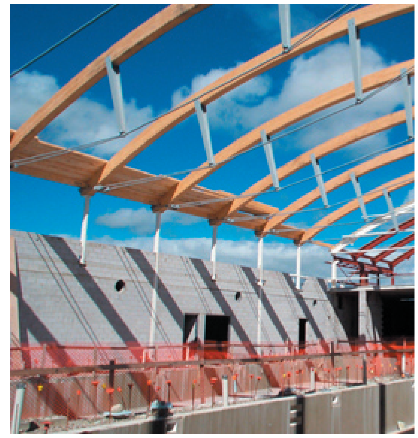
Teaching Technology:
Skins vs. Structures



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Introduction:

Technological developments over the last hundred years have resulted in the compounding of materials issues as they relate to architectural design. Structural steel and concrete systems, as well as different varieties of load bearing masonry design have radically altered the structural design processes for buildings. The changeover from the predominant use of load bearing exterior walls to curtain walls and rainscreen elements, has also complicated issues related to the design of exterior wall systems. Environmental awareness has been introduced to the equation and has required significant changes to envelope design as relates to climate and energy issues.

WHY is Skins Teaching Different?

Numerous texts have been written which are used to teach building construction to students of architecture. Most of these texts[1] present a uniform approach to the instructional aspects of "structural systems"; i.e. excavation methods, foundation types, steel structures, sitecast concrete, precast concrete, load bearing masonry and wood frame/timber framing. Although calculation methods and units might vary from Canada to the United States and Europe, in practice, structural requirements and the techniques of constructing this portion of the building are relatively uniform. Also, the construction methods and practices for "structural systems" are quite typical in spite of regional differences, code variations and diverse climatic requirements. Basic structural systems (excluding seismic design innovations) are for the most part, logical. They are very accessible to students as they are highly visible components of both construction sites as well as finished buildings. Many are purposefully dramatically exposed, sculptural, tactile and thereby easier to comprehend.

Skins, on the other hand, are quite inaccessible to most students. In viewing completed buildings, the exterior and interior surfaces of the skins are visible, but the highly complex, multi-layered, interior is (forever) hidden from view. Understanding the building science, performance and code requirements of skins is difficult for many students to both comprehend and then apply in the form of good building construction practice. Because skin design must respond to diverse climatic conditions and considerations, teaching skins requires that the building construction courses address issues that are normally covered in environmental courses.

Although the same *general* building construction texts do cover information on cladding and roofing systems -- AKA skins -- the majority do NOT attempt to address the complex building science, environmental, code related and performance issues that vary as a result of climatic location and jurisdiction. More specific documents, often laboratory, manufacturer or government publications, must be relied upon to supplement and sometimes CORRECT what is presented in the general text.

For these reasons, the *teaching* of skins is an aspect of the field of building construction that presents itself as a very complex task. It demands a different teaching methodology than the teaching of basic “structural systems”. It exposes a unique set of problems related to regional differences. Teaching skins also challenges professors to find *reliable, up to date* teaching and reference materials.

WHAT Should We Teach?

Five Points Towards the Teaching of Skins:

There are five major issues that must be addressed when teaching building envelope design. This requires ***teaching*** on many levels, not simple delivery of the facts. Students need not only to be delivered “the facts”, but they need to be *taught how to think* about the information. This will help to assess the correctness of information, its applicability to specific design problems, and the possible interpolation/manipulation of examples.

Firstly, students must be **taught general principles**. It is more than fair to stress envelope design criteria for the “home zone”, but students should be familiar with the general environmental principles which determine detailed envelope design for the four major climate zones: cold, temperate, hot-arid and hot-humid. Although many students graduate and work close to home, a large number choose to travel. Many grads may decide to seek employment in a climatic zone very different than the one in which they received their schooling. If they have been properly educated to understand “general principles” then they will have an easier time applying the codes and building science practices that are appropriate to their new locale. Case in point, the vapor barrier should be placed on the warm side of the insulation. Footings need to extend down to the line of frost penetration. Cold climate and hot climate case studies can be used in opposition to illustrate comparative climate related variations such as vapor barrier placements. Teaching “climate” is often left to the “Environmental Control Systems” courses. It must become a key part of the introductory Building Construction course in order to give validity and reference to the teaching of the “general principles” that affect the design of skins.

Secondly, students must be **taught climate specific design solutions**. General principles are extended to include *detailed* case studies for all climate regions. This should include specific reference to regional building code and performance standards. These include thermal insulation values, climate data tables, air and vapor barrier requirements, and other relevant performance standards.

Thirdly, students must be **taught how to read/interpret periodicals and reference materials**. Most of the design ideas that enter the Studio do so through the latest issues of “Architectural Record”, “Architecture”, “Canadian Architect” or “Architectural Review”. There are five issues that must be addresses: *new* magazines, *old* magazines and books, *“local”* technical reference materials and *“foreign”* technical reference materials and the *publication dates* on technical data sheets.

Students need to be taught to look beyond the seductive glossy photographs in magazines and monographs. They need to look for the geographic location and understand how it has impacted the detailing and performance of the skin and appropriate use of all materials. They need to appreciate when the building was constructed. Early modern or International Style architecture has numerous technical problems associated with the performance of its skins. This kind of knowledge may require that the student discard the example if the solution is climatically or technically inappropriate, or is too difficult to modify to suit local conditions.

Technical publications are not without fault. Much information has become outdated over the last 10 to 30 years. There were numerous building science and energy performance documents commissioned after the oil embargo during the mid 1970's. Many of these have not been updated since their early 1980 publication dates as a result of the reluctance of governments to spend the funds. These documents may still be found in our libraries and are still being used (for lack of anything new or easily accessible).

Fourthly, students need to be **taught to understand the evolution of modern architectural design**. Heroes are not only found in current periodicals, they are found in the modern masters: Le Corbusier, Aalto, Mies, Wright. Teaching the historical technological development of the modern movement can highlight scientific deficiencies of these buildings in current terms. Most of the "Modern Masters" designed in a time when insulation was either token or non-existent, "thermal bridge" was not a known term[2], glazing was single, energy was cheap and "performance" not a consideration. Introducing such historical issues in the Building Construction course can help students to identify changes in construction/skin techniques and can help them to understand contemporary detailing.

Lastly, and most importantly, students must be **taught to develop a critical eye**. This will assist when they look at anything. Just as students grow to understand that not all Design is good Design, not all technical publications are entirely accurate. The accuracy of the content may be quite limited and specific to either the material or the topic. Students need to understand that the researchers who create technical publications expect that they will know to cross-reference their details with those of bordering disciplines.[3] Students, when working on a problem that involves detailing, are generally looking for details that can be directly incorporated into a design. When using technical publications that emanate from National testing agencies or research firms, assumptions are made that these details are correct, not only for the central material but also for conjoining materials. This is often far from the truth.

Regional Differences:

"Skins" are constituted by the *entire* building envelope, walls, roofs and glazing systems. The design of these elements varies greatly from climate region to climate region. Students need to be taught that different approaches are required based upon the general climate as well as on the basis of the relative number of "heating or cooling degree-days". Buildings in a heating dominated climate will require a different approach to fenestration, orientation, shading and insulation than buildings in a cooling dominated climate.

When examining some regional building methods, the term "skin" can be misleading. It is difficult to think of many building envelopes as "skins". With the exception of siding or stucco on frame, most walls are at least 300 mm (12 inches) thick. They are often assemblies comprised of many different layers of materials, each with a specific job to do: rain screen, pressure equalization space, air barrier, thermal barrier, vapor barrier, interior finish, and structure. Performance and building science must be important considerations when designing the building envelope. Skin systems must also account for earthquakes, wind, humidity and overheating. Designing systems that achieve a high standard, under such severe weather loads is very difficult and often demands a compromise of the aspirations of the design and the Designer. Rain, snow and deicing salt are also major enemies of the building skin. Inadequate design performance results in extremely expensive lawsuits.

Including Passive and Sustainable Design Practices:

In these days of climbing fuel costs and power blackouts, we need to teach students to rely less and less on non-renewable fuel sources to heat and cool our buildings. Passive heating and cooling principles, which are tightly tied to regional conditions, add another dimension to the detailed design of our building skins. The teaching of passive and sustainable design building practices is an aspect of architectural design that has historically arisen out of ECS courses and is seen incorporated less often in normal building construction courses.

Passive design principles have a ramification on envelope design as well as the structural design of buildings. Concentration of windows on south facing facades, incorporation of shading devices, increases in insulation, cross section shape and the addition/placement of thermal mass, changes the approach to detailing buildings and selecting materials. Even the selection of a thick adobe wall to make use of diurnal cycles brings the issue of passive design to the building envelope designer.

The Problems with Reference Texts and Publications:

Within the United States and Canada, minor code and standards differences, imperial versus SI units, and seismic zones aside, structural system requirements are quite consistent. The same steel skeleton structure can be erected in Toronto as is possible in Houston. This allows for an economical proliferation of very good texts, industry publications and building case studies that can be used across the breadth of schools that populate the various climatic regions of the continent. The same cannot be said for publications that detail “skin systems”. However excellent the Building Construction text, it does not normally discuss the design implications and detailing of skin systems in the full range of cold, temperate, hot-arid and hot-humid climate zones. *General* building construction texts must be supplemented by publications that explore and detail the building science and performance aspects of building envelopes for specific geographic, climatic and legal regions. These publications must account for regional differences; i.e. building codes and climate data, as well as up to date industry and building science input.

Herein lies the root of the problem. Each scientist or industry partner develops expertise pertaining to its own *discrete* sector of the building industry. Researchers study masonry OR wood OR roofing OR air barriers OR thermal insulation. They create publications about their specific concern. By and large what is published is correct inasmuch as it speaks about the field of expertise, but often, errors are published when information is included about periphery material – structural systems or materials that are included in diagrams simply to “complete the picture”. It is not intentional. These publications assume that the reader understands that they are reading about masonry and that the wood frame details attached are “framework” and not pertinent. A knowledgeable researcher or practitioner may be able to identify these inconsistencies or errors. Students don’t. They copy. They get confused. They don’t understand that the blind copying of details from government or industry publications can lead to problems in their building details. They are looking for answers. They are trying to find some reference book that covers the difficult part of detail design – i.e. what happens when two different materials or systems meet?? They cannot understand how their professor could have them refer to documents, often published by reputable agencies, that are erroneous.

HOW Do You Teach Skins?

Beyond the set of ingredients presented thus far, "The 5 Points Towards the Teaching of Skins", Regional Differences, Passive/Sustainable Design and References Materials, lies the issue of teaching pedagogy or STYLE. Not WHAT but HOW do you TEACH skins. The majority of building construction or skins teaching takes place in a lecture style format course. This teaching is sometimes, but not consistently supported or reinforced, with detailed design exercises or drawing requirements in the parallel Design Studio. If WHAT we teach, is not presented in an inspired manner, students may retain very little. The majority of students find building construction information rather dry and uninspiring. The format of the course is key to engaging the students' interest in the material given.

The materiality of both the structure and the envelope is intrinsically entwined with Design. Neither design nor building construction can be considered in purely abstract terms. Three types of lectures are necessary to properly develop skins material. The first type is historical in nature and traces the evolution of a material/system (like steel, concrete or veneer systems) from its introduction into modern architectural design to the present. The lecture takes a case study approach and looks at the impact of the material or system on the development of modern architecture. The material or system is looked at primarily as a form/style giver, and without much reference to detailed construction practices or technical problems.

The second type of lecture takes a very detailed approach to the system/material in light of modern construction technologies/requirements. Again case studies are used, but these quite contemporary and illustrating wherever possible images of actual construction sequencing. Overhead transparencies of details and periodical articles can be used to supplement slides. (I require that the students keep a sketchbook of the course. I use an overhead projector and continually draw details for their reference that they are required to copy. The details supplement their study notes and texts.)

The third type of lecture is unfortunately quite dry and very serious. It delves the deepest into the technical information pertaining to specific code, constructional, detailed requirements of systems. It often involves important rules and calculations. It is the type of lecture that must exist, and survives only because of the placement in the curricular flow that sees the three types as a sequence/pattern repeating itself throughout the term.

ASSESSING What Students Have Learned:

Beyond what we give the students as information and how we deliver that information, what do we ask that they *give us back* to show how much they have learned?? What assessment methods are both effective as *evaluation tools* as well as *learning tools*? What type of exercises are the best? Tests, projects, drawings, models? Although we may have inspired ideas of what we would like our students to do, how much time can we ask our students to spend on our course, will usually impact the type of assignment. The precise nature of "construction – design" exercises varies from topic to topic and from School to School as a result of local restrictions in time and budget.

Skins/Construction Projects at UWSA:

Hence, in addition to the numerous quizzes that students must write, mostly as an incentive to have them keep abreast of the readings and technical information, and the sketchbook that they must keep of details presented in class, they complete seven projects that are employed improve the level of absorption or understanding of the subject, and that reinforce various of the “5 Points”. Scales and techniques are used that highlight contrast to emphasize the various purposes of the projects.

a) The Oasis[4] Project:

In this project the students are divided into the 4 major bioclimatic regions. They must design a discrete architectural space for their specific climate region that focuses on experience and comfort. They present and share their projects. It involves first year students in the teaching of the class. It forces cold-climate thinking students to begin to understand the ramifications of designing in other climate zones. The project addresses general principles, regional differences and begins to bring in issues of detailed design and passive/vernacular influences.

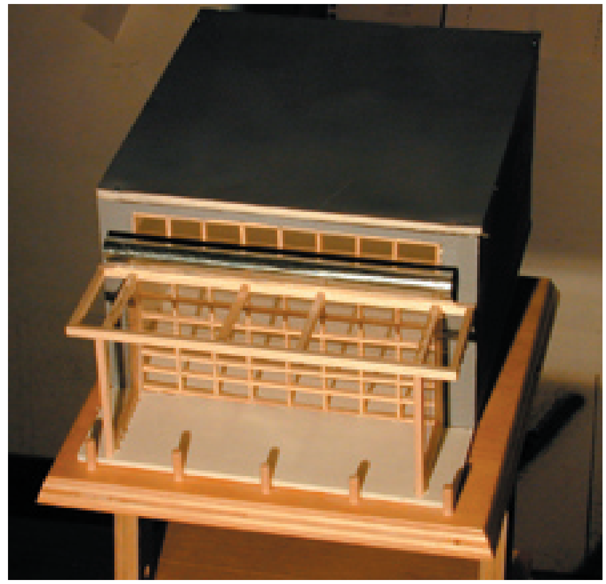
b) Masonry Wall Building:

The students participate in a hands-on session held at the regional masonry training headquarters. There they must construct a masonry veneer wall comprised of concrete block back-up, air barrier, rigid insulation and brick veneer. This project is intended to highlight the contrast between the act of drawing and the act of building. Precision versus roughness.

c) The Modernization Project:

This project refers to design in a cold climate. Ontario, Canada has very stringent building standards. In this project a list is assigned comprised of early modern buildings or contemporary buildings from warm climates. The students must redesign the key wall section and meet our building code and insulation standards. It is a tough project and in a few days work forces the students to think about detailing, materials, and how modification is necessary if you are borrowing ideas from areas or times that are not in agreement with their own. Students see the technical shortcomings of early modern design and the connection between design ideals and technical limitations/considerations.

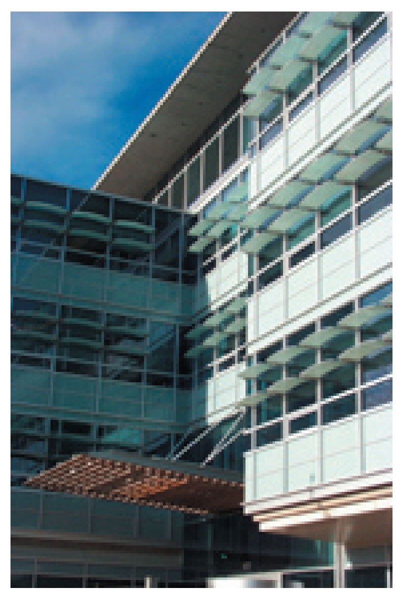
d) The Light Box [5]:



Purposeful holes in the building envelope are a major design issue. Students can begin to understand the technical and thermal considerations of this aspect of the skin through lecture material, but the "architectural" design and passive design aspects are also critical. The students must build a 1:10 metric foamcore model of a room and test their fenestration, glazing, and shading strategies on a heliodon. This project helps them to understand basic design of shading and to introduce principles of daylighting design into their vocabulary. The project can be used to highlight specific climate and latitude issues and is an excellent potential cross over into design studio.

e) The Design Project:

The final Design Project is the "pièce de resistance", the challenge that forces the students to "put it all together". It is given in lieu of an exam. It disallows rote memorization and demands research and ingenuity. It mimics a "real" design problem. It can be relied on each term to ask the student to extend the "D"esign exercise into one that must address specific materiality and detailing of both the structure and the skin of the building. At the end of each course the students are assigned the detailed design of a small building. Understanding that time (and available student energy) is limited, only 3 drawings are normally required: a plan at 1:50, a detailed/labeled wall section at 1:10, and a structural axonometric at either 1:25 or 1:50. They must use most of the materials that have been covered in the term as well as address major teaching issues. This a more reliable way to integrate the notion of Technology with Design than expecting the crossover to take place in the Design Studio. That can be hit and miss depending on the professors involved. Often relevant design competitions can be used as a subject, with the option open for the students to enter. Competition work seems to increase the amount of effort students are willing to put into a (time consuming) project for a course outside of Design Studio.



f) Detailed Building Case Studies: Looking at <u>Special</u> Skins:

To investigate more unusual skins systems requires that students engage in detailed case studies as a means to personally investigate the tectonics of architectural design. Research investigation and seminar presentations in small groups are excellent methods of both teaching and learning. Also presented at this conference, a paper on the Tectonics of the Double Skin, addresses a senior research elective that explored these more innovative environmental skin systems. The students have put together a web page with their results and pdf files for their case studies. In this way they learn and leave the information behind in a format that is available for other students.

g) The Vital Signs Case Study [6]:

The project is based on the Vital Signs Case Study model from UC Berkeley. It requires students to assess the "performance" aspects of an existing building. The project type is an excellent way to look at the impact of detailed technical design on the skin's performance. Depending on the design intentions of the building chosen to study, various aspects of performance can be studied. It relies on the availability of data collection equipment making it more appropriately available to a smaller number of students in an elective setting.

A student team won an Honorable Mention in the 1998 Vital Signs Student Case Study Competition for their research on "Green on the Grand", Waterloo, Ontario.

These exercises have been designed to reinforce and expand/extend the information and ideas taught in lectures. By engaging the students with design motivated problems it forces the connection between the technology of skins and its incorporation into or influence of architectural design. It is neither a finite nor complete list of potential projects. It represents a good variety of relevant problems that can be accommodated by curricular limitations. Visits to actual construction sites are well received, although problematic for large groups. Some schools are able to engage students in actual building and testing programs for skins. Real life, hands-on exercises are the best teachers and reinforcements of learning. We have recently mounted electives in which the students can participate in a Habitat for Humanity build. Although the subject buildings may be mundane, it does allow the students to engage in the "act of building" and to see a project from foundation to completion within a two-week period.

Suggestions:

Industry sponsored technical documents have shortcomings insofar as they may only be seen as reliable for "core" information as it pertains to the material in question. They are, however, available. Since the tragic events of September 11, 2001, much building case study material is no longer available. Drawings and documents that were previously found on the web, have disappeared. Municipal building departments are no longer releasing building plans for academic study and teaching. Most architectural offices, for reasons of liability, are not willing to share detailed building documents. It will become increasingly important for academia to engage in a proactive publication and sharing of developed building case studies.

It would be helpful if there were a "clearing house" for detailed technical material, construction documentation, and case study information that could be used as a teaching/learning resource. Much in the way that CREST has sponsored a website that provides key links to sources of environmental design, perhaps ARCC might host a central (web) index for (verified) sources of relevant technical information, academic papers and building case studies.

The reviewer's comments for this paper asked whether or not there was any way to assess the learning/teaching effectiveness of the various exercises. It was suggested that there might be a sampling of studio work before and after the teaching to show influences. Such assessment could be done for individuals or classes as a whole and also include interviews to understand what the retained message, principles and practices might be. This might also include a before and after survey assessment to evaluate what is learned. Such analysis would provide more concrete feedback and allow for refinement of both the teaching and project outlines.

Conclusion:

As a result of its unique position as the membrane that connects the teaching of "structures" and the teaching of "environmental systems", the teaching of "skins" requires, as outlined above, both carefully staged teaching and a varied approach to project selection and testing. As the technical curriculum continues to develop in its intensity and requirements, it may mean that designated courses, portions or lectures need to be developed to address specific issues related to skins – breaking away from either the structures or environmental systems courses. Skins issues might also need separate identification in the NACB criteria.

For the above outlined reasons, the *teaching* of skins is an aspect of the field of building construction that presents itself as a complicated task. It demands a different teaching pedagogy than instruction in basic "structural systems". Skins expose a unique set of problems that must address regional differences in order to properly respond to issues of climate and performance. Teaching skins also challenges us to find *reliable, up to date* teaching and reference materials for both ourselves and our students.

Because "skins" are different, their instruction demands that we approach teaching in an innovative and comprehensive manner – and that we reinforce our teaching by providing means of assessment that can continue to teach and stimulate our students to learn.

Notes:

[1] Allen, Edward. Fundamentals of Building Construction: Materials and Methods, is one of the most widely used texts in North America.

[2] The first official mention of thermal bridges in Canada was in Canadian Building Digest No. 44 titled "Thermal Bridges in Buildings", published in August 1963 by the National Research Council. It is still cited as a pertinent reference on the NRC website.

[3] Upon reviewing the recently published "Masonry Details That Work", 2000. Version 2.0, it was apparent that the details that were included presented not only a range of performance solutions but were also erroneous when drawing/detailing the non-masonry details adjacent. When the author/editor was queried they responded that this information was there as a reference only and not purported to be correct.

[4] The Oasis Project was developed at a Retreat sponsored by the Society of Building Science Educators and is still used by many members, in various forms.

[5] Thanks to Bruce Haglund, SBSE, at the University of Idaho for the basis of this project.

[6] More information on the Vital Signs Curriculum Materials project may be found at <http://www.arch.ced.berkeley.edu/vitalsigns/Default.htm>