# Level and Plumb Without Rhino: Problem Solving Issues of Making Beyond the Digital Realm

The computer has become a dominant mode of inquiry in contemporary architectural education. This encourages students to imagine complex forms without having to consider material resistance or issues of gravity at the onset of a design project. The following case-studies present examples of Design-Build efforts that were guided by a craftsman when design proposals met actual problems of construction. The craft of making has a long history that has evolved almost entirely without influences of the digital realm. Fundamental lessons of geometry, leveling and *plumb*-ing at full scale are essential in the education of a designer, especially when the computer enables lines and planes to be effortlessly snapped into place on the screen.

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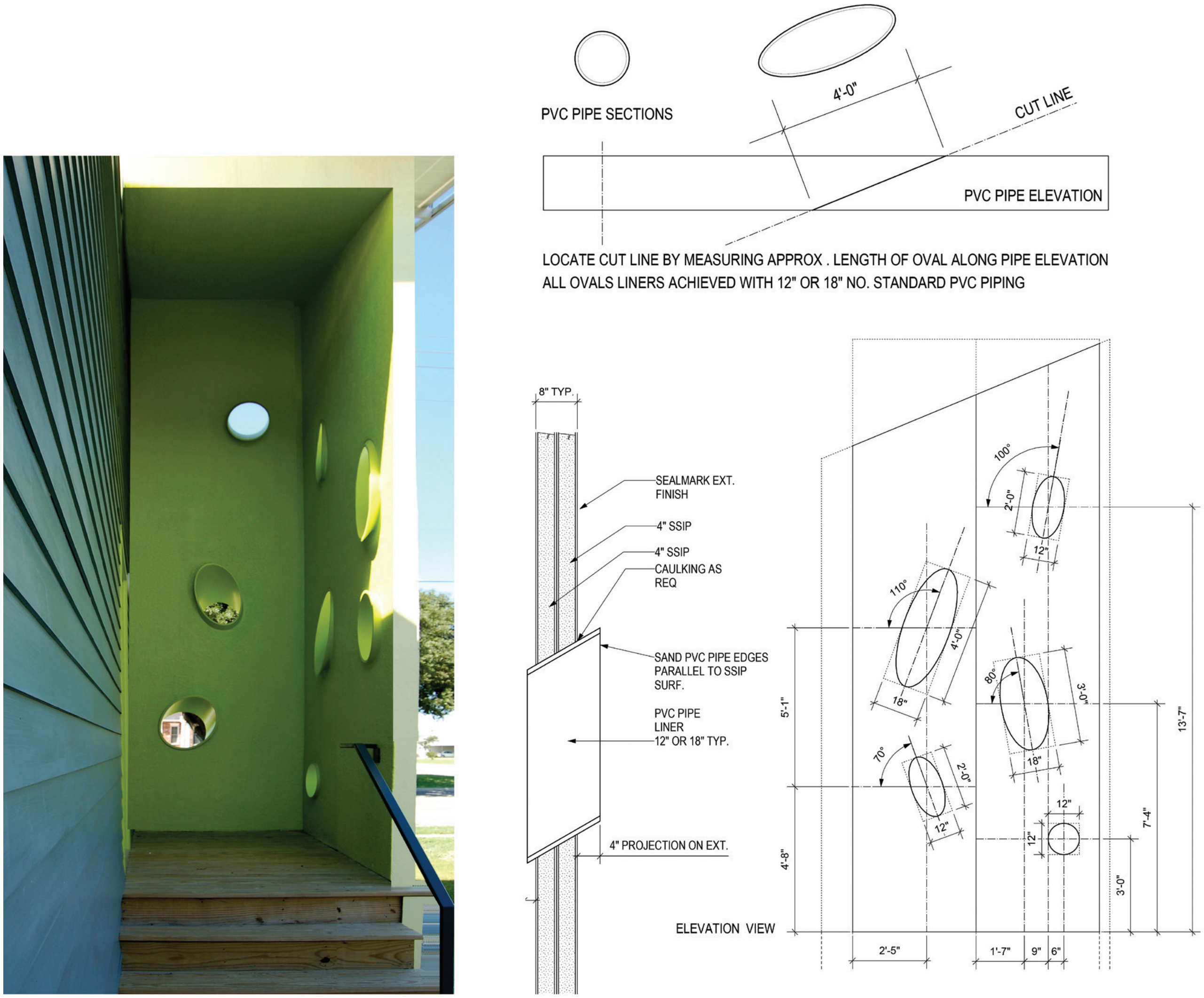
Far too often, students default to the use of oversized templates plotted from the computer as a means of translating imagined geometry to full-scale construction. In the mind of an unwitting designer whose primary facility is digital, the hurdle between representation and reality is simply resolved by printing shapes at a larger scale. The dialogue between artisan and object is lost in these cases, along with important lessons of tactility, material negotiation and gravity. Design-Build exercises provide students with necessary exposure to the satisfaction of solving real-world problems in the course of becoming well-rounded *Architects*. The following examples will describe specific solutions to obstacles of construction when computer-generated templates were not a viable solution.

**WATER IS LEVEL** : SunShower SSIP House

Early builders learned the indispensable skill of using water and gravity to find what is “level” with the earth. Contemporary spirit levels can be found on job sites of every scale and are based on the fundamental principle of liquid and gravity. Long clear tubing can still be found at hardware stores today, sold as “water-levels” among a myriad of more sophisticated instruments. Water was a means of leveling the foundations of the Egyptian pyramids nearly four thousand years ago. The ancient Egyptians dug extensive trenches and filled them with water to

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find a horizontal datum. The waterline would then be scored into the sides of the trenches as a guide for stones that later filled the excavation after the water was removed. In this way, the Egyptians were able to create level base foundations for their monumental pyramids.[1]

The simple concept of the water-as-level inspired a moment of epiphany in the forming of oval apertures for the SunShower SSIP House. This project was the result of a winning design competition entry for an off-grid disaster relief house that aspired to demonstrate innovative uses of Steel Structural Insulated Panels (SSIPs). The design of this prototype proposed porch walls that were punctuated by a series of ovals, lined with recycled PVC pipes, cut and inserted into the panels. These playful forms provide light and ventilation into the entry porch area without the need to frame conventional windows. The oval portals also minimized any loss of rigidity in the SSIP panels, showcasing the flexibility of this type of shell construction.

This seemingly straightforward design element proved to be a challenge when met with the reality of construction, exacerbated by a limited budget and limited access to the appropriate tools. As described in the Figure 1 drawings, oval sleeves were to be made from cylindrical PVC pipes of varying diameters, cut at an angle to produce the desired shape. The design of these ovals was effortless in the computer,

Figure 1: *(left)* Photo of the entry porch at the SunShower SSIP House with completed oval apertures. Photograph courtesy of Architects Judith Kinnard and Tiffany Lin. *(right)* Detailed drawings from the SunShower SSIP House construction drawing set. Oval apertures formed with recycled PVC pipes cut an angle.

as intersecting an angled plane with a cylindrical tube requires nothing more than a “boolean” command in Rhino. The digital tube could be “split” at the intersecting plane to expose an exact oval profile. In reality, however, the angled plane needed to slice a hefty PVC pipe would translate into an unrealistically long band saw, or chain saw, neither of which was available. Cutting the pipes with a jigsaw seemed to be the most feasible (and most safe) solution, but finding the guideline for each cut became a curious academic challenge. The obvious, digitally-driven solution would have been to computer model each pipe with its exact oval profile, “unroll” the ruled surface of the cylinder, and plot a full scale paper template to be wrapped around the actual pipe to be cut. This would have required an exorbitant amount of time and plotter paper as there were sixteen unique oval profiles forming the eight proposed apertures. After frustrating trials involving strings, ribbons, and industrial-sized rubber bands, the solution was ultimately found by a craftsman, to whom the basic principle of the water-level was innate. If the PVC pipes were submerged into a vessel filled with water, the outline of each oval could be found by simply angling the pipe as needed and marking the waterline. Using this principle, but not literally using water, a temporary frame was built to both hold pipes at an angle and serve as a horizontal guide for swinging a straight edge around each cylinder to mark oval guidelines (Figure 2).

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The completion of this project involved various other problem-solving efforts that could not have been imagined during its design phases. The SunShower SSIP House received an AIA New Orleans Honor Award in 2012 with the following jury comment: *“This is an elegant solution to the challenge of creating low cost housing. The execution and use of materials are both clever and thoughtfully composed. Its beauty lies in its restraint.”* [2]

**PAPER STRETCHES** : URBANbuild House 7

URBANbuild is a Design-Build program at the Tulane School of Architecture in which teams of students take on the design and construction of prototypical structures for New Orleans’ neighborhoods. The program is an educational collaboration of individuals, organizations, and businesses committed to revitalizing New Orleans’ rich cultural and architectural heritage. Students develop as designers with a deep understanding and commitment to the built urban environment.[3]

Figure 2: *(left)* Marking the profile of an oval onto a cylindrical PVC pipe, using the concept of a water-line. *(right)* PVC pipes cut into oval sleeves to be inserted into SSIP panels to create portals for light, air and view.

Architecture students are the greatest assets in Design-Build projects as they possess not only the enthusiasm for realizing a design vision but the powerful work ethic that allows for the testing of customized details, otherwise not possible in low-cost construction. In URBANbuild House 7, TSA students reconsidered the familiar configuration of ship-lapped siding seen in most traditional, residential projects in New Orleans. They proposed facades that were patterned with a gradient effect by varying the vertical spacing between each piece of horizontal siding (Figure 3). In the design phases, a uniform gradient is easily controlled within computer parameters, but orchestrating the installation of such a proposal became an interesting design challenge.

At the onset of the cladding process, students eagerly plotted out each elevation drawing at full scale with the intention of fastening them to the actual façades to 3
guide installation. The team quickly learned an important lesson about the effects of



Figure 3: *(top)* Elevation drawings of UrbanBuild House 7. A horizontal facade gradient is created by varying the spaces between ship-lapped siding.

*(bottom)* Photograph of the completed street facade. UrbanBuild House 7 was designed and built by architecture students under the direction of Architect Byron Mouton, Professor of Practice at the Tulane School of Architecture.

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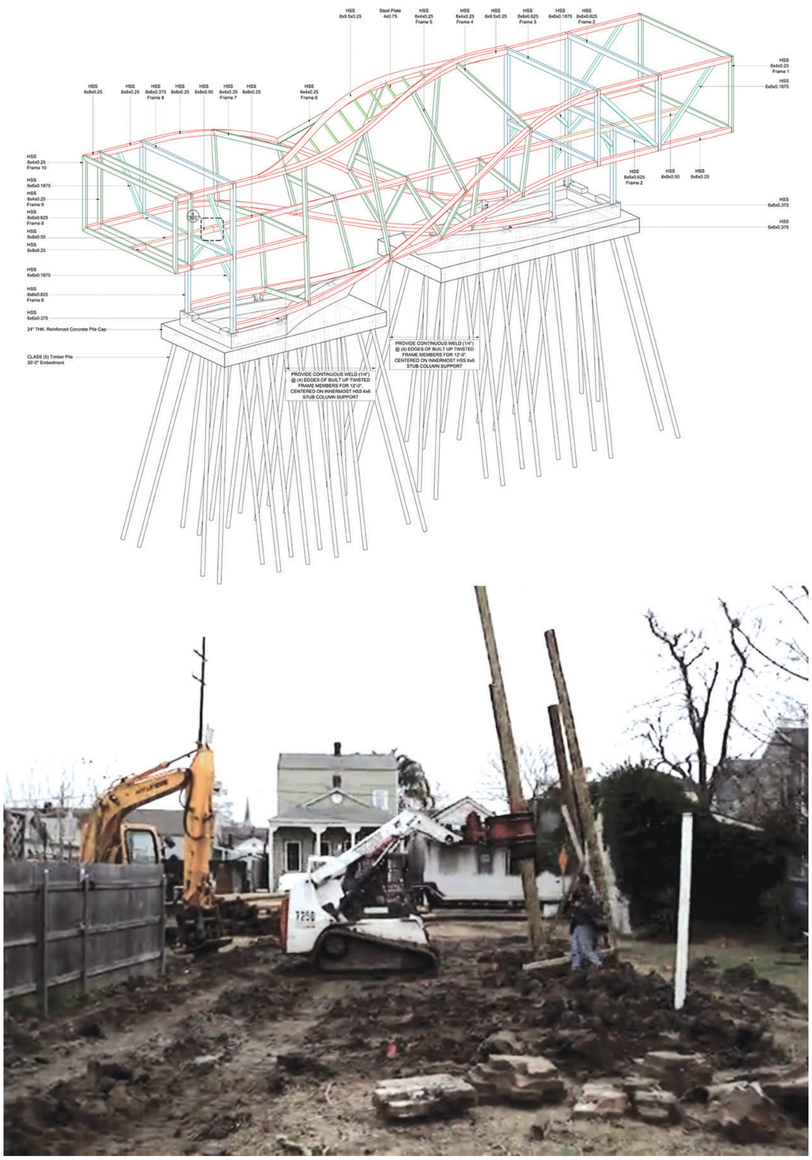
Figure 4: *(top)* The “Hexadecastick” invented by craftsman, Sam Richards.

*(middle)* Laser cut templates used as a spacers for installation of gradient siding.

*(bottom)* An UrbanBuild student using a custom cedar template to mark the location of shiplap siding to create a gradient effect.



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humidity as the paper templates began to stretch and sag with their own self-weight. When measuring and marking each piece of siding proved to be impractical, TSA shop director and craftsman, Sam Richards, offered a solution by whittling a custom tool he later coined as the “hexadecastick” (Figure 4, top). The hexadecastick was a double-ended and multifaceted story-pole that registered all sixteen dimensions necessary to generate the proposed gradient siding effect. Notches on this stick could be pushed up against each piece of siding to mark the location of a subsequent piece. Ultimately, one unique handmade tool was not enough to be shared, but inspired the design of triple-edged jigs that were later used on site with success. Each jig was laser-cut from a cedar plank and inscribed with its relative dimension on each edge (Figure 4). The set of jigs were cleverly assembled on a keychain for ease of coordination and distributed to every member of the siding installation team to ensure consistency.

The quality of the URBANbuild House 7 facades is a testament to the effect of the rhythmic horizontal siding, diminishing in height as the building meets the ground and varying in pattern at each vertical section. This project received an AIA New Orleans Merit Award in 2013.

Figure 5: *(top)* A structural drawing by AEDS that describes the unique configuration of battered piles on pile caps. The foundation supports an irregular steel frame which touches down in only two locations.

*(bottom)* A construction photo showing contractors approximating the 10-degree angled piles with a crude measuring device fashioned from 2x4s. This image is a still from a video that can be found on the AEDS Blog: http://digit-all.net/Blog

*"Students working together to resolve the coordination of hundreds of parts and pieces, the development of a shared vision, adherence to a schedule and budget - are demanded to nurture skills of diplomacy and collaboration if they wish to achieve project completion. They quickly realize that they are each independently accountable for portions of a group project, they realize that others might actually be better at certain tasks, and the construction site is often a great leveling field. The great designers are humbled, the quiet detailers are treasured, teamwork is necessitated and project managers are born. Students become professionals."* [4] Byron Mouton

**PRECISION IS RELATIVE** : J-House

The J-House is an extraordinary personal project of Ammar Eloueini, principal of Ammar Eloueini Digit-all Studio (AEDS) and Professor of Architecture at Tulane University. The award-winning work of AEDS explores complex geometries that cannot be conceived or executed without the agency of sophisticated computer software and digital manufacturing techniques. Students enrolled in Professor Eloueini's studios often engage in design proposals that study variegated geometry, parametric modeling and digital fabrication.

*"Ammar Eloueini was among the first to begin his creative exploration with a grounded education in CNC manufacturing processes. Beginning with simple principles of two-dimensional templates and building to more complex three-dimensional compound joinery; he has developed a personal signature, a technical expertise and new formal and material sensibilities that is coherent and rigorous… Ammar is not experimenting and relying on happy accidents as many designers were a decade ago. He is among a new generation of architects who are building a repertoire of linked design and fabrication techniques that are leading towards a very provocative, personal and innovative architectural and spatial vocabulary."* [5] Gregg Lynn

The J-House is composed of two spatial tubes, each rotated 90 degrees to form a twist in mid-air. The formal choreography of this design creates a minimal footprint, allowing for space underneath the house to be occupiable and meet flood requirements prescribed by zoning. In order to accommodate the unique structural needs of the design, Buro Happold Engineering generated a set of three-dimensional structural drawings and detailed specifications to describe the foundation condition.

*"Each pile cap, including self weight, exerts 140 kips of vertical force into the piles. Therefore (16) Class (9) piles at a 10 degree batter angle are required for each pile cap to resist vertical loading."* [6] Buro Happold Engineering

The two images in Figure 5 show a striking juxtaposition between an intricate, three-dimensional structural drawing and a photo from the construction site. This latter image is clipped from a video that documents the pile-driving process for the J-House. In this recording, one can appreciate the relative precision *(or imprecision)* that transpires during the actual construction of most buildings. To reference the 10-degree angle specified by renowned structural engineers, a construction crewmember fashioned a life-sized angle from 2x4s to be held next to each pile as it is driven into unsettled Earth. He waves his hand left and right signaling directions to the Bobcat operator who maneuvers a cumbersome pile, trying to approximate the 10-degree angle. The reality of construction at full-scale requires a high tolerance as the variables involved (building materials, the hand, the eye, the Earth) are all unexacting. As evidenced in this set of images, the mud and lumps of a construction site are very different from the pristine "white space" of a computer. This realization is a critical lesson for architecture students who are genuinely interested in the craft of building. It can liberate students from the anxiety of designing in the computer where one could zoom in endlessly to ensure two elements meet at a perfect point in anti-gravitational, virtual space. The reality of construction should be acknowledged and celebrated in the process of translating digitally conceived forms into palpable physical artifacts.

As exemplified in the J-House, the intersection of knowledge between the designer, the engineer, and the builders all interact to cull complex forms from the digital realm into physical reality. Architecture's manifestation should ultimately amplify the design intent and applaud the ingenuity of its conception *and* execution.

## CONCLUSION

*"We're in a post-conceptual era where it's really the artist's idea and vision that are prized rather than the ability to master the crafts that support the work. Today, our understanding of an artist is closer to a philosopher than to a craftsman."* [7] Jeffrey Deitch

This criticism by Deitch, a curator and former Director of MOCA, pertains to fine art yet has resounding relevance in contemporary architectural discourse. Design-Build exercises are more necessary in current architecture curricula than ever before, as they provide the necessary bridge between the digital and physical world. Understanding the translation from design to construction requires another set of instincts that can often liberate students from the perfect scaleless space of a computer. Only by extending the design process into the techniques of making can student designs be embodied with an artistry that allows built form to transcend its representation. The Vitruvian architectural principles of *"Firmitas, Utilitas, and Venustas"* are evermore true. The difference between art and architecture, one could argue, is competency in negotiating design intent with materials and gravity in physical space. Architecture without strength or utility is art.

## ENDNOTES

1. Root, Mary. "Egyptian Surveying Tools." Backsights Magazine published by Surveyors Historical Society. Web. This article describes various methods of measuring and surveying used by ancient Egyptians.
2. A quote from a juror of the AIA New Orleans awards committee. The SunShower SSIP House by Judith Kinnard and Tiffany Lin received an AIA New Orleans Merit Award in 2012.
3. URBANbuild is a Design-Build program at the Tulane School of Architecture. This description is paraphrased from the URBANbuild website: http://www.tulaneurbanbuild.com
4. Mouton, Byron. Personal interview. 10 Sept. 2014. Mouton is the Director of UrbanBuild at the Tulane School of Architecture who has led over a dozen Design-Build studios including the UrbanBuild House 7.
5. A 2006 quote from Greg Lynn describing the work of Ammar Eloueini, excerpted from the AEDS website: http://www.digit-all.net/profile
6. Buro Happold Engineering. Excerpt from the structural specifications for the J-House describing the battered piles, courtesy of AEDS | Ammar Eloueini.
7. Chan, Jane and Thomas, Kerry, eds. Book of Research on Creativity. Northampton, MA: Edward Elgar Publishing Limited, 2013. p.468. Quote from Jeffrey Dietch, a gallery owner in New York who later became the Director of the Museum of Contemporary Art, Los Angeles (MOCA) between 2010-2013. Dietch discusses the changing value of contemporary art in which many acclaimed artists have visions that are actually executed by teams of assistants rather than the artist themselves.
8. Vitruvious. The Ten Books on Architecture. New York: Dover Publications Inc., 1960. "Firmitas, Utilitas, and Venustas" are the well-know Vitruvian principles of structure, utility, and beauty, sometimes also translated as firmness, commodity and delight.

## ACKNOWLEDGEMENTS

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