Design-Build: Multi-Disciplinary Learning Beyond The University

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The Naramata Roof Structure and the Huilo-Huilo Viewing Platform are multidisciplinary design-build projects that explore applications of digital wood fabrication technologies. Material studies, structural considerations, and an understanding of assembly sequences under conditions particular to each project are central to the development and critical review of the design-build projects. Both projects were integrated into the curriculum of the Master of Architecture program at the University of British Columbia, where they provided opportunities for students, faculty, and researchers to participate in collaborative design research that places architectural design and building in a broader cultural context. Through inter-departmental research within the university as well as international collaborations and the active involvement of industry and clients, the projects situate design education equally in research and concept studies and in the realities of architectural production and building.

The Naramata Roof Structure and the Huilo-Huilo Viewing Platform projects are part of a comprehensive design research approach that combines studies on context, material, structure, and technology with built form. This approach enables students to critically review the methodologies and significance of digital fabrication and integrated design and their interdependencies with local and global contexts. The design-build projects we describe in this paper illustrate several ways that regionally specific applications of digital wood fabrication technologies enhance the learning experience: First, the focus on regionally specific application of wood fabrication technologies introduces students to the discourse on regionalism and on digital media and fabrication technologies. Second, the collaborative projects introduce students to multi-disciplinary research, design, and building methods that highlight the wide range of influences on the design and building process. Third, design projects are extended beyond conceptual research and design studies to include the design development, fabrication, and building process with detailed material studies, structural explorations, and the work at the building site.

PROJECT DESCRIPTIONS

Naramata Roof Structure, 2007

Figure 1. Naramata Roof Structure – west elevation

The Naramata Roof is located on the east side of Lake Okanagan on a small organic farm in Naramata, B.C. The Design-Build project explored CNC wood fabrication technologies for the design, fabrication, and construction of a small roof structure for farm use. Students participated in all phases of the project from May to September 2007. The work in the course included research on wood properties, wood fabrication, a site survey and site preparation, initial design studies, design development, preparation of fabrication data, fabrication of project components, assembly at the site, and a project documentation. Work on the project was conducted in collaboration with a software provider, a fabricator, a structural engineer, and a wood fabrication consultant. Structurlam Ltd. in Penticton, B.C. provided access to wood fabrication facilities with a Hundegger K2 4-axis beam processor and staff support for the fabrication of roof components. Cadwork Inc. made digital wood fabrication software available for the design and the preparation of fabrication data the roof structure. Affordable building materials were provided by a local lumber store. Throughout the design process, the design team worked in collaboration with a structural engineer to coordinate and incorporate structural considerations, and with a wood scientist and fabricator to develop digital models and data for the fabrication of the roof structure.

Figure 2. Folded roofscape from above

The roof structure is based on an independent spatial and structural unit that is replicated and reversed, modulating as it responds to site and environmental considerations. The roof is designed as a folded plate structure with a diaphragm that contributes to the structure's lateral stability. Sloping beam members that alternate between higher and lower placements span between support trusses. Two trusses span between exiting foundations and provide lateral stability. Additional diagonals within the interior space assisted with lateral stability in the direction of the roof span.

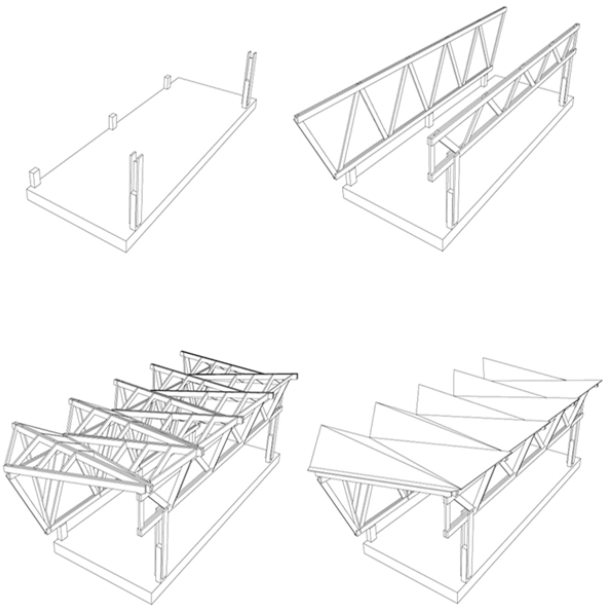

Figure 3. Assembly sequence

Huilo-Huilo Viewing Platform, 2008

Figure 4. North elevation

The Huilo-Huilo Viewing Platform, located at the Huilo-Huilo Nature Reserve near Neltume in southern Chile, was built in collaboration with the Universidad Mayor in Temuco, Chile. Placed on a sloping site, the viewing platform will be connected to an elevated boardwalk that runs through the park. The perforated curved wall of the viewing platform protects visitors against the northern sun. From the north, the project presents itself as a curved wall with a descending fold created by the interlocking members. Depending on the position of the sun during the day, the project's appearance changes from an opaque wall to a structure that reveals its layered configuration.

Figure 5. South elevation

Developed as a 3-dimensional curved deep bending member with cantilevers supporting the ascending viewing platform, the project is designed with spatially and structurally interlocking components. Structural loads from the stepped platform are transferred into the interlocking members of the perforated 'skin' on both sides, providing moment resistance to the platform loads. The placement of the cantilevered beams for the viewing platform is alternated with the vertical 'skin' members as well as coordinated with the diagonals of the curved truss. Vertical members on both sides of the structure are designed to transfer tension and compression from the cantilevered beams into the curved truss.

The perforated surface also provides a tension element for the truss. This ability of the 'skin' to carry tension loads allows the main truss joints to transfer only compression loads, thereby facilitating the design and fabrication of the wood-to-wood connections. Forces in the curved truss are then transferred into three small concrete foundation walls placed in radial configuration. The curved configuration of the truss element helps in resisting overturning loads from the cantilevered walkway. All components of the project were fabricated on a 5-axis CNC beam processor available both in Canada and in Chile.

Figure 6. Curved truss + interlocking wall members

Figure 7. Integrated cantilevered platform supports

INTEGRATION OF DESIGN-BUILD PROJECTS INTO THE ARCHITECTURE CURRICULUM

A comprehensive approach to ecological design makes interdependencies between a broad, multi-

disciplinary research approach and collaborative design and construction methods essential, primary references for design-build projects are discussed here in separate but related concepts to illustrate implications for design education.

Regionalism and Technology

The Naramata Roof Structure project engaged in the discourse of regional applications of digital wood fabrication technologies primarily through studies of local conditions at the site and availability building materials and fabrication technologies in British Columbia. The seminar and design-build courses for the Huilo-Huilo Viewing Platform extended the discourse by broadening the research to contribution of global technological developments to regionally specific design and building in a global context. As a theoretical basis for the research and design studies, students were introduced to a broad overview of concepts of regionalism and a range of discussions on digital fabrication technologies. Throughout the project, concept explorations, design development, to translations of design ideas into building were vetted through multi-disciplinary collaborations with structural engineers, fabrication consultants, construction workers, clients, and providers of building materials both in Canada and Chile. Introductions to and work with digital wood fabrication technology in Canada and Chile highlighted differences in the approach to the use of similar technologies in the two countries. The work with consultants and local collaborators in Canada and Chile introduced the students to cultural distinctions on the design, fabrication, and building process.

The design-build courses for the Naramata Roof Structure and the Huilo-Huilo Viewing Platform are designed to foreground design and building process as formation. This comprehensive approach that acknowledges a wide range of influences on design and building is reflected in the focus and structure of the design-build seminars where digital wood fabrication projects are related to an extended definition of ecology that expands the scope of design beyond material, structure, and types of construction to broader cultural, social, and environmental considerations. Design particular to local conditions and the responsiveness of the design and building process to the specific context of a project are explored and reviewed. The projects are guided by an ecological design approach that emphasizes interdependency between design methods and their particular context in material science, economy, and culture. Thus, context-specific material expression and built form become significant references for design research and education, and modes of design and production such as digital media and fabrication technologies then play a central role in design education grounded in ecology.

Regional building cultures today are a result of local and global influences. Concepts of place are a statement about attitude to geography, history and resources, and particular characteristics of a region are as much a reflection of local environmental conditions as a reflection of extended cultural context. The use of locally available technology is central to regionally specific building, material applications, and building methods. In our design-build projects, applications of digital design and fabrication technologies, that are available due to developments specific to local economies and building traditions, are understood as responses to regional conditions. The design, fabrication, and assembly process of the Naramata Roof Structure project and the Huilo-Huilo Viewing Platform are a result of the negotiation of globally available technologies and local social, economic, and environmental circumstances and building traditions.

The courses and projects provide a learning environment that introduces students to a multi-disciplinary collaborative design approach and extends the conceptual discourse and design explorations typical of architecture programs to the realities of local building applications. Both courses provide students with the conceptual understanding, media skills, and practical experience as a basis for a comprehensive approach to ecological design and building. Similarly, the focus on regionally specific applications of digital wood fabrication technologies grounds the projects in the discourse on regionalism and studies on the potential of digital media and fabrication technologies.

Course Structure and Collaboration

The organization of the design-build courses reflects the focus on multi-disciplinary collaborative approach to ecological design. The Naramata Roof Structure project was designed as a one-term seminar. The collaborative work included research and

design sessions, regular meetings with engineering and wood fabrication consultants, site visits to conduct a site survey and to meet with future users of the roof, the preparation of the construction site, participation in the fabrication of roof components, and the assembly of the roof structure at the site. Introductions to wood fabrication software and the use of a CNC Beam Processor were also significant for the approach to the course. As a group design and building project, exchange and interaction between members of the research team were also central contributing factors. Quality of design and building depend directly on the skills of each participant. Coordination of abilities and interests becomes an important factor in the group collaboration. Ultimately, the use of technology and materials and the quality of the execution of the design and building phases depend on the ability to coordinate and incorporate available resources.

The Huilo-Huilo Viewing Platform project was organized in two consecutive graduate courses that foreground the multi-disciplinary and collaborative nature of design-build projects. An initial seminar - *Digital Fabrication: Global Concepts and Local Applications* - focused on implications of the use of digital fabrication tools in design and fabrication. Concepts related to the use of digital media and wood fabrication were introduced, discussed, and applied to context-specific design studies. In the first phase of the seminar, students were introduced to the discourse on regionalism and on the effects of digital media and fabrication technology on the design and building process. A second phase introduced digital wood fabrication technology and software and focused on design applications. Students worked with wood fabrication software to development design ideas and fabrication data for a small wood structure. All designs in the seminar were developed in collaboration with a structural engineer and a wood fabrication consultant. These seminar collaborations foregrounded the comprehensive nature of design and building. Structure, materiality, cost implications, fabrication processes, and assembly sequences were considered as part of the initial design phases.

Subsequently, the design explorations and discussions from the initial seminar served as a basis for the design-build seminar to construct a viewing platform at the Huilo-Huilo Nature Reserve in Chile in collaboration with students and researchers at the Architecture School at the Universidad Mayor in Temuco, Chile. The multiple aspects considered in the project were reflected in the diverse team of designers, consultants, fabricators, and suppliers who participated in the design-build project. While continuing the theoretical explorations and design studies of the seminar, students in the course participated in the development of the project design, the preparation of fabrication data and drawings, organization and fabrication, and the assembly of the viewing platform at the site in Chile.

The design development, fabrication, and assembly of the Huilo-Huilo Viewing Platform was coordinated with faculty and students at the Universidad Mayor in Temuco, Chile. Together with consultants in Canada and Chile, the research and design team in Chile developed a similar design project and collaborated on the subsequent fabrication and assembly of the projects in Chile.

Research, Design, and Building

Both courses included a broad range of research and design studies. The structural explorations for the Naramata roof focused on properties of wood as a building material, wood joinery, and efficient configurations of wood structures. Particular focus was given to compression-based joints as a basis of a truss design. The work in the seminar focused on collaboration within the student group as well as with a structural engineer and a wood scientist who participated in all phases of the project. The course was organized in 5 phases: initial research, design, preparation of fabrication data, fabrication, construction, and project review and documentation. During the initial research and analysis phase, the students developed samples using CNC timber framing software. These explorations of compression-based joints formed a basis for roof trusses that were subsequently integrated in the roof design.

The Naramata Roof Project explored both distinctions between conceptual and spatial potential of digital design and fabrication technologies and the actual application in design, fabrication, assembly, and construction taking into account material and site conditions as well as structural considerations and fabrication. Mass-customization processes using digital design media and wood fabrication technology allowed for the material- and time-efficient

translation of spatially complex designs. Variations of structure, joints, and building configurations that respond to site, program requirements, structural requirements and available materials were generated without compromising the efficiency of the fabrication process.

The work for the Naramata Roof Project included the use of a variety of media, fabrication, and construction methods. While highlighting the potential of digital wood fabrication technologies for the design and fabrication of context-specific projects, the project illustrated effects of the translation from digital design media to building. During the design and building process, the particular conditions for the use of digital design media, wood fabrication software, wood fabrication technology, and for the assembly of the structure at the site, all contributed to the realization of the built project.

A particular focus of both the Naramata Roof Structure and the Huilo-Huilo Viewing Platform projects was the translation of the design concept developed using digital modeling and wood fabrication software into the built structure. Concepts developed as digital models with variations of joints and roof configuration were translated into the built structure with the quality of the available building materials, sequence of assembly, and level of craft as guiding and limiting factors in the building process. While collaborations with the engineering and wood fabrication consultants throughout the research and design phase of the project helped to anticipate issues arising during fabrication and construction, the assembly of the roof structure at the site highlighted distinctions between the spatial potential of digital modeling and fabrication techniques and the translation of design concepts into a built structure. Material tolerances, assembly sequences, and the accuracy of the digital fabrication process as well as the limitations of manual construction methods under site conditions constituted limiting factors for the project.

Through adaptation of the design concepts and methods to the consecutive phases of the design, fabrication, and building process, the potential and limitation of each stage became apparent. With that, the roof project – from concept to realization – served to critically review the potential of digital wood fabrication methods to contribute to architecture specific to its context. As a study focused on ecological design interventions efficiency of design particular to local conditions and responsiveness of the design and building process to the specific conditions of the project played a central role in the development and review of the project.

Similar to the Naramata Roof Structure, the Huilo Huilo Viewing Platform project focused on contribution of digital fabrication technologies to regional building from conceptual studies to fabrication and building. The project equally resulted from a multidisciplinary design and building process in collaboration with range of consultants. As an international collaboration with the Architecture School at the Universidad Mayor in Temuco, Chile, however, explorations of regional applications of digital wood fabrication technologies were extended to include regional studies abroad under specific cultural, economic, and environmental conditions. Collaborators included researchers and fabrication consultants in Canada and Chile. The work with students and researchers in Chile included the reevaluation of assumptions about forms of collaboration, availability of materials and support, and work conditions. While providing insights in the conditions for design and building in Chile, the project also allowed for reflection on the working conditions in the Pacific Northwest. In additional to the context-specific translation of digital media and fabrication technologies in both projects, the studies highlight the significance of structural considerations and understanding of material behavior during the design and building process in general.

Critical Review

The organization of the design-build projects in phases with regular reviews and discussions with collaborators provided opportunities to continuously evaluate the research and design process. On both projects, students participated in assessments of their own design ideas, design documents, and fabrication data by the collaborating consultants to illustrate specificities of local applications of digital fabrication technologies. Through these review processes, students were exposed to distinctions between general concepts of regional application of digital wood fabrication technologies and context specific applications. Parallel to active collaborations and practical considerations of design, fabrication, and building, student research papers furthered the academic discourse by positioning the

design-build projects in the broader discourse on regionalism and digital fabrication technologies.

Project documentations that review the research, design, fabrication, and construction of each project provided another opportunity for critical review of the design-build process of the Naramata Roof Structure and the Huilo-Huilo Viewing Platform. These project brochures serve as reference materials for upcoming design-build courses and projects and allow for the continuous development of design-build projects in the design curriculum.

CONCLUSION

Designs are complex energy and material systems and products of diverse cultural, economic, and environmental conditions. They need to engage with their extended context and require a comprehensive approach to design and construction that considers all phases and aspects of the building process. Interdisciplinary studies on digital modeling and fabrication software, available fabrication technologies, structural and environmental performance, social and economic conditions, as well as the application of available technology in design-build projects equally contributed to the Naramata Roof Structure and Huilo-Huilo Viewing Platform projects. The ability to compare regionally specific applications of digital fabrication technologies through international collaborations adds further to the learning experience of the participating students.

The regionally specific design-build projects in Canada and Chile are seen as expressions of regional formation. Design as formation responds to the dynamic conditions of a location rather than to generalized concepts of place. In this approach, geography takes on a broader definition that encompasses the social, economic, cultural, and technological factors of a given locality and their global influences. In the Pacific Northwest, this particularly applies to wood construction, as wood constitutes a primary characteristic of place in several ways: the particular ecology with forestry as a principal economic factor; the development and use of wood products and their industries and craftsmanship; and, available contemporary wood fabrication technologies. Similar conditions can be found in parts of Chile. With some of the students participating in both projects, the design-build studies in Canada and Chile allow for comparative reviews of the design and building process, and position design education in the discourses on globalization and the significance of regional distinctions in a global context. With our teaching collaborations on design-build projects, design education is positioned in an architectural culture that simultaneously looks to global developments in digital media and fabrication and to the particularities of the local context.

The Naramata Roof Structure project and the Huilo-Huilo Viewing Platform illustrate how design-build projects that engage with local conditions significantly extend the learning experience of architecture students. They equally highlight the significance of an understanding of and active engagement in local conditions, materials and available technology that figure into the translation of design ideas into built projects. While introducing students to contemporary theoretical discourse on regionalism and concepts of digital media, the extension of studies to include design development and project realizations also prepares students to critically and creatively respond the realities of the multi-disciplinary building process.