TEX-FAB: A New Regional Platform for Computational Fabrication

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INTRODUCTION

TEX-FAB is a non-profit organization founded between three universities in Texas with the primary function of connecting design professionals, academics, and manufacturers interested in digital fabrication. The three co-directors established TEX-FAB as a collective action, one that endeavors to combine divergent interests and capabilities, for the purpose of strengthening the regional discourse around digital fabrication and parametric design. The three primary avenues for accomplishing this goal are set out as Theoria (Lectures / Exhibitions), Poiesis (Workshops) and Praxis (Competitions / Commissions). We see this type of effort as a new paradigm focused on providing a network of affiliated digital fabrication resources, and a platform for education and exchange on issues of parametric modeling. It is our position that TEX-FAB engages the new and growing awareness of a regional and global hybridization. We seek to leverage the burgeoning global knowledge base to produce a more specific and contextual dialogue within the region we operate, teach, and practice. We assert that TEX-FAB presents a new model for collaborative engagement through the framework of our organization. Specifically, we will use the international competition REPEAT our organization recently hosted to illustrate how collaboration is a vital tenet to the success of executing a complex full-scale installation entitled Minimal Complexity.

REGIONALISM

The use of *regionalism* in connection with acontextual terms like parametric modeling and digital fabrication might seem paradoxical. By extension the creation of an organization like TEX-FAB could therefore potentially be argued to be one of limitation rather than choice. However, we contend a new stage in the digital dialogue has emerged around issues of fabrication reverting back to regional identity and substantiates a localized approach. While digital technology by its design might make the case for universality, it can still be argued that digital fabrication must still meet the physical consequence of such universal processes with materiality, technique, and interpersonal relationships with fabricators which are often times still very much local transactions. This is not an either/or dilemma. It is rather, an awareness that while the digitization of fabrication starts to become more ubiquitous, we are still reliant upon local *ecosystems* of economy, politics, customs, materials, trade history, etc. and these influence how one makes decisions about building a knowledge base. With this approach a region is thus uniquely equipped to customize according to the localized identity markers. Maybe most important is an awareness that if the goal is to facilitate a more broad based dialogue between academia, the profession, and industry, that these three arenas do not all move within the same territories globally nor do they move at the same speed or utilizing the same methods. Therefore is it precisely by establishing a regional dialogue one provides a more centralized - if not geographic at least in process - method by which these three entities may converge and interact.

THREE MODALITIES of INTERACTION

TEX-FAB is organized around three primary tenets providing specific ways in which the collection, distribution, and sharing of information about digital fabrication and parametric modeling take place: Theoria (Lectures / Exhibitions), Poiesis (Workshops) and Praxis (Competitions / Commissions). These three avenues are not unique by themselves, and are certainly found collectively in other regions as well. However, it is when we survey our own context and examined the unique opportunities within the Texas and Southwest Region we see TEX-FAB filling a vital role in shaping the discourse.

Lecture offerings provided or co-hosted by TEX-FAB to date have attempted to provide a broad range of exploration into digital fabrication. Lecturers are from both the academic, professional and fabrication communities, all with significant accomplishments within the field. As well exhibitions have become a central element to our TEX-FAB event 2.0 in Houston. In 2012 TEX-FAB will launch our first traveling exhibition feature the work of the recently completed international competition hosted by our organization entitled REPEAT. In doing so this will allow some of the work, generated from a broad and diverse audience to be brought into a more focused and more deeply penetrated set of regional venues to disseminate the work. We see the combination of hosting competitions and moving then subsequently rolling the work into a traveling exhibition as a potent combination of reaching further into the field beyond our symposia and events.

Workshops are currently the primary avenue for education and direct interaction between academics, professionals, industry partners, students and professionals. TEX-FAB maintains a policy of reserving half of all available seats for students and at the same time aggressive pursues participants from a wide range of architecture and affiliated design offices through out the region. Workshops are two-day events led by internationally recognized instructors within the field of parametric modeling and provide a robust opportunity for participants to be exposed to the highest level of concentrated learning possible.

Competitions are the third and most far reaching of the three TEX-FAB tenets. The competition is a platform for a very diverse set of designers to explore the potential of parametric modeling. Unique to our mission however is a desire to see competitions result in a built commission – regardless of scale. So to that end, TEX-FAB sees the process of fabrication coming out of the competition to be one that can leverage the TEX-FAB network and utilize its inherent values to provide a robust support system for fabrication, installation, and construction. In the summer of 2010 TEX-FAB took on the ambitious task of hosting an international design competition.

REPEAT COMPETITION

In June of 2010 the REPEAT competition launched with the explicit intent of promoting the role of digital fabrication and parametric design within the Texas region. With the organization and development of the competition brief, context and goals beginning March 2010 and the final installation planned for February of 2011, the competition cycle – start to finish – was to be one year. The deadline of October 31st, 2010 was established and promotional materials where distributed to over 200 Universities internationally and online within digital fabrication and parametric design communities. A total 95 teams of 1-4 designers from 19 states in the US, 18 countries and 5 continents registered while we ultimately received 73 submissions.

The REPEAT brief asked the entrants to look first at the connection and then, through repetition define of the whole. By reevaluating the design process and looking at it from the connection, what might emerge? We encouraged the generation of cutting edge design proposals for a structure with the only caveats being it be generated and conceived digitally, incorporate repetitive elements, be optimized for relocation and transportation and be produced through fabrication technologies available within Houston, Texas. These three 'programmatic' parameters served to be very open ended and broad, while another constraint was included that served to delimit the work, a budget. No more than $10,000 could be used in the competition proposal's production costs. The role of Houston as context was also significant and provided the perfect backdrop for the objective put forth by the competition. Within cities with atomized light manufacturing capabilities like Houston, that there exists a potential for designers to engage fabrication via connection with so called "job shops" that are open to small run projects and customization due to their association with the energy industry. Harnessing the network of fabricators already affiliated with TEX-FAB we established the means and methods of production for the winning entry and ensured the production and costs were not exceeded.

To further define the potential and enlist greater interest in REPEAT we invited five leading figures in the world of digital fabrication and parametric design to jury the competition: Patrik Schumacher (Jury Head), an internationally recognized educator, acclaimed theorist and Design Director at Zaha Hadid Architects; Marc Fornes, founder of the influential design practice theverymany; Lisa Iwamoto of Iwamoto + Scott, architect and author of the seminal work Digital Fabrications: Architectural and Material Techniques; Chris Lasch partner of the renowned experimental research studio Aranda \ Lasch; and Blair Satterfield, an educator, award-winning inventor and founder of the design collaborative Houminn.

Submitted to the competition was a rich and varied collection of proposals that explored and intently challenged preconceived notions of form, use and assembly. It can be argued that production and design have become two distinct processes in architecture since the advent of the formalized design document. It is evident within the numerous competition entries that that method is being questioned. Previously wherein the conception and production of drawings have occurred months and sometimes years before anything was realized physically, the digitally conceived work proposed in many cases was produced simultaneously along side small-scale tests and models that not merely represented the work, but instantiated it as a version - an iteration. These projects were on-the-one-hand speculations and reflections on the potential of digital fabrication and parametric design, while on-the-other hand realizations of that potential.

The success of the competition was evident in the winning entry designed by Vlad Tenu, a young Romanian architect practicing in London. His ongoing research focuses on the integration of computation, science and technology in the architectural design process, involving generative computational methods, digital fabrication techniques and interactive design. He studied architecture in Lasi, Lisbon and in London at the Bartlett, UCL, where he was awarded a MSCin Adaptive Architecture & Computation and a Certificate in Advanced Architectural Research.

The jury selected Minimal Complexity for the aesthetic beauty, technical superiority and elegance of detailing. It employed structural robustness, material efficiency and an inherent logic of assembly embodying the principals of the competition brief to the highest degree. While a great many of the submissions showed real promise the jury focused on a selection that was feasible by adhering to the context and budget. In keeping with the spirit of the competition intent the jury enumerated four Runners-Up and another seven Honorable Mentions that embraced the brief as is reflected in the comments by Chris Lasch for one of the Runners Up, "it uses a low tech solution to leverage high tech design thinking and does it through a clear assembly logic that seeks to combine the abstract logics of geometrical assembly with the fine grain affordances of their chosen material."

MINIMAL COMPLEXITY – OPTIMIZATION AND CONSTRUCTION

With Minimal Complexity selected the optimization process was initiated between TEX-FAB and Vlad Tenu. One of the primary interests for the Directors of TEX-FAB in generating REPEAT was to find a collaborative partnership with a designer or design team and work through the spectrum of issues needing resolution in order to bring the design to realization. In this manner, TEX-FAB would not just a serve fabrication consultant, but work closely with the winner to resolve a wide range of issues resulting ultimately in our constructing the piece.

Stage one in the optimization came though weekly teleconferences between TEX-FAB and Vlad Tenu in addition to a regular cycle of email communication. We also made use of an online communication and work coordination system to provide a central location for the exchange of ideas, files, technical information, scheduling, etc. This stage took approximately three weeks to complete and was an essential part of establishing a collaborative dialogue with Vlad as well as resolving issues needing clarification prior to fabricating anything. Stage two of the optimization process was to construct a half scale version of Minimal Complexity at the University of Texas Arlington. The goal for this phase was to understand the intricacies of the piece as well as resolving certain fabrication issues. Because Vlad had already constructed versions of the scheme at smaller scales and with range of materials, we were able to start with a very developed understanding of what was required in working with the design as proposed.

Figure 1. "Minimal Complexity" Under Construction.

Over the course of ten days the University of Texas Arlington team was able to successfully fabricate and assemble the seven foot scaled version of Minimal Complexity. With this in place the TEX-FAB directors along with Vlad could more effectively understand both technical details and assembly sequence concerns discovered through the construction process. This was an invaluable step in the collaborative process because it raised a series of issues that required collective resolution. Issues like part numbering, templates for sub assemblies, bolt length and type, time studies, and special installation equipment needs were all resolved during this optimization process.

MINIMAL COMPLEXITY – FINAL CONSTRUCTION

After the optimization phase operations moved to Houston where final fabrication and installation would take place. The competition was predicated on the ability to utilize resource for materials and fabrication partners in the greater Houston area. To that end, very early on in the process of developing the project for construction, Crow Corporations who is a digital fabrication partner with TEX-FAB and metal fabrication company located in Houston, was brought in to help resolve technical issues for laser cutting aluminum. Once TEX-FAB, Vlad and Crow Corporations established that 14-gauge aluminum was the desired thickness for the several thousand pieces needing to be cut the next step was to check for structural soundness of the design, material properties and connection detail. For this Buro Happold in New York was enlisted to coordinate a detailed structural analysis. The Finite Element Analysis model was run on the geometry as both a shell and beam structure. The Global Shell Model, using iso-parametric finite shell elements, indicated to be very sound under the dead load of the piece overall. The final structure is composed of 148 basic quad sections of the Schwarz's P Surface with each section being made out of 16 parts resulting in 2368 total pieces. The true strength of the design is found in the simplicity of repeating the same 16 parts through out the entire surface. When each of the basic quad regions are set up for assembly, the double-curvature of the surface is introduced through the alignment of the 16 parts with fasteners.

Based on the optimization model, the FEA analysis and the consultation with Crow and the direct communication with Vlad Tenu, TEX-FAB initiated a 2-week assembly process. Because of the limited number of unique parts, the process of assembling the basic quad regions was highly repetitive. It was determined by that creating sub assemblies out of the 16 part quads would allow for easier installation. This size and division of the sub assemblies

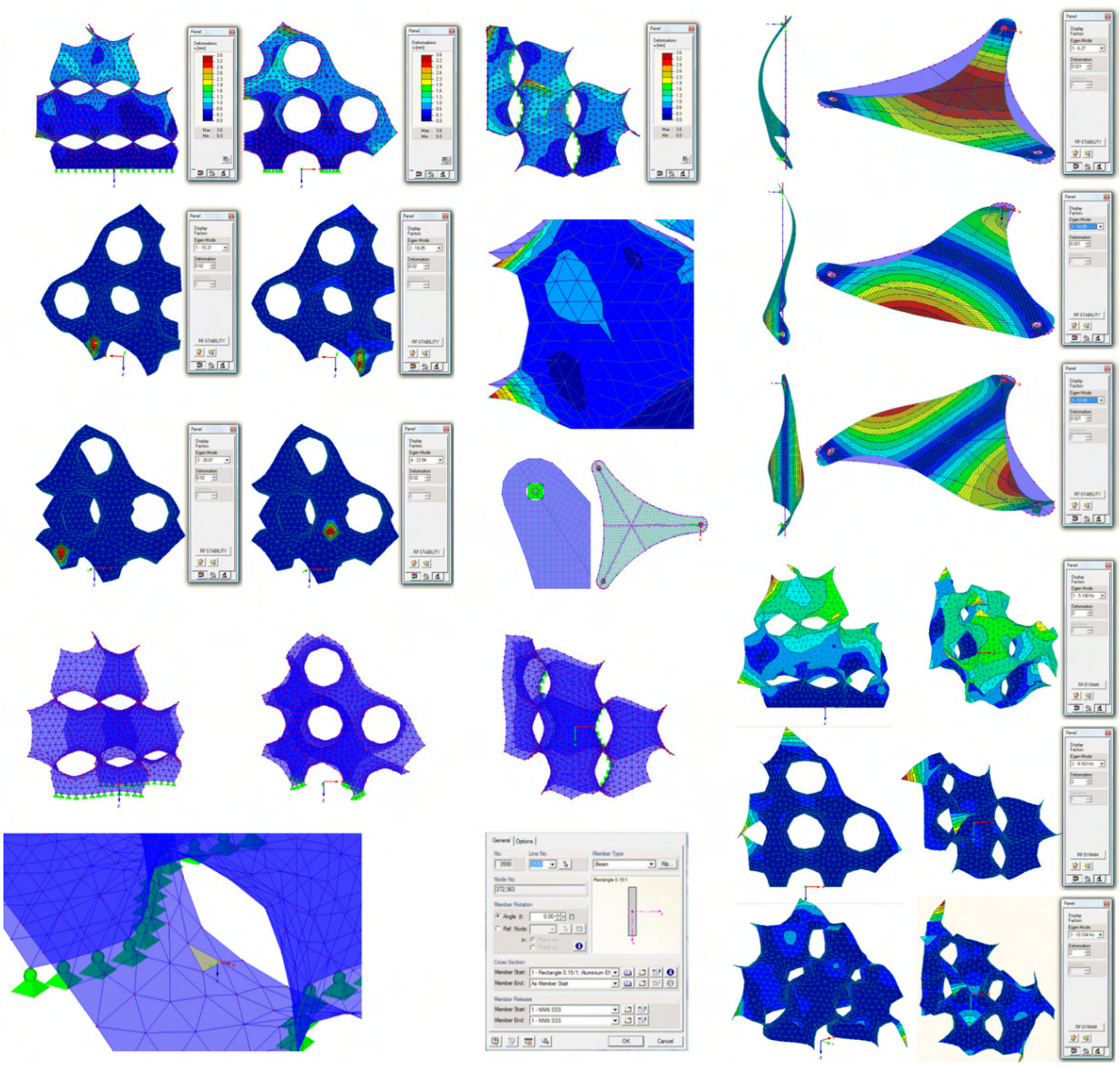

Figure 2. Structural Analysis of *Minimal Complexity* performed by Buro Happold of New York.

was based on how two people might be able to handle the part for installation in terms of both weight and size. Once all the sub assemblies were constructed final installation began.

TEX-FAB took control of the means and methods of final assembly by employing a series of templates, base plates, ballasts, shoring, scaffolds and hoists to manage the vertical development of this self-organizing structure. The process of building up the system up into 16 part quads led the planning and construction of larger subassemblies or sections of the structure that could be build on the ground and then positioned correctly and bolted in. The choice of 14 gauge laser cut aluminum with ¼” holes proved to be ideal for workability and joining with a variety of fasteners that served to align the parts progressively. A pattern of tightening and loosing the fasteners at adjacent components was learned by the assembly team in order to allow for hole alignment before final bolting was accomplished. The structure's progressive rigidity as the fasteners became fully engaged was further proof of the designer's concept, the engineers FEA analysis and TEX-FAB's expertise as fabrication and logistical consultants. The main assembly took approximately twenty hours with a team of four members.

ADAPTED STRUCTURAL PRINCIPALS

The concept of digital fabrication and parametric design was also successfully adapted for the structural engineering of Minimal Complexity, where a large number of interconnected elements needed to be modeled to check stress utilization (ULS = ultimate limit state), static deflections & frequencies (SLS = serviceability limit state), connections as well as local and global stability. The approach essentially first set up a 3D beam model based on lines extracted digitally from the master geometry file, where straight lines connect center connection points in space, ignoring local bending of the elements. This model then determined the force flow through the entire piece from borehole to borehole, loaded mainly by self-weight and human local impact. A second finite element model based on 3D iso-parametric shell elements was then built to compare and calibrate both models with each other.

Local deflection peak plots were useful results to inform the assembly team, whether to stiffen the structure locally and what static deformations to expect during installation. Material capacity utilization was checked from a code design point of view, however very thin metal pieces were not fully covered by code, especially local connections that

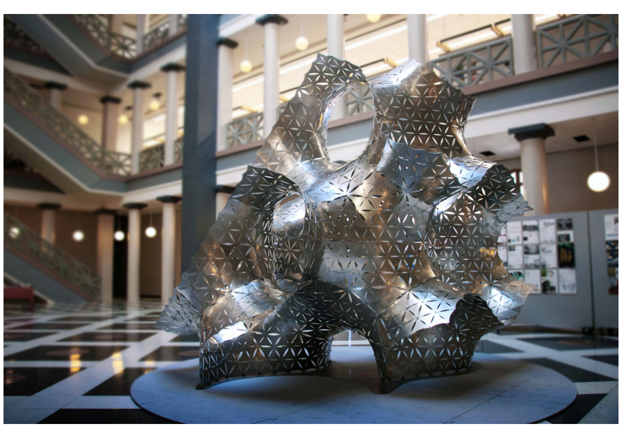

Figure 3. "Minimal Complexity" Final Installation

work both in bearing as well as friction. Therefore, a refined finite element model including explicit borehole modeling for critical individual panel segments was built, this time including the cold-bent geometry of the tessellates, to check local stress peaks, stability and connection capacities.

For lightweight designs like Minimal Complexity that has slender parts, it is essential to also check global and local stability, since no part of the design - as whole or individual elements -was allowed to buckle out or sway/twist sideways. Global eigenvector modes were identified using the global beam and shell model eigenvalue stability analysis (in this instance: global safety for lowest critical mode = 15 >> 1 – ok), while the refined local panel segment model with corresponding compressive normal and shear forces applied as external loads checks local stability modes (plate buckling with lowest critical mode = 6 > 1 - ok). For additional information about structure vibrations, natural frequencies of the sculpture was determined to be in sufficiently high range of 5 Hz and above.

The above described structural calculations carried out by Will Laufs of Buro Happold NYC allow for complex art geometries with large numbers of elements, like the ones found in Minimal Complexity, to be modeled and checked with reasonable effort, switching from global 3D beam models to local 3D shell element models to catch both global as well as local structural behavior.

REGIONAL and GLOBAL COALESCENCE

In an effort identify what we see as a critical step in the evolution of the dialogue on the issue of computational fabrication, we have asserted that regional operation is a more integrated and agile model for implementing the technical and detailed aspects of what is involved with the methodology related to the hardware and software. In both sides of this equation there are individuals, businesses, and organizations who have built up a brain trust of tested and proven modes of operation and we know this to be an indispensible aspect of the actual implementation of the work into the built environment. However, we also know technology has rapidly altered the modes by which we communicate, transform, and revise our knowledge base and therefore we must acknowledge the role of a global community within this discourse. Often times elements like tech support for software/hardware troubleshooting, open-source programming, and user-group forums are more immediate and useful as an aspect of a global network. The goal of creating an organization like TEX-FAB or conducting international competitions like REPEAT is to illustrate the mutual exclusivity of the networks but rather to collapse the two together.

While there will always be on-line global communities for information exchange, we also see there being an opportunity to link larger global operators in field of computational fabrication into these regional contexts and find this to be one of the most important aspects of the service that an organization like TEX-FAB can provide. Bringing this into the regional setting, whether it is an instructor of innovative methodology or companies operating at a transnational level, we also see there being a valuable and fertile interaction that should and can take place. Ultimately though we contend based on our own experiences and through similar discussions we know to be taking place simultaneously in regions throughout the United States and beyond, that the regional dialogue has a vibrancy based on its bottom up, self-organizing potential. We believe it will be this loose aggregation of regionally articulated groups that can collect under the umbrella of a larger national or international group that will facilitate a robust and vital discourse on the issue of computational fabrication will progress and evolve.

CONCLUSION

In the course of the 28 months since the establishment of the TEX-FAB, the three outlined avenues: Theoria (Lectures / Exhibitions), Poiesis (Workshops) and Praxis (Competitions / Commissions), have all been tested and proved successful. Our growing network of collaborators within the region is reinforced to a greater degree as needs arise – creating a dynamical relationship adaptive to specific challenges. Additionally the local intelligence of our structure is extended and enhanced by a link to a broader, global, affiliation that we can call upon to a greater degree for material and technique specialization.

In the case of the REPEAT Competition, our local network partners in manufacturing, such as the Crow Corporation, helped facilitate the completion of Minimal Complexity. We foresee the inclusion and expansion of our local network as an array of fabricators located in each of the urban centers that we currently operate as an important step and service that we will provide for those who we are connecting. These fabrication partners will continue to enable our endeavor in the illustration and implementation of parametric design and digital fabrication in other cities in the state and serve as a model for how the local and region might work together for production and fabrication purposes. The extension beyond the Texas region into New York for the FEA, and ultimately the inclusion of Vlad Tenu, in London, as a catalyst for a project, in effect reinforces the porous nature of TEX-FAB. Additionally, our own tri-city base of operations for TEX-FAB joined with affiliation to three different academic institutions, provide a layer of collaborative and interconnected opportunities for the advancement of digital fabrication issues. As a platform for education and exchange, and a collaborative partner in the production of projects, TEX-FAB serves as a unique and new model for advancing issues that will only continue to transform the way we design and produce architecture.

Figure 4. “Minimal Complexity” final installation.