“Do You Own a Hardhat and Safety Boots?”: Maximizing Potential Learning through Construction Case Studies

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The developing tectonic culture of architecture, as expressed in the effective use of materials in design and construction, requires that the designer have a high level of expertise in the development of structural and cladding systems as well as details. It takes a great deal of innovative teaching and “tools”, to bring architectural students to a level of expression in the technical aspects of design that is reflective of a good knowledge base in the requirements of the material, as well as inspired thinking when it comes to the actual detailing of the material, its construction and connections. Basic construction teaching must be followed by exposure to high quality case studies that address the full range of design, fabrication and construction concerns. Such learning is more easily developed if highly detailed case studies are available to reference.

The Nodding Off Factor + Credibility:
In an ideal world, most professors would like to own a “Magic School Bus™”, and transport their students (and themselves for that matter!) for live visits of all of the buildings and projects that form the basis for their teaching. There is truly nothing that can effectively replace the direct experience of a space or a construction site. Although I can cite no hard statistical evidence to back up this point, empirical evidence would indicate that the “nodding off in class” factor seems more prevalent when instructors are speaking to “pictures from books” as opposed to images taken during a personal experience with a space or building. Credibility is also at stake when using the images of “others”. If the sum total of the professor’s learning and experience is derived from the same books to which the students have access, there may be nothing substantive that can be added to the discussion. Such can parallel the classic problems encountered with teaching from a text. If the professor only uses the text, many students skip classes as they find nothing extra is offered.

A very renowned Architectural historian was presenting at our University several years back. Having long used his text in one of my courses, I was keen to hear him present in person. The talk drew from examples in his most recent book. The images presented in the talk were the same black and white images that were included in the book. It soon came to be apparent that the author had never visited the subject buildings, and was also relying on stock photographs, taken by others. Not only did the experience leave me feeling skeptical about the authority behind the research, but it also revealed an increased distancing from the source material by referring to the work of this author. Rather than citing work that was immediate, that work was an additional step away from any direct experience with the actual architecture. Where this might be acceptable when speaking in terms of theory, form and planning, it does fall short of describing issues of construction process and tactile aspects of structural materiality.

Difficulties in Obtaining Live Construction Information:
Unfortunately, whether the teaching of building technology is grounded in its beginnings in history and theory, or based upon current examples, it is fairly safe to predict that the majority of lectures on the subject make extensive use of images of buildings. Since our audience is North American, and much of the early material and structural innovation in Western Architecture occurred in Europe during the 18th and 19th centuries, distance also removes both us and our students from direct experiential access of historically significant structural and material

examples. The work of Pier Luigi Nervi, for instance, was a critical influence on subsequent North American efforts in innovative use of cantilevered and plastic concrete shaped in buildings.

For lack of travel budget, I had included historic construction images of Nervi's Palazzo dello Sport in the EUR from the first offering of a lecture on the origins of innovative concrete construction, delivered in 1985. Twenty years later, I finally had an opportunity to experience the building and it was so much more inspirational than I was ever able to convey in a lecture based upon book images.

Figure: Palazzo dello Sport, Pier Luigi Nervi, under construction 1956 and complete (image taken 2005).

New architectural movements also tend to emanate from Europe or the Pacific Rim, and this also causes distance issues. Most innovation in the realm of double façade construction, for instance, has happened in Europe, with few North American examples to be found. The corporate culture of the United States and Canada has tended to limit highly innovative and ground breaking projects. Norman Foster's Swiss Re, Wembley Stadium and Greater London Authority projects[1] may all have their unique construction and performance problems, but from a purely academic perspective, these can be some of the more beneficial lessons for our students. What can be learned from the World Trade Center project, which could have been an exciting and innovative tower project, is that politics overrides. The final building will likely have little to do with any of the original design or technical inspirations behind the winning scheme.

Extensive site visits to either actual buildings or construction sites are not common and often difficult to fit within the time and financial constraints of most technical courses that are typically relegated to supporting roles within the curriculum. Many schools are not located close to significant buildings or construction projects. Although students of architecture and engineering should be encouraged to own safety boots and a hardhat to make site visits possible, many do not. Classes of 70+ students are logistically difficult to handle on a construction site tour as site conditions are often dangerous and congested. Noise is also a factor, making discussion difficult to hear.

[1] The Swiss Re building was sealed in April 2005 after a window fell out of its frame and crashed to the ground. Wembley Stadium is behind schedule due to strikes. GLA has been in the news due to issues of interior environmental quality and a green building that is not living up to its performance expectations. http://www.bdonline.co.uk/story.asp?storyType=80&sectioncode=448&storyCode=3050737

Additionally, most published images of notable buildings, focus on the completed work, and fail to document the construction process. This is particularly true of historic examples. Even current projects that tend to have more images available as a result of Monograph, periodical and internet based publication (legitimate and independent "blogs"), continue to fail in searches for construction images. If the particular project is not showcasing a highly expressed or exposed structural or cladding system, teaching and learning must rely on educated guesswork.

This tendency may be changing in light of more widespread adoption of BIM (Building Integrated Modeling) on high profile projects. Daniel Libeskind's Denver Art Museum has come in on time and on budget as a result of extensive use of computer modeling and integrated consultant efforts. Such success on a high profile project has resulted in a proliferation of interesting technical information.[2] This was also evident in publications on the Disney Concert Hall by Frank Gehry. Frenetic steel has a tendency to be more widely photographed. A movie of the construction of the Disney Concert Hall was made. Personal sites about more controversial buildings, such as those by firms such as Gehry and Libeskind, are beginning to proliferate. When researching projects for lectures, such passionate interests can yield valuable resources and construction progress images. Such a site can be found for Gehry's Disney Concert Hall, which includes an extensive site of exposed steel framing images as well as installation of the complex cladding system.[3]

Construction Sites as Impermanent Resources:
Construction projects are themselves ever changing and "impermanent". Architectural historian William Dendy, published a book in 1978 entitled "Lost Toronto". Its purpose was to document the many historic buildings that formed the foundation of the City of Toronto, that were demolished to make way for modern progress. Such photographic documentation provides the primary memory for preserving the time and place of building, once the people and their physical remembrances are gone. Completed buildings are not the only architectural artifacts that are evidence of the design and culture of a city. So too can be the construction sites, as they exist as indicators of the spirit, vitality or simple growth of any period. As with any temporal event, effort is required to make multiple and sequential visits to construction sites in order to both document and experience the phases of the project.

The increasing use of "webcams" to track construction progress of significant buildings is evidence on a growing cultural interest in the construction process as a significant event or state. Webcams can be found on many current projects and can be a source of sequential construction images, although somewhat lacking in enlargeable detail.[4]

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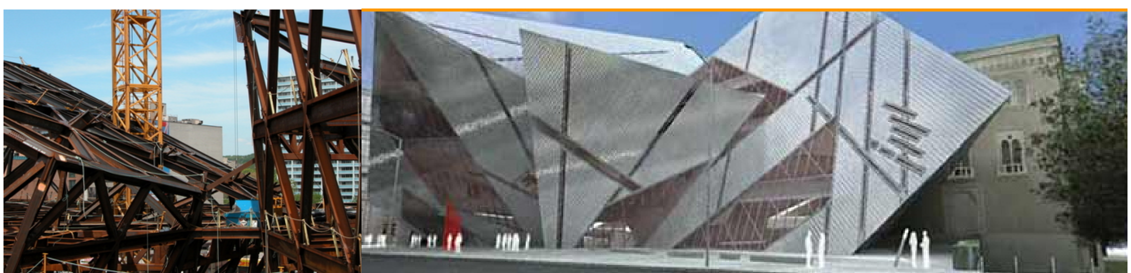
[2] Article in Engineering Record News, May 2006.
http://enr.ecnext.com/comsite5/bin/comsite5.pl?page=enr_document&item_id=0271-27583&format_id=XML

[3] "Frank Gehry Disney Concert Hall: A Construction Diary", by Paul Viapiano
http://home.pacbell.net/viapiano/gehry/gehryindex.html

[4] Denver Art Museum webcam:
http://www.mortenson.com/index.php?t=projects/denver_art_museum_expansion_web_cam

Figure: The ROM Webcam: December 2004, December 2005, May 2006[5]

Architecturally Exposed Structural Steel (AESS) and some heavy timber framing provide a permanent viewing and learning opportunity for students of Architecture and Engineering. The connections are highly visible, often exquisitely detailed, and extend the basic principles of connections from the rudimentary to the creative. In the case of AESS applications, much of the construction and erection process can be imagined by an “educated mind”, given its permanently exposed state. In the case of structural steel or timber construction that is to be clad, this is no longer the case. The construction process becomes a temporal event. Not only is examination of the structure, materiality of the building and connections permanently concealed from view, but in many cases, once gypsum board is installed, even the idea or rationale behind the structural system is no longer evident. In some instances it is not possible to discern whether a steel or concrete frame system has been used.



Figures: ROM steel under construction and the rendering of the completed building.[6] The steel will be, for the most part, concealed beneath gypsum board.

The Limitations of Textbooks:

Available building construction textbooks (Allen, Ching, et al) tend to focus on preparing students to design and detail relatively standard buildings with typical details. By virtue of the need to address all materials, and appeal to a wide geographic audience, textbooks on building construction also tend to sidestep various climatic, building envelope and thermal issues. Texts might provide a good base for subsequent development with respect to structural systems, but limiting use does compromise effective teaching of cladding systems as thermal insulation and moisture approaches vary so much with climate and geographic location.

With such a vast field of investigation and the potential complexity required via the addition of some contemporary buildings, this deference to standardized detailing is not surprising. Students, however, tend to design few buildings that can rely on the typical level of detailing that is addressed in most textbooks. If building construction and technology courses are intended to prepare students to handle more complex architectural design projects, constructed in a wide

[5] Renaissance ROM Webcam: http://www.rom.on.ca/renaissance/hyatt.php

[6] Image of completed building taken from ROM Website: http://www.rom.on.ca

range of geographic and environmental locations, such as those in the Comprehensive Building Design Studio, they need to be exposed to a higher level of detailing, coupled with climatic responsive design standards and real building references. Supplementary case studies are essential to address local climate, building code and detailing issues.

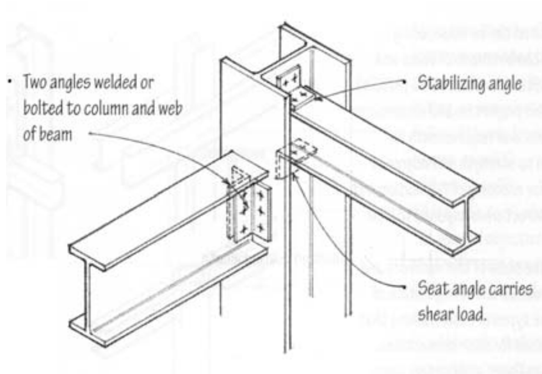


Figure (left): Excerpt from Francis Ching's "Building Construction Illustrated".[7]
Figure (right): CISC Member donated Teaching Aid installation at the University of Alberta.

The steel teaching aid pictured above is intended to expose students to full scale mock-ups of the full range of standard steel connections. Such devices are helpful in assisting students in the understanding of the scale of real building materials. It does take significant academic extension and exploration to adapt the same technical details to Libeskind and Gehry-like connections. Relating standard textbook information to more complex real projects is critical in empowering students to develop such expertise within their own design tools. An element of a construction case study can focus on issues like the design and generation of connections and details, showing how they simultaneously are similar to the text details, and how they vary or modify the status-quo to achieve particular project requirements.

The tubular connection below can be seen to be similar to the diagram, yet modified to incorporate round tubular members rather than WF sections. Discussion can be enlarged to address issues of transportation, limitations of geometry, numbers of connections to be made on each assembled piece, and potential (and real) difficulties arising during construction.

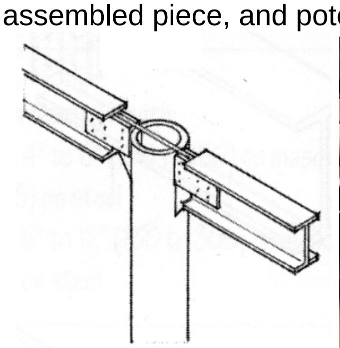


Figure (left): Detail from Ching of a type of tube to WF connection
Figure (middle): Detail of tube to tube connection with plate on the Leslie Dan School of Pharmacy by Norman Foster
Figure (right): crane lifting pod segment for placement

[7] Ching. p. 4.18

A study of the actual erection sequence on such projects is capable of providing a greater insight into the issues associated with transportation, staging, erection and accuracy of fit, than would be the case for more standard construction that would have less demanding geometrical complications. Such was the case for the installation of a large truss at the Leslie Dan School of Pharmacy in Toronto. A 50 tonne full storey truss was erected at the fifth floor level of the building, atop a leggy concrete atrium. The truss was ultimately used to suspend a “pod – classroom” within the atrium space below. The truss required precision alignment in a vertical slip joint at one end, a beam connection at one-third down the length, and alignment atop a column at the end point. Complex structures require great precision in fabrication, erection and alignment, as well as skilled ironworkers working at some risk to install large steel pieces. The study of such processes can highlight to the students the need for accuracy and constructability of details and connections. Students often have the mistaken impression that connections have a good deal of “play” in their fit – when the opposite is actually the case. Lack of precision can compound dimensional discrepancies that can ultimately mean unnecessary refitting of elements on site. Or in the worst instance, complete replacement parts that require special re-fabrication that cause construction delays.

Figures: Leslie Dan School of Pharmacy, University of Toronto, Norman Foster – erection of a 50 tonne steel truss at the fifth floor level.

Although I have been using Edward Allen’s “Fundamentals of Building Construction” as my course text since I saw it introduced at the very first ACSA Technology Conference in the early 1980s, it is necessary to take students beyond the basics of connections, as addressed in this and numerous other building construction source texts, and expose them to the potential “play” that lies in detailing. If you comprehend the basics, *the fun lies in really detailing the structure*. Case studies are an excellent way to tie basic construction teaching to an elevated presentation of architectural design. Real buildings can show students how to take the principle ideas of connections and begin to create expression in their structures and buildings.

Cultivating a Culture of Project Documentation:

It is essential, therefore, to cultivate a *culture of project documentation* that strives to create a permanent record of the construction process for a wide and ever growing range of buildings. It is only through this type of imagery, that students will be able to “see”, and subsequently “learn” about the technical realities and potentialities of material choices throughout the design and construction process. *If construction is not documented, this part of the history of architecture is forever lost.*

For the interest of architectural educators such documentation needs to be stored in or through an accessible place or medium or database. Such material is not likely to attract hard copy investors. Runs of architectural books tend to be limited and as a consequence, very expensive.

One of the great benefits in the creation of an interested network of Building Technology Educators – and one that might derive some inspiration from the Society of Building Science Educators[8] – is the basic notion that teaching resources are best if shared. One of the limiting factors to the collection of case study information lies in "access" to pertinent buildings and projects. We as a group, can create a network of resources to enable education that can step outside and augment our local examples. They may be "someone else's images", but they may have better technological and construction information than can otherwise be found. The use of the internet can be seen as a critical forum for information sharing and publication. In the spirit of SBSE, I maintain a very large database of images, including both finished and construction shots that are freely available to other educators.[9]

Do you own a hardhat and safety boots? <u>And a camera</u>?...

This is not a rhetorical question. Having taught building technology for over 20 years, and attended countless conferences and site tours, it is not uncommon to see more cameras at a wedding, than in the hands of architectural professors on a site tour. If these professors are not taking photographs, then they may not be visibly incorporating their own experiences of construction and architecture into their lectures; i.e. relying on the "classic" finished images available in texts and Google[10]. If those of us who teach construction technology to future architects, are not interested enough in finding out more about how more complex buildings are constructed, then who can we count on to gather and document this essential information? With digital photography, even contractors are more thoroughly documenting the construction process. These images, however, are not taken for publication purposes and may not necessarily focus on issues that are of interest to those of us in education. Documentation must be elevated to "photography" in order to engage students who tend to be a highly critical and easily bored audience.

Additionally, the inclusion of video footage, can increase the information and interactivity of the lecture material. Real time footage of steel erection processes, for instance, gives students a better understanding of the strategy, cooperation, time and "weight" involved. Video clips can also stress sequencing and access issues, as well as explain the range of construction aids that is necessary. Staging areas on the site for materials delivery, site access and crane operation, are all important to enabling an effective construction process.

Dissecting Case Studies:

Since beginning to create and teach courses in building construction in the mid-1980s, I have actively been collecting images for use in my lectures. Initial time and budget constraints created a reliance on the "images from books" that can be problematic. Time has allowed many of these to be replaced in whole or in part with images of personal experiences of buildings and construction.

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[8] Society of Building Science Educators website: http://www.sbse.org/

[9] Terri Boake website and Image Gallery: http://www.architecture.uwaterloo.ca/faculty_projects/terri/

[10] Googling for images, for instance, "Falling Water", normally yields a high percentage of repeat hits of almost exactly the same image, from the same vantage point, seeming to infer that there is really only one view of any building.

In 1995 I attended the first meeting of the Steel Structures Education Foundation, and viewed a presentation by Wayne Baigent who was the steel fabricator involved with the construction of the BCE Place Galleria designed by Santiago Calatrava. When the SSEF queried the educators present to respond to the presentation, the opinion was unanimous that all wanted access to the fabrication and erection process images. This has led to the creation of three educational CD-ROMs, funded by SSEF, that focus on the fabrication and construction of significant steel buildings.

The first CD looked at the construction of Caltrava's Galleria in Toronto, as well as the Vancouver International Airport by Architectura. The photographic data used for these projects was based upon construction images taken by the fabricators and erectors, with supplementary finished stills and video clips by myself during site visits. The second CD (due for release in Fall 2006) examined the Vancouver Skytrain Stations. Again the construction photographs were supplied by the steel fabricators and erectors, with supplementary finished stills and video clips taken by myself. All of these projects used Architecturally Exposed Structural Steel, and limited exposed heavy timber framing. Detailing was still very evident even after the buildings were complete.

Figures: BCE Place, construction and finished images. Excerpted from SSEF Case Studies CD-ROM Volume 1.

The current CD-ROM project, "Stars + Steel", highlights the construction of three recent/ongoing Toronto projects whose use of AESS is extremely limited. The Addition to the Ontario College of Art and Design by Will Alsop, The Leslie Dan School of Pharmacy by Sir Norman Foster, and the Addition to the Royal Ontario Museum by Studio Libeskind primarily use non-exposed structural steel systems. Each of these projects exhibits extremely innovative steel framing systems and construction techniques to erect the steel. In all cases, the majority of the steel will be clad in a fire protective system that forever hides it from view. The *mission* of this CD-ROM raises the notion of case study "documentation" to the point of preserving the vitality and "knowledge of" the steel structure, and its construction, before it is forever hidden and essentially lost. Although quite dissimilar from the demolition that was causal to "Lost Toronto", the effect is quite similar. The vitality of the construction and the understanding of the steel structure and its erection process vanishes forever once the construction is complete. There is a greater sense of urgency to capture these projects as case studies, than projects whose making is less concealed.

Figures: Erection sequence for HSS legs on OCAD project. Photos: PCL Construction.

The above images were taken by the constructor of the process of raising 90' tall steel legs in place to support a building. Site access was limited due to the narrow surrounding streets. As an "event" it must have been exhilarating to watch. After the fact, supposition of the erection process is not clear.

The focus of this paper/discussion/brainstorming session intends to look at the development and subsequent *sharing* of construction case studies.

Ingredients of an Effective Construction Case Study:
Thorough case studies are not easily found. The majority of glossy publications normally include only images of the recently finished building, and rarely any construction images or connection details. If in the final instance, the structure has been left exposed, such finished images can be useful when discussing the building. In the case of concealed structure, finished images give no useful information with which to address construction and detail related concerns. The type of structural material or system might not even be readily apparent.

Creating good case studies "from scratch" that can address the wide range of issues related to the teaching of structural design from an architectural viewpoint, requires not only dedication, but also "being in the right place at the right time". Access to construction sites is not always available, nor necessarily, is the time to make repeated visits to obtain sequence shots. Student field trips are difficult to arrange (although excellent opportunities for learning), and rely on a certain degree of serendipity – hence giving students in subsequent years an uneven chance of touring through a "good" building. Although constructors are required to document the construction process, these images are in many cases taken for legal protection, and most constructors are not willing to share or publicly distribute their images for the same reasons. Fabricators can also be guarded due to production "secrets" (particularly in the case of challenging and highly competitive AESS work) – or simply don't take an interest in documenting the process.

For a case study to be truly useful, it must come close to addressing the entire design and construction process. In this way, as an educational tool, it can be used to bridge the gaps that currently exist between teaching areas in most schools of architecture. A *thorough* case study requires:

- knowledge of the design intentions of the architect
- why was this structural or cladding system chosen?
- access to design sketches, models, computer renderings
- detail drawings that show the relationship between the structure and the skin
- connection development from an engineer's or fabricator's viewpoint
- fabrication images
- transportation images

- erection sequence images
- video footage, if possible, that can explain the actual erection process
- completed images

The final case study must be presented or available in a form that can be easily adapted to the specific course with respect to style of teaching/learning, amount of time available to address issues and the experience level of the students. Usefulness also unfortunately is dependent upon the technologies available at varying schools: from slide projectors, to DVD, to Powerpoint™ or video. Based upon conversations with professors of architecture, the *least* easily used format seems to be video, particularly if the run time exceeds the amount of time available. The most useful formats would be sets of digital images or slides, if accompanied by a "script or narrative" that explains the project, and CD-ROM or DVD format presentations that allow the instructor to select portions of a case study for use if time or subject area does not permit the inclusion of the full case study. Image based data that can be accessed via the internet for either download or direct use is helpful as it increases the ease and immediacy of access.

With every case study presentation, the "a-ha!" factor is important. There needs to be some key, unusual, value adding information that is not otherwise, or easily available. Anecdotal information is always helpful. This is usually only obtained through personal interaction with the people and project/site itself.

Other questions to be asked when preparing a construction case study:
1. What are the necessary attributes that elevates a building to warrant documentation?
2. Are there different types of case studies?
3. Primary ingredients/checklist for this case study to include?
4. Types of documentation: drawings, photographs and video.
5. How much material is *enough*? Do all require equal development?
6. Involving students in documentation.
7. Exploring the use of multimedia.
8. Next steps – are we doing enough with case studies?
9. How to maximize the learning potential of materials.
10. Logistical difficulties: site access, legal issues.

The Nodding Off Factor Revisited:
In the end sleep deprivation can and will govern, and all efforts of instructors to provide a meaningful, interactive presentation based upon unique personal experiences, images and video footage will still fail. But ultimately, through the fog, students will realize that they missed something important – something that cannot be caught up after class or through reference to the notes of "others".

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