Architecture + Structures: Ethics and Responsibilities in Academic Design/Build Studios

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Introduction

In a recent interview with Fred Bernstein for *Architectural Record*, published on February 2014, Rafael Viñoly, one of the most prolific architects of the modern age, made the following remark: *"It's a crisis for the profession. In the last twenty years, people have come into the field without knowing what construction is. In architecture, construction is the medium."* Viñoly later admitted that he recently "*made a lot of mistakes*" with his buildings in London, Vegas, and Manhattan and consequently criticized the current status of architectural education in falling behind the inquiry of constructive knowledge. Viñoly recalled that as a young architect he did rebar drawings. A notion that Chad Schwartz, in his book, citing Marco Frascari and Juhani Pallasmaa, pointed out to the disappearance of construction site apprenticeship in today's' architectural education which possibly resulted in the current crisis (Schwartz and Ford 2017). A year later, Piet Hein Eek, a famous Dutch designer, in an interview with Emma Tucker during the *Dutch Design Week* published in Dezeen on October 2015, said: *"Most architects are "not interested" in construction, most buildings are drawings filled in by engineers."* Eek added; "*many architects do little more than produce drawings and leave others to work out how to build them*."

Viñoly and Eek's recent remarks are a reminder to similar discourse, almost fifty years ago, that established a foundation for modern architectural education in the realm of construction. In 1964 Aris Konstantinidis said, *"Good architecture always starts with construction. Without construction, there is no architecture. Construction embodies materials and its use according to its properties, that is to say, stone imposes a different method of construction from iron or concrete."* One year later, in 1965, Edward Sekler, a renowned Austrian architectural historian, published his foundational essay entitled: *Structure, Construction, Tectonics* where he stated that "*through tectonics the architect may make visible, in a strong statement, that intensified kind of experience of reality which is the artist's domain – in our case the experience of forces related to forms in a building. Thus 'structure,' the intangible concept is realized through construction and given visual expression through tectonic."* Konstantinidis affirmed the impossible existence of architecture without constructive knowledge, while Sekler emphasized the role of the structure as the intangible concept in architecture where expressions become a product of understanding the relationship between forms and forces.

The Disconnect Between Structure, Construction, and the Design Studio

If Viñoly's remarks are true, and probably they are, a set of questions should be asked; what causes that disconnect between durable knowledge of construction and the design studio? How design educators overcome the reluctance and hesitation that still exists in students regarding constructive knowledge? Where does the question of constructive inquiry fall within performance-based architecture? With the ever-increasing specialization in performative demands, how do educators address construction as the art of building within today's design studio? And finally, does academic design/build studios address such disconnect?

To begin addressing those inquiries, it is necessary to return again to Eduard Sekler, who in 1965 distinguished between three critical terms that are still somewhat misplaced today; structure, construction, and tectonics. In his foundational article, Sekler elaborated on the relationship between the three terms as they referred to ultimately reaching an expressive "truth" in the making of architecture. A truth that demonstrates the architect's ethical imperative and is equally concerned with the relationship between forces, forms, and materials (Sekler 1965). The relationship between structure, construction and tectonics are indeed critical to achieving true expressive and timeless work of architecture. The relationship between architecture and structure in particular was noted by Don Watson, who stated that Louis Kahn would often refer to his colleague, the structural engineer, August Komendant, as an "equal partner" (Watson 1997). Theirs was an exemplary relationship that began in 1956 and lasted nearly two decades, Komendant at that time was known for his outstanding pre-stressed concrete work, which Kahn found a good fit for his architectural forms and ideas. Collaboration between architects and engineers resulting in masterpieces of architecture in the twentieth century dates back at least to the 1950s, In his book, *18 Years with Architect Louis I. Kahn*, Komendant reproduced a letter that Kahn wrote to the American Institute of Architects in 1973, recommending that Komendant be honored with the AIA's Allied Professions Medal for "*inspiring and influencing the architectural profession*" (letter from Louis Kahn to Eero Saarinen, March 23, 1959) (Komendant 1975). That relationship is one example of how closely architects and engineers should work, and how the design process can be inspired by both disciplines.

More recently, Catherine Wetzel reiterated that when architecture schools integrate design and structures in their curriculums, they increase the working vocabulary and expertise of students, as well as the potential for innovative collaborations in the academy and the profession (Wetzel 2012). Bruce Wrightsman also emphasized the importance of integrating structural knowledge in design/build studio by referring to it as "durable knowledge" which students gain by departing from the traditional pen and paper structural education curriculum (Wrightsman 2014). As design/build education began to take a critical part in architectural education, the role of structural knowledge integration, simulation, and testing to academic design/build are of vital importance in order to address two fundamental outcomes; the first is balancing the deliverables between the physical product (project) and the academic learning objectives (process), the second is related to assurance in safety, liabilities, and responsibilities. Students, faculty, university administrators, and beneficiary community members demand a form of safety and risk mitigation that no matter how elaborate and expressive a design/build project is, no one (student) will get hurt. It only takes one accident in a design/build studio to shut down the entire initiative, thereby resulting in the loss of a tremendous educational opportunity for an architecture school.

In light of Sekler's work and under the shadow of Kahn and Komendant's relationship, the presented design/build case studies have attempted to investigate the relationship between structure, construction, and tectonics. That is through two projects in design/build studios within the academic context which focused extensively on collaborating with structural engineers. In the following section, a critical description of the experiments in the two design/build studios, which were conceived at non-NAAB, accredited undergraduate four-year programs in architecture in two different countries (Turkey and the United States respectively) is presented. The first is an academic-based collaboration and the second is a practice-based collaboration. Both studios engaged students in designing and building projects from conception to realization, working with real clients, city officials and industry consultants.

Fig. 1: Physical Models and computer simulation were used in the coordination sessions with structural engineers

'Academic-based' Structural Knowledge Integration

The first design/build studio led by the author at one of the top-ranked Turkish universities was conceived as an experimental study that implemented careful observation and recording, followed by a qualitative opinion solicitation from the project participants to document their lived experiences. The physical product (The Kilim Project) and the process were compared to both historical and modern precedents. The project followed a traditional design process, starting with schematic design, refinement, and modification, and finally construction. Emphasis on collaborating with structural engineers was implemented throughout the process, and a faculty member from the structural engineering department collaborated with the studio from the beginning (figure1). Moreover, the project site happened to be in a seismic zone and therefore required a close consideration of issues related to stability and lateral forces. Literature suggests that the role of structural design integration in architectural education, specifically in seismically active regions such as Central Turkey is crucial (Ünay and Özmen 2006).

The setting of the design/build studio was conceived as a hybrid environment that was constructed from a building technology laboratory, an indoor fabricating facility (wood shop), and an outdoor assembly/testing yard. Although the workload was divided among students' groups, team leaders, and project managers, everyone was involved in every aspect of the project at some point. Since the project started with nearly no funding, students were asked to seek sponsorships and to raise funds and in-kind donations of discarded materials from vendors. Wooden shipping pallets were among the only materials donated, and a strategy for disassembling and sourcing structural members was developed. However, after consulting with the academic structural engineer, it became apparent that continuous framing members were essential to the structural stability and integrity of the project. At this point, the university provided a small amount of funding to purchase the appropriate structural framing members. After the completion of the project, a reflection phase consisted of two stages was performed. First, the students visited the Finnish pavilion at the Venice Biennale in 2014, which to their surprise shared similar aspects of their project. Second, a post-project questionnaire was administered to collect and record their lived experience.

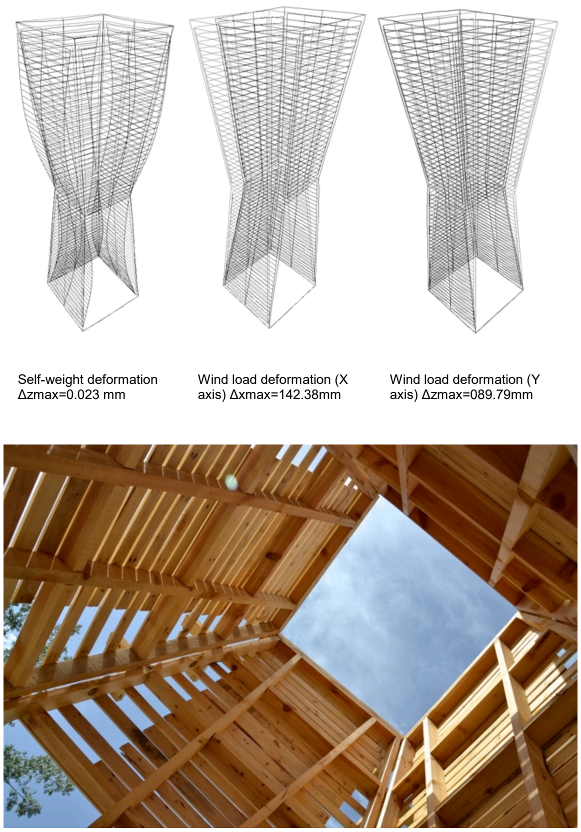

Fig. 2: Displacement Analysis for the Kilim project and a view from inside one of the two observation towers

Since the design/build studio was the first of its kind to be established at the Turkish university, concerns regarding students' safety were raised by the university administrators, who required a detailed assessment of the project's structural integrity. Demands were made clear that the studio must test the proposed design before the actual construction began. Computer simulated structural analyses were performed at the design development phase of the project to determine the stability of the proposed structure and to understand its performance under its weight, seismic, and wind loads. While the proposed framing and skin systems were initially found to be acceptable, the connections between the upper and lower modules and the whole structure to the ground were critical (figure 2). A permanent foundation was not suitable, since the two observation towers of twenty-five feet high each needed to be dismantled and relocated to different locations. A temporary foundation base larger than each tower's footprint was required to overcome the overturning effect of the structure. The exterior wooden skin attached to the structural frame could only carry its weight. The wooden frame, therefore, was subject to deformation, and steel connectors were needed to ensure stability. Also, a cross-bracing steel wire was determined to be sufficient for establishing rigidity, and only the sides of the structure subject to torsion needed additional bracing. Knee-bracing for the modules were recommended for providing rigid connections but couldn't be justified to the historical precedents that inspired the project. Continuous framing members were required, but the use of spliced short members salvaged from the shipping pallets was not suitable. In addition to scaled physical models, computer simulations of the towers' behavior were conducted. The structural analysis of the "Kilim Towers" was performed using SAP2000 software that considered the closest real dimensions and material characteristics. There were two load conditions: the self-weight of the frame and wind forces (considered according to Turkish Structural Analysis Codes). As revealed by the initial results, no critical conditions were found. Two overlapping timber members (50x100mm) were suitable for the main framework, but they had to be held firmly by steel connectors. The simulation models revealed deformation of the shape of the frame due to gravity and wind forces, respectively, as seen in (Figure 3). Additional details about the inaugural design/build studio were elaborated in details in a previous publication (Ali 2016).

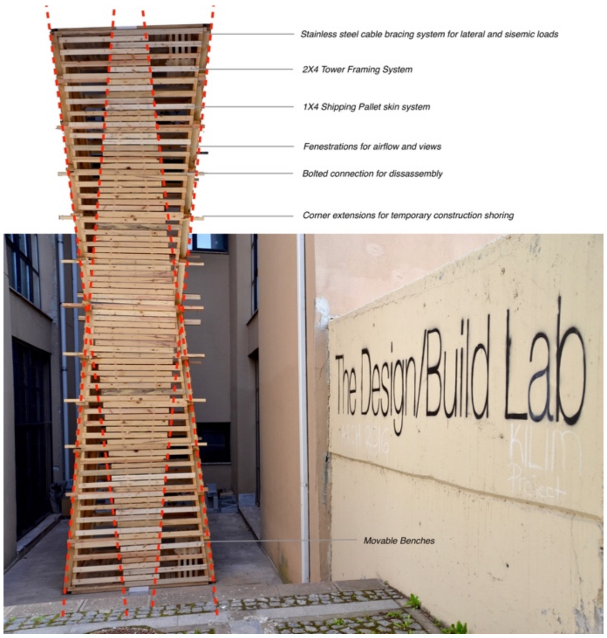

Fig. 3. The Design/Build Lab Assembly Yard with the steel Bracing Diagram

***'Practice-based'* Structural Knowledge Integration**

The second design/build studio also led by the author was conceived at a large state university in the United States and was part of a high-impact interdisciplinary service-learning initiative that focused on community projects. The interdisciplinary studio involved faculty and students from architecture, landscape architecture, and construction science who collaboratively developed projects from conception to realization, demonstrating the impact of design on their immediate local community. Students were immersed in an in-depth, hands-on, learning experience that was based on active participation from students and the peer-learning principals of funding, design, engineering, management, fabrication, production planning and construction. The overarching goal was for the students to be able to understand the value that other disciplines bring to the teamwork and learn to think as collaborators. The selected site which was located in the neighboring city of the University which included several properties that remained underdeveloped or in need of rehabilitation. The reclamation of these properties could potentially bring additional economic activities to the community as well as provide ecological and social benefits. The selected project site remained undeveloped for fourteen years except for some public parking, which was used by nearby churches. Development on this site needed to consider the site's history, culture, and its impact on the community. The design/build studio proposed developing a permanent farmers' market structure on the site to replace a temporary weekend farmer's market, which was held every Saturday in a parking lot. Temporary tables and tents made up the farmers' market, which is why a permanent, functional, and an aesthetically appealing structure was proposed. It was agreed that both the sellers from the current farmers' market and new vendors would move to the new location if an appropriate, functional, and attractive structure were built. Also, a visitor's center for the city was proposed for the eastern side of the site (Dvorak and Ali 2016).

The site for the design/build project was gifted by a private foundation to the city in 2001 under the condition, that it must be developed for the benefit of the public. The site included two of the oldest and historical buildings in the city, a house originally built in 1872 and a separate carriage house. The project was selected for funding by the University's College of Architecture's real projects initiative and achieved three major goals: First, a student design competition was offered to design a visitor center; second, a masterplan for the entire historic site was developed by the students; and third, a modular farmers' market was designed and built for the city's Farmers Association. During the Fall 2015 semester, the first two phases of the project were launched: a student's design competition for a visitor's center was announced and funded by the private foundation who gifted the site to the city. Next, graduate-level landscape architecture students conducted research and data collection through numerous meetings with the city and the private foundation members. During Spring 2016, and while the masterplan document was refined by the landscape architecture students, the design/build studio launched the design and construction of the modular farmers' market. The spring semester was divided into six weeks of design and six weeks of building. Architecture and construction students worked together in collaboration with the landscape architecture students in designing, scheduling, budgeting, and constructing the modular market at the University's fabrication facility. Input from landscape architecture students, faculty, city officials, and a local engineering firm was coordinated throughout the twelve weeks. Construction documents were approved by the city, and a building permit was filed and obtained. The modular farmers' market was named "The Tree," which was described as an autonomous shading structure with a multilayered roof that stemmed from a cluster of four columns. It is the prototype for a proposed series of identical sections that, when placed side by side, create a row of farmers' market stalls. Each section, or "tree," provides approximately one hundred square foot of shaded stall (8x12 feet of vendor space) supported by four 6x6 inch posts (Figure 4).

Figure 2: Farmers Market Structural Framing Plan, and a view after the prototype completion

Since the design/build studio acted as the 'project architect,' the city required a licensed engineer to approve and stamp the drawings to move forward with the plan's approval and the building permit process. Through the efforts of the author, a local engineering firm agreed to provide sealed structural drawings and consultation as 'pro-bono' service. The studio's students collaborated with the structural engineering firm from the beginning, and several charettes were conducted to inform their design decisions (figure 5). Contrary to the Turkish design/build experiment, no computer simulations were performed to determine the appropriate sizing and connection methods of the structure. Instead, simple calculations and practical experience of the structural engineers informed the design of the pavilion units' structural members. As a result, a slightly higher factor of safety was apparent in the sizing of the structural members. For example, each cluster of columns contained 4 members that were specified as 6”x6” instead of 4”x4”. The students, however, redesigned the ultimate height of the market roof and the layering logic of the roofing elements, so that the overall proportions remained elegant and harmonized the transition from column to roof despite the relative bulkiness of materials.

Fig. 3: Students in Collaborative Session with the practicing structural Engineer

The Design/Build Studio and the University

The two models presented in this paper offer two distinct perspectives on balancing both the product and the process deliverables. Also, issues related to risk and legal responsibilities that exist in the majority of design/build studios today drastically influence the mode of collaboration between architecture students and engineers. In the ‘*academic-based’* case, a safety protocol was established with the University based on computer modeling and simulations, which were performed in collaboration with a faculty member in structural engineering, while safety training was delivered to students both before and during construction. The ‘*practice-based’* case, however, relied on the knowledge and the practical experience of a licensed structural engineer. For example, the foundation and members connections were determined and drawn according to the engineer’s experience as seen in (figure 6). Safety training was performed according to the required University standards before using the fabrication facilities. In the latter case, students were insured as long as the work proceeded on the University’s property, but once the assembly of the project started off-campus, additional insurance was required.

In the two experiments, both the structural engineering collaborators had a Professional Engineers license (P.E.s). Although all licensed Structural Engineers (S.E.s) are also licensed Professional Engineers, all Professional Engineers are not licensed Structural Engineers. In fact, only a small fraction of Professional Engineers passes the state requirements that allow Professional Engineers to be licensed Structural Engineers. Both experiments were effective regarding learning and goals achieved, and it’s difficult to suggest one model over to the other. However, exposing students to real-world coordination with consultants to produce a set of construction documents and obtaining a building permit was daunting, but nevertheless provided an unmatched learning opportunity. Both projects offered an added-value to the typical design/build studios by allowing architecture students to move from ‘*engineers will figure out how the project will stand for us’* to ‘*the dialogue with engineers enhanced our design decisio*ns.' As stated by Ted Cavanagh, the transformation of design/build pedagogy from learning by doing to learning by experimenting increases the research agenda, and therefore closes the gap between abstract and reality (Cavanagh 2012). In addition, the understanding of the relationship between structure, construction, and tectonics is expressed through making. Wither collaborating with an academic or professional consultant, a raised level of responsibility is instilled in the students of architecture. From the presented models, structural integration professionally enhanced the experimenting process and added an ethical dimension to the design process.

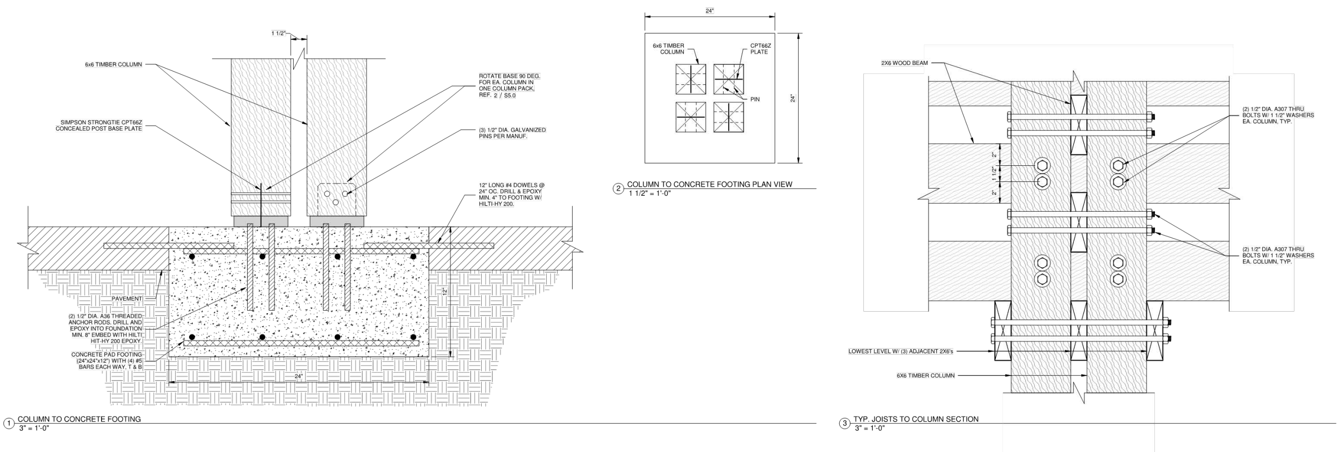

Fig. 4: The Modular Farmers Market Structural Framing Connection and Details

Conclusion

There exist a complex renegotiation of constructive relationships surrounding structure, enclosure, and performance that are reshaping the role that construction plays in the making of architecture. It could be argued that the structural and formal expression that articulated the regulating lines and tectonic expression of a work of architecture has steadily given way to performance-driven demands emerging from evolving codes and regulations. Balancing the need for delivering a completed design/build project and the forms of learning exploration within the academic design/build process requires orchestration and careful coordination between the different project stakeholders. Based on the two-presented experiments, the balance is highly achievable when paying careful attention to the fundamental relationship between structure and architecture. In both models, the integration of either the academic or the practicing engineer assured the clients regarding issues of risk, safety, and responsibility. Although that assurance may seem to be prioritized over the learning objectives, the reality is that it also allowed the students to gain substantial knowledge in coordination, refining and constructing with a focus on tectonic expressions.

The collaborative experiments with both academic-based and practice-based structural engineers challenged issues of liability, shared risk, and accountability in real projects built by unlicensed and inexperienced college students. However, the value of collaborating with structural engineers at the early stages of both projects differs from academic to practice settings. While the academic collaborative case allowed a substantial room for unconventional discoveries and further design exploration, the practice-based collaborative case involved real-world problems and liability requirements associated with licensure. Structural simulations were utilized within the academic setting, and design decisions mostly were based on computer programs and physical modeling. In the practice-based settings, intuition coupled with experience mainly influenced the major architectural and structural design decisions. The impacts of the two different collaborative models confronted both students and educators with the critical knowledge needed to further their efficiency and effectiveness in the practice. While the interdisciplinary nature of collaboration with structural engineers enhanced both models, challenges in addressing the relationship between structure and construction were expressed differently through the final built work. Here the question of tectonic expressions was distinctly explored through each model.

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