

February 11, 2021

NCSU ANNUAL REPORT 2020

## PCI FOUNDATION

### Creations in Concrete: An Integrated Architecture and Civil Engineering Instructional Project in Precast Concrete

North Carolina State University

School of Architecture and Department of Civil, Construction, & Environmental Engineering

Spring 2020 was the fourth year that the North Carolina State University School of Architecture (SOA) and Department of Civil, Construction, & Environmental Engineering (CCEE) taught a collaborative design course focused on precast concrete. We taught ARC 503 Advanced Architecture Design with associated software workshops, titled *Parametric Explorations*, and CE 675 Civil Engineering Projects. The courses connected students to local precast producers, allied organizations such as US Formliner, professionals, and members of PCI through the 2020 convention.

#### PROJECT 1 | CASE STUDIES



Figure 1 | B. Patel (CE), B. Lawing (ARC), and M. Layman (ARC) photographs of their fabrication process for Project 1. Casting was done with UHPC at the Constructed Facilities Laboratory

For the first weeks of the semester, ARC 503 and CE 675 students studied a noted architectural project that makes innovative use of precast concrete. Case studies included the Crematorium Heimolen (2008) by KAAN Architecten, Perot Museum of Nature and Science (2012) by Morphosis, 260 Kent (2018) by COOKFOX Architects, Queens Library (2017) by WORKac, MuCEM (2013) by Rudy Ricciotti, and Sugar Hill Development (2014) by Adjaye Associates.

In teams of 2 architecture students and 1 engineering student, the students analyzed the projects to better understand the role of precast concrete in the overall building design. Student teams created diagrams of their findings and cast small panels that were representational of the manufacturing methods for their case study. See Figure 1. Project 1 was reviewed by external reviewers.

#### PROJECT 2 | LARGE-SCALE COMPONENT

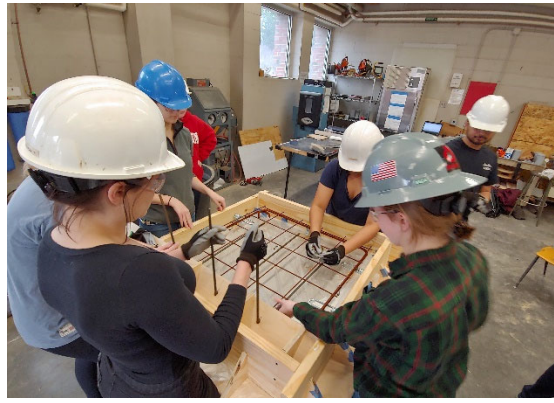


Figure 2 | Left: In the College of Design Materials Lab, ARC students strip their rubber molds from their CNC-milled MDF master molds. Right: At the Constructed Facilities Lab, ARC and CE students placing their reinforcing prior to casting.



Figure 3 | Cast Precast Panel Design Team 1 (Clockwise from Lower Left) A. Bagwell (ARC), K. Javali (ARC), T. Lavrick (ARC), B. Lawing (ARC), L. Pfaff (ARC), B. Patel (CE), N. Sardhara (CE), S. Surana (CE), and M. Layman (ARC). At NCSU Constructed Facilities Lab

Divided into two teams, the ARC 503 and CE 675 students were to design and fabricate two large-scale, precast concrete cladding panels for qualitative testing. The panels were non-load bearing and were to turn the corner of a prefabricated



steel frame mounted to a shake table in the CFL engineering laboratory. Each panel was designed to cover an approximate 3' x 3' area. Each mold needed to be used for a minimum of two pours. ARC students focused on the overall design of the cladding, the tessellation of the design, the fabrication of the form, manufacturing innovations (e.g. dams, mold inserts, formliners, etc.), repeatability, and finishes. CE students developed the panel mix design, reinforcement, structural connections to the frame, and lifting attachments. This project illustrated to the students a wide variety of architectural and engineering considerations, including repeatability, mix design, surface finishes and texture, shadow lines and joint widths, construction tolerances, connection stiffness, concrete curing, and more. Both teams decided to make a monolithic corner, cast in two pours, with a cold joint between them, and continuous reinforcing steel.

ARC 503 students made use of software and digital fabrication skills learned in *Parametric Explorations* and knowledge gained from the US Formliner Workshop, and support from the COD Material Lab staff. The teams designed the panels using Rhinoceros and Grasshopper (a software and associated plug-in). They used the Materials Lab computer numeric controlled (CNC) mill to fabricate their molds.

The first cast of the corner pieces was done prior to NCSU 2020 Spring Break with the intention that we would cast the second half after Spring Break. Unfortunately, due to COVID -19, in-person classes at NCSU never resumed after Spring Break, and we were never able to complete the casting of Project 2 for Spring 2020.<sup>1</sup>

### PROJECT 3 | TOTAL PRECAST BUILDING DESIGN

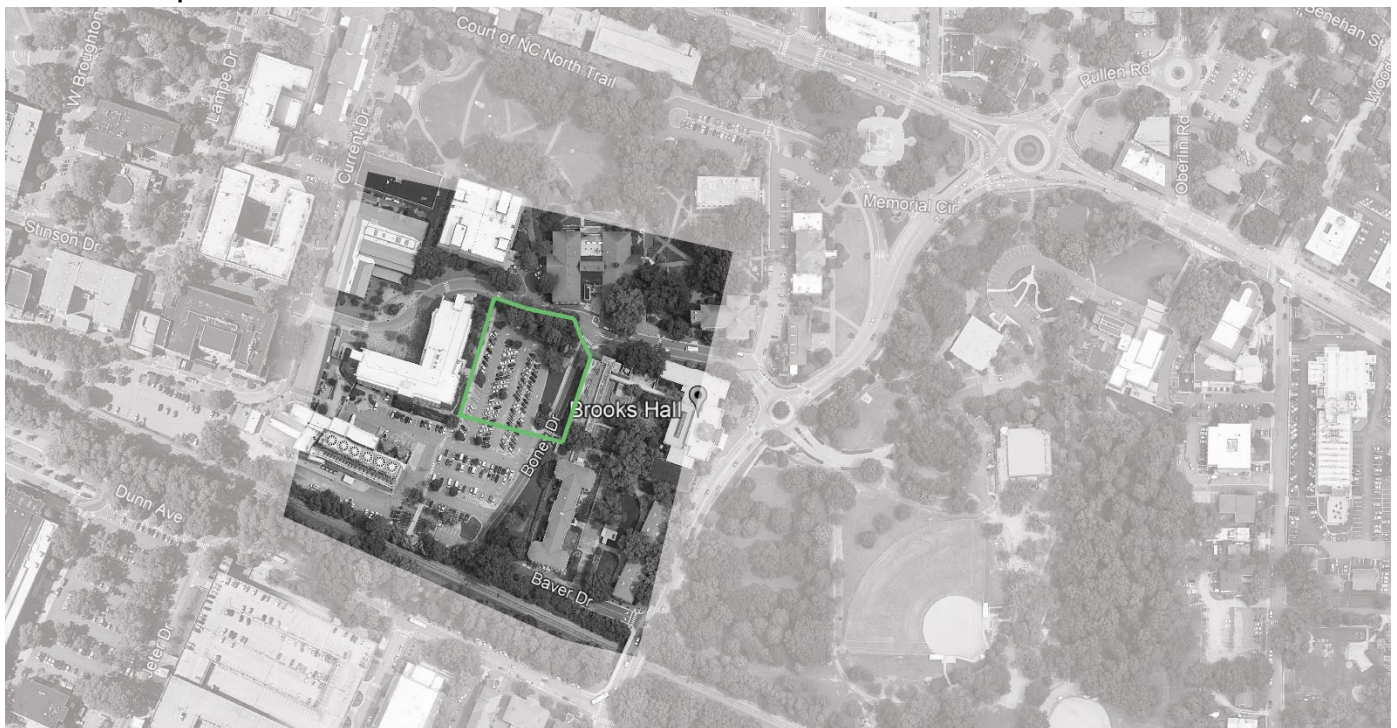


Figure 4 | Site Location for Project 3. NCSU Historic Campus on Boney Parking Lot, East of the College of Design Kamphoefner Hall.

Over half of the academic semester was focused on Project 3—an expansion to the NCSU College of Design into the Boney Parking lot, east of the College’s Kamphoefner Hall. The fictional project was to include the Design Library, gallery, review spaces, computer labs, and architecture studios. Students were asked to design their buildings with two key sustainable features. 1) The existing site has drainage issues, due to it being a low point on the campus. Designs must include green space and or rain garden to act as a retention pond during times of immense rain. 2) To help reduce

operating costs, the University has requested that at least 45% of the total façade area not be glass. Students were to consider placing windows only where daylight and views are critical.

The project brief stated that the University has recognized the strength and history of the School and College and asks that the architectural prestige of the new expansion reflects those. This gave the students the option to use architectural precast or to use embedded brick to follow the brick tradition of NC State's campus. The existing parking would be relocated to a planned addition on the nearby parking deck, but a small lot with 15 parking spaces would be included. Road access to the back of the neighboring buildings must remain; however, the access road (Boney Dr.) could be reconfigured or re-routed.

Individually, the ARC students designed a 50,000 GSF building with a consulting engineer (CE student) who offered guidance on the engineering aspects of each project. The students were challenged to design a total-precast project with precast concrete used both architecturally and structurally. The architectural panel design was to be based on lessons that the students learned from their experiences with Project 2.

Through their designs, students made use of a range of precast technologies, including fiber-reinforced concrete, hollow core slabs and double tees, load-bearing and non-load-bearing architectural precast panels, voided slabs, sandwich precast panels, post-tensioned members, and precast columns and beams. Precast concrete became a good material and structural solution for this project. It provided a durable interior finish surface for the studios.

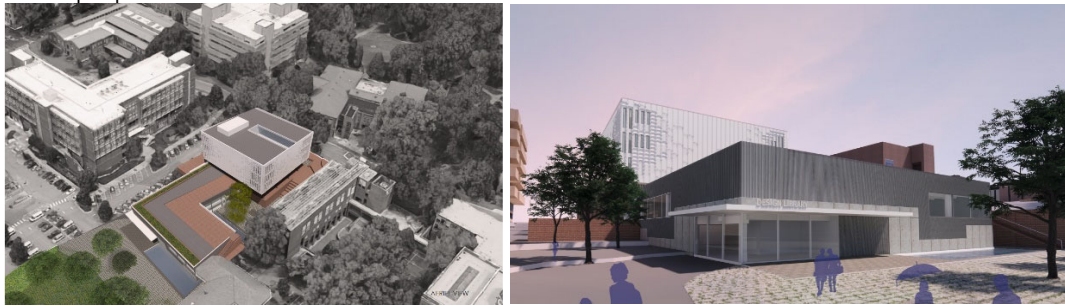
Student projects for Project 3 were reviewed formally, by faculty, community design professionals, and PCI members, during the design process and at the end of the project. This range of reviews gave the students feedback on their work from various viewpoints (e.g. design, material considerations, structure, etc.). A final, gallery-style review was held in early May where PCI and PCI Foundation representatives, industry supporters, faculty, and administrators participated.

Due to COVID-19, we moved the courses online with all studio work taking place on Zoom after NCSU Spring Break. This unexpected change meant that studio desk crits, student meetings, reviews, and pin-ups occurred remotely. To maintain the feeling of a traditional studio, we interacted with all students via a single large Zoom call where any student could join at any time to informally listen to comments made on their classmates' projects and incorporate that knowledge into their own designs. We were also able to invite other PCI Foundation funded professors, Alexis Gregory with Mississippi State, and Michael Carlos Barrios and Brandon Ross with Clemson, to our Project 3 Final Review.

Figure 5 | Keerti Javali (ARC) with Shreyans Surana (CE)



exterior perspective from Stinsen Drive of Northeast entrance of Architecture Studios



axonometric from SE corner and exterior perspective of South Library entrance



floor plans



technical wall section and overall building section



Figure 6 | Laura Pfaff (ARC) with Shreyans Surana (CE)



axonometric from Southeast corner of site

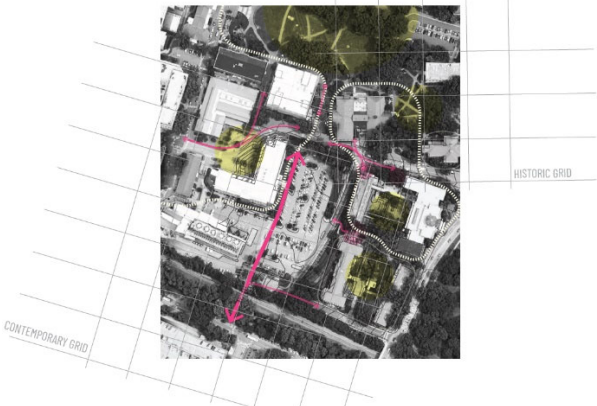


East-West Section Facing North

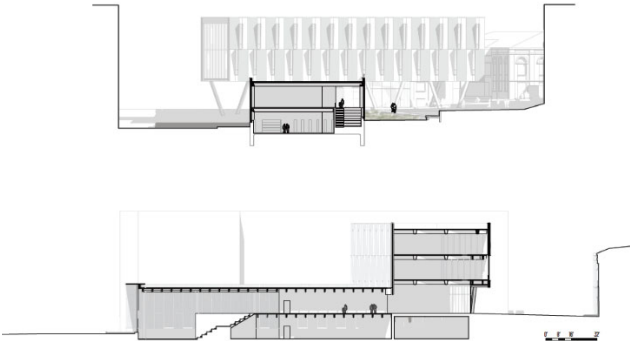


exterior perspective (left) entrance to Design Library from SW corner of site (right) entrance to architecture studios from Stinsen Dr.

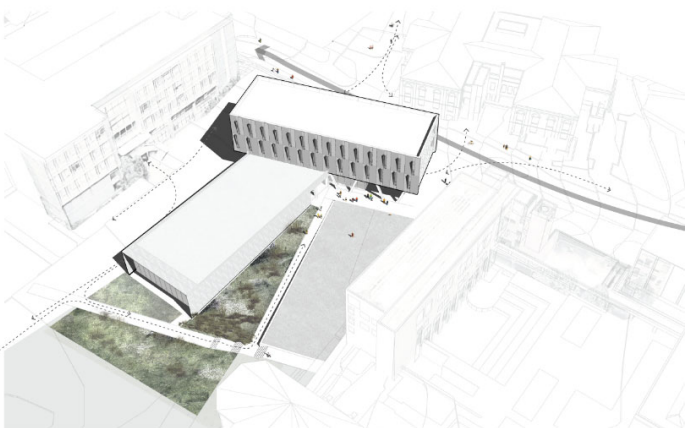
Figure 7 | Meredith Layman (ARC) with Bhavya Patel (CE)



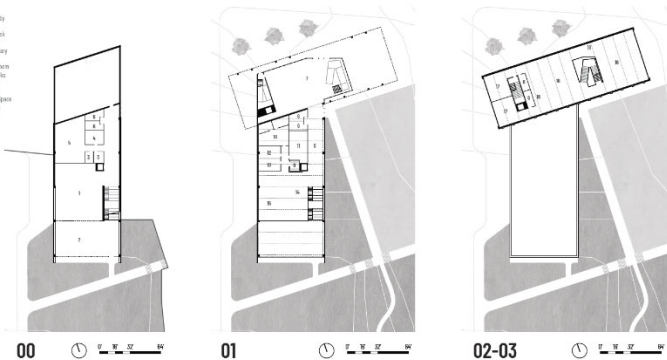
analysis and design concept drawings



building sections (above) EW section facing N (below) NS section facing W



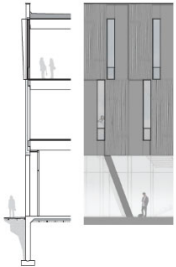
- 1. General Bank Station
- 2. Open Study
- 3. VR Room
- 4. Studio Room
- 5. Computer Lab
- 6. Reception
- 7. Entrance Lobby
- 8. Reference Desk
- 9. Office Space
- 10. Material Library
- 11. Faculty Room
- 12. Room Service Room
- 13. Reception Desk
- 14. Studio Kitchen
- 15. Open Studio Space
- 16. Studio Space
- 17. Studio Space
- 18. Studio Space



floor plans



perspective of rain garden with Design Library on left.



(left) perspective of ARC studios, looking down Stinsen Dr. (right) technical wall section and bay elevation of studio bar.



## ASSOCIATED ACTIVITIES

Throughout the semester, architecture and engineering students participated in additional associated activities. These included:

- G/CPCI lecture by Peter Finsen
- Tour of Gate Precast Concrete, Oxford, NC and Tindall Corporation, Petersburg, VA
- Multi-session software workshop, *Parametric Explorations*, to learn Rhinoceros and Grasshopper
- Workshop in rubber mold casting by US Formliner in the NCSU College of Design Materials Lab
- Attended the PCI Convention in Fort Worth, TX
- Altus Group lecture about graphic concrete surface finish techniques



Figure 8A| Trip to Gate Precast, presentation and lunch



Figure 8B | US Formliner workshop in NCSU COD Materials Lab

## CONCLUSION

Spring 2020 was the fourth semester of the PCI Foundation studio at North Carolina State University. As with the first years, the students especially enjoyed the hands-on work of Project 2 and felt that it demonstrated much about the manufacturing process of precast concrete. We heard from many students who wished they had been able to complete the second casting (the one canceled due to the pandemic). One of the benefits of Project 2 is that it demonstrates the care, planning, and expertise required for forming high-quality precast concrete surfaces. Interactions between ARC and CE students continue to reveal that the students appreciate working with other disciplines and appreciate the expertise and perspective of other students.





Figure 9 | *Creations in Concrete* Project 2 panels now on permanent display at the NCSU College of Design

We are proud to announce that we were able to coordinate with our Facilities team to permanently display some selected precast panels from Project 2. These panels were fabricated by students from each of the past four years and are now mounted and displayed in an outside courtyard on the grounds of the College of Design. This display serves as an excellent example of the unique and high-quality work created by the students in this funded studio.

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<sup>1</sup> Profs. Gulling and Lucier completed one team's casting to allow for permanent display at the College of Design.