INTEGRATIVE DESIGN WITH PRECAST/PRESTRESSED CONCRETE

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ABSTRACT

In 1987, the Brundtland Commission of the United Nations provided one of the first widely recognized definitions of sustainability. Ten years later, John Elkington defined the triple bottom line of environmental value, social value, and economic value in his book, Cannibals with Forks: the Triple Bottom Line of 21st Century Business. *In response to these and countless other realizations about the importance of environmentally and socially responsible development, architects and engineers are now transforming the design process. The conventional linear process, which provides limited interaction between project stakeholders as it assembles information, is yielding to the integrated design process (IDP). In the integrated design process most, if not all, project stakeholders participate in a rolling interactive process to identify synergistic opportunities for improving the triple bottom line. This is important to the precast/prestressed concrete industry because* ***producers*** *offer far more than* ***commodity manufacturers*** *in terms of system integration, life cycle assessment (LCA), and other design services. Capitalizing on this opportunity, Professor Brett Tempest, Ph.D., Civil and Environmental Engineering, and Thomas Gentry, A.I.A., Architecture, co-teach a multi-disciplinary design course at the University of North Carolina Charlotte that focuses on IDP and precast/prestressed concrete. This paper summarizes what has transpired during the past three years of teaching the course.*

Keywords: Integrated Design Process, Sustainability, Multi-disciplinary Course

INTRODUCTION

In 1987, the Brundtland Commission of the United Nations provided one of the first widely recognized definitions of sustainability. Ten years later, John Elkington defined the triple bottom line of environmental value, social value, and economic value in his book, *Cannibals with Forks: the Triple Bottom Line of 21st Century Business*. In response to these and countless other realizations about the importance of environmentally and socially responsible development, architects and engineers are now transforming the design process. To fully participate in this transformation the precast/prestressed concrete industry and academia must address the following questions.

- What is the integrated design process (IDP)? How does it differ from the conventional design process?
- Why is IDP important to the precast/prestressed concrete industry? What advantages does the precast/prestressed concrete industry have over other building industries in participating in IDP?
- How should IDP be taught in academia? How does teaching the integrative design process pedagogically differ from teaching the conventional design process?

What follows are the answers to these questions that emerged from three years of teaching a multi-disciplinary design course at the University of North Carolina Charlotte that fully engages producers and consultants in the precast/prestressed concrete industry.

THE INTEGRATED DESIGN PROCESS

Regardless of which design process is used – conventional or integrated – there are five basic services design professionals provide. These are defined by the American Institute of Architects as:

1. Schematic Design (SD) – "During schematic design, an architect commonly develops study drawings, documents, or other media that illustrate the concepts of the design and include spatial relationships, scale, and form for the owner to review. Schematic design also is the research phase of the project, when zoning requirements or jurisdictional restrictions are discovered and addressed." [1]
2. Design Development (DD) – "This phase lays out mechanical, electrical, plumbing, structural, and architectural details. …[T]his phase results in drawings that often specify design elements such as material types and location of windows and doors." [1]
3. Construction Documents (CD) – "These drawings typically include specifications for construction details and materials. Once CDs are satisfactorily produced, the architect sends them to contractors for pricing or bidding, if part of the contract." [1]
4. Bid or Negotiation – "The first step of this phase is preparation of the bid documents to go out to potential contractors for pricing. After bid sets are distributed, both the owner and architect wait for bids to come in. The owner, with the help of the architect, evaluates the bids and select a winning bid. Any negotiation with the bidder of price or project scope, if necessary, should be done before the contract for

construction is signed. The final step is to award the contract to the selected bidder with a formal letter of intent to allow construction to begin." [1]

5. Construction – "The architect's core responsibility during this phase is to help the contractor to build the project as specified in the CDs as approved by the owner." [1]

There are also additional services available beyond the five basics. Programming, which is also called pre-design or architectural programming, is an additional service that is provided before schematic design. Simply put, it is, "…the research and decision-making process that defines the problem to be solved by design." [2]

With the conventional design process, programming services are provided by a core group of individuals within the firm producing the design program, or by an outside consultant. Most of the project stakeholders are not actively involved in developing the design program, if they are involved at all. Instead, they are brought into the project at various points during the development of the project. For this reason the greatest effort in the project is made during construction documents phase to coordinate what is often a collection of piecemeal solutions. (See Fig. 1)

The integrated design process (IDP) brings most, if not all, stakeholders of the project into the design process at the onset of the project. This provides the opportunity to develop a more comprehensive solution by identifying synergistic opportunities that are often overlooked in the conventional design process. One firm that uses IDP describes it as, "… a discovery process that optimizes – (i.e. makes the best use of, or creates synergy between) – the interrelationships between all the elements and entities that are directly and indirectly associated with building projects in the service of efficient and effective use of resources." [3] It is also described as, "… the overarching theme that governs energy, resources, and environmental quality decisions. With integrated design, it is necessary to consider design variables as a unified whole and use them as problem-solving tools." [4]

IDP IN THE PRECAST/PRESTRESSED CONCRETE INDUSTRY

For those who are knowledgeable about the precast/prestressed concrete industry, the connection between the description for IDP that is provided above and the opportunities IDP offers the industry is obvious. Because industry members are **producers who custom fabricate components for clients,** as opposed to **commodity manufacturers who mass produce products for markets**, the integrated design process is the ideal working relationship to showcase and optimize the benefits of precast/prestressed concrete.

In the conventional design process, architects tend to bring the consulting engineers, landscape architects, and interior designers into the project near the end of schematic design or the beginning of design development. Product manufacturers, which for most architects includes precast/prestressed concrete producers, are brought into the project later yet. It is a practice that has the precast/prestressed concrete industry actively working to educate architects – through office box-lunch presentations, AIA and CSI meetings, plant tours, and more – on when to involve producers in the design process. However, the integrated design process circumvents the need for the industry to constantly educate architects on when to include producers in the design process because it brings most, if not all stakeholders into the design process early on.

Participating in the process early on with the architects, engineers, and other stakeholders allows the producers to design custom precast/prestressed concrete systems that capitalize on the synergistic opportunities that arise from the integrated design process to produce socially and environmentally responsible solutions. An example is when the producer collaborates with the interior design, lighting designer, and mechanical engineer to design a higher quality continuously insulated concrete wall panel with a high light reflectance finish on the interior wythe; thereby, 1) eliminating the need for paint, which is an energy/carbon intensive product, 2) allowing the lighting designer to take full advantage of the known condition and to design a less energy intensive system, and 3) resulting in the mechanical engineer down-sizing the cooling system because less heat is being produced by the lighting system, and the thermal mass of the inside wythe dampens the interior diurnal temperature swings.

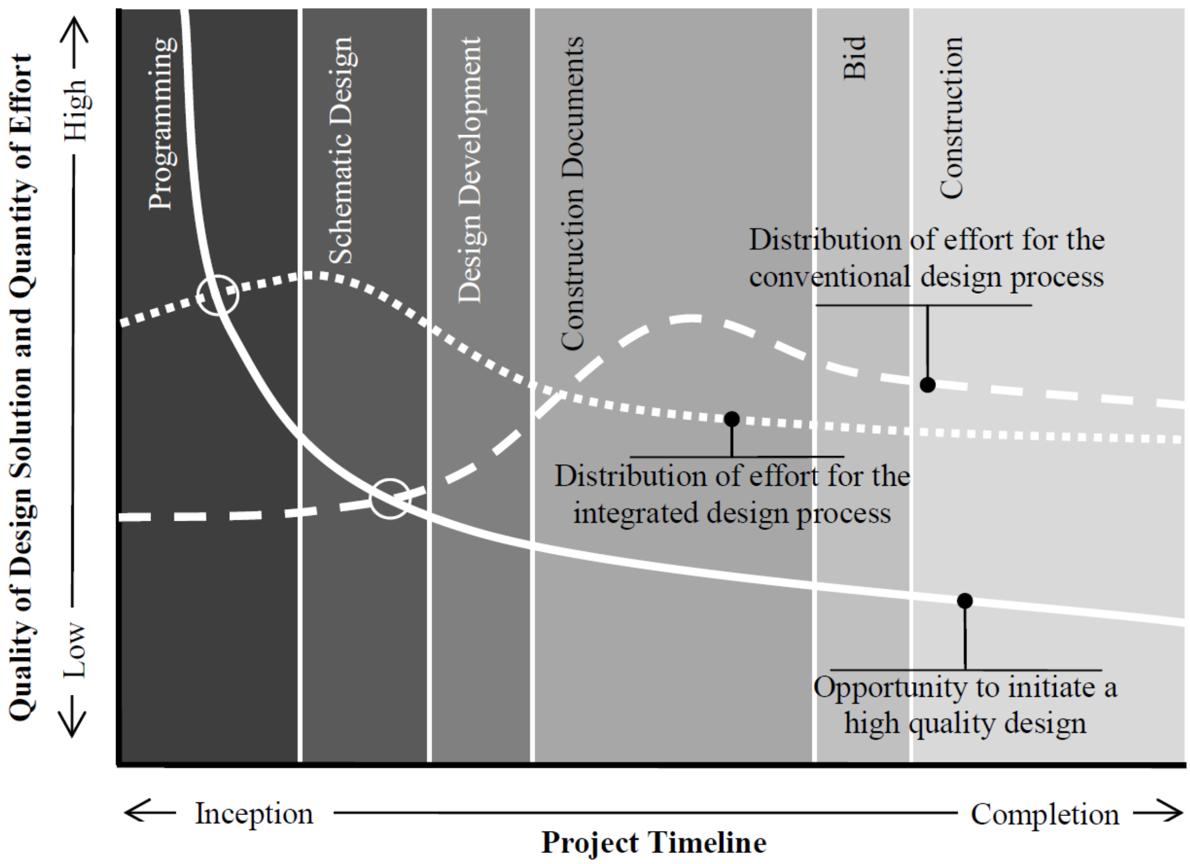

Fig. 1 Comparison of Conventional and Integrated Design Processes

IDP IN ACADEMIA

As mentioned before, one of the key characteristics of the integrative design process is it requires greater effort in the initial phases of the project than what is required for the conventional design process; but, the trade off is that less effort is required during the construction documents phase. (See Fig. 1) In professional practice this requires shifting the completion dates for each phase – programming, schematic design, design development, construction documents, bid, and construction – to accommodate the additional time required to complete programming and schematic design. (See Fig. 2) However, using IDP in an academic setting presents a different challenge. With the amount of time in an academic semester or quarter fixed, and the existence of long standing expectations about how far each student should develop their semester projects, it is critical to setup the semester project so the students experience the integrative design process while approximating the level of project development attainable with the conventional design process. What follows is a narrative on how the authors have wrestled with this issue in the first three years of an ongoing program.

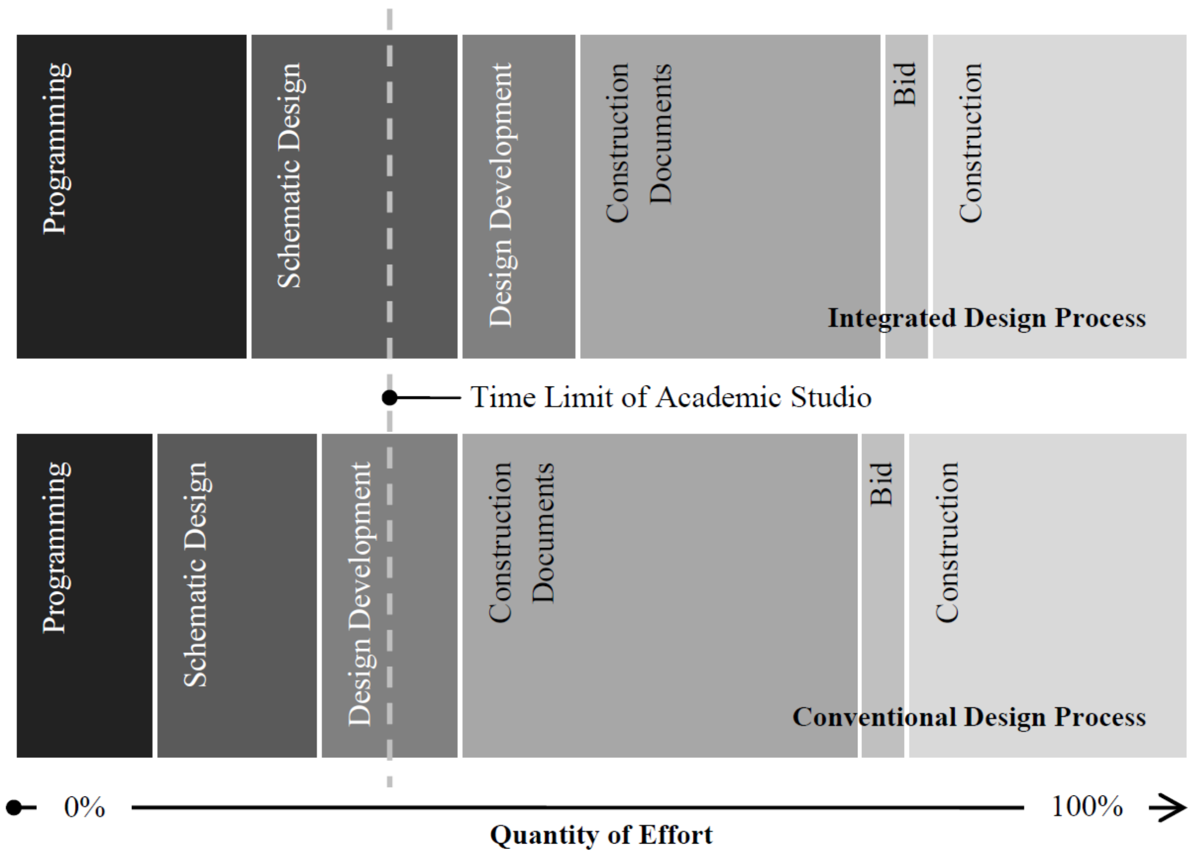

Fig. 2 Timelines

BACKGROUND

In the summer of 2008, Peter Finsen – Executive Director of Georgia/Carolinas PCI, and Ken Lambla – Dean of the College of Arts & Architecture (formally the College of Architecture), began discussing the creation of a precast/prestressed concrete design studio for architecture students at the University of North Carolina Charlotte. To facilitate this program they decided to seek three years of underwriting from the PCI Foundation and Georgia/Carolinas PCI. In September 2008, one of the authors, Professor Thomas Gentry, was brought into the conversation, and asked to develop a proposal. Knowing that Professor Thomas Brock at Illinois Institute of Technology had recently completed teaching his first year of a PCI Foundation studio; and, having taught concrete design studios at Illinois Institute of Technology with Professor Brock for several years, the author pulled together the resources at hand and started crafting the proposal.

A desire to have the program at the University of North Carolina Charlotte build upon Professor Thomas Brock's PCI Foundation Studio at Illinois Institute of Technology, and Professor Gil Snyder's Spancrete® Studio at the University of Wisconsin Milwaukee, lead the author to reach out to the Department of Civil and Environmental Engineering and producers within the Georgia/Carolinas PCI organization for support in developing a robust multi-disciplinary IDP studio.

In reaching out to the Department of Civil and Environmental Engineering to create a truly multi-disciplinary studio, Professor Brett Tempest, the other author, stepped forward. Professor Tempest's dissertation on the use of geopolymers in precast concrete made him the logical choice to help teach the studio. And, the enthusiastic support of the department chair, Professor David Young, reinforced the value of the program.

The final piece was to bring producers and students together in a hands-on environment similar to what the International Masonry Institute does with their IMI Masonry Camp. Peter Finsen took the lead on this task. At a producers' meeting in Greenville, South Carolina he pitched the idea to all of the producers in the room. Ultimately, it was the Gate Precast Company out of Oxford, North Carolina that stepped forward.

PEDAGOGY

One of the first challenges in setting the multi-disciplinary studio was coordinating the engineering and architecture teaching calendars. Engineering at UNCC uses a four-day calendar, while architecture uses a five-day calendar. Then there was the issue of cross-listing a course between two programs that have no common courses. Eventually, all of the minor obstacles were taken care of and the task of generating the first syllabus was at hand.

Writing a syllabus for a multi-disciplinary course with industry involvement is an exercise in melding together multiple agendas. The agenda for the PCI Foundation and Georgia/Carolinas PCI was to have each student develop a working understanding of precast/prestressed concrete design and construction. For the School of Architecture – then the College of Architecture – the agenda was to have the course tie into faculty research, which is socially and environmentally sustainable housing. And, the agenda for the Civil and Environmental Engineering Department was to have the course fulfill an environmental elective for the engineering students. Meeting each of these agendas required identifying the perfect project and balancing the time spent on design theory, precedence studies, site analysis, building science, presentation skills, and more.

Drawing from firsthand experience with teaching a multi-disciplinary, multi-university housing studio involving Kent State University, DePaul University, and Illinois Institute of Technology, the authors chose senior housing as the project and started soliciting senior assisted living providers to serve as the client for the students. Shortly after starting the search, Julie Lee, a rising fourth year undergraduate architecture student who preregistered for the studio, requested she be allowed to work on an intentional community for seniors that was being proposed for a family-farm near New London, North Carolina. After visiting the farm and talking with two of the three women wanting to develop the community it became clear this was the perfect project – a senior cohousing development with community supported agriculture (CSA). An urban version of this project consisting of senior cohousing and urban farming was used in the following two years, with the most recent being the soon to be built Durham Central Park Cohousing Community in Durham, North Carolina.

Moving on to act of teaching, the authors organized the studio into teams containing three to four architecture students and one to two engineering students. Recognizing that the academic cultures of engineering and architecture have little in common, the semester is kicked off with a Saturday charrette to address some of the basic site engineering. With the working conditions being familiar to one group of students and the content being familiar to the other group of students it proves to be a good way for the teams to begin to coalesce.

Gate Precast Company provides a significant part of building science instruction in the form of a two-day, hands-on, in-plant workshop. One the first day, the students work in teams to complete the fabrication of forms for architectural wall panels, each with four different finishes. They then assist in the pouring of concrete by placing the reinforcing steel and embeds. The balance of the first day is spent touring the shops and batch plant. On the second day the students assist with stripping the forms and power washing, and they observe the sandblasting of two of the finishes. (See Fig. 3) The balance of the second day is spent touring the hollow core plant. The authors feel this immersion into the fabrication process is a far more effective way for the students to learn than spending the time in PowerPoint lectures.

Rounding out the on-site building science instruction is Metromont Corporation of Charlotte, North Carolina. They host project site tours, including is a highly informative tour of a parking deck. They also give tours of their Charlotte plant, which provides a good contrast to the Gate Precast plant tour.

Fig. 3 Student team with the architectural precast concrete sample panel they fabricated.

DELIVERABLES

Returning to the notion of there being expectations of how far each student should develop their semester projects, the strategy at the end of the semester is to have each student take possession of one aspect of the project and prepare a detailed presentation about their chosen aspect. Done correctly the student need only produce a few well developed drawings or an accurately crafted model that demonstrates the depth of understanding that comes from the robust interaction that demands so much time on the front end of the integrated design process. For example, the structural system shown in Fig. 4 is unmistakably precast concrete. Furthermore, to the trained eye the rendering show how well the student understands precast concrete construction. The overhead deck is constructed with double tees that span a reasonable distance in the correct direction. The double tees are supported by inverted tee beams, which are supported by columns and haunches. The rendering also provides insight into how the building façade is designed to be climate responsive, and how care was taken in the proportioning of the walkway to make it a pleasing space to walk.

However, experience has demonstrated a disastrous outcome can still result when a collection of well developed drawings and accurately crafted models are not seamless integrated into a whole. In the ideal presentation the students are able to hand off to one another without causing disruptions in the flow of information. When this happens the multi-disciplinary team is no longer a collection of disciplines, but rather a group of well informed individuals. An example of how well this can work was when the Dean of Architecture sat in on a final presentation. Afterwards he comment on how well a particular student did in presenting part of the project, but admitted he was unable to recall the student's name. When it was pointed out to him the student was from engineering he was surprised the student was not from architecture given how intelligently he spoke about the architecture. Granted, this is anecdotal, but the cross-discipline understanding that occurs is not unique to this one situation or to the engineering students. Several architecture students have done well in presenting the engineering.

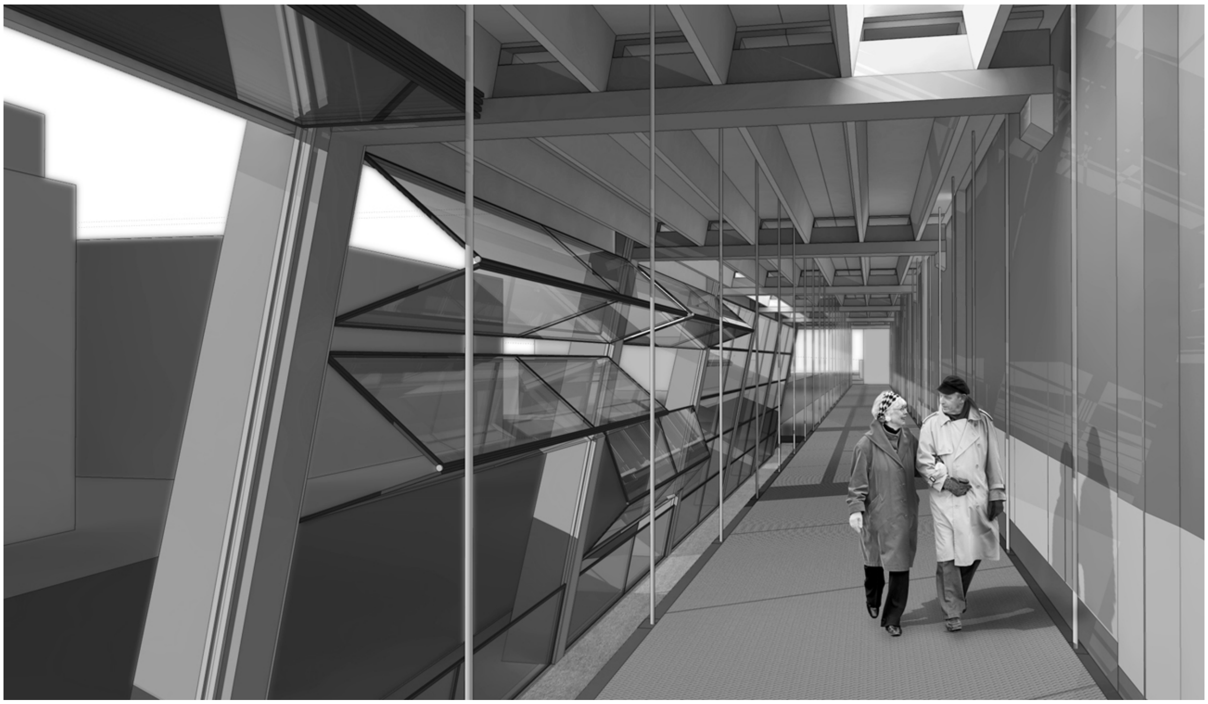

Fig. 4 View of Walkway in Senior Cohousing Project, Rendering by Ryan Martinez

LOOK FORWARD

In preparing for the next year, the authors have invited mechanical engineering students and faculty to participate. Having them on the team will enrich the exploration of precast/prestressed concrete in improving thermal comfort while reducing the carbon footprint.

CONCLUSION

In facilitating the design of environmentally and socially responsible development, the integrated design process (IDP) is superior to the conventional design process in identifying synergistic opportunities for reducing the impact of development. It does so by including most, if not all project stakeholders early in the process, and devoting a greater percentage of effort to the programming and schematic design services. For the precast/prestressed concrete industry this is an advantageous transition because it favors the producers who custom fabricate components for clients business model over the commodity manufacturers who mass produce products for markets business model. However, teaching the integrated design process in a university setting does present some challenges due to the fixed amount of time available in a term, and expectations to have the students reach a specific level of development with their projects. To address these challenges at the University of North Carolina Charlotte the authors teach a multi-disciplinary, team-based design course that utilizes the integrated design process to meet, 1) the agenda of the PCI Foundation and Georgia/Carolinas PCI to have each student develop a working understanding of precast/prestressed concrete design, 2) the agenda of the School of Architecture to have the course support faculty research, and 3) the agenda of the Civil and Environmental Engineering Department to have the course fulfill an environmental elective for the engineering students. Critical to the success of the course is the involvement of producers and consultants in the precast/prestressed concrete industry. They provide the technical expertise for rounding out a comprehensive teaching plan that has and continues to yield a high quality education experience for the students.

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