# BESS

Integrating Design & Building Practices

# PROCEEDINGS

Building Enclosure Sustainability Symposium 2011

HOSTED BY SIMPSON GUMPERTZ & HEGER + CAL POLY POMONA

APRIL 29 - 30, 2011 POMONA, CALIFORNIA

# Quantifying Sustainable Design: Select Case Studies
## The Green Scale Research Project at the University of Notre Dame

AIMEE P. C. BUCCELLATO
University of Notre Dame School of Architecture

**ABSTRACT**

This paper will present the author's on-going research in quantitative analysis of construction methods, materials, and principles of design through a pair of Case Studies involving both proposed and built projects focused on measuring, evaluating, and comparing purportedly "green" materials and methods of assembly alongside their traditional predecessors:

**The Placebo Effect and LEED**
Loyola University of Chicago's new Information Commons (LEED Silver)

**Emerging Technology: The Concrete** (Ana)**Log**(ue)
How modern technologies may extend or enhance the already durable qualities of traditional materials and methods.

Both Case Studies involve the comparative quantitative analysis of primary building components and whole building design for each Subject Case building and allied Design Case counter-proposals, including: material properties and thermal performance; material embodied energy and embodied water; building site impact; footprint, actual and operating; and material life-cycle analysis, as related to baseline building life expectancy (100 years).

By reaching beyond polemics and positions grounded largely on aesthetic premises, The Green Scale Research Project (TGSRP) intends to expand our ability to make informed design and material decisions from the outset of the design process, leading ultimately to the creation of *truly* sustainable buildings, and meanwhile seeks deeper understanding of the following related premise: What responsibility do we assign to modern technology to generate "sustainable" design solutions; how have we come to prioritize novel, advanced building technologies above immediately accessible, customary methods – and at what cost? What *is* responsible technology?

### 1 WHAT IS THE RESPONSIBILTY OF TECHNOLOGY IN SUSTAINABLE DESIGN?

Today, prevailing discourse on "green" building practices centers on a presumed corollary between sustainability and advanced building technologies – or the perceived dependence on the latter to achieve the former. As a result, research and discussions about achieving sustainability and greener building methods generally focus on the capabilities of modern technology to generate "sustainable" design solutions. But in our pursuit of high-tech optimization – in the form of "smart" building skins and "green-gizmos" soaked in embodied energy – are we overlooking materials and methods that are presently available, immediately accessible, and inherently durable and sustainable? As we advance novel technologies to generate change in the unsustainable world that we have created, are we headed towards a future of global standardization, cultural ennui - and *more* industrialization - while overlooking more immediate solutions?

**If we accept that sustainability means using building systems and materials that collectively have *less* of an impact on the environment, then by principle, the use, manufacture, and implementation of these systems and materials should be of *less* consequence to the environment than any potential gains to be had in their utilization.**

Before the dawn of the thermostat age, buildings were designed to perform in their environment *without the benefit of active intervention.* The orientation of a building, its materials, methods of construction, massing, scale of openings, and other bioclimatic factors were all primary design considerations before the advent of active measures. These design considerations, although not highly-technical, are not merely commemorative of an earlier, "less complicated" time, but remain central to the design of buildings that are site-specific and well-adapted to their environment. What can be gained from the study of traditional methods of construction and principles of design?

Throughout time, building traditions and systems of construction have necessarily been born out of what was readily available: local resources, skilled labor, economics, climate, and ultimately, the combination of necessity and beauty. These methods are generally low in embodied energy, have been vetted, refined, and mastered over time, are climate and context-specific in their selection and assembly, and when executed in conjunction with fundamental principles of design, have produced some of the most enduring, efficient, practical, and beloved buildings standing today. A return to the design pragmatics of the pre-fossil-fuel and pre-thermostat age, and a renewed commitment to understanding the full impact of our design decisions – both in the present and the future - may perhaps bring us closer to finding truly responsible technology.

## 2 METHODOLOGY

In an effort to understand the broader implications of our design decisions and material and method choices, students involved in TGSRP engage in directed Case Studies of existing buildings through the quantitative analysis of that building, the Subject Case, relative to its particular site, the primary construction methods and materials employed in its execution, and any design decisions that were fundamental to its conception, if known or articulated.

This paper will present two related types of Case Studies:

> **Type I: High Tech/ Low Tech** quantitative analysis of an existing or proposed building, the Subject Case, that has been designed and constructed using primarily novel, non-traditional materials and methods, oftentimes accompanied by claims of "greenness", sustainability, or enhanced performance, compared side-by-side with quantitative analysis of a counterproposal to that building, the Design Case, which is an alternate design and construction of the Subject Case using traditional materials, methods, and principles of design.
>
> **Type II: Alternative Construction** quantitative analysis of an existing building, the Subject Case, that has been designed and constructed using traditional materials, methods, and principles of design, compared side-by-side with quantitative analysis of the Subject Case building using alternate methods of construction, including at least one contemporary mode and related materials.

Both types of study involve the dissection of the Subject Case building into primary building construction systems, assemblies, and components, and the empirical evaluation of those materials side-by-side with the dissection and empirical evaluation of the Design Case or Alternative Construction Cases. Data and analyses related to these studies used modeling and analysis programs such as Revit, Ecotect Analysis, Green Building Studio, and Athena Impact Estimator, along with manual calculations and materials databases, like the Inventory of Carbon & Energy (Hammond and Jones 2008).

TGSRP methodology differs from similar quantitative comparisons and case study-based inquiries, like those published by Robert Adam and Atelier 10[1]; the theoretical and experimental comparative studies of the performance of mass wall technologies summarized by researchers at the Oak Ridge National Laboratory[2]; and the "green" test houses built recently by the Prince's Foundation in the UK[3]. Where these studies are largely focused on comparative modeling or field experimentation to measure the thermal performance of standard building envelopes, TGSRP is focused on generating comparative data on actual buildings, particularly those that purport to be *sustainable,* in order to consider side-by-side the broader implications of our decisions at the earliest stages of design, and the range of impact that those decisions may have when our buildings become manifest in the built world.

Today, sustainable building is more often than not described, illustrated, and executed using novel, high-tech solutions which are fundamentally at odds with the concept of sustainability. Is novel necessarily better; advanced technology necessarily more efficient, more sustainable? What are the affects of streaming innovation? Beyond the up-front costs – both monetary and resource-related – of research and design, constantly changing technology demands agile, specialized labor forces, sophisticated mechanisms and processes capable of accurately testing and evaluating new methods, and ultimately, time to respond to failure. Innovation can bring about progress, but it can also be extremely taxing on the environment and a stressor on society, potentially contributing to a loss of confidence in what we already know and the skills that we have already mastered.

## 3 TWO CURRENT CASE STUDIES

**The Placebo Effect and LEED**; Type I: Hi Tech/Low Tech

Much attention today is focused on minimizing a building's operating footprint by optimizing raw energy consumption; meanwhile, the construction of hyper-efficient buildings, by virtue of their design and particular component parts, can consume exponentially more energy than what the most energy-efficient building uses annually. Novel materials, methods, and connections of assembly are unique and in many cases experimental, requiring specialized knowledge and proficiencies, and are not typically found locally. What are the *true* costs of these novel systems? As we endeavor to produce new technologies and materials that will make our buildings more efficient while at the same time attempting, ultimately, to use less energy, there emerges a significant – if often inversely-proportional – relationship between embodied energy consumption (for research & design, extraction, transport, fabrication, and construction) and a building's lifetime operating energy consumption (CWC 1997).

The focus of the first Case Study is the 70,000+ SF Richard J. Klarchek Information Commons, located on the eastern shore of Lake Michigan, in the heart of Chicago's Loyola University. Our objective: to quantify the broader impacts of specific decisions made at the outset of the design process, including: building orientation, response to site, climate, and transparency, the materials used and methods employed, including assertions of advanced performance[4]; compared to an alternate design and construction of the Subject Case, using traditional principles of design, materials, and methods of construction.

In response to their client's priorities, priorities – day-lighting, transparency, thermal comfort, and efficiency, among them – the architects, Solomon Cordwell Buenz, designed a pair of 150 foot glazed façades bound by pre-cast concrete-clad "bookends"; what has been characterized as a four-storey glass box (Gonchar 2009). The broadest exposure of the existing, Subject Case building (Figure 1a), faces nearly due east, exploiting an (otherwise) unobstructed view of Lake Michigan.

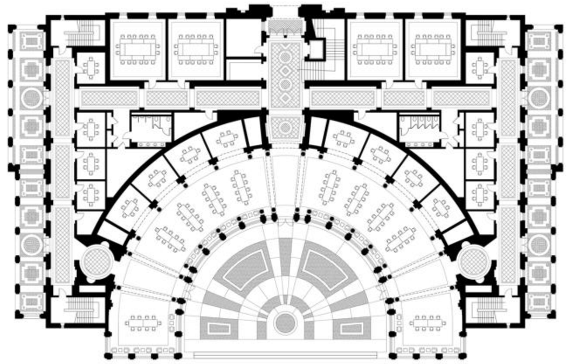

**Figure 1a. (Left) Subject Case: Loyola University of Chicago's new Klarchek Information Commons (LEED Silver); Figure 1b. (Right) Design Case: Proposed Ground Floor Plan. Image credits: John C. Mellor.**

*Preliminary Results*

Among the building's various novel design responses, the west-facing glass façade is a double-skin curtain wall (average assembly R-value: 4.35) designed to engage and integrate many of the building's mixed-mode operating systems; the lakefront façade is a single-skin curtain wall (average assembly R-value: 2.17).

Included in its application for LEED status were the building's novel HVAC systems and energy conservation strategies, including higher than anticipated thermal performance, despite the fact that the average R-value for over 47 percent of the building – the glass curtain walls – is 3.26. And while post-occupation energy use exceeds ASHRAE's baseline (Standard 90.1-1999), the building's *actual* energy use is still notably higher than the design model (McLauchlan and Lavan 2010).

The counterproposal or Design Case (Figure 1b) evaluated is a masonry structure, self-supporting limestone and brick façades (33 and 55 percent of the total façade surface area, respectively) in front of a single wythe of structural reinforced concrete masonry (CMU). The average façade R-value for the Design Case, including punched openings (insulated glass; 13 percent of the total façade surface area), is 23.6. And while the total façade surface area of the Design Case is 10 percent greater than the total façade surface area of the Subject Case (44,605 SF: 41,034 SF) – by virtue of the proposed design's footprint (Figure 3b) – heat loss through the Subject Case's envelope is considerably greater: 462K BTU/hr versus 152K BTU/hr (calculated on a 15 degree day).

Beyond considering the thermal performance of the materials used, the estimated embodied energy (and water) involved in the execution of each Case was also studied. Due to incomplete information about the roof and floor assemblies of the Subject Case, and to maintain comparable side-by-side evaluations, our quantifications do not include the embodied energy calculations for the roof, floor, or foundation systems for either Case. Conservative assumptions were made about the use of recycled aluminum in the Subject Case (20 percent recycled: 80 percent virgin), and the quantity of stainless steel cable, fittings, and connections in the curtain wall assemblies was estimated at 1000 lbs. The embodied energy calculation for the Subject Case does not include the 6,625 feet (or 1.25 miles) of silicone sealant in the glass facades and joints between the precast panels.

While the existing façade has slightly less embodied energy than the proposed, 6027mBTU versus 6526mBTU, it is important to note two critical influences: the difference in total façade surface area between the two designs (10 percent) and the volume of brick masonry material calculated for the Design Case, which could be significantly reduced if a single wythe brick veneer construction were employed in lieu of the multi wythe self-supporting system proposed. The use of recycled brick versus virgin material would also significantly reduce the EE figure.

Our analysis of this Case Study and preliminary data suggest that there *can* exist quantifiable differences between newness and effectiveness – or that an implicit connection between the two should not necessarily be assumed. As with the Subject Case, can a building with façades composed of over 50 percent glass make credible claims about *increased* thermal performance, sustainability, and efficiency? And if so, are the ways that we currently measure and qualify sustainable and efficient design, like LEED and ASHRAE, sufficient – and do these standards necessarily lead us to the design and execution of truly sustainable buildings? At minimum, additional metrics are warranted so that the up-front and lifetime costs of the materials used and the assemblies employed – no matter how highly engineered – are included in our overall assessment of building performance; and per the intent of this research, that these factors become greater influences on the way that we set out to design truly sustainable, durable, and efficient buildings.

**Emerging Technology: The Concrete** (Ana)**Log**(ue); Type II: Alternate Construction

Today there are modern technologies and materials that *may* extend, enhance, or perhaps even *exceed* the already durable qualities of traditional materials and methods. These technologies do not necessarily merit praise on their own; innovation alone does not necessarily make a better, more sustainable building. As the 18$^{th}$ century theorist Laugier observed, the solidity of a building – arguably its most important quality in the context of durability and sustainability – distinctly depends on two things: the choice of material *and* its efficient use.

The Subject Case building of the second study, a residence in northeastern Idaho made out of cast concrete logs, was just the seventh structure of its kind to be constructed out of the novel material (Figure 2a). According to the engineering and performance data published by the manufacturer, Everlogs[5], the insulated concrete composite logs won't shrink, swell or settle; they're air-tight – on an order of six times that of light wood framing (per testing by the National Center on Appropriate Technologies); are resistant to mold, rot, and insects; and achieve a three-hour (no burn) fire rating. Unlike its organic predecessor, the CIC (*core-insulation-core)* system (Kosney et al.) is steel reinforced to perform optimally in hurricane and seismic-prone areas (such this house which sits in a level 4 seismic zone).

While recognizing these many superior benefits, are there consequences associated with using a structural wall assembly that, despite its baseline R-19 insulation value, consists primarily of composite concrete, steel, and rigid insulation, as compared to a the construction of a similar structure using traditional timber log construction or light wood platform framing?

**Figure 2a (Left) Subject Case: A Residence on Henry's Lake, Idaho; (Author Name) Design 2007. Image credit: J. K. Lawrence. Figure 2b (Right) Thermal model generated using AutoDesk Ecotect Analysis 2010. Image Credit: Evan Possley.**

*Preliminary Results*

Evaluation of the Subject Case was based upon the primary assemblies used as built: reinforced poured-in-place concrete foundation; 8" thick steel reinforced insulated composite concrete log wall assembly with an interior, non-load-bearing 2x4 frame wall filled with Polyicynene closed-cell insulation[6] (Figure 3; A); and a cold roof constructed using engineered wood trusses insulated along the bottom chord with Polyicynene. The foundation and roof assemblies remained the same in both Alternate Construction Cases, but the two wall assemblies quantified and compared to the concrete log assembly were: 2x6 light wood or stick-frame construction, filled with standard batt insulation and clad with exterior grade plywood and stained wood clapboard (Figure 3; C); and 8" traditional timber log construction with an interior non-load-bearing frame wall, filled with standard batt insulation (Figure 3; B) An interior frame wall assumed in both the Subject Case and this Alternative Construction Case for the purpose of securing interior finishes and running electrical and plumbing services.

In this Case, the wall assembly that involves the least embodied energy in its execution, light wood frame construction, is also the least thermally effective assembly of the three systems (see Figure 3). The alternate, traditional timber wall assembly performs marginally better thermally than the stick-framed assembly, but is percent less effective than the concrete log wall assembly. On the other hand, the embodied energy associated with the Subject Case wall assembly – which can only be estimated at this time based upon the evaluation of similar commonly-used components – is notably greater than the embodied energy of the two Alternate Construction Cases (approx., $1.15x10^9$: $9.7x10^7$: $1.12x10^9$ EE; CIC, timber log, and stick framing, respectively).

Although the initially energy-intensive Subject Case requires less operating energy for heating and cooling – and therefore fossil fuels – than the Alternates, the thermal performance of the assemblies and their energy "costs" must be evaluated holistically alongside other considerations, like sourcing (a potentially significant "cost" for a traditional timber log construction, both in terms of harvesting and transportation), lifetime maintenance, and construction waste. In each of these categories, the novel material improves upon long-standing tradition: each log is cast to exact size, almost eliminating construction waste; in this case, the primary wall assembly materials were "local", traveling less than 250 miles to the job-site (as opposed to timbers which would likely have originated from Canada); and unlike their organic counterparts that need to be routinely treated, stained, and patched, the concrete logs do not require *any* subsequent treatment or chinking.

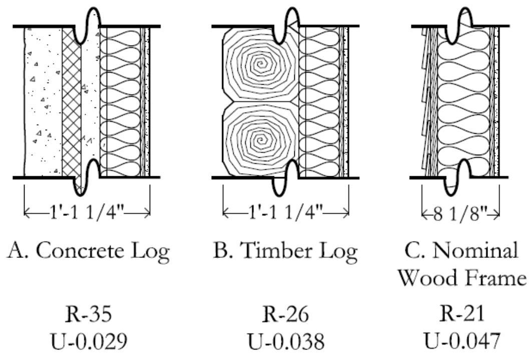


**Figure 3 Subject Case and Alternative Construction Case wall assemblies and associated R and U-Values. Image credit: Evan Possley.**

For many, the emblematic goal in building design today is how to express in built form what many consider to be the Era of Sustainability, signified by novel, high tech methods and cutting-edge building technologies. Ironically, these very same materials and methods which are meant to convey a sense of progress by achieving (or, as in some cases, merely claiming) superior performance, are not necessarily the most ecologically responsible or culturally sustainable practices, and therefore, may not be the most durable nor *truly* sustainable ways of making in the long-term.

The data and analyses generated by The Green Scale Research Project, such as the four Case Studies presented in this paper, contribute quantitative analysis as an means to enhance our ability to make informed design decisions, establishing both a premise and a methodology for empirically evaluating side-by-side the full impact of our decisions on the built and natural environs, and a means for discovering *truly* responsible technology/ies.

TGSRP recognizes that individual system performance is only as good as the connections made between those systems and the treatment of the penetrations made within those systems; the durability and therefore sustainability of a building is also largely dependent upon how a building is put together. To this end, TGRSP generates a catalogue of primary connections and penetrations for the Subject and Design Cases as an additional way to evaluate and describe best practices.

## 4 CHALLENGES AND OUTLOOK

Current modeling software limits our ability to make accurate, certifiable comparisons of as built conditions and design and material alternates germane to this research. At present time, prevailing modeling and whole building analysis software are not capable of holistically and empirically evaluating building designs at the level of an individual component or custom assembly, but only according to a very basic, limited, palette of predetermined assemblies[7]; nor are the programs able to integrate accumulated design-specific data or outcomes into a concurrent design process.

Because we are not able to validate data generated by these programs or account for incongruence between our manual calculations – which we *can* qualify – and the digital outputs, we are largely reliant upon data collected manually, and are restricted, to some degree, in our evaluation of certain material properties, like embodied energy and water, by the limitations of the databases currently available. Accordingly, our Case Studies currently focus on the evaluation of primary systems: foundation, envelope, roof, openings; and the intrinsic properties of those systems.

As the aim of The Green Scale Research Project is to evaluate and arrive at quantitative data capable of describing and influencing the broader impacts of our design decisions, the future of the research lies in the development of a dynamic modeling program that will enable the user to evaluate the use of specific materials and methods simultaneously with site-and-context-specific design decisions. Our research necessitates the ability to evaluate and compare different ways of making at the granular, rather than the macroscopic level, which is not yet supported by present technology.

## ACKNOWLEDGMENTS

The author would like to recognize the involvement of the following people in this early and on-going research: **The Green Scale Research Project Research Team 2010-2011**, including Senior Research Assistants: John Mellor (MAUD '09), Mary Myers, and Evan Possley; Research Assistants: Meaghan de la Rosa, Whitley Esteban, Amanda Miller, and Martin Wieck; support of the Dean's Office, School of Architecture, University of Notre Dame and the Center for Undergraduate Scholarly Engagement, University of Notre Dame; collaborative efforts with Professor Francisco Uvina and the students of Design and Planning Assistance Center in the School of Architecture and Planning at the University of New Mexico, members of the Bernalillo Chapter of the Youth Conservation Corps., Maria Rinaldi, Director of Planning for the Town of Bernalillo; important conversations and meetings regarding the St. Gerard's project with John Albanese and Angela Janesheski from Harrison Design Associates in Atlanta, Georgia, Philip Hauserman, John Cayce, The Reverend Father David M. Dye, Mark Wendell; conversations regarding thermodynamics and thermal reconciliation with Professor David B. Go of the Department of Aerospace and Mechanical Engineering at the University of Notre Dame; research-stimulating exchanges regarding material property databases, and current digital modeling, and evaluation tools with Professor Shahin Vassigh of the College of Architecture and the Arts at Florida International University; and special assistance from John Herridge, Autodesk Education Solutions Specialist for Green Building Studio and Ecotect, and the sharp-penciled Nora Jean Wedemeyer.

## REFERENCES

American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE)/ American National Standards Institute (ANSI). (2007). Standard 90.1-2007: Energy Standard for Buildings except Low-Rise Residential Buildings. Table 5.5-5: Building Envelope Requirements for Climate Zone 5(A, B, C), 23. Atlanta, Georgia: ASHRAE.

Adam, R., Atelier 10, et al. (2008). Energy and Environmental Assessment: A study of the energy performance of two buildings with lightweight and heavyweight facades. In the *Executive Report*, April 2008 (unpublished), 1-5.

Adam, R., Atelier 10, et al. (2007). Sustainability and Traditional Architecture. In the *On Green Architecture and Urbanism* Council Report VII: The Congress for New Urbanism (Conference Proceedings), 14-15. Alexandria, Virginia.

Bolgar, B. (2007). A New Culture in Building. In *On Green Architecture and Urbanism* Council Report VII: The Congress for New Urbanism (Conference Proceedings), 13. Alexandria, Virginia.

Canadian Wood Council (CWC). (1997). Comparing the Environmental Effects of Building Systems: a Case Study. In *Wood the Renewable Resource,* No. 4.

Childs, P., Christian, J., Desjarlais, A., Gawin, D., Kosny, J., Petrie, T. (Date Unknown) Thermal Mass – Energy Savings Potential in Residential Buildings. The Buildings Technology Center, Oak Ridge National Laboratory. Online: http://ornl.gov/sci/roofs+walls/research/detailed_papers/thermal/index.

Hammond, G. and Jones C. (2008). Inventory of Carbon & Energy (ICE), Version 1.6a. Bath, UK: University of Bath.

Gonchar, J. AIA. (2009). Case Study: Loyola Information Commons. In *Green Source Magazine* on-line: http://greensource.construction.com/projects/0811_LoyolaUniversity.asp.

McLauchlan, D. and Lavan, D. (2010). Efficiency by the Book; Case Study: The Richard J. Klarchek Information Commons Building. In *High Performing Buildings Magazine.* American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE). Online: www.hpbmagazine.org.

Offin, M. (2010). Straw Bale Construction: Assessing and Minimizing Embodied Energy. Queen's University.

[1] Referring to the methodology and results of two theoretical Case Studies described in two similar articles: "Energy and Environmental Assessment: A study of the energy performance of two buildings with lightweight and heavyweight facades" (2008) and "Sustainability and Traditional Architecture" (Adam, R. and Atelier 10, et al. 2007).

[2] Referring to the methodology and summary results of field-based Case Studies carried out by researchers affiliated with the Oak Ridge National Laboratory in the article: "Thermal Mass – Energy Savings Potential in Residential Buildings".

[3] Refer to the brief article written by Ben Bolgar on two test houses built by the Prince of Wales Foundation.

[4] See the article in Green Source Magazine for broader description of novel systems, energy and building performance data.

[5] For more information on the novel envelope system and manufacturers' specifications, refer to: EverLog Systems", http://www.everlogs.com/pdfs/ELS-Brochure.pdf.

[6] Referring to the 2010 specifications for Icynene LD-C-50; see: http://www.icynene.com/assets/documents/pdfs/Products/ICYNENE-LD-C-50-Specification-Sheets-US.pdf.

[7] Per our use in support of this research of the following programs: Autodesk Revit 2010 and Green Building Studio: Whole Building Carbon Analysis); Ecotect Analysis 2010; Athena Impact Estimator; and per conversations and special training sessions with John Herridge, Autodesk Education Solutions Specialist for Green Building Studio and Ecotect.