"SOFT-FORMED" PRECAST CONCRETE SCREENS AND PANELS

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ABSTRACT

The topic of a recent design brief issued to undergraduate Architecture Students caused great interest in a University course of Materials and Methods of Construction. Students were asked to design and build a modular precast concrete wall panel of variable thickness that was comprised of "soft" curves. The modular nature of the panel was a control factor to unify the total composition of these concrete components.

Students were excited by the possibilities of designing, building formwork and casting solutions that explored the design brief. They were able to cast these panels after a lecture of concrete basics and a tour of the nearby PCI Precast Plant. The paper is illustrated with castings, that are a delightful combination of ignorance and innovation, which created interesting, results. As expected, several failures did occur when the formwork was stripped. The disappointment of the student was personal, albeit educational.

The paper illustrates a collection of fantastic discoveries and the educational process that generated them. This is a joint-effort, between the PCI precast plant, a university professor and architecture students, which is beneficial to all parties. Other PCI members could adapt this educational model to their own circumstances.

Keywords:
Aesthetics and Finishes
Creative/Innovative Solutions and Structures
Research

INTRODUCTION

The paper contains a collection of architecture students' fantastic discoveries and the educational process that generated them. This is a joint-effort, between a local PCI precast plant, a university professor and architecture students, which is beneficial to all parties. Other PCI members could adapt and modify portions of this educational model to their own circumstances.

PRECAST CONCRETE INSTRUCTION FOR ARCHITECTURE STUDENTS

Architecture students see things quite differently than most. In order to explain this approach, a description of a typical architecture student might be of value. Many architecture students learn at an early stage of their education to challenge standard methods of perception and design. They tend to focus on programmatic, spatial and material finish issues when they are designing a building. Economy and the means of construction are normally not significant components in their studio design work in their early formative years. That awareness comes later, when and if the student evolves into an architect.

EARLY MEMORIES OF CONCRETE

Our earliest childhood impressions of "cement" sidewalks, as we then called them, were endless gray paths that were abrasive enough to "skin" your knees with the certainty of a saw blade and were lined with cracks that you were forbidden to step on, if you valued your mother's health. Magic occurred when colored chalk was applied. Colors and textures transformed the surface with the personal significance of a Paleolithic cave painting.

Somewhere in our education, we learned that "cement" sidewalks were made of the ingredients of concrete, how to make them harder and to predict and almost, control the locations of those cracks. We also learned that color or texture, added a further level of control difficulty and increased cost of the end product. We still likely didn't appreciate the weight of concrete or the gullible nature of this liquid stone material to tenaciously cling to and mimic all of the imperfections of our formwork.

HOW WE TEACH

A traditional undergraduate course in a university level architecture program will explore the material qualities that one might expect for concrete. It will cover concrete principles: mixtures, chamfers, draft, air entrainment, form release agents and perhaps superplasticizers. Noted author, Edward Allen divides the topic of concrete into three chapters in his 5th Edition textbook, *Fundamentals of Building Construction Materials and Methods*. He is a widely subscribed author on this topic in the architecture schools in North America. He devotes a chapter to "Concrete Construction", a second chapter to "Sitecast Concrete Framing Systems" and a third chapter to “Precast Concrete Framing Systems."

Fig. 1 Architecture students at Miami University working to release precast concrete panels from their formwork.

This third chapter in 32 pages, is comprised of topics: Precast, Prestressed Concrete Structural Elements; Preliminary Design of a Precast; Assembly Concepts for Precast; Manufacture of Precast; Joining Precast Elements; Fastening to Concrete; The Construction Process: Precast Concrete and the Building Codes; Considerations of Sustainability in Precast; and the Uniqueness of Precast Concrete. The subject matter that is so important to the reader is necessarily reduced to serve as an introduction due to the range of the building materials that the text covers.

SUPPLEMENTAL INSTRUCTION TECHNIQUES

Over the years, editions of Allen's book have been the mainstay of my arsenal for teaching a "Materials and Methods of Construction" class. The information contained in this book is the source for what many accredited schools of architecture cover in their coursework for Precast Concrete. It is well written, but in an effort to supplement the material, I refer to examples from Chapter 1 of the *PCI Handbook*, as well as invite professionals from the local precast plant to the university to share their expertise on current industry practices.

HOW STUDENTS LEARN

Students learn the most by personal experimentation. (Fig. 1) Professionals from the local PCI precast plant do a fantastic job in a classroom session. Students are exposed to the concepts of the material, multiple uses of formwork, delivery and field erection techniques, as well as the economics and the daily operation cycle of the plant.

A CASE STUDY APPROACH

I also include a lecture that features images of "cutting-edge" design projects that are very important for architecture students in their understanding of how the industry is evolving and where it might be going next. Images selected from PCI Publications such as ASCENT Magazine are good sources for these case studies. I usually include a diverse short list such as the Perot Museum of Nature and Science in Dallas by Morphosis, the Contemporary Art Center in Cincinnati by Zaha Hadid, the Jubilee Church in Rome by Richard Meier Associates, the Baha'i Temple in Wilmette, IL by Bourgeois and Fuller, the University of Cincinnati Stadium by Bernard Tschumi, and the Ohio State University Chiller Plant in Columbus, OH by Ross Barney as diverse examples that can illustrate the range of contemporary pre-cast buildings.

Fig. 2 Miami University architecture students touring the local precast plant

CASE STUDY DESIGN CREDITS

Three of these case study buildings were produced at the local PCI precast plant. When the precast representative later shows these images in the technical lecture, students appreciate that the local plant is capable of producing high quality precast. The sales representative also mentions several former students from previous years that have served as project architects for innovative projects that the students may have seen in the local region. Many architecture students find this cutting edge precast design to be very interesting. They see it as validation of their own creative studio work.

VARIATIONS FROM THE SAME FORM

Novice students are initially uncertain as to how the exterior skin of the building was formed, but are now interested in finding out how it was cast. (Fig. 2) As they learn more, they become interested in closely examining the texture and how natural light and shadow define the building. An exercise to determine how many times a form could be used by altering the length and texture of the panel is a powerful learning exercise to reinforce the repetition of a form for economy. Students, who understand the concept of the repetitive nature of formwork from the lecture by the local precast plant representatives, then seem very interested in where similar panels occur and what degree of repetition occurs in order to establish the seemingly irregular exterior wall panel pattern. They also are interested in the casting sequence and what "block out" areas could be utilized in the formwork to create different panels. (Fig. 3)

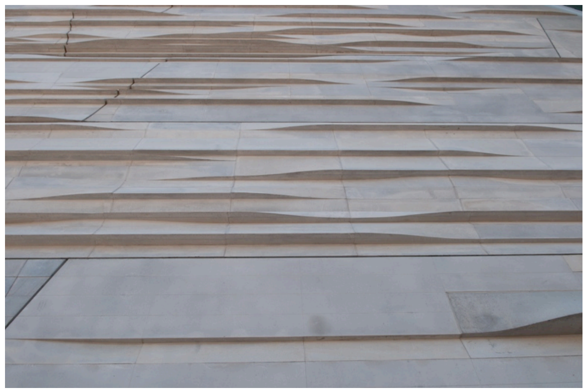

Fig. 3 Exterior wall detail (looking upwards)
of the Perot Museum of Nature and Science in Dallas

THINKING BACKWARDS

Architecture majors have been trained to think and see things differently than most other University students. "Design process," a series of drawings, that are done to inform the next generation of design decisions, is a mantra that is fervently followed in most architectural design studio environments. For precast design, the ability to envision and draw the "negative" form that will cast or generate the desired "positive" object is an analytical ability that many architects possess. This skill is sometimes referred to as one's ability to think backwards. Some designers are facile enough to draw the negative image while envisioning the final positive object in their mind. However, it is an exercise that requires a devoted focus, with few interruptions, which is something that we seem to find increasingly endangered in today's world.

For the majority, I recommend that the "positive" object be drawn first, so that the "negative" can be overlaid, analyzed and traced to ensure that forms will be cast as intended. I encourage the student to first draw the end result, then to "think backwards" to envision and design the relevant formwork that can be easily disassembled to hatch the object without damage and minimal effort.

The next stage is to refine the formwork to be easily built and disassembled while remaining stabilized, upright, watertight and texturally relevant. This is something that most architectural students find to be a very satisfying academic exercise. However, in their exuberance, they tend to design an object that is very intricate for what they envision will be the ultimate object to prove their brilliance. This stage of the project is high in optimism. The aspect of an easily disassembled formwork is often overlooked due to the rush of getting the formwork fabricated. One's level of confidence of stripping formwork is so much higher, if you haven't been humbled by previous personal experience.

LEARNING FROM EXPERIMENTATION

Students can read about the rules and watch videos of proper formwork fabrication. However, architecture students seem determined to find and bend this conventional wisdom of the industry to create their desired vision. The indelible educational moment occurs when they personally strip their own concrete casting. These lessons are valuable for any novice designer. Students relish the opportunity to design and build their own formwork, (Fig. 4) to get their hands dirty while casting and later hatch their masterpiece creation. In the process, they inherently appreciate the effort, time and skill that are required for formwork design and removal.

The resulting piece commonly surprises the designer with varying degrees of disappointment. However, upon reflection, most want to re-design and re-cast, realizing that they can improve their initial ideas as evidenced by what worked and where improvement is needed.

Fig. 4 Precast foreman suggesting additional reinforcement
for student's formwork prior to casting.

They realize that the quality of their formwork remains an outspoken informant telling of their "mistakes". Concrete fabrication is PASS or FAIL. With either success or failure, the best self-teaching moments occur when the students present their blemished castings to their peers who have participated in the same exercise. Discussion ensues between the students, the faculty, and precast professional as to why "mistakes" happened and what revisions might lead to a more successful result. In the process of this project, they appreciate the effort, time and skill that are required for formwork design and stripping. They gain respect for precast professionals who have the difficult job of translating a design idea into a precast building component. The stage is thus set for a better quality "shop drawing" dialogue between architect and precaster in future years.

PRECISE FORWORK FABRICATION

Some students decide that the task of formwork fabrication is too time consuming. They might be inexperienced (or intimidated) with the machinery in the wood shop. Students, who rely heavily on their computer-based technology, increasingly do not understand that the degree of precision of a laser cutter is not relevant for formwork, if the joint between precast panels will be sealed with backer rod and caulking.

Some students might also have difficulty in the design process and revert to an uninspired solution of what could be considered the "cake decoration" approach. They tend to favor an additive "foreign" decoration applied on the surface, as if a baker was decorating a cake.

THE PRECAST PLANT TOUR

The coordination of forming and stripping start to be comprehended and appreciated in the noisy, aggressive environment of the concrete plant that students find to be complex, intimidating and interesting.

Fig. 5 Miami University architecture students observing the pouring of a precast panel

The cacophony of large front end loaders, mixers, overhead cranes and power sprayers in an oversized, open-ended building, set between large bins of colorful aggregate and a continuously muddy staging yard is an eye-opening experience for these students. (Fig. 5) They are intrigued with the seemingly endless palette of materials, finishes and textures. They respect the skill, craftsmanship and labor at the precast plant. Even those students, who don't fully appreciate the necessary timing and coordination of the precast plant operation, finding it chaotic, start to appreciate their own privileged situation as a college student.

FURTHER LEARNING - A HANDS ON APPROACH

Once they see the range of textures and finishes available in the PCI literature and slideshow, they are excited to experiment with this versatile material first hand. The casting of a small personal panel that the student has designed is a great educational tool that brings to bear the previous lessons.

A PROJECT DESIGN STATEMENT

The students receive a project statement in which they are asked to design and cast an object that meets the design criteria. A typical exercise is designed to focus on a maximum of two of the following attributes of concrete forming at a time in order to understand the limitations.

Over the years, I have challenged students to explore various design investigations such as using concrete to:

- incorporate integral color(s) dye in experimental ways
- reflect a slick smooth texture without mechanical polishing
- explore fabric formwork
- transmit light and/or view
- develop a dissolvable formwork for ease of stripping
- develop a twisted object
- shape a floatation structure
- achieve a minimum thickness

Note: For illustration purposes, a recent project design statement that was issued to the class is attached in the appendix, at the end of this paper. The focus of exploration of this particular exercise was to design a (visually) "soft" modular concrete panel.

The modular requirement is one recommended by the author in an effort to limit the dimensions of the panel and hence the weight of the casting. The size must be small enough so that any student can lift and strip their own concrete panel including formwork, but large enough for the student to appreciate concrete's weight of 145 lbs/cu ft. Over the years, the author has found that a range of 1/8 cu ft to 1/4 cu ft seems to work well.

TEACHING RATIONALE

My requirements are to examine and understand the rules, and then bend them one at a time. Bending or twisting the rules is the preferred method in which students can find and stretch the boundary limits. I feel that if students can experiment with concrete in unusual ways that are more in keeping with the ways they approach design and problem solving, concrete can transcend it’s common reputation in the eye of the public, that thinks “cement buildings”(as they call them), are gray, boxy and uninspired.

SMALL CASTINGS LEAVE BIG IMPRESSIONS

The experimental pieces are intentionally small so that the student can physically build the form, cast and strip the form without the use of lifting machinery. The weight of concrete is appreciated, if the student can lift their relatively small object, albeit with substantial effort. If the concrete experiment is too large and a crane is effortlessly employed, the experiment is no longer portable and several learning opportunities are lost.

Rotation of the object is usual since the finished side is normally, but not always, cast face down. The irregular top surface of a casting is one lesson that catches many students by surprise. Eventually students better understand the role of form release agents. They also understand that different absorption rates of formwork components affect the texture and ease of release.

POURING CONCRETE TO REINFORCE LEARNING

Most architecture students relish the opportunity to get their hands dirty and build. They enjoy working with tools. I find that the student will appreciate and respect the skills of the professional craftsmen more if they have endured the limitations and failures of trying to craft quality formwork themselves.

Fig. 6 Student at the precast plant with custom dye (color) mix

To reinforce the lessons learned in the short time available, I find that allowing students to pour concrete is both therapeutic and educational if done on a small scale and in a controlled environment. (Fig. 6)

Some instructors I have met, feel that this is best done by having the students hand-mix, pour and finish concrete slabs in order to have them appreciate the labor intensive processes and achieve less than acceptable concrete finishes. In my opinion, this approach lends little to further exploration in the design potential of concrete and doesn't help the student's appreciation of the precast industry.

THE CASTING PARTY (AT THE PRECAST PLANT)

With the technical expertise and assistance of a few dedicated precast professionals, we set forth to explore the perceived limits of the material, they work with every day. We arrive at the precast plant near the end of the workday and inhabit a small area adjacent to the quality control testing area.

There is no shortage of volunteers from the plant that stay behind at the end of their day to advise and reinforce shoddy formwork. The workers enjoy the "weirdness" of the formwork that the students have built. Students are encouraged to use recycled and discarded materials in their formwork. The craft of the formwork ranges from exquisite to shoddy with forms held together with super glue, drywall screws, duct tape and hope. Any weakness readily produces a puddle during the pour, which causes a scramble for more duct tape.

Many students can't wait to incorporate color dye pigments that illustrate command of their newfound versatile material. Our architectural precast concrete "bartender" dispenses advice and mixes small quantities of white cement in a wheelbarrow, ready for the student's request for a specific color. He helps each student mix the preferred color and predict the quantity of cement dye needed for the resultant color. At the plant the cement dyes are catalogued and stored on shelves and were noted by students to be reminiscent to bottles of liquor.

Fig. 7 "Stripping Party" at University working from precast company's flat bed truck which is strategically parked close to the dumpster

JOY OR DISAPPOINTMENT AT THE STRIPPING PARTY

A week later, the collection of "weird" forms are delivered to the university by the precast plant for the much anticipated "Stripping Party". (Fig. 7) Students are anxious to strip out their masterpieces. Again no shortage of volunteers from the plant comes along to see what hatches out of the forms. From past experience, the truck parks near the dumpster so that the "clean up" after stripping is expedited.

Our desire for a pristine object to hatch from the formwork is often challenged by reality. Mistakes and failures are humbling experiences. It is the analysis of why concrete did what it did, that is the lesson to take forward. Some of the best results are fantastic discoveries. Some are structural failures that become post-mortem discussions before the project is interred in the dumpster or reduced to colorful aggregate with a sledgehammer. All students give opinions and ridicule, when a project cracks during the stripping operation or if the form doesn't release its' captive and tedious labor is required. (Fig. 8) The best way to respect the obstinate grip of a re-entrant corner is to try to strip it without damage.

Fig. 8 Stripping formwork is not as easy as it looks

WHY

What happens when these students break or at least bend some rules? Amazing new concrete castings are produced, if they understood the limits and possessed some degree of skill with their formwork fabrication. Shattered dreams, unceremoniously delivered to the dumpster, if they rushed into design or fabrication error or didn't appreciate the weight and seepage of wet concrete. With either result, the best self-teaching moments occur when the student presents their design intentions with their physical results to their peers who have participated in the same exercise. Their peers can discuss which aspects failed and how others were able to achieve success. If students can gain hands-on experience, concrete will educate them as they wrestle to train and contain this amazing material that has humbled most of us.

STUDENT DISCOVERIES

A few of the student's discoveries that have lead to significant personal learning experiences are illustrated on the following pages.

DESIGN CREDITS

All projects are from original sources, each designed and fabricated by individual Miami University architecture students at the local PCI precast plant and advised by the author, from 1997 to 2015, unless otherwise noted.

**A STUDENT PORTFOLIO
OF MOSTLY INTENTIONAL MISTAKES AND DISCOVERIES
IN CONCRETE CASTING**

Fig. 9 Wrinkled Sheet Vinyl
warped sheet vinyl as form liner with low heat applied

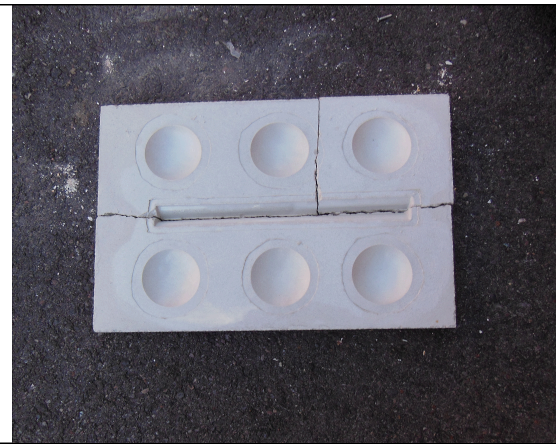

Fig.10 Plastic Dome Lids
a grid pattern of domes set in bottom of formwork

Fig. 11 Light Transmitter
styro-foam and duct tape with fiber optic whiskers

Fig. 12 Dye Swirled in Paper Formwork
two colors of swirled dye with negative image

Fig. 13 Cylinder Grid Relief
thick plastic grid floated above sand bed

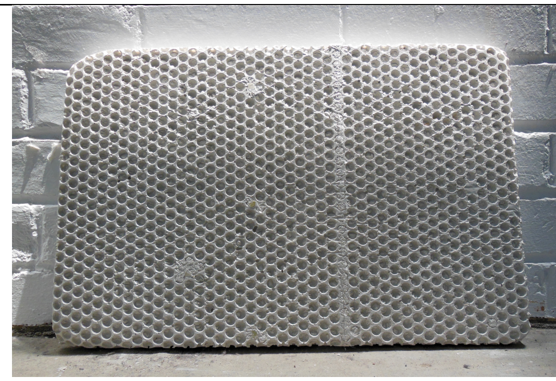

Fig. 14 Indented Circular Grid
plastic bubble wrap used as a form liner

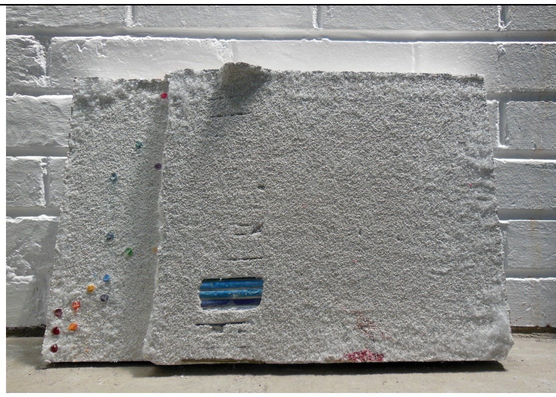

Fig. 15 Light Sand Finish
blasting sand with embedded found objects

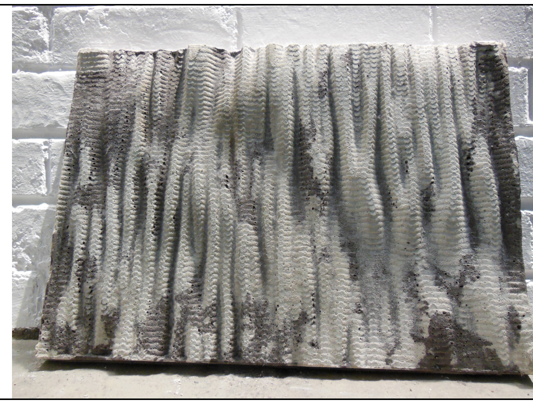

Fig. 16 Black Dye + White Cement Swirl
on insulation board distressed with a dinner fork

Fig. 17 Modular Wall Panel
prototype for stack bond and reversing

Fig. 18 Textural Wall Panel
distressed liner fragment inserts in repetition

Fig. 19 Soft + Slick Warp
heated + shaped plastic insert that is easily stripped

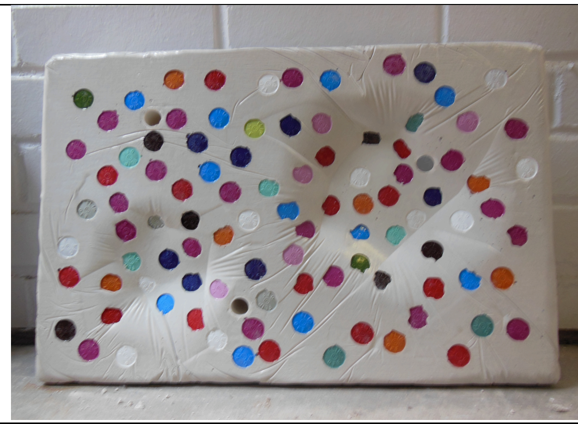

Fig. 20 Soft Form with Plastic Disks
plastic buttons set on heat warped plastic sheet

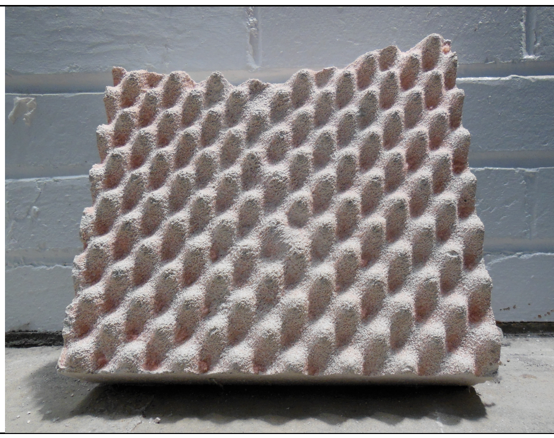

Fig. 21 Soft Grid
foam panel used for packing glass as a form liner

Fig. 22 Scorched Corrugated Cardboard
re-entrant corners + absorbent formwork = difficulty

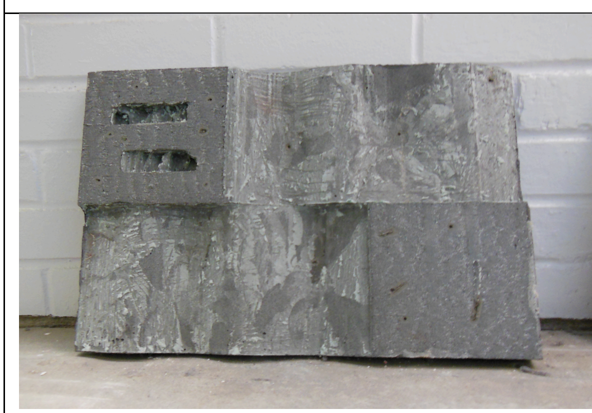

Fig.23 Foam Insulation as Liner
styro-foam absorbs more water than anticipated

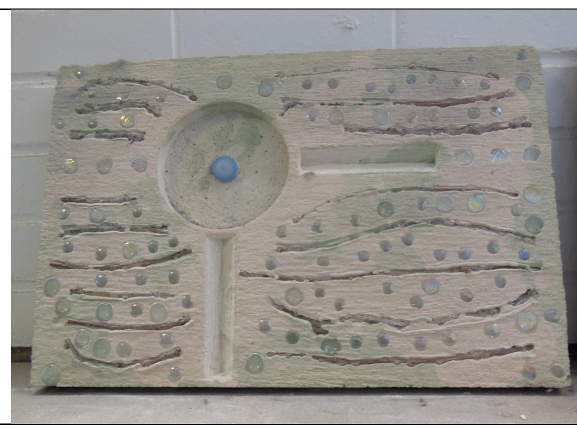

Fig.24 Craft Approach to Design
embedded decorations are time consuming to cast

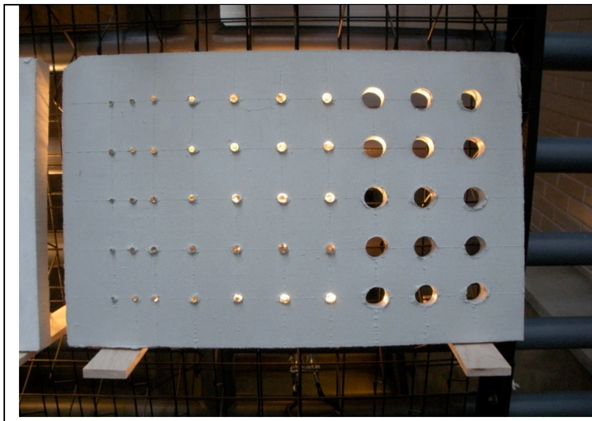

Fig. 25 Concrete Screen
a grid of various sized cylinders

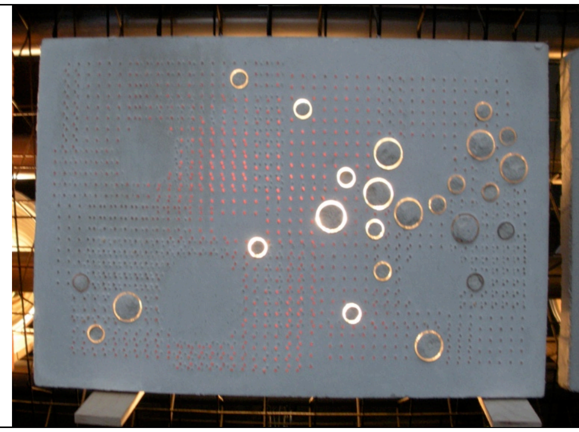

Fig. 26 Light Transmitter
grid of fiber optic whiskers and Plexiglas tubes

Fig. 27 Variable Thickness (2" to 0")
slick panel with edges at voids that are paper-thin.

Fig. 28 Wrinkled Panel with Voids
texture telegraphed the thin plastic sheeting formwork

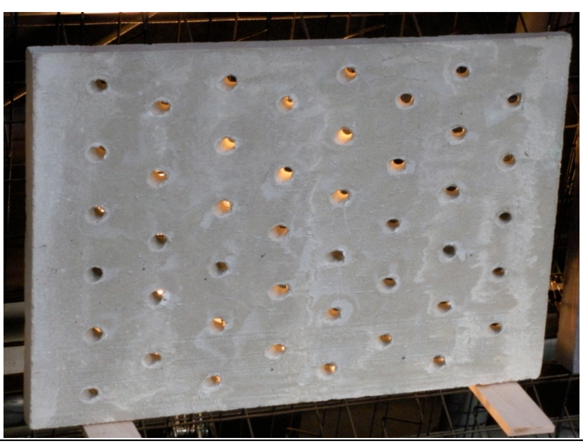

Fig. 29 Angled Screen Wall Panel
diagonal penetration affords privacy + ventilation

Fig. 30 Warped Grid Screen
warped sand bed cast with slick cylinder inserts

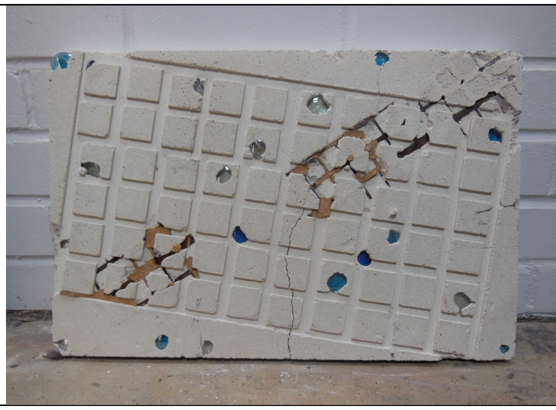

Fig. 31 Multiple Grid Shift "Mistake"
result didn't match student's expectations

Fig. 32 Martian Landscape "Mistake"
wrong (top) side of the panel proved more interesting

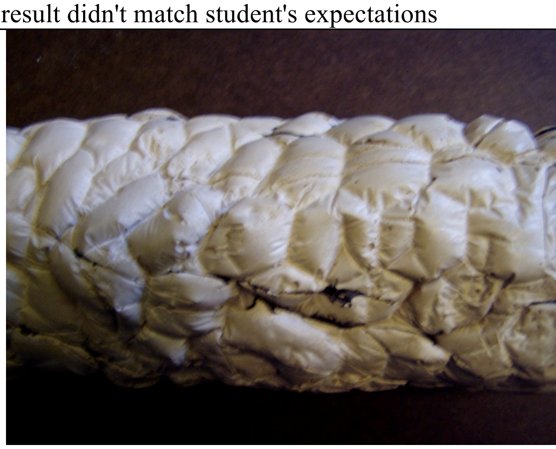

Fig. 33 Deformed Cylinder
soft (fabric) formed lined with light wire mesh

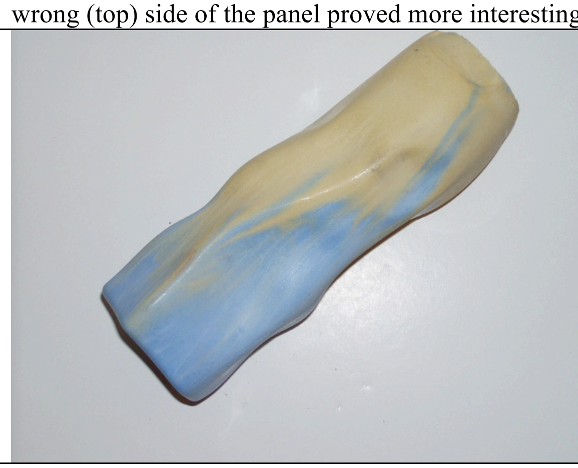

Fig. 34 Twisted Cylinder
heated plastic formed with two colors of swirled dye

Fig.35 Glacial Remnant
two sides of a self- stripping box form were ice filled

Fig.36 Warped Grid with Copper
mounded plastic grid with some cells capped

APPENDIX:
SAMPLE PROJECT STATEMENT

ARC 418/518 Construction Methods 2015

Professor Craig L. Hinrichs
100 A Alumni
Class: 10:00-11:20 am TTh
Office Hours: 11:30 am-12:30 pm TTh
or by appointment 513-529-7036
hinriccl@miamioh.edu

Issued: 17 March 2015
Due: 31 March 2015

design exercise #4a (alternate)
a "soft" modular concrete panel

With the technical expertise and assistance of [redacted] the course is about to reach the dirty stage. **Yes, we are going to build!** This exercise is intended to explore one of the most plastic of the common building materials. The projects will be judged on the basis of the tripartite formula of function, constructability and aesthetics.

Project Statement.

Design/build a modular precast concrete panel that is exactly 1"deep x12"high x18"long with a 2" flat margin on all 4 sides, 2"wide x 1"deep, like a picture frame.

The surface of the panel can be flat, concave or convex using "soft curves" of any thickness from 3" to 0" (a hole).

The panel may be opaque or it may transmit either natural or artificial light. A perforated concrete screen can be an elegant solution to this project. Additional explorations of color, additive materials and/or texture can also be a part of your panel

Formwork design

The ability to design the "negative of object" is a particular skill that you will explore. "Thinking backwards" is a great mental and physical challenge to hatch the desired object out of your formwork creation. You will find that the careful demolition of the formwork is more difficult than building it.

Recycled form materials are encouraged. Dumpster diving is an approved sport. Imperious materials yield slick textures, while more absorbent forms reflect the materiality of the form but are harder to release. Form release agents are recommended on all castings.

Calendar

12 March	concrete basics-Dwayne Robinson, [redacted]
19 March	Plant tour and **Casting Party** in [redacted] at 11:00 am
31 March	**Stripping Party** at Alumni Hall at 10:00 am

Reminder

The modular nature will allow it to be a part of a larger wall panel. This material will be presented to the Construction Methods class and will reside in the Alumni Hall stairwells with previous students' work. It will become part of the Department of Architecture Archives.

ch/15