ACSA Distinguished Professor

2013-2014 Winner: Submission Materials

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Patrick Rand
Notes regarding teaching philosophy

My mission as an educator is to impart not only knowledge, but also the values and reasoning skills that will prepare students to apply the knowledge to unforeseen situations in the future.

The making of excellent architecture, perhaps like many human endeavors, depends upon insightful conceptualization and skillful implementation. The architectural concept is made possible through the construction materials and assemblies. Elements of construction are not merely of technical concern. They have compositional and symbolic content that make them potent catalysts for form and meaning.

It is rare in design or architecture that there is only one correct answer to a question, an assignment, or a project that students undertake.
Rather, the emphasis is placed on instilling in students a capacity to be broadly inclusive in their thinking, rational in their path toward a solution, and capable of presenting their reasoned conclusions.

To do this, students must be able to adeptly fuse knowledge-based technical professional realms with creative aesthetic realms.
For students to become skillful at this, we as educators must provide them with many examples, and must ourselves be models. This integration of technology and design is embodied in variety of lecture courses, labs, seminars and design studios that I teach.

Project-based instruction dominates in my courses and studio offerings, as this most closely simulates the abilities needed for architects to succeed in their licensing exams and professional careers. Outcomes-based learning places emphasis on how students/professionals use the information, imbedding the kernels of information into a relevant context. The instruction becomes “ready to use”. Outcomesbased education focuses everything in an educational system around an essential and evolving intellectual core, for all students to be able to successfully synthesize and apply at the end of their learning experiences, and hopefully long thereafter.

My task involves constantly making the information visible and memorable, while engaging the senses, instilling an intuitive sense of proportion and relationships between parts. These awarenesses are needed early in the design process, well before calculations are made. Architects (perhaps many others as well) are visual learners; they tend also be active experimenters in terms of their learning preferences. Our courses must empower the student to see and engage the information in a variety of modalities.

My areas of teaching contribution occupy a position at the center of the discipline, unapologetically. My required courses and studios fulfill crucial components of our NAAB-accredited professional degree programs. While I address these topics in some depth and rigor, I also place them in a larger context through collaborations with architects at other institutions, and also with engineers and landscape architects on funded research projects, teaching symposia, scholarly papers, and books.

My teaching philosophy has touched every architecture student that has matriculated in our school for more than 3 decades. Through invited presentations at national teacher’s seminars I have also reached a generation of architecture faculty at schools around North America. The educational models I have developed for the curricula, courses and capstone studios are considered exemplars at a national scale. They provide a conceptual framework that will serve practicing professionals for a fruitful career.

Optimal learning in building technology courses takes place when technology and design are engaged together.
I seek to integrate technology with design, and knowledge with imagination.

Teaching Technology through Design

The following thoughts were first put forth in a paper I presented at an ACSA Technology conference approximately 20 years ago. In reflection, this paper was pivotal in that it brought clarity to the first half of my career as an educator, and laid the foundation for the second half.

The making of buildings forms the intersection between architectural concept and implementation. Concept is dependent upon detail. Detail is dependent upon concept. In architecture, the general concept and the specific detail are simply two aspects of the same thing. Elements of construction are not only of technical concern, but have potential compositional and symbolic content that make them integral to, and inspiration for, the making of form. Construction materials and details give voice to the architectural concept.

Optimal learning in building technology courses takes place when technology and design are engaged together. To integrate technology with design, and to integrate knowledge with imagination, faculty may have to overcome a tendency unintentionally taught by our years in the discipline. We sometimes erroneously tend to think of technical knowledge and imagination as two separate and even antagonistic domains, perhaps the result of misappropriating tools for analyzing architecture as tools for generating architecture. Traditional frames of reference, such as the scientific method with its emphasis on measurable data, or the aesthetic mode, with its emphasis on qualitative features, are quite useful as tools for understanding and analyzing architecture. However when used as tools for **generating** architecture, the result is often a univalent design, lacking in sophistication. Great works of architecture typically are significant in terms of many frames of reference. One aspect is not pursued at the expense of others. These are simply lenses for viewing the same comprehensive whole.

Architecture curricula should integrate technology instruction with design instruction

Architecture curricula have historically included discrete courses regarding construction materials, usually coexisting with the design studio, but not connected to it. Is that curricular model ideal? For several reasons, the answer is no. Construction materials and other technology subjects should be reconsidered in an effort to present their fact-based content in a manner that fosters quick integration into the design process. There are three important reasons for doing so.

1 Understanding comes from critically engaging information
2 Knowledge triggers new design ideas
3 Integrating technology and design enhances teaching effectiveness

1 Understanding comes from critically engaging information

To understand a subject, one must acquire the information, then must internalize the information by transforming it to fit new tasks. Psychologist Jerome Bruner, in his classic *The Process of Education*, outlines the learning process as initially qualitative in nature, and chiefly oriented toward fundamental principles. For example, the child asks: Why does the rain fall? Only much later is the scientific description needed as the scientist explains: masses attract; gravity causes object to fall at the rate of 16 feet per second squared, etc. "Statistical manipulation and computation are only tools to be used after intuitive understanding has been established. If the array of computational paraphernalia is introduced first, then more likely than not it will *inhibit* or *kill* the development of probabilistic reasoning." (Bruner, p 46)

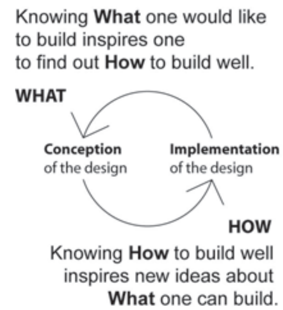
A common pitfall in building technology courses is that a vast array of information is presented without a clear hierarchy, in never-ending episodes, with no climax in understanding.

If learning indeed involves the ability to manipulate knowledge and apply it to relevant situations in an appropriate way, then our courses must constantly provoke the student to engage the subject matter as designers. The student needs to rehearse the initially perplexing trek through this new information-rich terrain, trying out various paths toward the solution. Our courses should serve as atlas and roadmap, or even as visitor's centers along the path.

2 Knowledge triggers new design ideas

As the student gains new knowledge, confidence increases and intellectual risk-taking begins.
"Yet it seems likely that effective intuitive thinking is fostered by the development of self-confidence and courage in the student." (Bruner, *The Process of Education*, p 65) The more you know, the less you fear.

It is not enough to merely teach technology through technology courses; we must try to teach Architecture through them. If construction materials courses only address technical considerations, then we implicitly teach our students that there need be no connection between general concept (***WHAT*** *the building is*) and specific implementation (***HOW*** *the building is made*).

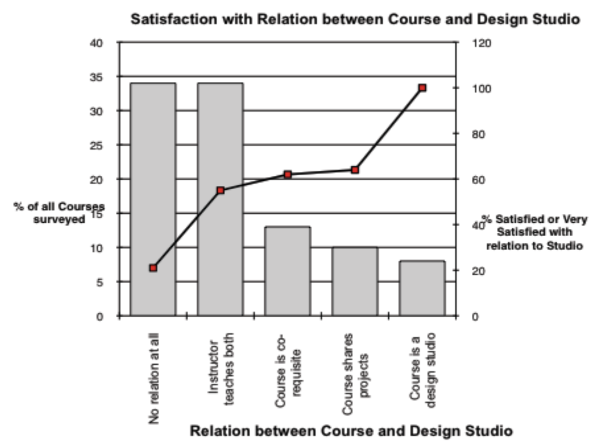


3 Integrating technology and design enhances teaching effectiveness

In 1986 Rand received an ACSA / wood industry grant to survey faculty who teach structures and construction materials courses in the US and Canada. The purpose of the survey was to find out how structures and construction materials courses were taught, and to assess faculty satisfaction with those courses. Of the 112 schools surveyed, 71 responded, including data regarding 69 structures courses, 46 materials courses, and 51 construction systems courses.

The survey showed that

- In a surprising 34% of technology courses there was no linkage in course content with a studio, nor did the faculty who taught the course teach a design studio.
- On the other end of the spectrum, 8% of the courses surveyed actually were design studios, with an emphasis on structures or construction materials.
- Most courses (58%) fell in the middle range, having some relation between studio and technology courses (such as: instructor teaches both, co-requisite with studio, or sharing project with a studio), but they were not studios themselves.
- When instructors were asked about their ***satisfaction*** with the relation between courses and studios, there was a direct correspondence between satisfaction and relation to design studio. Satisfaction was highest (100%) when the course was a design studio, and lowest (21%) when there was no relation at all to a design studio.
- Ironically, the most common teaching format was the least satisfactory, and the most satisfactory format was the least common.



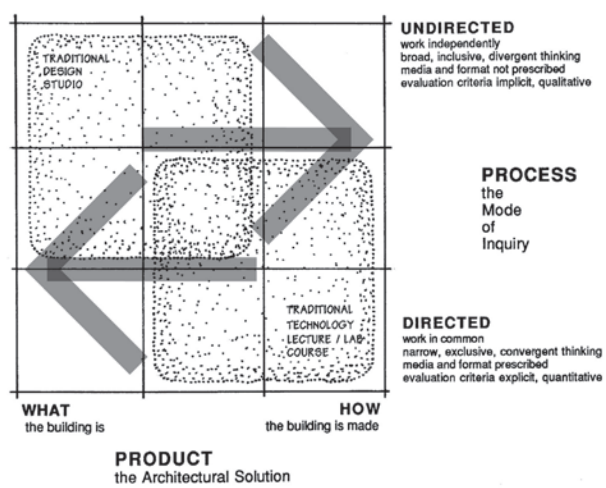
This data demonstrates that for the teaching of technical courses to be effective, the technical subject matter should exist in the context of the design process. This may be achieved through thematic studios, and by integrating the design process with technical subject matter.

Two viable curricular models

Curricula should carefully avoid the segregation of technology issues from the act of design.
There are two obvious ways to integrate design with masonry technology:

- **Incorporate Technology content into the Design studio.**
- **Incorporate the act of Design into the Technology courses.**

The following diagram describes a traditional architecture curriculum. The design process on the vertical axis, and the design product (the architectural solution) on the horizontal axis.



A traditional studio is in the upper left of this diagram. In a traditional design studio the work is often undirected, that is the students work through a process that is broad and inclusive of as many ideas and issues as possible. They work independently or in parallel, but not as a team. Their thinking is divergent.

A traditional technology course is in the lower right of this diagram. In a traditional technology lecture lab course, the work is directed. That is, the focus of the project is typically narrow, rather than broad and inclusive, and convergent thinking, focusing on a particular issue in the technology course would be a priority.

The **arrows illustrate the expansion of scope** of a traditional design studio toward the right, engaging new content regarding **How** the building is made.
The technology course is expanded to the left, engaging additional content regarding **What** the building form is.

Manifestations of Teaching Efforts

Earnest L. Boyer's landmark 1997 book *Scholarship Reconsidered*, described four overlapping forms of scholarship relevant to the discipline of architecture.

- Rand's greatest contribution is in **scholarship of teaching**, manifest through ongoing pedagogical experimentation in the classroom and studio, followed by papers and conference presentations to colleagues involved with architectural education. Rand has co-authored four books published since 2006 that have enhanced the teaching effectiveness of educators at other institutions in the US. One of these was described by a prominent book reviewer in *Architectural Record*: "In short, this is textbook that many of us wish we had in architecture school." Rand's pedagogical research regarding architecture curricula has been presented at more than 50 educator's conferences, serving as a catalyst for enhanced technical course instruction in architecture curricula at many institutions.
- Next is **scholarship of discovery**, manifest through research regarding how exterior building walls perform, and how to improve their performance. Findings regarding masonry wall design and construction have received national recognition and have influenced how this ancient method of construction has adapted to contemporary practice. Investigations comparing various exterior materials in terms of sustainable design objectives (embodied energy and CO_2) are also examples of this form of scholarship.
- **Scholarship of integration** has been engaged through involvement with other disciplines in various formats, including research collaborations, multi-disciplinary courses, invited lectures, and multi-disciplinary graduate student committees.
- **Scholarship of application** has been pursued through Rand's own professional architectural practice and consulting as a registered architect. Practice and consulting aid in keeping content of courses and studios current and relevant.

The Curricular Context in the College of Design

Selected course descriptions will follow, but it is important to place those courses in the relevant academic context. As shown in the curriculum vitae, Patrick Rand has been an active teacher in the Architecture program continuously since 1977. Initially his teaching was chiefly at the undergraduate level, but for the past 20 years has chiefly been at the advanced level. From 1988 to 2005 Patrick Rand held several administrative positions. Only two of those positions, Assistant Dean and Associate Dean for Research, had partial (50%) release time for administration. No other form of leave has ever been used.

In the College of Design a full/normal teaching load for faculty is 18 credits per year. Final Projects, Independent Studies, etc. are in addition to this 18 credit/year load. In the past five years Rand has taught an average of 344 student credit hours per year (# students x credit hours). Education in this discipline places great emphasis on *active learning* through the design studios and labs associated with technical lecture courses. Both of these are labor intensive, but are the most effective means to provide advanced education at high quality.

Courses and Curricular Contributions

Rand's contact with Undergraduate, Graduate and Professional degree students occurs in three forms.

One is the **lecture or seminar format**, in which the faculty substantially controls the format and content of the learning experience. The student is expected to come to understand and be able to use the subject matter. The relevant courses are Architectural Construction Systems (ARC 432), Design of Architectural Details seminar (ARC 534), and Project Preparation Seminar (ARC 581). Rand initiated Design of Architectural Details (ARC 534) in 2006. Materials for Design (ARC 590), was initiated in Fall 2010, and is now being taught for the second time.

The second form is the **design studio**, usually with approximately 12 to 14 students working in parallel under the close supervision of the faculty member on one or more hypothetical architectural design projects. The primary course of this type is Professional Architecture Studio II (ARC 502), in which candidates for the post-baccalaureate professional B Arch degree complete their capstone Final Project.

The third form is the independently structured **Final Project** for Architecture students, in which the individual student and faculty committee collaborate typically for one term in Final Project Research (ARC 697) and one additional term in the execution of the Final Project Studio (ARC 598). At this point the student is expected to be able to take initiative to define and research an architectural issue, articulate a position relative to it, and define a methodology through which they test their position via a vehicle project.

Courses and Studios Taught in the Past Four Years

• ARC 405; Arch. Design: Technology Studio (6 cr)		
• ARC 432 and ARC 432 Lab; Arch. Construction Systems (3 cr)	each Fall semester	(additional info to follow)
• ARC 581; Final Project Preparation Seminar (3 cr)	each Fall semester	(additional info to follow)
• ARC 502; Professional Architecture Studio II (6 cr)	each Spring semester	(additional info to follow)
• ARC 534; Design of Architectural Details Seminar (3 cr)	each Spring semester	(additional info to follow)
• ARC 590; Special Topics: Materials for Design Seminar (3 cr)	each Fall semester	(additional info to follow)
• ARC 697; Final Project Research (3 cr)	as required by student plan of work	
• ARC 598; Final Project Studio (6 cr)	as required by student plan of work	

Final Project (thesis)

Professional degree curricula in the School of Architecture contain a Final Project, which is required in the **Bachelor of Architecture** curriculum, and is an option in the Master of Architecture curriculum. Rand helped create the Bachelor of Architecture Final Project curricular model many years ago, and has been responsible for its implementation ever since. Examples of this 2-semester Final Project are presented later in this submission.

Rand has also been active in the **Master of Architecture** Final Project process, having served on more than 100 individual student thesis committees, more than half as chair.

In the independently structured Final Project for Master of Architecture students, the individual student and faculty committee collaborate typically for one term in preparation and one additional term in the execution of the Final Project. The student is expected to be able to define an architectural issue, articulate a position relative to it, and define a methodology through which they test their position via a vehicle architectural design project. The topics are highly variable due to the natural variety of student interests. Through these student-initiated projects, Rand's intellectual horizons have been greatly expanded. Most of the students also chose a concentration outside of their major, requiring that they include a faculty member from the other discipline on their graduate final project committee.

Architectural Construction Systems (ARC 432 and the co-requisite ARC 432 Lab) 3 cr

Catalog description: Building construction systems related to architectural design. Historical and current building practices. Implications for design and systems selection. Case study analyses. Field trips are required.

Approximately one-third of the 50 – 60 students are graduate Architecture students; the remaining are undergraduate Architecture students. For both groups of students, this course is part of a series of tightly coordinated courses and studios that quickly lay a foundation for advanced studies. Patrick Rand teaches Architectural Construction Systems, which is part of this foundation. He created this course in 1989, and substantially revised it in 1996 to conform to changes in the architecture curriculum. The course format involves two lectures per week, plus a weekly laboratory, which is used for group mini-design projects, field trips to construction sites, and tutorial instruction related to ongoing projects.

This course was cited by the two most recent visiting teams from the National Architectural Accrediting Board for its innovation and strength in the curriculum. This course has also received an Honorable Mention from the American Institute of Architects Education Honor Awards program.

Excerpt from Syllabus:

ARC 432 ARCHITECTURAL CONSTRUCTION SYSTEMS

Patrick Rand, Professor of Architecture (Brooks 310A, tel: 515.8319, email: patrick_rand@ncsu.edu)

Construction is the medium through which architecture is made. Architects are expected to be thoughtful and skillful with this medium, including material selection and the detailing of construction assemblies. Excellent architecture results from the convergence of insightful design and mastery of the medium of construction.

An academic foundation in construction methods is important for several reasons. An architect is responsible for the design of a building and all of its constituent parts, including its physical fabric. Construction technology is becoming increasingly sophisticated, resulting in a greater challenge for designers to be proficient with principles and methods of construction. Without knowledge about construction materials, well-intended design ideas are doomed to inept implementation.

For the designer, a grasp of construction methods can also be a catalyst for generating new and unforeseen design possibilities, thereby broadening rather than limiting the range of possible design solutions.

The lecture / laboratory format is important in order to link academic learning with application to real design situations. The laboratory projects, field trips and case study investigations are intended to stimulate the student to synthesize the abstract information from assigned reading and lectures. Tests and exercises are intended to simulate actual decision processes regarding the design of a building's construction systems.

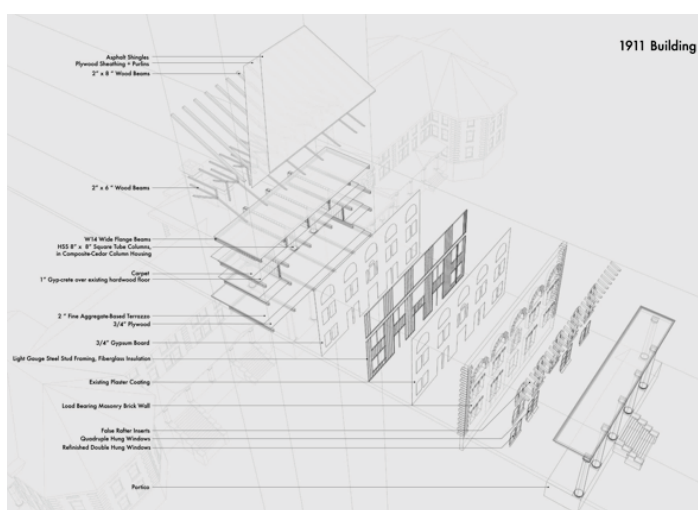
COURSE OBJECTIVES:

- To develop a basic conceptual framework and vocabulary for dealing with building construction issues
- To examine various construction systems so that students are better able to design with construction principles in mind
- To outline processes for comparing and selecting appropriate construction systems for a given application
- To show the relationships between various subsystems of a building, and to examine their influence on design
- To present the complexities of current construction practices in a clear way, and to develop abilities to discriminate good from bad practices

Two of the weekly laboratory sessions provide opportunities for field trips to observe construction processes directly, and engage in dialogue with key architects and construction superintendents. At right, a site visit to the new university library, designed by Snøhetta.

In addition to scheduled field trips, students also form small teams to carry out a term-long observation of a building under construction. In this Case Study project they study the project drawings and compare them to the work in the field. They also examine one construction trade in detail. Anxieties about contact with construction processes and personnel are dispelled. At the end of the term students present their findings to the class.

This longitudinal contact with a project for 3 months provides valuable perspective for the students. Principles taught in the class can be affirmed, or may challenged based on the particular project circumstances.



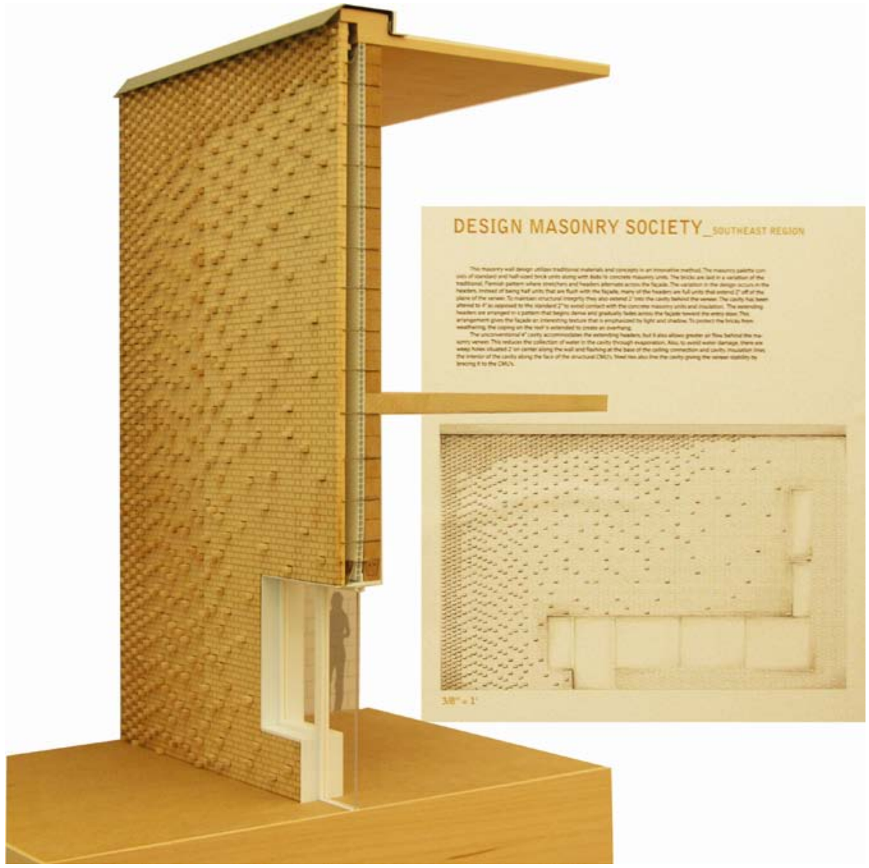
Students prepare detailed technical drawings of wall sections and exploded views of the building assemblies, such as the one illustrated to the right of the NCSU 1911 Building, when it was renovated a few years ago. Analytical drawings such as this enhance student skill and comprehension of technical assemblies. They also often reveal features of the building that are not evident through direct observation.

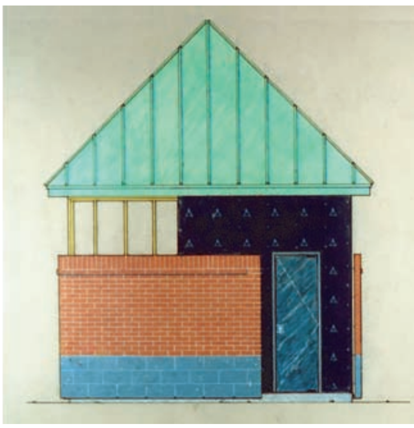
Students are challenged to apply the information from lectures and readings to small scale design projects in each of four major construction materials: concrete, wood, masonry and steel.

Solutions strive to be innovative and competently executed. Structural performance, building code conformance and weathering resistance are among the criteria used to assess the projects.

Scholarship support from industry and publication in national trade journals sometimes provide added incentive to students.

Three tests also assess student grasp of subject matter, often using questions that simulate project-based critical reasoning challenges.





A Weekend Lodge: Balloon Frame Construction

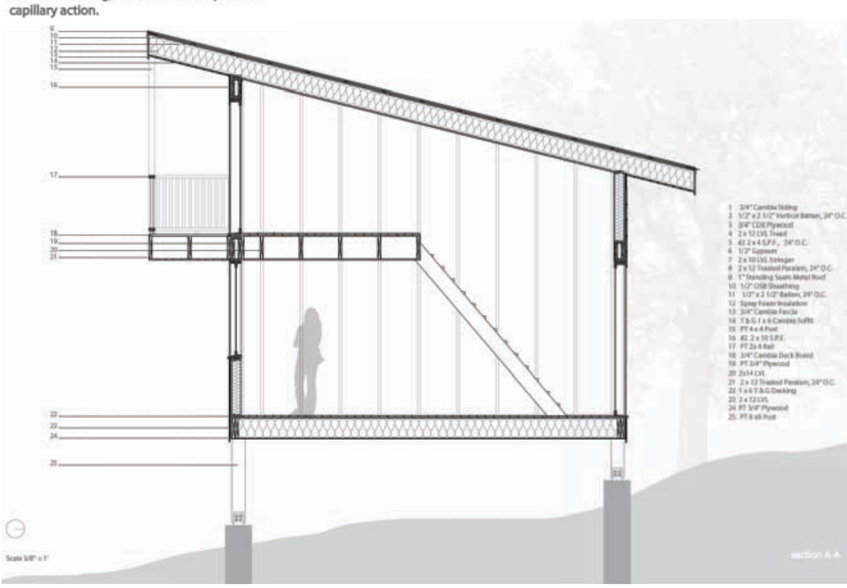
Our team used readily available wood products to create an inexpensive yet comfortable weekend lodge in Western North Carolina. We also chose to use a more expensive Cambia wood for siding in order to reduce maintenance costs over the life of the cabin. The cabin is set on a hillside overlooking a valley to the south. On the south side, we placed generous windows as well as a loft and balcony from which to enjoy the view.

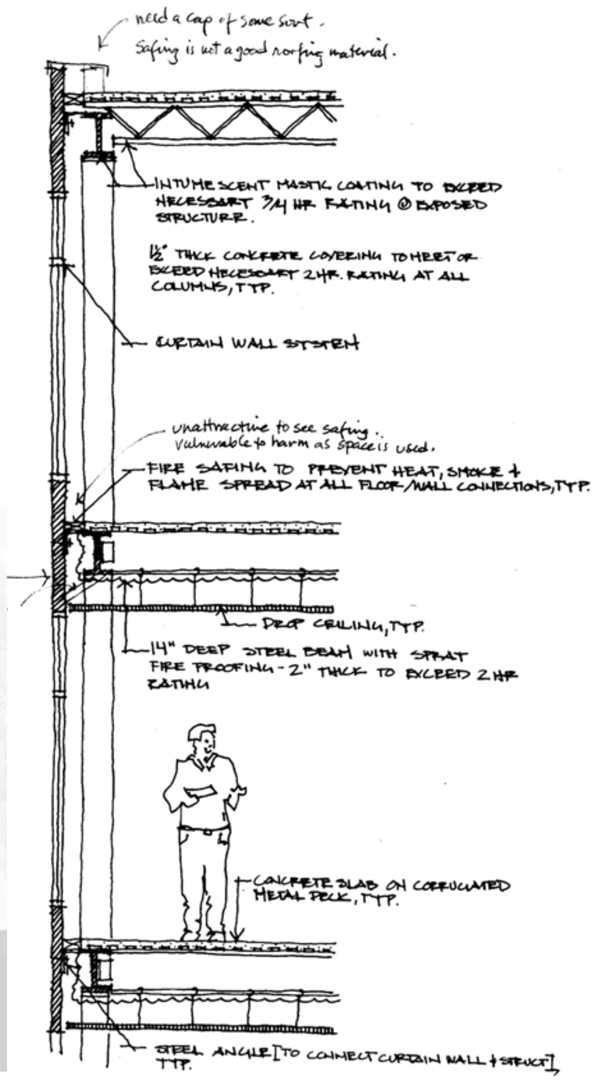
The overhang and balcony on the south side protect the cabin from extreme solar angles, and the overhangs on both the north and south help minimize moisture exposure to the siding. In order to further isolate exterior, vapor infiltration penetration, vertical battens provide an air-flow pathway for moisture to escape from behind the siding, which eliminates potential capillary action.

The cold winters and warm summers of the climate called for extra thermal insulation and good air-sealing. The walls are 2x6 and the ceiling is 2x12 in order to accomodate a generous amount of spray foam insulation.

Advanced framing was used in order to save on construction costs, environmental impact, and to allow yet more insulation with less thermal breaks.

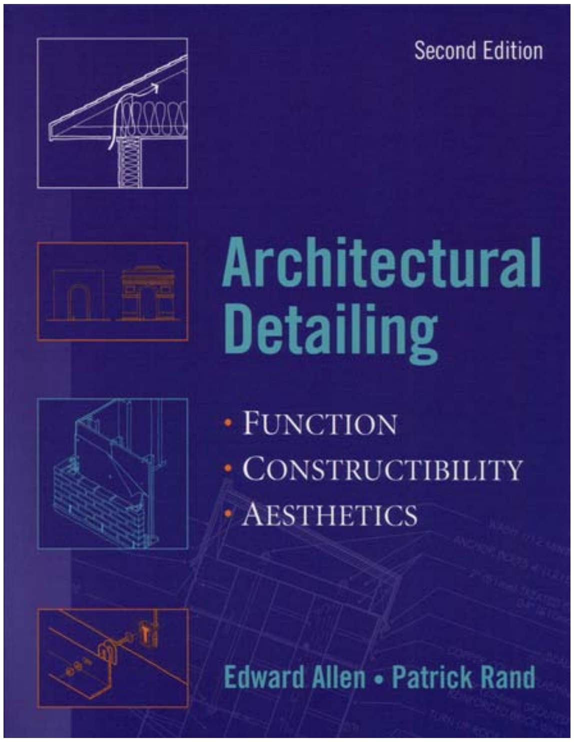
Engineered lumber was chosen for several applications within the building. LVLs were used for the floor and roof joists. Parallam was used in exterior framing applications. The siding is made from thermally modified wood to resist biological attack.





Architectural Detailing: Function Constructibility Aesthetics

Published: John Wiley & Sons, c 2007



At the request of Edward Allen, FAIA, Rand prepared the second edition of Allen's 1993 book. All changes were initiated by Rand, and reviewed by Allen. Every pattern from the preceding edition was revised, and new patterns and drawings were added to reflect changes regarding building codes, sustainability and other factors that affect current building design and construction.

Educators have found the book useful in building technology courses and studios that have a technology focus. It contains hypothetical case studies that apply the principles to projects, and suggested class projects. Others have called it "the thinking person's *Graphic Standards"*, because it teaches you how to create countless viable details.

Detailing is the language of the architect, the means by which architectural ideas are transformed into built reality. It is the one technical area in which the architect must be expert.

Rather than being an inventory of stock details, this book describes and illustrates the most important principles that affect the design of architectural details. These are the "patterns" that affect the function, constructibility, and aesthetic qualities of a building. These detailing patterns can be used to produce countless effective detail solutions, enabling students and practicing professionals to detail a building competently. The case study projects that reveal the thought process involved in detailing buildings.

Since its initial publication this book has been accepted as a text in many architecture courses and studios. It has been used by architects and educators around the world, and has been translated into French and Korean. Two of the chapters were further developed for Wiley's online Continuing Education tutorials for architects.
Bulletin 9/9/13: Wiley just sent Rand a contract for the production of a 3rd edition of this book.

Expected Life, **Simulated Assemblies** and **Composing the Detail** (next page) are new patterns that Rand wrote and illustrated for the second edition of *Architectural Detailing: Function Constructibility Aesthetics*

Expected Life

How long should a material or detail last? The durability of a specific building material or detail must be proportional to its intended useful life.

1. The useful life of a material or an assembly is determined by how its intrinsic physical properties resist deterioration caused by conditions of its environment, use, and errors of workmanship at the time of installation. The life span is also affected by nonphysical factors such as economic forces, aesthetics, and functional obsolescence, but these are beyond the scope of this book.

2. Decisions regarding materials and details are based on a premise about the anticipated life span of the building. We should always build well, but materials and details appropriate in a building meant to serve for a few years may be different than those for a building meant to serve for 100 years or more. For instance, stainless steel flashing is less appropriate in an exposition building that will be used for two years than it is in a state capitol building that has an unlimited life expectancy. Conversely, it would not be appropriate for the stone-clad statehouse walls to use PVC flashing, which has a service life of only about ten years.

Premature failure of a building material may result in damage to adjoining materials and will require costly and disruptive repair. Premature failure is especially disruptive when an otherwise durable assembly fails because of one weak link. Ideally, the detailer should anticipate the forces acting on an assembly and design the details so that the components of an assembly expire uniformly or in magageable segments.

Predicting the service life of a detail or an assembly is difficult because there is insufficient knowledge about the actual performance of specific materials and details. Therefore, detailers and owners should establish durability criteria for materials and details based on past experience.

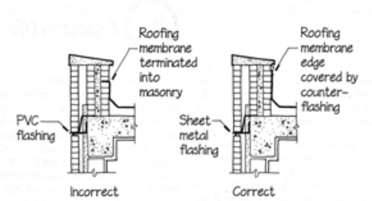
3. Establish a premise about the service life of the building in general, for instance, 25 years, 60 years, or 100 years. There are no legal standards for this, but precedents for the type of building are a good indication. Recognize that it is not essential that all elements of an entire building expire at the same time. Establish service-life tiers or categories, within which the elements should last about the same length of time. ▷

TABLE 10-1: Service Life Tiers

1. Primary structure and primary enclosure system	Major load-bearing elements and building envelope	Permanent: Should last as long as the intended life of the building
2. Major building service systems	Elevators, furnaces, boilers, chillers, major fans, plumbing and electrical systems	Long life: Should last 20 years minimum
3. Interior enclosure systems	Partitions, flooring, ceilings	Medium life: Should last up to 20 years or with change in occupancy
4. Furnishings, interior and exterior finishes	Surface finishes, sealants	Temporary: Should last up to 10 years

Source: Adapted from "Guideline on Durability in Buildings," Canadian Standards Association, S478.

4. To lower initial construction costs, elements of a detail are sometimes eliminated, or less durable alternative elements are chosen, often with disastrous results. Many expensive recladding projects are the result of hastily made cost-trimming decisions that saved less than 1 percent of the eventually needed repair costs. Lower quality execution during initial construction often results in higher maintenance costs or shorter service life. Detailers are well informed and should assist in making optimum choices regarding substitutions of materials and details.



6. Anticipating Service Life—Two Versions

5. Just as we have an operating manual for our automobile, architects may offer to provide building owners with a guide summarizing the maintenance and replacement cycles anticipated for each tier of the building systems. Owners and maintenance staff are collaborators in determining the building's life span; maintenance procedures need to be followed if the predicted service life is to be realized.

6. Details for all building elements should be designed to be accessible in proportion with their longevity. Building elements that are to be replaced at the most frequent intervals, such as lighting tubes and air filters, should be detailed to make routine maintenance easy. Low-slope roof membranes should be detailed so that the membrane can be replaced without requiring that the parapet be reconstructed. ■

SECTION 1 ■ FUNCTION 127

Simulated Assemblies

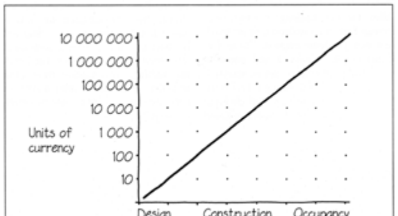
Build representative samples of challenging or unusual details to simulate the construction processes and to reveal the qualities of the finished product. The sample is the dress rehearsal of the intended building assembly.

1. Simulating the construction of unusual building assemblies helps to avoid costly and difficult removal of unsatisfactory work, and establishes acceptable standards of appearance and workmanship. This is especially important when materials or construction techniques are innovative, unfamiliar to the builder, or dependent on a particular quality of workmanship.

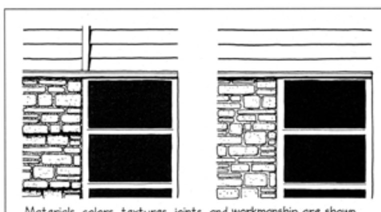
2. Much of the flow of information in a project is from the architect to the builder. The simulated assembly allows the builder to demonstrate what the result will be, at minimal cost. It is an excellent vehicle to bring expectations of architects, builders, and owners into convergence. Once accepted, the simulated assembly sets the standard for quality of work and appearance. It should be left safely on the site for the duration of the project, serving as a record of many qualitative features that are difficult to describe through drawings or specifications.

3. Changes in a detail are easiest and least expensive to make early in the design process, and they are most difficult and costly when part of the finished building. Costs of changes escalate steeply at each stage in the design and construction process. Erasing a sketch is much easier than jackhammering concrete. Simulated assemblies help identify areas where changes are needed before they become part of the finished building.

4. A sample panel may be used to demonstrate the exposed appearance and workmanship of the detail or assembly. The materials, colors, textures, joints, and accessories intended for the building are used in the sample panel. It may be freestanding, apart from the building, or may be the first portion of the actual building. Sometimes multiple freestanding samples can be prepared, each revealing a variation in material or finish, to give the best possible basis for final selection. ▷



3. Cost to Change a Feature During a Building Project

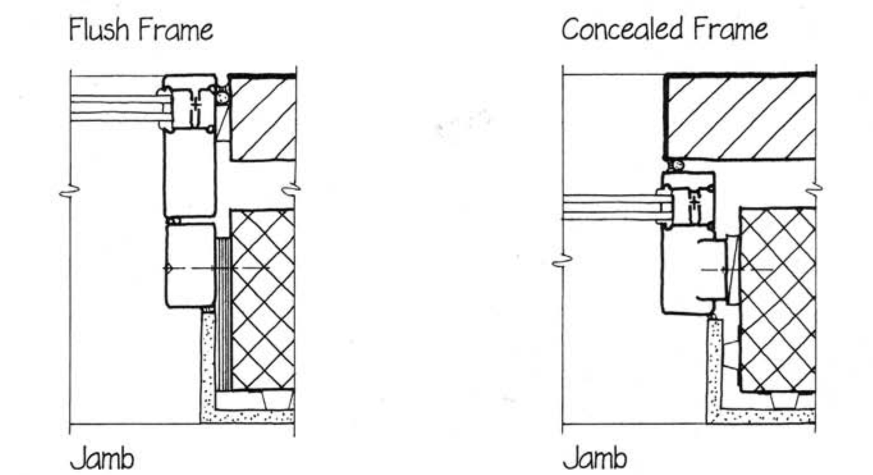


4. Sample Panels and Mockup Panels

SECTION 2 ■ CONSTRUCTIBILITY 155

Composing the Detail

Aesthetic goals are often catalysts for exploration of a detail's technical possibilities. The detailer fuses aesthetic composition and technical exploration to find the best solution.



3. Window Frame in Masonry Wall--Two Versions

1. In the best architecture, the details go beyond the technical realm to convey important compositional qualities and meaning. A well-composed detail can capture the essence of the building design in a vivid way and can explain the relationships between the parts of the building they are joining. The wood siding that is scribed to meet the irregular face of the ashlar stone wall tells us that the stone hearth is the dominant element, anchoring the composition. The detail demonstrates the basic architectural concept.

2. Many buildings have one little feature that people can fall in love with. The potency of the detail as a memorable building feature is sometimes underestimated. Details that are seen up close or touched have the greatest potential to positively influence the observer. Grasping the door pull that was designed by the building's architect is as close as one can come to shaking that architect's hand.

3. Compositional questions such as whether a shadowline is desired, whether the window should be flush or recessed, and whether or not a joint should have a piece of trim all provoke technical exploration. The detailer probes what must be done to produce a shadowline, for glass to be in the same plane as the exterior cladding, or for a joint to be trimless. What the detail looks like and how the detail is made are inseparable aspects.

4. A detail can join elements in countless ways, from an almost seamless weld as in a Mies steel frame, to the boldly expressed joints and fasteners of a Greene and Greene connection. Is the connection to be celebrated and objectified or to be quietly competent, not calling attention to itself? If fasteners or splices are used to make the connection, should they be prominent in the composition or should they be downplayed?

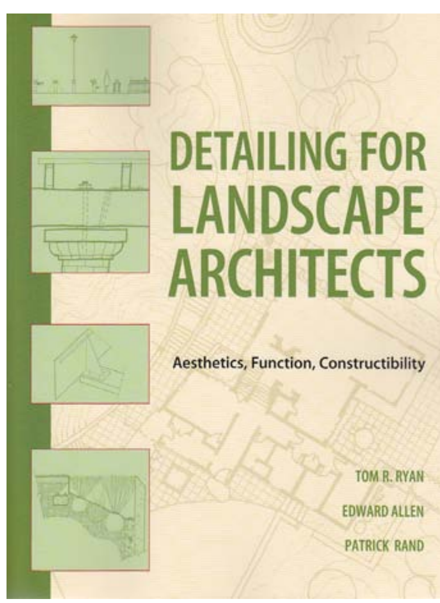
5. Details must be visualized in three dimensions. It is wise to develop details in three-dimensional sketches or models to visualize completely their forms and implications. Three-dimensional development also helps to explore how each detail turns the corner or intersects another element. ■

Detailing for Landscape Architects: Aesthetics Function Constructibility

Published: John Wiley & Sons, c 2011

At the request of the publisher, Rand collaborated with Tom Ryan and Edward Allen to prepare a new book following the successful concept and format of *Architectural Detailing*.

Approximately 50% of the content was entirely new in this publication, and all of the remaining content was revised. Since its publication this book has been accepted as a text in many landscape architecture courses and studios.



The new industry standard on Landscape Architectural Detailing

Detailing for Landscape Architects takes the reader on an educational journey across three major areas of landscape architectural detailing—aesthetics, function, and constructibility—to demonstrate how powerful design patterns can transform thematic ideas into awe-inspiring built realities. Richly illustrated examples accompany concise discussions of a varied blend of landscape design/detailing issues such as water movement, soil environments, articulating structures and construction assemblies, life cycle costing, sustainability, health and safety, and more. This book approaches the subject of detailing in a systematic manner, and provides a balanced framework for design and workmanship that conveys the essence of the built landscape.

Detailing for Landscape Architects shows how details can:

- Reinforce design ideas through the continuity and discontinuity of patterns
- Actively contribute to the overall form or geometry of the design
- Be designed to be durable and flexible while enhancing the entire design
- Gracefully accommodate the natural growth and change of plant materials
- Anticipate maintenance needs to minimize future disruptions
- Maximize their cost effectiveness through understanding their function while designing to meet those functions

After publishing the *Architectural Detailing* second edition, Rand began to offer a graduate seminar on this subject.

Design of Architectural Details (ARC 534) 3 cr

Catalog description: Using detail patterns based on function, constructibility, and aesthetics, students analyze existing successful building details, diagnose problems in existing buildings, and design details for their own projects.

Rand initiated this graduate seminar in Spring 2007, based on the book *Architectural Detailing; Function Constructibility Aesthetics*. Students gain a working knowledge of principles that are elemental to all building details. They represent an accumulation of wisdom about what works in building construction and what doesn't. Many detail patterns are firmly grounded in scientific fact. Others are based just as solidly on common sense and the realities of human behavior and performance. Fear of detailing is replaced with curiosity and competence.

This is a graduate seminar, typically with 12 – 16 students enrolled. It is taught in a tutorial format, with class discussions centered around projects in which students design a series of building details, following principles the instructor presents in the textbook and in class.

Excerpt from Course Description:

ARC 534 Design of Architectural Details
Intended for: M Arch and B Arch students
Prerequisite: Architectural Construction Systems (ARC 432) or equivalent

Course Outline

Details have been referred to as the DNA of the building. In the best architecture, the details contain the genetic code that transcends the pragmatic and technical to engage the intellectual and spiritual domains. It follows that details explain the intended relationship between the parts of the building they are joining, whatever that might be. Just as idea, site and program are the designer's basis for the building's overall features, so too are they the basis of the details.

Details have always been important, but they have never been more important than now. Whereas previously, the architect relied heavily on the craftsperson in the field or shop to competently design the detail, now that responsibility largely falls to the architect. The opportunity to extend the core principles of the building's design to the details has never been greater than now. As architects we should not squander this opportunity.

Rather than being a review of stock details, this course focuses on the fundamental principles that affect the design of architectural details. These are the "patterns" that affect the function, constructibility and aesthetic qualities of a building. These detailing patterns can be used to produce countless effective detail solutions.

Students will gain a working knowledge of a set of detail patterns that are elemental fragments of natural phenomena relevant to all building details. They will exercise critical reasoning skills necessary to make appropriate choices. The patterns fall into the following three groups.

Function: Designing details that are airtight, watertight, allow for expansion and contraction, take a sustainable life-cycle perspective, and weather gracefully.

Constructibility: Designing details that are easy to build, forgiving of small lapses in workmanship, and use resources efficiently.

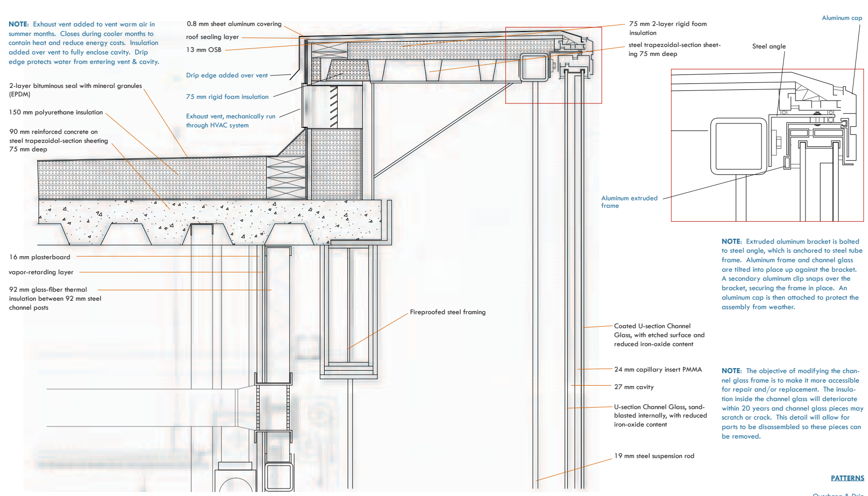
Aesthetics: Designing details that are pleasing to the eye, contribute to the building's architectural expression, and create beauty out of necessity.

The structure of the course anticipates the day to day workings of the practicing architect whose activities frequently involve data collection, analysis, and interpretation of architectural issues prior to their resolution in tangible building proposals. Legal (e.g.: building code) parameters and generalized cost implications will be included in the scope of the analyses. High quality architecture can only be made when these factors are creatively addressed.

Course Objectives / Learning Outcomes:

The primary objective is to gain the ability to use a comprehensive set of principles for the design of architectural details. In accomplishing this goal, students will need to address the following secondary objectives:

- Become able to define the performance objectives of architectural details.
- Develop a working knowledge of basic methods and resources relevant to the design of details.
- Identify and analyze precedents regarding their architectural details.
- Develop ability to design architectural details for particular applications.
- Represent the conclusions of the investigations in oral, written and graphic form.



PATTERNS
Overhang & Drip
Sealant Joints & Gaskets
Sliding Joint
Life Cycle
Expected Life
Similar Metals
Accessible Connections

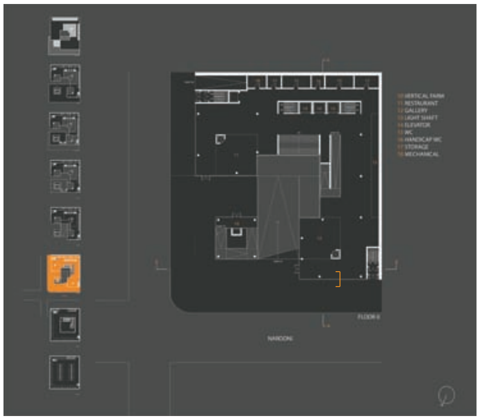
Nelson - Atkins Museum of Art
Kansas City, MO
Completed 2007
Steven Holl

Students learn to detail a building by carrying out a series of four projects in which they apply the principles contained in the book.

In the above project, a student analyzed the details of an existing building, Holl's Nelson Atkins Museum, then proposed improvements **(in blue)** that would enhance performance while adhering to the architect's aesthetic objectives.

The three student projects on this sheet are typical of the types of projects carried out in the Design of Architectural Details seminar. For instance, to the right, Emmie Tyson revisited a project she had designed in a previous studio, drawing the steps of construction to visualize those processes, and adding new thought to the wall and roof details.

Below left, Benjamin Chappel detailed and illustrated features of the exterior wall of a building he was designing in a concurrent studio. Below right, Matt Shelton wrote and illustrated a new pattern that might be added to the book.

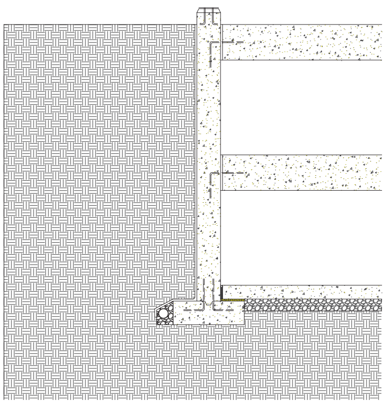


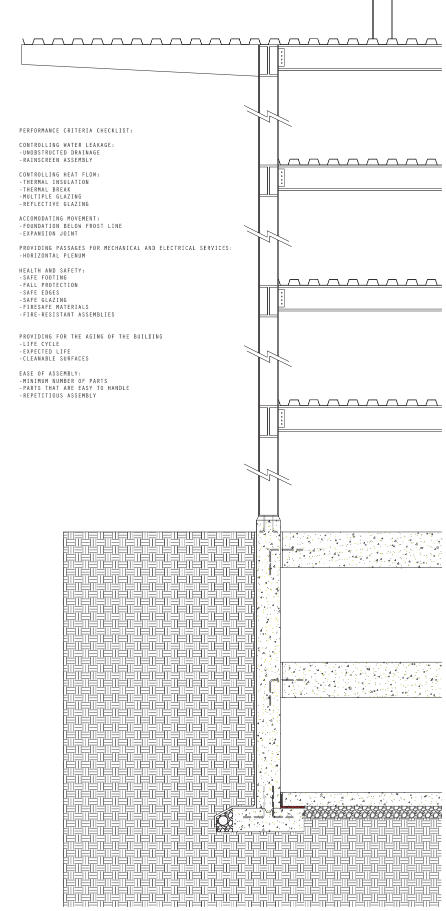
APPLE HEADQUARTERS

PRAGUE, CZECH REPUBLIC

EMMIE TYSON

LOCATED IN THE DENSE URBAN FABRIC OF DOWNTOWN PRAGUE, CZECH REPUBLIC, THE APPLE HEADQUARTERS IS MEANT TO BE THE "ICON" FOR APPLE IN EUROPE. THE BUILDING IS LOCATED ON A CORNER AND MEANT TO CREATE A "SLEEK" BUT SUSTAINABLE LOOK FOR APPLE. A SMOOTHE ALUMINUM RAINSCREEN CLADS THE BUILDING ALONG WITH A TWO-STORY REFLECTIVE CURTAIN WALL. THE DETAILS AND CONNECTIONS IN THE BUILDING ARE SUPPOSED TO APPEAR "SEAMLESS", CREATING THE MINIMAL LOOK APPLE STRIVES FOR. THE BUILDING CODES IN THE CZECH REPUBLIC ARE NOT NEARLY AS STRICT AS THE BUILDING CODES IN THE UNITED STATES, BUT SINCE APPLE IS LOOKING TO BE CONSIDERED SUSTAINABLE, THE APPLE HEADQUARTERS WILL CONFORM TO THE US INTERNATIONAL BUILDING CODE. THE BUILDING IS ALSO INTENDED TO BE LEED CERTIFIED, WITH THE VERTICAL FARM LOCATED ON THE STREET CORNER, INSULATION VALUES, PROXIMITY TO PUBLIC TRANSPORTATION AND DOUBLE PANED LOW-E GLASS. THE BUILDING SHALL PERFORM VERY WELL IN THE CLIMATE OF PRAGUE, WHICH IS COLD AND DAMP. THE CONTINUOUS MOISTURE BARRIER AND DOUBLE PANED CURTAIN WALL SYSTEM ADDRESS THE MOISTURE PROBLEMS, WHILE THE DOUBLE INSULATION (IN THE GALLERY LEVELS) PROVIDE VERY GOOD RESISTANCE TO HEAT TRANSFER.





PERFORMANCE CRITERIA CHECKLIST:

CONTROLLING WATER LEAKAGE:
-UNOBSTRUCTED DRAINAGE
-RAINSCREEN ASSEMBLY

CONTROLLING HEAT FLOW:
-THERMAL INSULATION
-THERMAL BREAK
-MULTIPLE GLAZING
-REFLECTIVE GLAZING

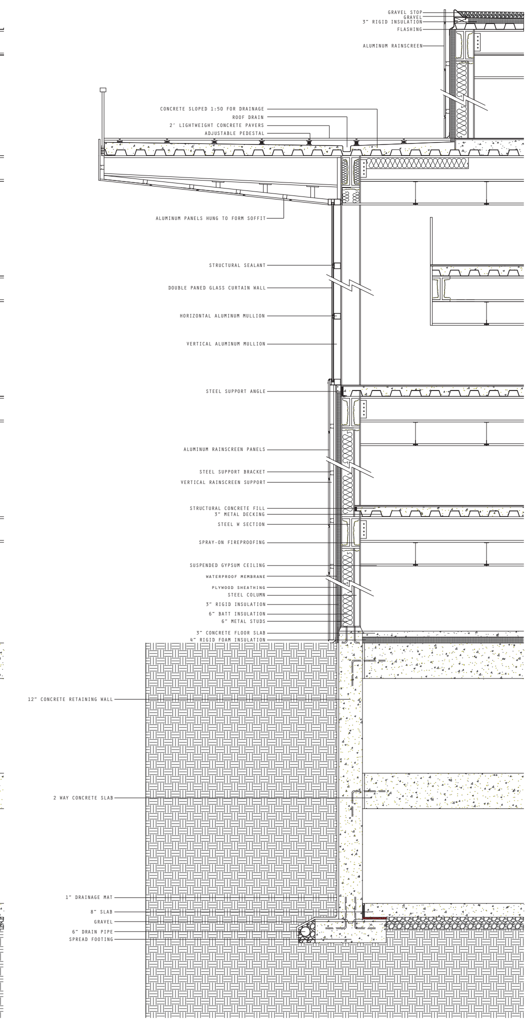
ACCOMODATING MOVEMENT:
-FOUNDATION BELOW FROST LINE
-EXPANSION JOINT

PROVIDING PASSAGES FOR MECHANICAL AND ELECTRICAL SERVICES:
-HORIZONTAL PLENUM

HEALTH AND SAFETY:
-SAFE FOOTING
-FALL PROTECTION
-SAFE EDGES
-SAFE GLAZING
-FIRESAFE MATERIALS
-FIRE-RESISTANT ASSEMBLIES

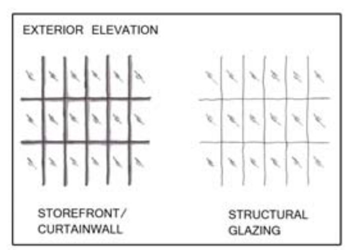
PROVIDING FOR THE AGING OF THE BUILDING
-LIFE CYCLE
-EXPECTED LIFE
-CLEANABLE SURFACES

EASE OF ASSEMBLY:
-MINIMUM NUMBER OF PARTS
-PARTS THAT ARE EASY TO HANDLE
-REPETITIOUS ASSEMBLY

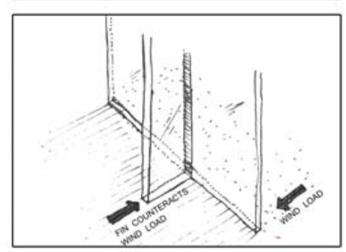


Structural Glazing

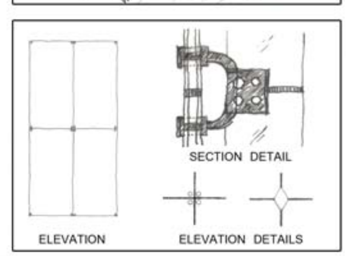
Designers often wish to incorporate large window walls or glazing into their buildings. Traditionally this could be done with curtain wall or storefront glazing systems. Using structural glazing systems as an alternative to curtain wall can help the detailer maximize the size and maintain the desired transparency of single or multi-story glass walls. Consideration must be given to local code and wind load requirements.



Glass fins act as stabilizers for large glass walls. They may be used on walls up to 20 feet tall without a secondary horizontal structural system. They serve a similar purpose to storefront or curtainwall systems but without the mullions. Often, glass fins are used at the joints of butt glazed wall systems.

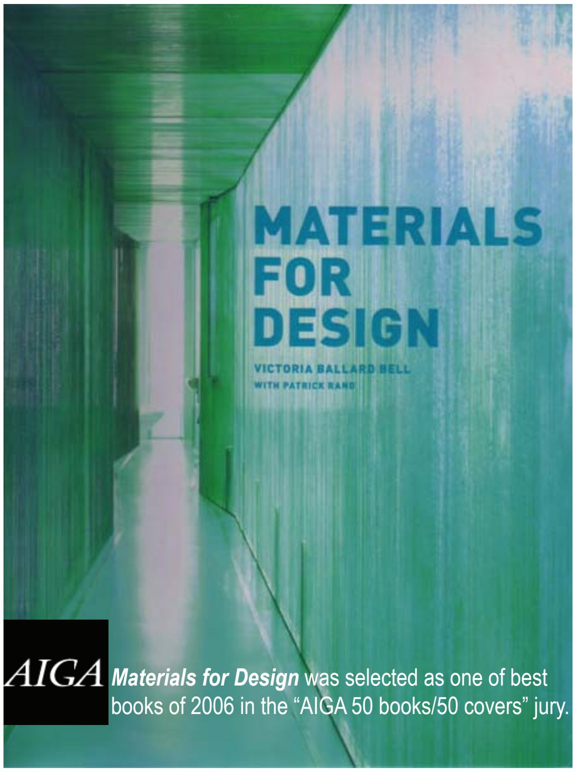


Spider fittings are a way of adjoining several sheets of glass in a structural glazing system. At the point where the sheets meet, one leg of the spider fitting is connected to each sheet and the fitting is connected back to the structural system (glass fins, cables, other structure). They can be used with single or double pane glass.



Materials for Design

Published: Princeton Architectural Press, c 2006



AIGA ***Materials for Design*** was selected as one of best books of 2006 in the "AIGA 50 books/50 covers" jury.

Materials for Design bridges the gap between construction materials and design. Architectural uses of glass, wood, metals, plastics and concrete are thoroughly discussed. Each is followed by a series of 10-12 case studies showing the material put to imaginative uses by today's brightest architects from around the world. Rand prepared the case study analyses of the 60 projects in this book.

Each project is described and illustrated to reveal its design qualities and the technical means used to achieve them. Students, interns and practicing architects have found the projects to be a catalyst for the advancement of their own investigations of design and technology.

Materials for Design has been accepted as a text in many architecture courses and studios. It has been used by architects and educators around the world, and has been published in Europe. At one time it was the best-selling book on architectural materials on Amazon.

Architectural Record:

"The authors impart a thorough knowledge of glass, wood, concrete, metal, and plastic. A weighty tome, the book is a reference tool, complete with histories, production techniques, and each material's properties, along with case studies of new work. In short, this is the textbook that many of us wish we had in architecture school."

Architect Magazine:

"*Required reading.*"

Azure:

"*Offers a well-illustrated compendium of the experimental leading edge. . . . Students will make good use of the book's technical side, and it should provide inspiration for anyone interested in contemporary building.*"

GLASS

Church of the Sacred Heart
Munich, Germany
ALLMANN SATTLER WAPPNER ARCHITEKTEN

Laminata Glass House
Leerdam, The Netherlands
KRUUNENBERG VAN DER ERVE ARCHITECTEN

Masons Bend Community Center
Masons Bend, Alabama, USA
AUBURN UNIVERSITY SCHOOL OF ARCHITECTURE: RURAL STUDIO

Glass Stair
New York, New York, USA
ARO WITH GUY NORDENSON

R128
Stuttgart, Germany
WERNER SOBEK

Crystal Unit III
Hiroshima, Japan
KATSUFUMI KUBOTA

The German Foreign Ministry, Lichthof facade and roof
Berlin, Germany
JAMES CARPENTER DESIGN ASSOCIATES

440 House
Palo Alto, California, USA
FOUGERON ARCHITECTURE

Architecture Pavilion at the Technical University of Braunschweig
Braunschweig, Germany
VON GERKAN, MARG AND PARTNERS

New 42 Studios
New York, New York, USA
PLATT BYARD DOVELL WHITE ARCHITECTS

CONCRETE

Maryhill Museum of Art Overlook
Goldendale, Washington, USA
ALLIED WORKS

Hafengebaude Rohner
Lake Constance, Austria
BAUMSCHLAGER & EBERLE

De Blas House
Sevilla de la Nueva, Madrid, Spain
ALBERTO CAMPO BAEZA

Valdemaqueda Town Hall
Valdemaqueda, Spain
PAREDES PEDROSA ARQUITECTOS

LOOK UP Office
Gelsenkirchen, Germany
ANIN JEROMIN FITILIDIS & PARTNER

Signal Box Switching Station
Zurich, Switzerland
GIGON/GUYER ARCHITEKTEN

Crematorium
Baumschulenweg, Berlin, Germany
AXEL SCHULTES AND CHARLOTTE FRANK

Harrison Residence and Winery
Euchuca, Australia
WARD CARTER ART & ARCHITECTURE

Retirement Home
Basel, Switzerland
STEINMANN & SCHMID ARCHITEKTEN

Falmouth Recreation Center
Falmouth, Massachusetts, USA
THE GALANTE ARCHITECTURE STUDIO

Price O'Reilly House
Redfern, New South Wales, Australia
ENGELEN MOORE

Yamaguchi Prefecture Pavilion
Ajiso-cho, Japan
KATSUFUMI KUBOTA

Burley Barling House

WOOD

Messenger House II
Nova Scotia, Canada
BRIAN MACKAY-LYONS

Bamboo Canopy
Queens, New York, USA
nARCHITECTS

GucklHupf
Mondsee, Austria
HANS PETER WÖRNDL

House in Kromeriz
Kromeriz, Czech Republic
ARCHTEAM

Think Tank
Skibbereen, County Cork, Ireland
GUMUCHDJIAN ARCHITECTS

BTV Commercial and Residential Building
Wolfurt, Germany
BAUMSCHLAGER & EBERLE

ILMASI School
Garbsen, Germany
DESPANG ARCHITEKTEN

Sirch Woodworking Manufacturing
Böhen, Germany
BAUMSCHLAGER & EBERLE

METALS

Tram Stations
Hanover, Germany
DESPANG ARCHITEKTEN

Future Shack
Various locations
SEAN GODSELL

Christ Pavilion, Expo 2000
Hanover, Germany
VON GERKAN, MERG AND PARTNERS

Kew House
Kew Melbourne, Australia
SEAN GODSELL

Springtecture H
Hyogo, Japan
SHUHEI ENDO

Modular VII Chiller Plant
University of Pennsylvania, Philadelphia, Pennsylvania, USA
LEERS WEINZAPFEL ASSOCIATES

Sudwestmetall Reutlingen
Reutlingen, Germany
ALLMANN SATTLER WAPPNER ARCHITEKTEN

Liner Museum
Appenzell, Switzerland
GIGON/GUYER ARCHITEKTEN

Power Station North
Salzburg, Austria
BÉTRIX & CONSOLASCIO ARCHITEKTEN

Kavel 37
Borneo, Amsterdam
HEREN 5 ARCHITECTEN

Schemata XI
Lawrence, Kansas, USA
STUDIO 804, UNIVERSITY OF KANSAS

The Aluminum Forest
Houten, the Netherlands
ARCHITECTENBUREAU MICHA DE HAAS

Raum Zita Kern
Raasdorf, Austria
ARTEC

Max Planck Institute
Dresden, Germany
HEIKKINEN-KOMONEN ARCHITECTS

The Embassies of the Nordic Countries in Berlin-Tiergarten
Berlin, Germany
BERGER & PARKKINEN

Sauna Pavilion
Berkshire Mountains, Massachusetts
ARTIFACT DESIGN & CONSTRUCTION

Mining Archives
Germany
VON GERKAN, MARG AND PARTNERS

Melbourne Museum
Melbourne, Australia
DENTON CORKER MARSHALL

PLASTICS

Shiloh Bus Shelter
Asheville, North Carolina, USA
DESIGN CORPS SUMMER DESIGN/BUILD STUDIO

Church in Urubo
Urubo, Bolivia
JAE CHA / LIGHT

Colmenarejo Municipal Hall and Main Square
Madrid, Spain
ABALOS & HERREROS

Ma Atelier and Gallery, Fukuoka Prefecture
Kyushu, Japan
HIROYUKI ARIMA

50 Argo Street
South Yarra, Australia
O'CONNER & HOULE ARCHITECTURE

House in Imazato
Imazato, Takamatsu Kagawa, Japan
KATSUYASU KISHIGAMI

Arauco Express
Santiago, Chile
FELIPE ASSADI

EKO Park Expo Pavilion
Warsaw, Poland
APA KURYLOWICZ & ASSOCIATES

Polymer Engineering Centre
Broadmeadows, Victoria, Australia
COX SANDERSON NESS

Montreux Parking Garage
Montreux, Switzerland
LUSCHER ARCHITECTS

The Olympic Amenities Building
Sydney, New South Wales, Australia
DURBACH BLOCK ARCHITECTS

The analyses of New 42 Studios and Think Tank were two of the sixty that Rand wrote for **Materials for Design**.

New 42 Studios

NEW YORK, NEW YORK, USA // PLATT BYARD DOVELL WHITE ARCHITECTS
DICHROIC GLASS, FACADE LIGHTING

DESIGN INTENTION

This ten-story building on 42nd Street and Broadway in New York City holds rehearsal studio space for performing arts groups, administrative offices, and a ninety-nine-seat black-box theater. It is located in the heart of the Theater District, where LED and neon signs pulsate all day and night. Lighting designer Anne Militello worked with the architects to give the facade a colorful and textured presentation that works suitably with the structure of the building and within the vibrant urban landscape. The design concept works with the rhythms and pace of this lively district by creating a building that changes throughout the day and night with color, light, and energy. The combined effect of various light sources and systems results in a seemingly infinite variety of lighting patterns.

MATERIALITY

This building has one primary facade, which is animated through form and proportion by day and through light and reflection by night. This project demonstrates that conventional glass can be transparent, translucent, mirrorlike, or opaque, depending on its luminous context. Further, it also reveals the special qualities of dichroic (two-color) glass, which transforms full-spectrum natural light into either magenta, blue, or yellow hues, depending on the light's angle of intersection with the glass. Dichroic glass is a manufactured product that can cast a range of colors depending on the position from which it is viewed. A piece of dichroic glass has a dielectric coating or thin layers of metal oxides, which produces these prismatic colors. Static glass elements yield dynamic lighting displays as the source light either moves, as sunlight during the day, or is dimmed or pigmented via lighting fixtures at night.

This building's glass curtain-wall system is synchronized to work with light, color, and metal louvers to create a remarkably dynamic facade. In front of the glass curtain wall, painted steel fins extend from the building's floor slabs. These fins hold an even lighter layer of perforated stainless steel louvers, which act as brise-soleil and as a light monitor for the facade. The reflections from the metal fins, attached to the armature, constitute most of the facade's visual content by day. The glass creating the enclosure is in a separate plane 4 ft. (1.22 m) away from the array of louvers. The glass and perforated metal are exploited for their ability to simultaneously reflect and transmit light.

Additionally, light is projected from a battery of over three hundred artificial lighting fixtures (five in each bay) set on the catwalks. Some have dichroic glass lenses, others have colored gels. These lights can be "played" as if notes from a musical instrument. They are programmed for a seven-day composition, although theoretically a new composition can be programmed at any time.

The lower left portion of the front facade is composed of acid-etched glass with an arrangement of dichroic glass pieces placed vertically, horizontally, and perpendicular to the plane of the facade. From every direction, pedestrians will see an interesting visual display.

The transparent glass skin is a water-repellant backdrop to the externally animated lighting displays. Translucent studio curtains are drawn at night, providing a neutral backdrop for the visual display outside. Glass and the mediating fenestration system convey the rigorous order of the underlying architectural form, and even the "ghost" of the Selwyn Theater, which formerly occupied this part of the site. The layered elevation permits the visual qualities of glass and non-glass elements to form a complex, dynamic collage using elements that are actually static. Thus, the architectural skin is shown to be easily manipulable to convey specific meaning, or can simply stimulate the senses.

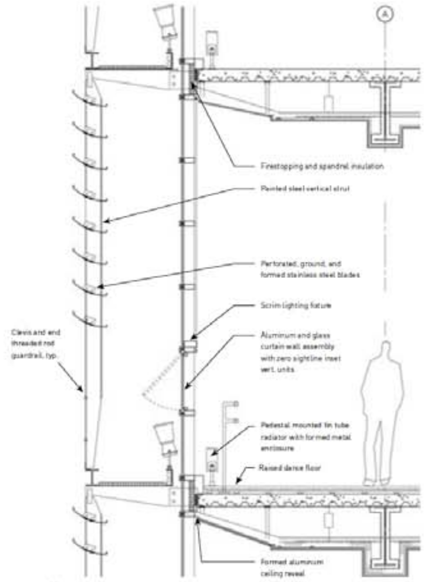
TECHNICAL

A wide variety of glass and non-glass products with differing physical properties can be made as laminates applied to the surface of glass. Dichroic glass is a manufactured product made of polymer sheets sandwiched between panes of glass, which produces prismatic properties. When sunlight passes through at various angles, magenta, blue, or yellow colors are emitted. Artificial light produces no colors in this glass unless the light is designed to provide a full spectrum source.


01


02


03



04

01 Facade assembly
02 South elevation
03 Dichroic glass fins
04 Wall section

Think Tank

SKIBBEREEN, COUNTY CORK, IRELAND // GUMUCHDJIAN ARCHITECTS
POST-AND-BEAM, WOOD AND STEEL FRAME, CEDAR BOARD ROOFING

DESIGN INTENTION

This small retreat was designed for a filmmaker as a place to withdraw to for contemplation and reading. It is 592 square feet (55 sq. m) and sits atop a stone plinth on the River Ilen, against a backdrop of lush green trees and adjacent to a freshwater pool. Inspired by the structural precedence of boathouses and Japanese pavilions, the design goal was to create a simple open plan that is built of a bold wood construction that has been reinterpreted for a modern use.

MATERIALITY

This iconic post-and-beam structure builds upon a traditional diagram with modernist spatial features and materiality. It is the essence of shelter: base, frame, and roof. In general the project handsomely merges with its context, serving both as a retreat and as a birdwatching "hide." But up close it reveals innovation and sophistication in its details, incorporating contemporary amenities without doing harm to the purity of the basic form. Some construction materials are durable and never-changing, such as the stone plinth upon which the pavilion is built. Other materials are ever-changing in response to nature. The red cedar exterior materials darken when the drizzle begins, only to be bleached again as the sun returns to dry them. Over time this material will change from its warm hue to a cool dove gray, near that of the stone in the plinth. Beyond its aesthetic qualities, red cedar is also a good selection for a structure near water in a temperate wet climate, due to its inherent anti-decay properties.

The openness of the basic frame is enhanced by the absence of engaging walls or the clutter of program within. Insulated glass is the weather barrier on all walls, with screens made of red cedar on all or part of three elevations to filter light and view. Even the slender spaces between the roof rafters and ceiling are glazed, silhouetting the frame with clarity.

TECHNICAL

The columns in this pavilion are actually steel sections, wrapped in fine iroko wood. This contemporary solution provides a moment-resisting frame, eliminating need for shear walls or diagonal bracing, which would not be possible if the columns were made of a stout piece of timber. The wrapped columns also provide a small vertical chase through which minor building services can be concealed. Beams and rafters are one-piece heavy timber elements also made of iroko wood.

The roof uses the familiar red cedar material often used as shingles, but here in an unfamiliar configuration: a series of eave-to-ridge boards that interlock in a roman tilelike manner. This reduces vulnerability to wind-driven rain that can push moisture into the numerous small spaces in conventional cedar shingle roofing. The relieved back on the boards produces a c-shaped profile that will reduce the chance that the wood will distort by cupping as its moisture content changes. The cedar roofing is elevated over a cavity, permitting drying of the wood from the underside, and limiting the chance that moisture will migrate deeper into the assembly. A bituminous felt layer isolates this cavity from the plywood and thermal insulation below, making the cedar roofing layer become a variation of the rain screen wall. A hidden gutter made of copper sheet metal collects water at the bottom of both the cavity and the roof surface, preventing water from blemishing the cedar fascia or other surfaces below. The roof ridge is made of cedar boards oriented longitudinally, which interlock with the upper ends of the roof boarding to cover their end grain. In this narrow building, ventilation of the cavity can occur laterally across the ridge, from eave to eave.

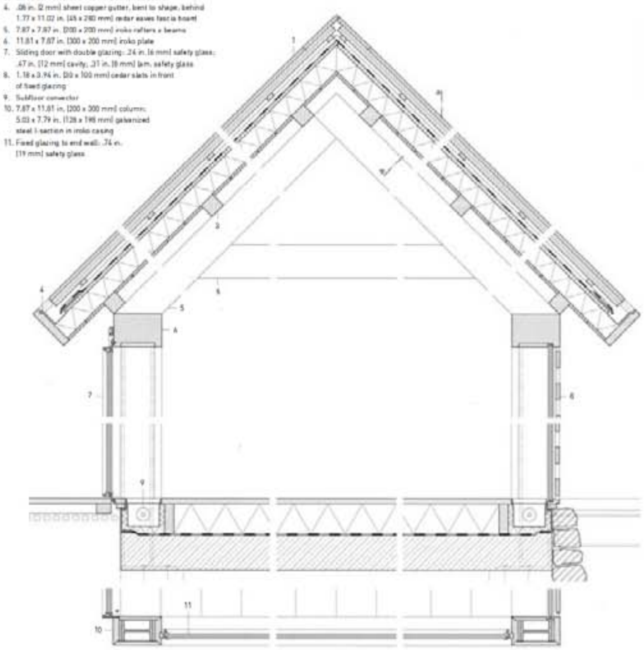
The roof boards are 1.38 in. x 7.09 in. (35 x 180 mm), and are full length, so they have no splices along their length. Cedar slats in screens over the glass in some locations are 1.18 in. x 3.94 in. (30 x 100 mm), secured to a frame very near the fixed glass skin.

01 View from pier
02 Exterior view
03 Transverse section


01


02

Vertical and horizontal sections
1. Roof construction: two 1.38 x 7.09 in. (35 x 180 mm) interlocking cedar boarding ventilated cavity; .98 x 1.77 in. (25 x 45 mm) battens and counter-battens on .08 in. (2 mm) bituminous felt waterproof layer .79 in. (20 mm) plywood sheets 3.94 in. (100 mm) glass-wool thermal insulation .98 in. (25 mm) cedar tongued-and-grooved boarding
2. .94 x 11.02 in. (24 x 280 mm) cedar verge fascia board
3. 3.94 x 3.94 in. (100 x 100 mm) softwood bearer
4. .08 in. (2 mm) sheet copper gutter, bent to shape, behind 1.77 x 11.02 in. (45 x 280 mm) cedar eaves fascia board
5. 7.87 x 7.87 in. (200 x 200 mm) iroko rafters + beams
6. 11.81 x 7.87 in. (300 x 200 mm) iroko plate
7. Sliding door with double glazing: .24 in. (6 mm) safety glass; .47 in. (12 mm) cavity; .31 in. (8 mm) lam. safety glass
8. 1.18 x 3.94 in. (30 x 100 mm) cedar slats in front of fixed glazing
9. Subfloor connector
10. 7.87 x 11.81 in. (200 x 300 mm) column: 5.03 x 7.79 in. (128 x 198 mm) galvanized steel I-section in iroko casing
11. Fixed glazing to end wall: .74 in. (19 mm) safety glass


03

Materials for Design / Volume 2

Published: Princeton Architectural Press, c 2014

Materials for Design 2 is a survey that bridges the gap between construction materials and design sensibility. Volume 2 revisits the format of their award-winning first volume and present 60 new case studies by today's brightest architects. Each material type—glass, concrete, wood, metal, plastic, and masonry. *Materials for Design 2* exists because of the favorable assessments made by readers and reviewers of the first volume of this title.

As in the first volume, Rand prepared the case study analyses of the 60 projects in this book. Unlike the first volume, Rand also identified candidate projects for the book and corresponded directly with the architects to secure detailed project documentation.

This book recognizes that materiality is an important and quickly expanding influence in the construction process. Industries that once serviced a small segment of products are now engaged in much more in-depth research and development of new materials that are more effective, more efficient, and more environmentally sensitive. Once merely a tool for architects and largely confined to the realm of engineering, materiality has now become an instrumental methodology for a clear and bold design statement. The wealth of innovations in this realm has made materials a compelling field of study.

Architects are challenged to keep pace with rapid advances in materials science, manufacturing methods, and installation practices. This book helps students, interns and practitioners engage construction materials with renewed enthusiasm and competence.

Materials for Design 2 is in press at the time of this submission, and is expected to be available to the public in November of 2013. Like the first volume of *Materials for Design*, it will be distributed internationally.

Glass

Basque Health Department Headquarters
Bilbao, Spain
Coll-Barreu Arquitectos

Glass Townhouses
Venice, California, USA
Sander Architects

Factory Extension
Murcia, Spain
Clavel Arquitectos

Diana Center at Barnard College
New York, New York, USA
Weiss/Manfredi Architecture/Landscape/Urbanism

Spiral Gallery
Shanghai, China
Atelier Deshaus

The Crystal (Nykredit Bank)
Copenhagen, Denmark
Schmidt Hammer Lassen Architects

Cité du Design
Saint-Étienne, France
LIN Architects

Ernst Koller Pavilion
Basel, Switzerland
Berrel Berrel Kräutler Architekten

Apple Flagship Store
Shanghai, China
Bohlin Cywinski Jackson

Concrete

Hämeenlinna Provincial Archive
Hämeenlinna, Finland
Heikkinen-Komonen Architects

Casa Pentimento
Quito, Ecuador
Jose Maria Sáez + David Barragán

Design Indaba 10×10 Housing Project
Cape Town, South Africa
Design Space Africa Architects (formerly MMA Architects)

Hanil Visitors Center and Guesthouse
Chungbuk, Korea
BCHO Architects with CAST (Center for Architectural Structures and Technology)

Harmonia 57
São Paulo, Brazil
Triptyque

Hiroshi Senju Museum
Karuizawa, Nagano, Japan
Ryue Nishizawa

Italian Pavilion at World Expo 2010
Shanghai, China
Iodice Architetti

Nk'Mip Desert Cultural Centre
Osoyoos, British Columbia, Canada
DIALOG (formerly Hoston Bakker Boniface Haden)

RATP Bus Center
Paris, France
ECDM

Wood

Stork Nest Farm
Dvůr Semtín, Olbramovice, Czech Republic
SGL Projekt

Private Residence in Riedikon
Uster, Switzerland
Gramazio & Kohler

Viikki Church
Helsinki, Finland
JKMM Architects

Soe Ker Tie House
Noh Bo, Thailand
TYIN Tegnestue Architects

Harry Parker Community Boathouse
Boston, Massachusetts, USA
Anmahian Winton Architects

EcoWoodBox Kindergarten
Hanover, Germany
Despang Architekten

Nature Boardwalk at Lincoln Park Zoo
Chicago, Illinois, USA
Studio Gang Architects

Dairy House Annex
Hadspen Estate, Somerset, England, UK
Skene Catling de la Peña

Metropol Parasol
Seville, Spain
J. Mayer H. Architects

Skating Shelters
Winnipeg, Manitoba, Canada
Patkau Architects

Metals

Tampa Museum of Art
Tampa, Florida, USA
Stanley Saitowitz | Natoma Architects

St. Andrews Beach House
Victoria, Australia
Sean Godsell Architects

Prefabricated Nature
Cedeira, Spain
MYCC Architects

OMS Stage
Winnipeg, Manitoba, Canada
5468796 Architecture

Lady Bird Lake Hiking Trail Restrooms
Austin, Texas, USA
Miró Rivera Architects

Kunst-Depot, Henze & Ketterer Art Gallery
Wichtrach, Switzerland
Gigon/Guyer Architekten

Herstedlund Fælleshus Community Centre
Albertslund, Denmark
Dorte Mandrup Arkitekter

Halftecture O
Chūō-ku, Osaka, Japan
Shuhei Endo

Cantonal School Canteen
Wettingen, Switzerland
:mlzd

Artists' Studios in Aberystwyth
Aberystwyth, Wales, UK
Heatherwick Studio

Plastics

SelgasCano Architecture Office
Madrid, Spain
SelgasCano Arquitectos

El B Conference Hall and Auditorium
Cartageña, Spain
SelgasCano Arquitectos

Novartis Entrance Pavilion
Basel, Switzerland
Architect Marco Serra

UK Pavilion at World Expo 2010
Shanghai, China
Heatherwick Studio

Cellophane House
New York, New York, USA
KieranTimberlake Architects

Anansi Playground Building
Utrecht, The Netherlands
Mulders vandenBerk Architecten

Miroiterie Retail Building
Lausanne, Switzerland
B+W Architecture

International Committee of the Red Cross Logistics Complex
Geneva, Switzerland
Group8

Plastic House
Gothenburg, Sweden
Unit Arkitektur

MOOM Tensegrity Membrane Structure
Chiba, Japan
Kazuhiro Kojima Laboratory/Tokyo University of Science

Masonry

Secondary School
Dano, Burkina Faso
Diébédo Francis Kéré

Brandhorst Museum
Munich, Germany
Sauerbruch Hutton

Padre Pio Pilgrimage Church
Foggia, Italy
Renzo Piano Building Workshop

South Asian Human Rights Documentation Centre
New Delhi, India
Anagram Architects

NUWOG Headquarters and Housing
Neu-Ulm, Germany
Fink+Jocher

Pope John Paul II Hall
Rijeka, Croatia
Randić-Turato Architects

Chapel of St. Lawrence
Vantaa, Finland
Avanto Architects

Warehouse 8B Conversion
Madrid, Spain
Arturo Franco Architecture Studio

Butaro Doctor's Housing
Burera District, Rwanda
Mass Design Group

Silk Wall + J-Office
Shanghai, China
Archi-Union Architects

Center for Design Research
Lawrence, Kansas, USA
Studio 804 / University of Kansas

La Pallissa
Catalonia, Spain
Cubus

The analyses of the Apple Flagship Store and SAHRDC were two of the sixty that Rand wrote for **Materials for Design 2**.

GLASS 47

Apple Flagship Store

Shanghai, China — Bohlin Cywinski Jackson
Curved tempered laminated glass

DESIGN INTENTION

The design of Apple's flagship retail stores often display innovative uses of glass, especially for fixtures and stairs. The Shanghai store is no exception. A crystalline lantern, the store's prominent glass cylinder connects the surrounding urban plaza to the retail space below. Its prominence and high visibility in this location called for a unique and unprecedented structure. Transparency was the entry piece's primary design goal. Because polymers can fade, haze, or discolor over time, especially when exposed to ultraviolet light, glass was preferred whenever possible.

The space is arranged around a central circulation tower that suggested the radial geometry of a lantern, appearing here as a cylinder with a strong vertical axis. A 10'-wide (3 m) reflecting pool surrounds the cylinder, complementing the use of glass with increased reflectivity and light. The pool encircles the glass structure except at the entry, which is a 60-degree segment of the cylinder.

MATERIALITY

Glass, while beautifully transparent, also forms the building's hardworking exterior envelope. Featuring previously unrealized dimensions and shapes of glass products, the envelope functions structurally in novel ways.

Crystal-clear glass is sometimes undesirable for a particular application, such as the stair treads at the lantern's center. Imagine the privacy concerns of a see-through staircase, or the danger its smooth, impermeable surface might present on a rainy day. To eliminate both concerns, the layers of the glass treads are frosted and have a raised diamond tread pattern, like those commonly found on metal steps. Though still impermeable, the texture provides safer footing while maintaining the stunning ephemeral quality of glass.

Glass, like many dense, mineral-based materials, has a high level of thermal conductivity. In cold weather, this can lead to abrupt changes from a comfortable interior air temperature to the cool inner face of a glass skin, whose heat is quickly conducted to the outer surface. When the interior temperature falls below the dew point, condensation droplets may accumulate, detracting from the intended visual clarity. To mitigate the potential for condensation, air-conditioning supply grilles are located at the interior base of the lantern. Fan coil units propel dehumidified air toward the glass, preventing condensation by removing moisture.

TECHNICAL

The Shanghai Apple Store's cylindrical lantern is 41' tall × 32' in diameter (12.5 x 9.75 m) and is structured using laminated, tempered glass. The glass cylinder is composed of twelve vertical face panels, supported by triple-laminated structural glass mullions at 30-degree intervals. The panels run the full height of the building, an unusual and admirable feat; the only interruptions are two curved doors and their flanking panels.

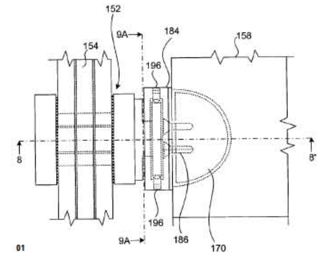
The glass cylinder challenged designers and fabricators to find new processes to produce the glass elements, which had to be curved to very specific shapes. Because of the store's urban location, the designers anticipated various potential impacts, from toddlers to excited shoppers and errant equipment. To provide appropriate durability and load-bearing strength, the glass had to be tempered and then laminated. Of course, once it is tempered, glass cannot be altered in shape or size, so each layer in this project had to be given its final configuration beforehand. This labor-intensive process brought together curved glass pieces that differed slightly in radius and size, so that when the three pieces were finally laminated, their edges met in proper alignment. Using a process adapted from the automotive industry, a thin layer of polyester film was placed between layers of tempered glass, and the entire sandwich was then placed under high pressure and temperatures to melt the film without de-tempering the glass.

In an effort to maintain clarity throughout the lantern, the designers used custom-made metal hardware to join all finish wall surfaces and structural glass fins. The fins are composed of three layers of tempered and laminated glass. Glass panels are fabricated with holes to receive the stainless steel hardware, with dense rubber washers between them to soften the forces.

This hardware strategy is also applied to the structural glass elements that support the 16.17'-high spiral stair (4.93 m) with an outside diameter of 20.5' (6.25 m). The stair's central glass tube is anchored to the floor at the retail level below. It is composed of six pieces of glass of uniform height. Its outer curve is a ribbonlike stringer that is only supported where it touches the floor near the lowest tread, and where it is connected to landings and glass beams cantilevered from the central cylinder at 60-degree intervals. The treads themselves are composed of four layers of glass. One of the inner layers is recessed to accept inserts and hardware that connect the treads to the vertical supports. Each of these trapezoid-shaped treads has two such connections at the outer end and one at the inner end.

The cylinder's glass roof has a subtle slope and is supported by glass beams spanning the fins. All of the fittings are made of stainless steel or titanium. The joints between the exterior panels are sealed with structural silicone.

The glass innovations in this project were the result of diligent collaborations between parties on at least three continents. The project team included architects and engineers, but also glass systems engineers, specialized manufacturers, and fabricators. Separate interior and exterior assembly crews installed the finished glass products. The architects' drawings, including many 1:1 scale details, became federally registered patents owned by Apple.



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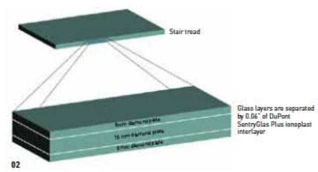

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01 Plan detail of connection between laminated glass treads and structural glass supports. A full description is available in US Patent "Staircase" D478999 S, August 23, 2003.

02 Diagram of laminated glass treads

03 Exterior view at entry from urban plaza

04 Glass treads and structural glass supports

05 Curved glass stair and floor assemblies

MASONRY 237

South Asian Human Rights Documentation Centre

New Delhi, India — Anagram Architects
Bonded masonry, modular coordination

DESIGN INTENTION

The South Asian Human Rights Documentation Centre (SAHRDC) is an administrative office for this non-governmental organization to investigate, document, and disseminate information about human rights. SAHRDC is a small office with limited resources; their facility was designed on a small urban corner site, which emphasizes spatial efficiency and cost-effective construction.

The 538 sq. ft. (50 sq. m) site is located at the intersection of two busy pedestrian streets, so controlling and restricting street-level acoustic and visual disturbance into the workspaces was a critical priority. The site's longer dimension faces the western sun, which in this climate required strategies to reduce solar thermal gain while permitting ventilation of interior spaces. The outer wall is intended to optimize solidity and privacy while still conversing visually with the urban realm. The street wall is animated to reflect the energy of the city outside, satisfying the need for privacy using a richly engaging masonry surface.

The building is diagrammatically simple, organized with a single, open administrative space on each of its three aboveground floors, which are buffered by a service and stair bar on the western, sun-facing side. The porosity of the stair wall permits natural ventilation horizontally and vertically.

MATERIALITY

To meet the tight budget, walls were constructed of exposed brick. Floors and roof decks are made of gently vaulted brick spans with a concrete topping, eliminating the need for beams and reducing slab thickness. The underside of the brick vaults are exposed, making a hung ceiling unnecessary and reducing floor-to-floor heights to only 10.33' (3.15 m).

A single repeating brick module creates a visually complex pattern in the manner of traditional South Asian brise-soleils. This is achieved with standard solid brick, and without joint reinforcement in the masonry walls. No material other than brick masonry was to be visible in the facade. This innovative bricklaying method uses a common material in an unconventional manner to engage the urban streetfront and stay within the limited budget. The masonry's sense of movement and textural qualities exemplify innovative designers that use common materials creatively and thoughtfully, to the benefit of everyone.

TECHNICAL

Twirling cubic stacks of brick (three shiners in one course and three rowlocks in the other) repeat to form an undulating wall surface. By laying the bricks on their edges, voids created by omitting brick in certain locations enhance ventilation.

The construction of the screen wall was the result of a five-week collaboration between masons and architects, searching for a solution that would be well crafted using structural bonding of the brick courses. The architects used computer modeling to show the masons that a simple rotating module of bricks would create the kind of visual and textural complexity needed to address the design objectives. Architects and masons used full-scale mockups to find a simple and practical bricklaying technique that could be replicated by the various masonry teams without requiring the skills of a master mason. The designers prepared a set of six individual course drawings, setting forth the angle of rotation of each brick. From these, sets of triangular wooden templates were made, which the masons used to accurately place the bricks.

The bricks used were 9" × 4.5" × 3" (230 × 115 × 75 mm), which is the standard size of a brick in India. Like modular bricks worldwide, the longest dimension is exactly two or three times its two smaller dimensions. The bricks were wire cut but are primarily handmade. Both the head joint and bed joints were 0.4" (10 mm). The mortar is a simple cement/sand mortar in a 1:3 ratio.

The masonry wall is load-bearing, so structural performance could not be compromised by the visual pattern making. The centers of the cubic modules in a stack had to perfectly align in a vertical axis, around which the module would rotate. This was difficult to accurately craft during bricklaying due to human error. Conventional mason's strategies such as dropping a vertical plumb line were not feasible because brick faces were not all in the same plane.

The floor vaults and slabs bear on the walls where two sets of cubic modules align to make the wall thickest and strongest. Structural bonding between modules results from the cross-stacking of the bricks in the modules. In the more perforated central portion of the facade, brickwork is reinforced horizontally by laying a thin reinforced concrete beam within the wall thickness in place of the center brick.

01 Perspective of brick coursing; plan views of each course shown to right

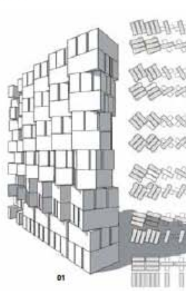
02 Exterior view of west screen wall

03 Exterior view of west screen wall with interior illumination

04 Exterior view of tall unreinforced masonry wall from northwest

05 Interior view of screen wall adjoining stair

06 Detail of finely crafted twirling cubic forms of bonded masonry



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After publishing the first volume of *Materials for Design*, Rand began to offer a graduate seminar on this subject.

Special Topics: Materials for Design (ARC 590) 3 cr

Catalog description: This seminar is being offered for only the third time Fall 2013. It has not yet been submitted as a permanent course and thus does not yet have an official catalog description.

Rand initiated this graduate seminar in Fall 2010, based on student interest in the book *Materials for Design*, which he co-authored in 2006. The book had been used at other universities for several years, but not at NCSU until this offering. Some projects that students have identified in this seminar were later analyzed by Rand for inclusion in *Materials for Design / Volume 2*.

This is a graduate seminar, typically with 12 – 20 students enrolled. It is taught in a tutorial format, with class discussions centered around case study analyses that students carry out individually or in 2-person teams, as dictated by enrollment. Students select built works from around the world that display keen insight into its architectural materials. They examine detailed drawings and photographs of the project, and often engage in direct dialogue with the architects to secure unpublished information, or to verify their hypotheses regarding how the material was applied in the project. Emphasis is placed on finding buildings of exemplary design, but which also display technical refinements that are responsive to contemporary cultural and environmental criteria. For many students, engaging in direct dialogue with architects from different cultures regarding their common passion for architectural materials is a profound learning experience.

Excerpt from Course Description:

ARC 590 Materials for Design

Intended for: M Arch and B Arch students
Prerequisite: Architectural Construction Systems (ARC 432) or equivalent

To a great extent, an architect's palette of materials has been unchanged for thousands of years. The number of materials has grown somewhat in the past century as polymers and composites have been introduced. New industrial processes have also expanded the range of applications of all materials, including the most ancient.

Contemporary practice calls for new insights into the use of materials, and industries have made many new materials and processes available for designers to explore to address emergent objectives. Material selections are among the most significant decisions an architect makes. With the advent of integrated design and production, the relationship between a project's aesthetics and its materiality has never been more immediate or important.

Materials for Design aims to inspire the designer to discover how an idea or a concept can be made tangible with the use of a material. This course engages the physical and technical properties of materials, but also their impact on design choices. It searches for resonance between the facts of a material with the construction details, and with the overall building design.

A case study method will be employed to see how contemporary practitioners have insightfully joined design intention and materials. First, students will review the 60 examples in the text that show insightful use concrete, metals, glass, plastics, and wood. Students will then identify new recent works, which they will analyze and critique in search of lessons about the materials used. Published drawings and images will be the initial references for these analyses, but it is likely the students will also need to contact the designers for additional documentation. Students will analyze and present drawings that show construction details, because it is often at this scale that the subtle qualities of a material are most evident. They will also write careful technical analyses about each case studied.

Small to medium-scale projects will be chosen to allow a focus upon understanding the building in its entirety; projects of these scales are best suited as didactic prototypes. In some cases, new materials may be used; in others, properties of traditional materials may be discovered and exploited in new ways.

Emphasis in this class will be placed on students developing a grasp of the relevant material properties, and finding exemplary projects that demonstrate those properties. Students' repertoire as designers will be broadened by this emphasis on technical knowledge and its vivid embodiment.

Course Objectives / Learning Outcomes:

- Become able to define the performance qualities of architectural materials.
- Develop a working knowledge of resources relevant to various architectural materials.
- Identify and analyze case study projects regarding architectural materials.
- Represent the conclusions of the analyses in oral, written, and graphic form.

Students learn rapidly and durably when they examine the work of an architect they admire. Beginning with published drawings and photos, they interrogate the material's use in the project to search for any extra-ordinary features.

Each student uses a cyclic process to analyze each of the four projects that they analyze. The first pinup simply uses published information. The intermediate pinup adds to that student investigations of the state of the art, dialogue with the architect, and perhaps the fabricator or manufacturer. The final pinup presents the findings by each student.

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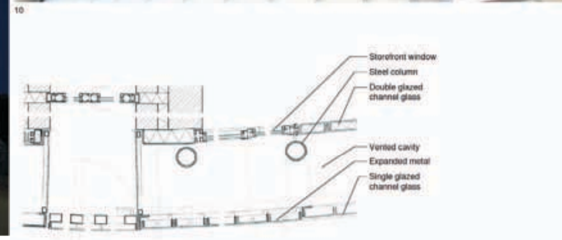


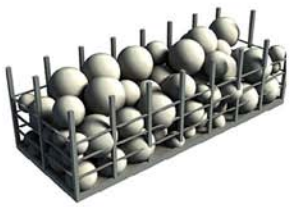
To the right, the student examined the curved double envelope of channel glass that was used at Hartwig Schneider's Art Gallery and Arts Education Center in Germany.

Martha and Daniel Gantenbien Winery

Bearth & Deplazes Architekten
with Gramazio & Kohler
Flasch, Switzerland, 2006

DESIGN INTENT

Functionally a new service building to an existing vineyard, this building is comprised three parts; a cellar for wine barrel storage, a grape fermentation and processing room, and a top floor with interior and exterior rooms for wine tasting and gathering. The façade reflects this use with its building scale pattern referring to a basket full of grapes. Bearth and Deplazes Architecten designed the building and the concrete façade frame before consulting with Gramazio and Kohler at ETH Zurich for the façade. The precision and subtly of the brickwork on this façade also reflect the surrounding texture of the vineyard.



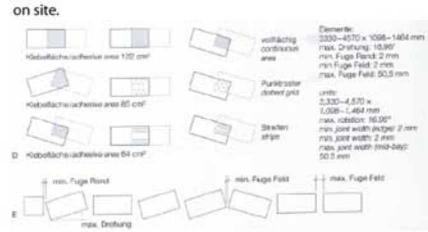
MATERIALITY

The 20,000 limestone colored clay bricks used on this facade were laid in the simple stretcher bond; 240mm x 115mm x 61mm. While this may not be unique, the use of a robot to precisely lay the bricks is. The architects took advantage of the modular nature of masonry to create a subtle building scale pattern of grapes only achievable through this high tech method. The angling of the bricks in addition to vertical voids between each brick create a rain screen which filters light and temperature to help create the ideal atmosphere for the fermentation room. Similarly, the supporting layer of polycarbonate panels is protected from direct sunlight lengthening its lifetime. Each wall was designed and constructed to maximize the advantages of controlling light and air permeability per orientation. Taking advantage of the robots precision, the architects were also able to create a façade with a "dynamic play between plasticity, depth, and colour, dependent on the viewer's position and the angle of the sun." (Gramazio and Kohler) The pattern of grapes dissolves as the user moves closer, and becomes instead a soft yet "solidified dynamic form" (Gramazio and Kohler) which relates to and transitions into the adjoining stonework.

TECHNICAL

The first stage in creating this 'informed architecture' was to computer generate grapes falling into a basket simulating gravity. The resulting digital image was then transformed into a rotation plan for the brick which in turn guided the one of a kind robot in laying the brick. Once begun, the robot took only 2 weeks to complete this 400 sq meter façade. The individual panel size was dictated by the ability of this robot more so than limitations inherent with the increased transportation needs of a prefabricated system. The cost of using such a high tech system could have been offset somewhat by the use of the typically low-cost material of brick. Similarly, the increased energy use involved with this fabrication system might also be offset by the inherent sustainability of brick as a local, abundant, and durable material requiring little maintenance.

In addition to precisely placing each brick, the robot also applied the two part impregnated resin adhesive. This was intended to accelerate the process considering the unique bonding placement needs of each brick, but appears somewhat inefficient. This bonding agent did prove to be very successful however in load testing disqualifying the need for the typical additional reinforcements. The use of adhesive rather than mortar as a bonding agent also lowered the construction tolerance contributing to the precision of placement. Taking this tolerance into account, the brick panels were prefabricated including a precast concrete beam. The panels of brick and concrete in turn were then placed by crane between concrete columns on site.



At the top of this page, the student project focussed on the innovative means used to place common brick by robots, following parametric designs of Gramazio & Kohler, who collaborated with Bearth & Deplazes to produce the Gatenbien Winery in Switzerland.

Below on this page is the student's analysis of the cold-formed insulated glass skin on Frank Gehry's IAC Headquarters in NYC.

For this analysis the student contacted the architect for technical information and made a personal on-site assessment of the completed project.

IAC Headquarters

NEW YORK. NY. // GEHRY PARTNERS, LLP
GLASS - COLD FORMED PANELS

Design Intention

The design of InterActiveCorps Headquarters in New York City is based on the client's love of sailing. It is meant to represent billowing white sails, appropriate given the site located along the Hudson River, just across the West Highway from Chelsea Piers. It is a visual tribute to IAC's innovative and creative products as well.

Curved modules twist as they rise from the ground. It was important that the facade appear flush and smooth, given the sculptural nature of the building. To accomplish this, a concrete superstructure with sloped columns is concealed behind a curved glass facade. Curved glass was used to ensure the flush looking facade rather than using flat panels.

Natural light was a high priority to provide a positive workplace for employees, making a glass facade an appropriate solution. In order to control light, white ceramic fritting on the glass fades from opaque at floor and ceiling heights to transparent at eye levels.

Materiality

The intriguing aspect of this building is not just the glass, but the method in which it is constructed. The glass is curved on-site in a process called cold-bending. The idea came from a previous project by Frank Gehry, Disney Concert Hall, in which steel panels were manually bent into place to from a curved sculptural facade. In the IAC Headquarters, Permasteelisa worked with Gehry Partners to create a smooth glass facade.

Traditionally, curved glass panels would be heat tempered and formed to their intended shape in a factory. Here, the glass is made in a flat sheet and inserted into an aluminum frame, forming the panel. The panel is manufactured to precisely the correct shape based on 3D modeling. During construction, the panel is lifted to its correct place where three corners of the panel are attached to brackets that are embedded in the concrete superstructure at each floor. The fourth corner is then manually bent into place. The tensile strength of the silicone adhesive anchoring the fourth corner of each sheet of glass to the frame determines the maximum torque of the panel, rather than the flexibility of the glass.

A ceramic dot pattern fritting creates the white, sugar-coated effect on the glass. The fritting reflects light, keeping the space inside shaded and cooler. It has a gradient from opaque to transparent that allows views from interior spaces and creates a unique banding effect on the exterior. Sixty of the glass panels had to be replaced during construction because of scratching or improper fritting. No panels had to be replaced due to the glass breaking during bending.

Technical

Of the 1,437 glass panels, only 88 are the same. They are specified to be bent up to four inches per panel and are fabricated in rectangular, trapezoidal, and triangular shapes. The precision in fabricating each panel was critical in order for the bending to work properly.

The concrete superstructure also had to be constructed to great precision. The steel embeds that connect to and hold up the glass panel brackets must be set to .01 inch precision. The concrete slab edges are segmented radii with steel embeds every four feet. No two floor plates are the same and are rotated slightly one above the other, creating the twisted exterior effect.

The panels are double-pane glass with a .5-inch sealed air space set inside aluminum frame extrusions that are designed to handle up to 5 degrees of rotation. It was difficult to find a glass fabricator willing to warrantee this new type of glass construction. The first step was to set bending limits and constructability parameters (building mock-ups and running stress tests and other performance tests). Zadra produced the double glass units while St. Gobain provided the low-iron fritted glass to them.

Cold-warping glass saves money in this situation because of the variety of panel shapes and curves. Rather than heat tempering that many different curved glass pieces, they could be made flat, which is cheaper, and curved on-site.


01

01 Overall View, west facade
02 Embeds / brackets supporting panels
03 Ceramic fritting / connection between panels

Final Project Model / Bachelor of Architecture Professional degree program

Excerpt from paper presented at ACSA Southeast Region Conference:

A Final Project Model; Optimal Independence to Address Three Basic Elements

Any design project can be described as having three basic elements:

- an **idea** or theoretical position,
- a **program** or statement of practical objectives, and
- a **site** or physical context.

Since 1995 Patrick Rand has been the coordinator of the Bachelor of Architecture program, and has set forth the pedagogy for the Final Project process that is at the core of this 5th-year professional degree program. The Final Project process includes the capstone studio project, which takes place in the final semester. The studio is based on Project Preparation that the student completes in the previous semester.

In a conventionally taught studio in architectural curricula, faculty typically define these three elements. The terminal academic design experience should be different than undergraduate studios. Specifically, the student should have latitude to articulate the theoretical position, frame the programmatic task, and identify the physical context, but within general parameters that are shared among all students.

In this model, each student actively collaborates with the faculty to define the idea, program and site. Faculty present a general outline for each of these three components, upon which each student develops a specific project brief. Each student produces their own 60 - 80 page project brief, upon which the final studio is based.

This model provides the group of students with sufficient commonality to make discussions and design explorations synergistic. It also gives students important experience in defining a design challenge worthy of their attention, and in managing a complex design task, all of which are valuable preludes to fruitful professional careers.

The Project Preparation seminar is the first opportunity for the student has had to define their own project, in which they articulate all of the parameters of the architectural task. The capstone project is highly individualized, with no 2 students from among the 22 – 28 total having the same theoretical position, program or site parameters. The vehicle project is typically a substantial public building. This studio is challenging to teach because the expectations are very high and the projects are each unique.

Though not required, the vehicle projects for the capstone studio have been different each year under Rand's instruction. Projects are chosen by the instructor to address specific architectural themes, while also being of sufficient functional complexity and technical challenge to advance student skills. The projects are also chosen to address real-world needs of the city, such as the downtown transit center, and an urban farming demonstration facility.

Project Preparation Seminar (ARC 581) 3 cr

Catalog description: Quantitative and qualitative conditions, considerations and determinants as preparation for architectural design. Emphasis on research methods, data collection and interpretation, theoretical discourse, site analysis, programming and architectural precedent.

In this seminar, students are given a general framework regarding the guiding architectural theory, the building program and the general site parameters. They then overlay their own objectives upon this general framework to develop a set of specific project objectives. They prepare a complete project brief, very similar to what practicing professionals might prepare leading in to a major commission. The results of this seminar then become the basis for the capstone studio project that they carry out in the following semester.

The Final Project curriculum is unique nationally. This pedagogical approach has been praised in NAAB Accreditation team reports, and has been presented by Rand at an ACSA Southeast Region scholarly conference.

Professional Architecture Studio II (ARC 502) 6 cr

Catalog description: Design investigations aimed at the development of an understanding of the major issues confronting the contemporary architect and at the expanding of problem solving abilities in architectural design.

The design studio is the heart of the architecture curriculum. In it, students receive 6 credit hours and generally work at least 40 hours per week; contact time with the faculty is at least 12 hours per week. This particular studio is expected to be ambitious relative to design, but also to meet rigorous technical criteria, much as might be expected of an architect in practice.

The National Architectural Accrediting Board sets forth 32 specific student performance criteria that each student must satisfy. This matrix indicates that these courses address several important areas.

These courses actually meet several additional criteria, but they are not checked here because other courses have been charged with primary responsibility in those areas.

Bachelor of Architecture
Courses and Studios Cross-referenced with the NAAB Student Performance Criteria that they Fulfill

Student Performance Criteria		Communication Skills	Design Thinking Skills	Visual Communication Skills	Technical Documentation	Investigative Skills	Fundamental Design Skills	Use of Precedents	Ordering System Skills	Historical Traditions + Global Culture	Cultural Diversity	Applied Research
	Proficiency level required: Ab = Ability Un = Understanding	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Un	Un	Un	Un
		A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
Course Number	Course Title											
ARC 581	**Project Preparation Seminar**					X		X				
ARC 502	**Professional Architecture Studio**	X	X		X				X			

Student Performance Criteria		Pre-Design	Accessibility	Sustainability	Site Design	Life Safety	Comprehensive Design	Financial Considerations	Environmental Systems	Structural Systems	Building Envelope Systems	Building Service Systems	Building Materials and Assemblies
	Proficiency level required: Ab = Ability Un = Understanding	Ab	Ab	Ab	Ab	Ab	Ab	Un	Un	Un	Un	Un	Un
		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12
Course Number	Course Title												
ARC 581	**Project Preparation Seminar**	X											
ARC 502	**Professional Architecture Studio**		X	X	X	X	X						

Student Performance Criteria		Collaboration	Human Behavior	Client Role in Architecture	Project Management	Practice Management	Leadership	Legal Responsibilities	Ethics and Professional Judgment	Community and Social Responsibility
	Proficiency level required: Ab = Ability Un = Understanding	Ab	Un	Un	Un	Un	Un	Un	Un	Un
		C1	C2	C3	C4	C5	C6	C7	C8	C9
Course Number	Course Title									
ARC 581	**Project Preparation Seminar**	X		X				X		
ARC 502	**Professional Architecture Studio**							X		

Reflections Regarding this Final Project Model:

- This studio paradigm is in fact substantially different than that of undergraduate studios.
- The model is readily adaptable to varying faculty who teach the Final Project Studio, and by students who have varied academic and professional backgrounds.
- The two-semester experience functions as a coherent unit with minimal logistical effort by the faculty. Faculty teaching the seminar may also teach the subsequent studio, but this is not required.
- Student projects produced in this model have generally met or exceeded the goals outlined above. They are meritorious with regard to design, represent substantial critical reasoning skills, demonstrate skills in integration of technical issues, and often represent viable and professional development strategies.
- Self-assessment and accreditation analyses that the institution regularly undergoes have cited the Final Project Model as meritorious. In fact, the Chair of a recent NAAB Visiting Team stated in his concluding remarks to the School that he had seen no other program in the country that better prepared students for a leadership role in the profession. Whether that statement is true or not, the point here is that this Final Project model seems effective at demonstrating the student's ability to meet many educational objectives that are part of a professional degree program in architecture.

Example of one student's ARC 581 Project Preparation document: Laura Reed's project was based on a quote she selected from Peter Zumthor. Her building program was for a NC Urban Horticulture Center, on a site that she selected at the seam between the university campus and a parkway.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quote: Peter Zumthor **idea**

physical context/quality of space:

"Every new work of architecture intervenes in a specific historical situation. It is essential to the quality of the intervention that the new building should embrace qualities, which can enter into a meaningful dialogue with the existing situation. For if the intervention is to find its place, it must make us see what already exists in a new light. We throw a stone into the water; sand swirls up and settles again. The stir was necessary. The stone has found its place. But the pond is no longer the same."

"... The building has to be beautiful for its use, and has to resonate of its place." "I believe that the language of architecture is not a question of a specific style. Every building is built for a specific use in a specific place and for a specific society."

"[an architectural atmosphere is] this singular density and mood, this feeling of presence, well-being, harmony, beauty... under whose spell I experience what I otherwise would not experience in precisely this way."

means of execution/tectonic language:

"In order to design buildings with a sensuous connection to life, one must think in a way that goes far beyond form and construction."

"I resolved to begin my work with the simple, practical things, to make these things big and good and beautiful, to make them the starting point of the specific form, like a master builder who understands his metier."

"I work a little bit like a sculptor. When I start, my first idea for a building is with the material. I believe architecture is about that. Its not about paper, its not about forms. It's about space and material."

"Materials react with one another and have their radiance, so that the material composition gives rise to something unique, material is endless."

"I want to create an architecture of atmosphere and many times I find that... the material helps me, like it helped Beuys to make sculptures, he uses this tree trunk to make his sculptures, to make his statement."

"A young colleague asked me how I would go about building a house of wood after working for some years with stone and concrete, steel and glass. At once, I had a mental image of a house sized block of solid timber, a dense volume made of the biological substance of wood, horizontally layered and precisely hollowed out. A house like this would change its shape, would swell and contract, expand and decrease in height, a phenomenon that would have to be an integral part of the design."

commentary re quote:

This quote is all about materiality and emotive qualities of space within architecture. In application, the design process will begin with material studies along with site studies. Both of which are infused with ones personal experiences. As the author explains, every building should humbly respond to and accentuate its site and all of the specificities involved creating a "sensuous connection to life".

Still, this quote acknowledges the necessity to begin with the practical, rational and functional, but attempts to describe how to use materiality, subtlety, and simplicity to go beyond them toward the ultimate goal of emotive atmospheres. The author also describes the importance of attention to details and joints, whether the intention is to minimize visual presence or to use them to inform the larger scale aspects of order and rhythm. Material studies will then lead to detail and joint studies which will in turn lead to the overall ordering system. Ultimately, architecture, and more specifically structure should remind us of "the living bodies of nature."

sources:

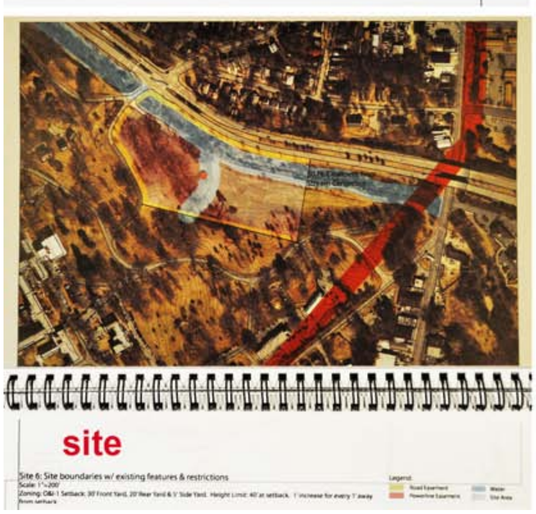
Zumthor, Peter, *Thinking Architecture*. Princeton Architectural Press, 1969

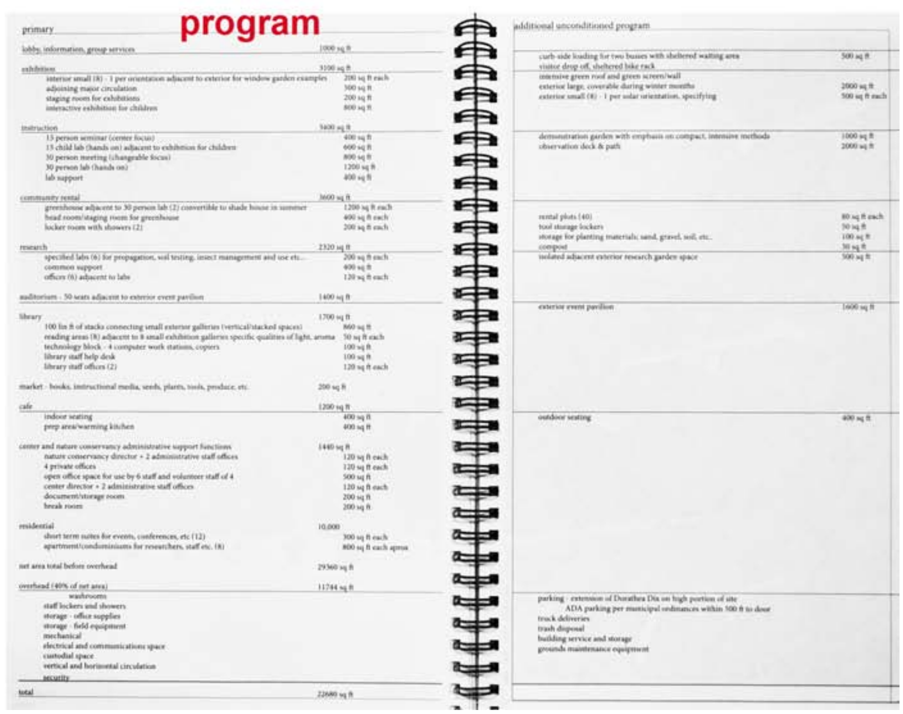
http://www.archiquotes.info/architecture/240-peter-zumthor-2009-pritzker-prize-winner

http://thinkingmakingarchitecture.blogspot.com/2010/04/interview-with-peter-zumthor.html

http://www.archdaily.com/106352/bruder-klaus-field-chapel-peter-zumthor/

http://archinect.com/forum/thread/84393/elusive-zumthor-quote



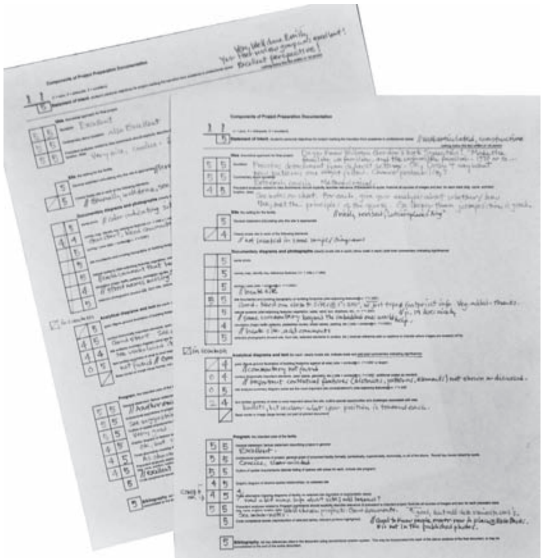

primary **program**

lobby, information, group services 1000 sq ft
exhibition 3100 sq ft
interior small (8) - 1 per orientation adjacent to exterior for window garden examples 200 sq ft each
adjoining major circulation 300 sq ft
staging room for exhibitions 200 sq ft
interactive exhibition for children 800 sq ft
instruction 3400 sq ft
15 person seminar (center focus) 400 sq ft
15 child lab (hands on) adjacent to exhibition for children 600 sq ft
30 person meeting (changeable focus) 800 sq ft
30 person lab (hands on) 1200 sq ft
lab support 400 sq ft
community rental 3600 sq ft
greenhouse adjacent to 30 person lab (2) convertible to shade house in summer 1200 sq ft each
head room/staging room for greenhouse 400 sq ft each
locker room with showers (2) 200 sq ft each
research 2320 sq ft
specified labs (6) for propagation, soil testing, insect management and use etc... 200 sq ft each
common support 400 sq ft
offices (6) adjacent to labs 120 sq ft each
auditorium - 50 seats adjacent to exterior event pavilion 1400 sq ft
library 1700 sq ft
100 lin ft of stacks connecting small exterior galleries (vertical/stacked spaces) 860 sq ft
reading areas (8) adjacent to 8 small exhibition galleries specific qualities of light, aroma 50 sq ft each
technology block - 4 computer work stations, copiers 100 sq ft
library staff help desk 100 sq ft
library staff offices (2) 120 sq ft each
market - books, instructional media, seeds, plants, tools, produce, etc. 200 sq ft
cafe 1200 sq ft
indoor seating 400 sq ft
prep area/warming kitchen 400 sq ft
center and nature conservancy administrative support functions 1440 sq ft
nature conservancy director + 2 administrative staff offices 120 sq ft each
4 private offices 120 sq ft each
open office space for use by 6 staff and volunteer staff of 4 500 sq ft
center director + 2 administrative staff offices 120 sq ft each
document/storage room 200 sq ft
break room 200 sq ft
residential 10,000
short term suites for events, conferences, etc (12) 300 sq ft each
apartment/condominiums for researchers, staff etc. (8) 800 sq ft each aprox
net area total before overhead 29360 sq ft
overhead (40% of net area) 11744 sq ft
washrooms
staff lockers and showers
storage - office supplies
storage - field equipment
mechanical
electrical and communications space
custodial space
vertical and horizontal circulation
security
total 22680 sq ft

additional unconditioned program

curb-side loading for two busses with sheltered waiting area 500 sq ft
visitor drop off, sheltered bike rack
intensive green roof and green screen/wall
exterior large, coverable during winter months 2000 sq ft
exterior small (8) - 1 per solar orientation, specifying 500 sq ft each
demonstration garden with emphasis on compact, intensive methods 1000 sq ft
observation deck & path 2000 sq ft
rental plots (40) 80 sq ft each
tool storage lockers 50 sq ft
storage for planting materials: sand, gravel, soil, etc.. 100 sq ft
compost 50 sq ft
isolated adjacent exterior research garden space 500 sq ft
exterior event pavilion 1600 sq ft
outdoor seating 400 sq ft
parking - extension of Dorathea Dix on high portion of site
ADA parking per municipal ordinances within 100 ft to door
truck deliveries
trash disposal
building service and storage
grounds maintenance equipment

Examples of Final Project assessments

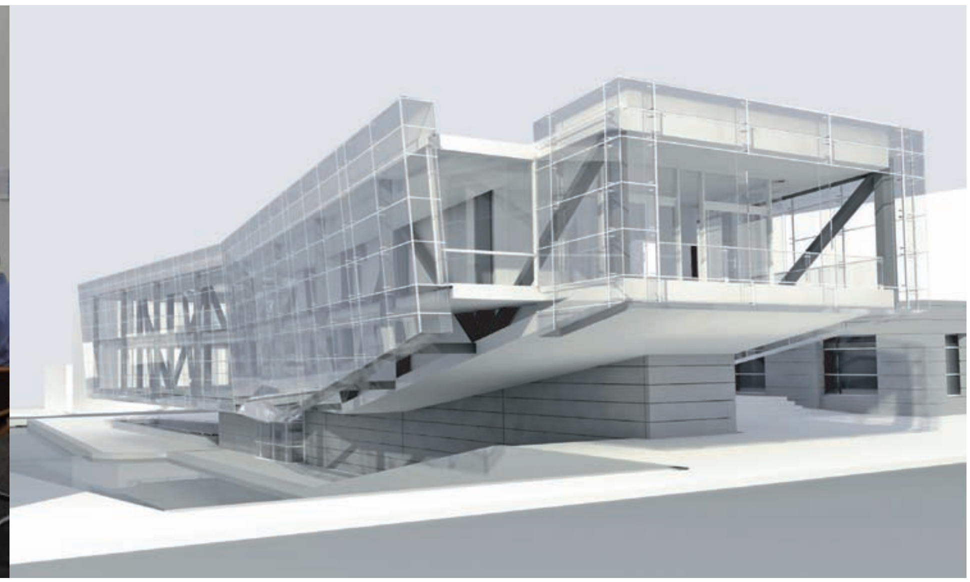


Assessment of student work is a teaching opportunity.
The seminar and studio syllabi explicitly state what is to be expected at each stage of the process. It contains easily measured elements, such as whether a drawing is submitted at the prescribed scale, but it also contains qualitative elements, such as the clarity of he information and whether the proposed design has responded appropriately to relevant spatial and even conceptual objectives, such as those of the selected quotation.

Individual assessments of the 22 - 28 students are carried out several times during both the preparation seminar and the final studio. Because the projects are individualized and rather complex, assessments place a significant demand on faculty time, but assures optimum student achievement.

At the left are evaluation sheets that Rand has used to indicate to the student how each element of their prep document was evaluated technically and qualitatively. Students in this seminar submit each element to the instructor in draft form, a second time in intermediate form to classmates for peer evaluations, then in final form to the instructor. This iterative multi-reader process enhances product quality, engenders mutual respect between student and instructor, and between students.

In the final studio, students are rigorously evaluated in each of 3 major reviews leading up to the final review. We also ask the students to assess themselves on each of the required deliverables, provoking them to gain skills at self-assessment that they will need after leaving academia.



Education efforts outside of the normal academic settings:

Please refer to *curriculum vitae* for complete listings.

TEACHING EDUCATORS

Rand is a frequent invited speaker at education conferences nationally. He was a founding member of the Building Technology Educators Society, He has co-authored 4 books since 2006, all of which are used in colleges and universities throughout this country. Rand has twice been the principal investigator for nationwide surveys of faculty in architecture and engineering programs, researching their teaching methods and identifying needs that academia would like to bring to the attention of industry. He chaired the ACSA Southeast Regional Conference in 1993 "Architecture: the Act/Art of Building". He has also assisted as moderator and paper reviewer for many ACSA conferences.

TEACHING PRACTITIONERS

Rand's teaching outside the classroom includes seminars for interns preparing for the registration exam and continuing education programs for licensed professionals. He has shared his technical expertise in dozens of presentations to practitioners from Florida to Washington. He serves on juries for national design awards.

TEACHING INDUSTRY

Rand has carried out funded research regarding exterior wall assemblies, and has presented his findings at many industry and professional conferences. Rand is the only architect elected to lead The Masonry Society, and to receive its President's Medal and Fellowship. His tenure as President in 2003-2005 included the creation of the Society's first Sustainability Committee, which he subsequently chaired for four years. He also realized an alliance between the industries in the United States, Canada and Britain, which facilitated the sharing of masonry standards and peer reviews. His 1999 paper "The Contemporary Masonry Wall," was a finalist for ASTM's Yorkdale prize as one of the top ten research papers of the 3-year period worldwide.

Activities related to Interdisciplinary and Interinstitutional Advancement

- Rand has made more than 50 invited presentations about his innovative teaching methods regional and national educator conferences. These began when ACSA had an annual Technology Conference, but since those ceased have been provided through other vehicles. Several have been cited by others in published articles. Many Architecture faculty members who attended have applied these models to courses at their own colleges and universities.
  Comments from architecture faculty who were University Professors Masonry Workshop participants:
  - *Thank you for the University Professor's Masonry Workshop. The workshop was excellent, and filled with great information. Presentations by Professor J. Patrick Rand were especially relevant for my class at my University. He gave great examples of student projects that I hope to be able to incorporate into my class.*
  - *I very much appreciate the opportunity to attend the University Professor's Masonry Workshop at Clemson University. The Workshop had an excellent agenda, was well man aged, had good speakers, and provided useful information. Coverage of material was at an appropriate level for professors such as myself. The speakers in general were excellent. Pat Rand's presentations were especially helpful to me in offering me ideas for my architectural studios.*

- Initiated an interdisciplinary Concrete Masonry Design Competition at NCSU; starting in 1996. Students in Architecture and Landscape Architecture work in small teams to either design a new concrete masonry unit for mass production, or to design and build a wall using stock units. The project is one of the few to engage students from more than one Design department; approximately 60 students took part annually. Initially, the competition was sponsored by the Carolinas Concrete Masonry Association. This competition has continued at our school, and has also been adopted by the National Concrete Masonry Association; schools nationwide now compete, with the top 3 entries receiving generous industry awards.

- Initiated a Student Research Grant Program through which 3-5% of the College's returned overhead each year was awarded to students from various disciplines based on the merits of their proposals. This program helped support student initiatives and developed research skills in students.

Recognitions from outside of the candidate's College and University:

In addition to 12 teaching awards received at the College or University level, Rand has received several national recognitions.

- Institute Scholar, American Institute of Architects, National Award 1990
- Education Commendation Award; CSI National 1991
- ACSA Service Award; for service as Regional Meeting Chair 1994
- AIA Education Honor Award, Honorable Mention 2002
- Fellow, The Masonry Society 2006
- College of Fellows, American Institute of Architects 2007

DesignIntelligence 30 Most Admired Educators for 2013

Each year, **DesignIntelligence** honors excellence in education and education administration by naming 30 exemplary professionals in these fields. The 2013 class of education role models was selected by **DesignIntelligence** staff with extensive input from thousands of design professionals, academic department heads, and students. Educators and administrators from the disciplines of architecture, industrial design, interior design, and landscape architecture are considered for

PATRICK RAND

North Carolina State University

Rand has a special ability to teach both traditional and modern applications of building materials and assemblies in a manner that allows students to develop a well-rounded store of knowledge to draw from when deciding ways to articulate or inform design concepts. His own personal brand reputation is to "welcome new ideas," and students resonate to him.

(excerpt from **DesignIntelligence** *publication)*

Research projects such as the following are catalysts for better teaching of students; they also benefit educators and practitioners.

The Contemporary Masonry Wall: Problems and Solutions

Patrick Rand has been actively seeking to identify causes of extensive moisture damage in many contemporary masonry veneer exterior walls. In this project, sample assemblies were subjected to harsh weathering simulations, and their performance is evaluated. Innovative materials and assemblies have also been developed, tested, and their performance documented.

This project received an AIA Institute Scholars Program Award; awarded in competitive review process. A paper by this title was peer-reviewed and presented at the 8th North American Masonry Conference, and was a finalist for the Yorkdale Award.

Findings from this project have attracted international attention, and have assisted designers, researchers and industry professionals to improve the design and construction of exterior masonry walls. The technical courses and studios taught by the nominee have also been greatly enhanced from this investigation. Graduate students have been involved as research assistants in these experiments.

The research proved that accepted strategies for water to drain out of cavities were not as effective as previously thought. A second set of experiments explored the viability of other strategies to remove moisture from inside the wall. Passive convection of outside air through the cavity was found to be an effective and economical means to remove moisture. A paper "The Masonry Wall as an Enclosure System; Findings and Recommendations", was peer-reviewed and presented at the 9th North American Masonry Conference.

Rand has been invited annually to present these findings and his pedagogical research to faculty from the US and Canada at the annual University Professors Masonry Workshop. He has also presented the technical findings to mason contractors throughout North Carolina, which is an important audience, because the research showed that many of the problems are due to errors of workmanship by contractors. Rand has also written several articles in national industry publications, to better inform these vital collaborators.

Environmental Impact of Cladding Materials; Embodied Energy and Carbon Dioxide 'Costs'

Academic buildings on the NCSU campus employing a full range of architectural cladding materials were analyzed in terms of the investment of **energy** and **CO2** in their initial construction, as well as maintenance and repair over their lives. Long-term records from the University Physical Plant were the basis for the analysis.

The analysis compared masonry, concrete, wood, glass and metal exterior cladding installations. This research confirms that considerable differences exist between exterior wall materials with regard to their environmental impact. Durability of exterior materials also were shown to vary considerably.

Painted exteriors have a much greater environmental impact than most unpainted exteriors, due to the high embodied energy and embodied carbon content of paint and stain.

Unpainted, durable exterior wall treatments are the most environmentally sound option that an owner or architect could choose.

This was the first study that has quantified accurately the life cycle implications of maintenance and repairs. A paper summarizing this research was presented at the 11th North American Masonry Conference in 2010.