting as a sort of trombe wall. The water would act not only as the water supply for the plants, but also contain a full ecosystem, with underwater plant life and fish. It was also indicated that water gathered from the sloped roofs is also run down the window, cooling it in the day.



The intent was to test the distribution of temperature generated by the solarium throughout the rest of the building, showing that the heating/cooling design of the building was effective, even in the extreme conditions described, notably the lack of energy absorbing plant material and the abnormally warm temperatures experienced during the testing period.

Data was collected using a series of Hobo dataloggers. The students were able to see the varying temperatures in the environmentally discrete locations of the building and to make comparisons of heat levels for those areas under direct solar gain versus those on the north side of the building. The temperatures noted varied quite widely within the building, and as a direct function of the proximity of the area to the primary sunspace as well as areas where the heat was stratified. Although the temperature variation is great enough that it is possible to "experience" the temperature differential, the data loggers enabled the students to more accurately compare circumstances and hypothesize as to their causes and potential remedies.

The distribution of light as the sun travels through the sky was modeled using the heliodon. It was first raised and tilted to match the latitude and longitude of our site in correspondence with the time of year. The tests captured well the passage of the sun, not only for the time of the year under actual study, but for other times in the year. The light levels in the solarium were remarkably high, even in the winter. The students found it difficult to imagine just how hot it would be in the solarium in the summer considering that temperatures rose to 60 degrees centigrade in the winter through direct passive gain alone.

When equipment becomes available during the summer months, the students propose to follow up to determine the effectiveness of the proposed sheeting of water down the exterior of the glazing in an attempt to cool the glass and therefore the room.

The hypothesis was that the building's design would be flexible enough to compensate for extreme weather conditions and unforeseen circumstances, and would still be able to adequately transfer heating and cooling from the sunroom throughout the entire building. The students discovered, through the collected data, that the building was in fact not able to fully deal with the severe conditions of early spring heat, full sun, combined with a lack of plant life and its accompanying hydroponic system. While the temperature throughout the building remained fully hospitable, the temperature in the sunroom became unreasonably high, and cast real doubts onto the supposition that the room would be at all inhabitable in the summer. This test was outside the bounds of what the designer had intended, but the fact remains that these are the existing conditions. What must be stressed is that although the building's environmental performance suffers as a result of the removal of the plant life, the building's psychological performance suffers more. The sunroom appears barren and incomplete. One tends to call it a sunroom instead of a greenhouse, or an ecological system, or a microclimate -- as it was intended.

The scientific study of this building not only allowed the students to examine hard facts regarding the performance of this building in terms of energy production and circulation, but also pushed them to probe deeper into all aspects of design and construction.

Assessing Hobo Performance:

The students were able to obtain accurate, relevant post occupancy performance information through the use of Hobo dataloggers that would not have been possible otherwise. The Hobos proved to be invaluable tools in providing data by which to test performance hypotheses. It was also helpful that the dataloggers could provide continuous output over a period of time (in this case one week). This allowed the students to place the equipment and return a week later to collect the data. Under normal teaching circumstances for a site visit observations would have typically been limited to a short period on a single day and the data limited to instantaneous readings from that particular period. With a larger quantity of equipment (or a smaller class size) readings could be taken for a much longer period of time which would provide a much more comprehensive analysis of the building performance. Charles Simon, the architect responsible for the design of the complex, was extremely interested in the results of the study. His practice centers around passive heated solar buildings and up until this point he had not been able to see a quantitative performance assessment of the building under post occupancy conditions.

Feedback from the students indicated that this type of hands on, interactive learning experience provided them with invaluable learning and was much preferred to the typical classroom format. All of the case studies are, located at the tboake-UWSA website as a means to further the Vital Signs Case Study Library, and to provide a more long lasting record for reference by future students and practitioners.

Credits:

Much of the introductory information is excerpted from the Vital Signs Web Site. The key people involved at the Center for Environmental Design Research at the University of California at Berkeley with the development of the Vital Signs Project are: Cris Benton, Gail Brager, Bill Burke and Alison Kwok. More information, including the case study library, is available on the Vital Signs website.