CONCRETE TECTONICS II

UNIVERSITY OF TECHNOLOGY SYDNEY

This edition published in 2012 by

UTSePress
University Library
University of Technology, Sydney
PO Box 123
Broadway NSW 2007
Australia

ISBN: 978-0-9872369-8-2

Edited by
Associate Professor Kirsten Orr, Natalie Nicholas & Jessica Tringali

Designed by
Natalie Nicholas & Jessica Tringali

Preface 6

Studio Process 8
Associate Professor Kirsten Orr

Essays

(Im)material Computations: Expanding the form-finding traditions of architecture 14
Iain Maxwell and David Pigram

Prototyping as a paradigm for linking teaching and research in the architectural design studio 20
Associate Professor Kirsten Orr

Investigation

Scale: One to Twenty 30
Analogue Explorations of Form
Parametric Investigations

Scale: One to Ten 60
Ground Plane
Scaffolding

Scale: One to Five 88
Concrete Component Design
Casting Experimentation

Scale: One to Two 130
Joints & Reinforcement
Materiality & Lighting

Scale: One to One 162
Prototype
Final Assemblage

Conclusion 190

Concrete Tectonics II

University of Technology, Sydney
2012

Preface

Associate Professor Kirsten Orr, Natalie Nicholas and Jessica Tringali

The *Concrete Tectonics Studio* 2012 was a research based design studio of sixteen Master of Architecture students led by Associate Professor Kirsten Orr, at the University of Technology, Sydney.

The studio traversed the gap between analogue and digital spheres of architectural research, pursuing innovation in precast concrete through material experimentation and parametric design. The iterative nature of analogue-to-digital design ultimately manifested itself as an investigation of scale.

Multi-scalar prototype-based research focussed on innovative fabrication techniques resulted in student work that tested and challenged the limits of precast concrete against complexities of scale, dimensional tolerance, materiality and mass-customisation principles.

The students' practical and hands-on material testing and prototyping was supported by a parametric scripting tool developed by *Supermanoeuvre*. The dynamic process of oscillating between the analogue and the digital allowed students to more actively engage with the design process, and to wrestle with the frequent incongruence between digital simulation and physical artefact.

This book catalogues the *Concrete Tectonics Studio* processes into a series of scaled studies, enabling a detailed synthesis of the minute details of the individual components with the complexities of realising the whole. Scale is the lens by which the studio investigations are examined. At the scale of 1:20 is the exploration of form and parametric investigation. At 1:10, the design of the ground plane and scaffolding. At 1:5, the design of mass-customised concrete components and experimentation with casting techniques. At 1:2, the exploration of joints, reinforcement steel, materiality and integration of lighting. And at 1:1, are prototype investigations and the final assemblage.

Studio Process

Associate Professor Kirsten Orr

What could twenty-first century architecture in precast concrete look like, if the newest developments in material, design and production technologies are harnessed?

Concrete is one of the most ubiquitous materials in contemporary building practice. Its ready availability, strength and durability make it a relatively cheap and reliable building material. Nevertheless, the way concrete is currently produced and deployed in the built environment poses serious environmental, technological and formal problems. For example, the CO_2 emission from concrete production is extremely high (in proportion to cement content). Moreover, the architectural practice of featuring 'raw concrete' as a finish in its own right has been severely criticised for producing ugly buildings that lack the ability to enter into a dialogue with their surroundings and that detract from the quality of the built environment.

The UTS Master of Architecture *Concrete Tectonics Studio* 2012 spanned theoretical and practical work to explore the tectonic potentials of concrete and the capabilities of new fabrication technologies in the Twenty-First Century. It investigated casting techniques that minimise the environmental impacts of formwork and maximise the possibilities for producing mass-customised components better suited to contemporary architectural challenges. This was an investigation into the 'tectonic' potentials of concrete, exploring the complex connections between materials, the technology applied to them and the resulting architectural form. The investigation was deliberately framed to complement the sophisticated materials-based research currently being undertaken by the construction industry to enhance the environmental sustainability, strength and stability of concrete.

The *Concrete Tectonics Studio* 2012 was built upon a similar research-led studio run in 2011 as an international collaboration between UTS and Aarhus School of Architecture in Denmark. The 2011 studio asked students to achieve as much form/surface/architectural effect as possible using as little material and as little fabrication time and technology as possible. Hands-on experimentation with a variety of materials for casting concrete identified a range of innovative approaches, among them the possibilities of creating formwork from hot wire cut polystyrene, neoprene fabric and polyethylene terephthalate (PET).

The starting point for the 2012 studio picked up from where the 2011 studio had finished. Nicky Choi, one of the 2011 student participants, joined Kirsten Orr to pass on the knowledge generated by the previous studio's work. In 2012 the studio was deliberately focussed on the detailed investigation of the specific formwork material PET, and the specific fabrication technique of laser cutting. The material qualities of PET and the formal potential of laser cutting technology in combination with parametric design were investigated as the basis for the generation of mass-customised tectonic form in concrete.

PET is a readily available barrier material (commonly used for soft drink and water bottles) that easily lends itself to cost-efficient and environmentally sustainable recycling. Experiments completed in 2011 with PET sheets of various thicknesses revealed that PET below 1mm thickness is bendable, while thicker PET can be shaped using a heat gun, provided dashed fold lines have been laser cut. Laser cutting is a highly accessible, cost-effective and rapid fabrication technique suited to both large and small-scale industrial manufacturing applications. Its computer control of a high-power laser directed at the material to be cut allows for the cutting of complex shapes with a high degree of precision.

Students were asked to take explorative approaches to develop innovative practices that intensified the architectural properties of concrete. Hands-on physical experimentation with different concrete-casting techniques utilising laser cut PET were conducted in parallel with an iterative process of parametric design. Emphasis was placed on group collaboration and exploration through physical models and precast concrete prototypes at a variety of scales. Students were required to actively engage with the models and prototypes they built: to take them apart, reassemble them in different ways and refine the control of geometric tolerances, quality of surface finishes and connections between components.

A digital tool, developed specifically for the studio by *Supermanoeuvre*, assisted the generation of complex forms and the design of templates for laser cutting. This was based on *Supermanoeuvre's* "ReVault" software developed for the design of thin-shell sandstone structures and was adapted to suit the specific requirements of working in concrete with the financial support of a $10,000 UTS Vice Chancellor's Learning and Teaching Grant. The digital tool includes special form-finding and structural engineering operations, sliders to allow the geometry and thickness of individual concrete components to be varied, and computer aided manufacturing operations to assist the manufacture of the PET moulds by incorporating functions for the automated unrolling of 3D components into flat shapes for laser cutting and the automated addition of tabs and fold lines. Digital models built using this software are thus able to take account of casting techniques and the flexibility/limitations of PET formwork, the instantiation pattern and generative strategy of the system of architectural concrete components the formwork is capable of producing, and the suitability of these for construction.

In this way the 2012 studio investigated the ability of PET formwork to produce fully mass-customised, tectonic concrete components, its ability to cope with the hydrostatic pressure of wet concrete, its release capabilities and the surface finishes it is capable of producing.

Essays

(Im)material Computations: Expanding the form-finding traditions of architecture

Iain Maxwell and David Pigram

For the last 5 years Supermanoeuvre *has been vigorously pursuing and developing methodologies that increase the number and quality of feedback relations between design and making: intentions, matter and the methods of production. The pursuit has taken the form of speculative projects, technical research and experimentation – frequently in conjunction with teaching and through the production of large-scale prototypes. The* Concrete Tectonics Studio *2012 is a significant example and combines the research trajectories of Associate Professor Kirsten Orr with those of Iain Maxwell and David Pigram, additionally drawing on significant knowledge accumulated through a continuing collaboration between the University of Technology, Sydney and Aarhus School of Architecture, Denmark. Combining algorithmic form-finding techniques, material and production innovations, and articulate detailing and tectonic positioning, the final project of the* Concrete Tectonics Studio *is a highly speculative and contemporary re-exploration of the form-finding traditions of architecture, tested at full-scale.*

Introduction

Collaboration with the computational abilities of materials is a well-established trajectory within architecture; Gothic Cathedrals, Antonio Gaudi and Frei Otto's seminal work during the Twentieth Century serve as preeminent examples. Similarly, more traditional design methodologies take advantage of the positive formal constraints of specific design mediums. Charcoal sketches, clay models and procedural methods such as folding, cutting or weaving, all provide a consistency of character via a delimited 'phase-space of possibility.' However, the limitation of analogue modes of computation in relation to broader architectural speculation is precisely their fixed relationship to immutable physical laws and material properties. Without the ability to expand, intervene in, or tune the parameters of form-finding techniques, architects are either forced into subservience to imperfect analogies between these factors and a larger set of extrinsic design intentions, or, must remain content to limit themselves to structural and material investigations. When executed digitally however, form-finding processes enable a greater incorporation of architectural constituency; programmatic as well as material design goals in negotiation toward the elaboration of architectural affect, spatial experience, ornament and structural performance.

Form-finding Traditions

The traditions of form-finding within architecture trace our efforts to embed material as an active agent within the design process via the abstract modelling of material organisations as they actively-negotiate internal and external influences. These traditions enjoy a long history that stems not only from the physics, and thus pragmatic constraints, of our world, but equally from the desires of designers and engineers to invent and innovate within the space of possibility such realities afford. It is a rich trajectory that includes the invention of descriptive devices such as the catenary curve (and its reciprocal, the funicular curve) to direct the design of compression only masonry arch and vaulted structures; Antonio Gaudi's extreme elaboration of such understandings implemented via hanging-chains – analogue machines capable of computing complex load paths; and Frei Otto's study and ultimate abstraction of the tendencies and behaviours of minimal surface organisations, as found in soap film and bubbles to realise highly novel membrane structures. Resulting is a wealth of heuristic principles and modelling practices through which architecture attains not only a better understanding of form, but, more fundamentally, an operative knowledge of the events of formation that underlie it. It is also a body of work that compellingly shifts architectural thinking away from essentially design-extrinsic semantics, towards the very processes of production that potently feed the discipline's mastery of architectural space and form.

Computable Material

Computing material demands a necessary distillation or abstract representation of materiality itself. Indeed the research undertaken to date demonstrates that the principles, properties and tendencies evident in one material system are, in specific situations, scalable and curiously transportable to others. To elaborate through example, the expansive learnings of Otto's investigations into soap film have not only informed our understanding and command of somewhat 'similar' lightweight membrane structures, but have equally enhanced our knowledge and ability to augment large span shell, lamella and lattice structures – the latter in spite of the fact that they are constructed from seemingly contradictory materials, concrete, steel and timber.

As such outcomes reveal, absolute knowledge of a given material's properties or molecular anatomy is not evidently central to the development of simulation techniques. Instead, it is the establishment of computable descriptions of the events of self-organisation that become our focus. In the example of Otto's soap film, the construct of the 'body' can be understood as the process of one molecule acting upon another while simultaneously negotiating internally produced (surface tension) and externally imposed (surface pressure) influences. Form is therefore not a latent property of the single molecule, but a collective behavioural event. Such analogies become pertinent once extrapolated through architectural examples. Gaudi's computational machines comprised nested networks of chain links to simulate the force of gravity acting on discrete masonry elements. A more contemporary example is the use of particle-spring systems enacted digitally to simulate soap film (minimal energy) structures. In the second example, architectural geometry (surfaces, volumes, etc) is reconceived as a network of particles tethered to one another by springs. The constituent particles - akin to the analogy of soap film molecules - negotiate their immediate neighbourhood of connecting springs (topology) towards a state of equilibrium or equal residual force (i.e. spring length). This act of negotiation is essentially a mechanical process enacted digitally via numerical iteration, the two common strategies of which are either dynamic relaxation or the force density method, which in either case harness the mathematical protocols of Hooke's laws of elasticity. The particle-spring system is computationally efficient, robust and sufficient to reproduce the seminal work of Gaudi and Otto as it operates in essentially similar ways by compressing aspects of material behaviour into a computable geometric operation.

Algorithm: Matter versus Material

Form is the primary instrument with which architecture engages the world. A successful architectural form is one that operates with depth and richness across the qualitative domains of spatial, programmatic and ornamental experience in parallel with other more quantitative aspects such as material and structural performance. The limits of physical - or analogue - modes of computation is that they are intrinsically bound to physics via gravity and the materials through which they operate. It could be argued therefore, that all prevailing modes of form-finding within architecture can only serve the latter criteria as they fundamentally lack the mechanisms through which to engage the most basic demands of the architectural schema. For example, where is the front door?

Enacting form-finding techniques digitally through the medium of the algorithm however, permits a broader set of architectural intentions to be engaged. The algorithm supplants notions of material with a deeper and more abstract concept; that of matter. Matter, unlike material, is immaterial, pliant and potentially motivated by increasing orders of architectural intent and duty. Matter in this sense, can be understood as proto-architecture: an intelligent, volatile, non-hierarchical and non-linear design system capable of sensing, responding to, and consequently negotiating expanded sets of influences beyond the remit of material and gravity alone.

In the interests of outlining a tangible scenario of digitally enacted form-finding, we can return to the earlier example of the particle-spring system. Principally, in this model each particle possess two core behaviours; firstly to receive the force of gravity and secondly to attempt to resolve its topological neighbourhood toward equilibrium. Understood in this way, it becomes clear how such a model could be expanded via the addition of more architecturally specific motivations. Examples of such behaviours could include, but are in no way limited to, programmatic, geometric, ornamental and fabrication. Programmatic behaviours introduce multiple particle types and control particle-to-particle interaction within an environmental context rich in stimuli or external scalable forces of attraction and repulsion. Volatility may be introduced to the system or, more simply, topological connections allowed to be made and broken through particle interactions. Geometric behaviours introduce alignment angles, fixed lengths, weights, etc. Ornamental behaviours instantiate geometry to particles and springs that register latent information such as particle mass and velocity, or residual spring force and length. Fabrication behaviours define minimum and maximum lengths, degrees of permissible rotation or twist, number and angle of connections at particle, etc.

Digitally enacted and plurally motivated, particle-spring systems serve as only one of innumerable possible pathways to the conceptual and practical expansion of architecture's repertoire of form-finding techniques. What becomes critical in such expansions, however, is that the introduction of additional motivations does not seek to supplant the formative agencies of material and physical law, but rather to increase the number and nature of influences negotiated, hence expanding the architectural questions posed. The outcome of this process is not the optimisation of any single variable, rather the establishment of far richer and more tunable dialogues between many. The latter point is of particular importance to designers as it provides an explicit context (media) through which to establish, test, evaluate and evolve architectural relationships and outcomes.

Conclusion

The historical trajectory of form-finding has afforded architecture a richer understanding of architectural form and the processes that underlie it. Similar to many traditional design techniques, form-finding processes harness the positive limitations of a given media - material and force - to resolve formal characteristics in consistent ways. Unlike traditional methods however, form-finding methods invest a considerable level of material and structural intelligence within the design process and in doing so establish direct and productive pathways between the act of formal and spatial production and the affiliated aspects of material performance, optimisation and ultimately buildability. Enacted digitally, the remit of form-finding methods can be extended beyond the prevalent structural monoculture and can begin to engage more diverse sets of architectural concern, intent and desire. Further, the development of algorithmic models permits a meta-analysis of such processes and relationships, allowing them to be better understood, tuned and deployed. As such, the role of digital form-finding is not to replicate the seminal work that has preceded it, but rather to seek out new territories of invention and to expand this rich trajectory of architectural experimentation.

Prototyping as a paradigm for linking teaching & research in the architectural design studio

Associate Professor Kirsten Orr

The linking of teaching and research has always been considered an essential ingredient of a university education to develop graduate competencies in "critical thinking, analysing, arguing, independent working, learning to learn, problem-solving, decision-making, planning, co-ordinating and managing, and co-operative working, etc." The Commission of European Communities reported in 2002 that these are the "core competencies that appear central to employability."[1] In the university architectural design studio, the linking of teaching and research is important to equip students with these higher-order skills needed to support active inquiry in a rapidly changing profession. We all want graduates who are capable of working and thinking at the edge of their discipline and who will become the innovative architects of the future.

The problem for architectural educators lies in defining the nature of research as it relates to a creative discipline. Research is fundamentally a knowledge-producing activity that has been typically defined as a systematic inquiry leading to verifiable conclusions. In the sciences, new knowledge is commonly obtained through empirical enquiry, while in the humanities, the methodological principle is an interpretive one in which investigators or researchers evaluate data through a subjective or hermeneutic lens. In applied fields, knowledge production frequently comes about through acts of innovation or 'testing the boundaries' within a particular problem context.[2] Research in architecture can span all three methods but B. D. Wortham claims it has been undervalued by the constraints of a scientific paradigm and therefore calls for a broader understanding of research that recognises methods and processes as research in themselves.[3] Creative outcomes can be difficult to quantify because evaluation is largely subjective and not based upon established critical consensus.[4] Kazys Varnelis would argue that "works of architectural research aspire not just to represent the world but to help us look at the world in a fundamentally new way" and that this is the way in which architectural research makes a contribution to knowledge.[5] Work produced in the university design studio often has claims to being research, producing knowledge not obtained by a reliance on facts, hypotheses and reproducible results, but through speculative and inventive inquiry.[6]

Prototyping as a Specific Form of Inquiry-Based Learning

Inquiry-based learning has been identified by Ron Griffiths as an effective method of linking teaching and research in the built environment disciplines. It is a 'research-based' method with a focus on active critical inquiry into the processes of knowledge creation rather than the passive acquisition of subject content and vocational skills.[7] Griffiths refers to Angela Brew and David Boud who find that learning is the vital link between teaching and research and that inquiry is a common element of research and learning.[8] Deep learning is more likely to occur when students are engaged in producing knowledge through their own inquiry-based research activities than when they borrow knowledge from their teachers.

The methods and values of inquiry-based learning have been extensively investigated across a wide range of contexts to elicit optimum learning outcomes.[9] Prototyping is a specific form of inquiry-based learning that optimises learning experiences applicable to design and facilitates creative design outcomes. It is increasingly being introduced into the university design studio as an analogy to the prototyping activities employed by professional practices engaged in innovative architecture. It is the process of creating a specific type of model, built from representative materials in three-dimensions, often at full-scale, to explore design alternatives, test theories and confirm performance prior to starting production. Like other inquiry-based learning activities, the learning is student-centered and takes place through reflection on what has happened and why. In prototyping, students draw upon their previous experiences or knowledge to generate ideas that will be tested, refined and realised. They construct their own experience in the context of a particular social and cultural environment and the role of the teacher is to act as a facilitator.

Literature Review

In recent years there has been a proliferation of publications showcasing the eye-catching student work coming out of the university design studio accompanied by profiles of noteworthy studio programs. The impressive visual imagery of student prototypes is often divorced from any consideration of a broader theoretical context that might allow an assessment of pedagogical value. Fleeting references are made to John Dewey's theories of education and Project Based Learning[10] and Donald Schön's theory of reflective learning as applied to the university architectural design studio, in which a problem is framed and re-framed to generate problem-solving actions.[11] This lack of pedagogical and theoretical basis is noted in the introduction to the special 2004 issue on "Architecture, Technology and Education" in the *Journal of Architectural Education*: "Architectural educators frequently refer to their work in the studio, and in technology generally, without reference to any pedigree … much work needs to be done to establish the parameters and content of that teaching."[12]

Some of the creative outcomes of the architectural design studio have been written about at length as products of research-based processes. For example, the "Rural Studio" at Auburn University explicitly frames its studio projects as "research-driven" design-build undertakings for real clients that produce insights and knowledge that can be broadly applied to low-cost housing.[13] Another example is the pavilions built annually in Bedford Square by students of the London Architectural Association (AA) that produce new knowledge in the form of expanded design intelligence.[14] The success of both examples is that they build upon a well-established knowledge base and are part of an extended research program and pedagogical plan. Each year the students take an incremental step in furthering that knowledge.

All of the literature on prototyping emphasises the exploration of contemporary architectural problems. Case studies include exploring “the gaps between digital design and making and between scales and modes of production”;[15] experiments “to push material limits for greater performance and at the same time to investigate their aesthetic values and psychological effects”;[16] and collaborative studio projects “to learn about performance and its concrete relation to spatial situations”.[17] Such case studies challenge traditional university teaching methods by foregrounding the practical and applied, rather than the academic and abstract. There is strong evidence of student involvement and relevance to the profession. However, the question remains, is deep learning occurring through participation in these activities? And do the studio processes and outcomes link teaching and research?

Integrating Knowledge in Prototyping Inquiry

Prototyping falls into the category of inquiry-based learning that Rachel Spronken-Smith and Rebecca Walker identify as a “guided inquiry” in which “teachers provide questions to stimulate inquiry but students are self-directed in terms of exploring these questions.”[18] The research-teaching nexus that was established in the UTS *Concrete Tectonics Studio* in 2012 was based upon a series of research tasks found in architectural practice and engaged students in a research project in which they experienced some of the difficulties of synthesising theoretical and practical knowledge with a creative process. Students needed additional support of the kind referred to as “scaffolding” which Spronken-Smith and Walker recognise as an essential component of a “guided inquiry.” It involves the teacher providing support to students that might gradually taper off as students become more confident and able to do the task themselves.[19]

In the *Concrete Tectonics Studio* the students’ research was guided by a lecture series about the applications and techniques of precast concrete. Students also participated in “scaffolded” activities where they were required to follow a highly prescriptive process to understand the material properties of concrete and methods for casting it. After the initial “scaffolded” activities, students were required to pursue their own lines of inquiry in formulating an innovative design proposal, moving into what Philippa Levy identifies as a “discovery frame,” as distinct from an “information frame.”[20] Within the constraints set by the studio theme and project brief the students moved from a teacher-led stage of acquiring existing disciplinary knowledge – through both theoretical and practical research exercises – into an increasingly student-led and discovery-active stage in which they produced creative research outcomes. Their processes were similar to those adopted by architectural practitioners engaged in practice-based research but the creative outcomes were limited by the constraints of the 13 week studio and by the students’ lack of architectural experience.

Strengthening the Research Link

Establishing communities of practice

A studio structure informed by the specific research interests of academic staff establishes a research-teaching nexus through the transmission of specific knowledge and skills arising from the research. It also enhances the nexus as teachers communicate their passion for the subject and students become motivated by being involved in discussions of their teachers’ research. The *Concrete Tectonics Studio* was built around the expertise in precast concrete of the tutors from UTS. The students started as apprentices learning casting techniques and progressed to a status more akin to that of the research assistant, working alongside their tutors. This created an environment in which the students and tutors were co-learners and compatriots in the search for knowledge. This environment can be called a "community of practice." Brew suggests that "if the relationship between teaching and research is to be enhanced it is necessary to move towards a model based on the notion of academic communities of practice."[21] In this model "research and teaching are both viewed as activities where individuals and groups negotiate meanings, building knowledge within a social context."[22] Terry Wareham suggests that Brew's communities of practice model is an effective method of linking teaching and research in the creative arts.[23]

The *Concrete Tectonics Studio* successfully established its own community of practice, bringing together tutors from academia, architectural practioners with expertise in Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM), industry fabricators, material suppliers, a structural engineer and the student body. Students contributed ideas that drew on their individual knowledge, experience and research and which were tested in a student-led process involving the production of graphic representations and the construction of three-dimensional models and precast concrete test-pieces. The tutors, architects and engineer brought additional knowledge to the encounter. After a number of cycles of experimentation and reflection a plan of action was agreed upon and a prototype of the virtual design was built to test it against the reality of factors such as gravity, material properties and performance of connections, none of which could be fully understood in the virtual environment.

Focussing on process rather than product

The significance of speculative and inventive inquiry in architecture lies both in terms of its process and its product. Wortham, searching for a new way of thinking about research in architecture, explores the relationship between process and product. She finds that "in an architectural schema, it is not just the product that is of consequence. The process itself, the search, the inquiry, can be as substantial if not more so, than the rendering of conclusions."[24] Spronken-Smith and Walker confirm that the research-teaching nexus is strengthened when the focus of learning is discovery-oriented and focuses on an inquiry process.[25]

The *Concrete Tectonics Studio* emphasised the process of identifying innovative casting methods that might be capable of producing mass-customisable precast concrete components. The focus on material experimentation and the iterative process was explained to the students as being a form of practice-based research. As a result they strongly identified with their role as researchers, applying their theoretical knowledge to creating physical prototypes in precast concrete, which were then evaluated against digital models, performance criteria and aesthetic frameworks.

Upon reflection about the successes and failures and whether there could have been other or better solutions to the original problem, the process was modified and repeated. This enabled students to identify ways in which they might contribute to new knowledge about material performance. The concrete prototypes were assessed in terms of their speculative potential to inform the industrial production of customised concrete components that might have architectural applications. These prototypes were not an end in themselves, but were regarded as a small step in a long-term research process shaping architecture's future.

Student awareness of prototyping as a research activity

It is important to make students aware that their prototyping activities are a form of research or are assisting them to learn research methods. Spronken-Smith and Walker have identified a strong research-teaching nexus existing in situations in which students are aware of their role as apprentice researchers.[26] Students need to be given clear information about what constitutes research in a particular discipline and how they might be engaging in it. This becomes particularly important in a creative discipline like architecture where the nature of research is contested. Innovation theory suggests that the different viewpoints that can be generated within cross-disciplinary and cross-cultural collaborations can be the drivers for creative outcomes. Similarly, literature on linking teaching and research identifies the benefits of establishing communities of practice to stimulate both creativity and the production of new knowledge. These communities may comprise academics alone or include external representatives from the architectural profession, construction industry and other disciplines.

When prototyping is conceived as a research activity led by academic researchers in their own field of expertise it is easier for students to make the connections between their individual prototyping activities in the design studio and research in general. Knowledge produced by the studio is made public through assessment by external juries, exhibitions of student work, installations in public places and publications ranging from scholarly articles to catalogues and books such as this one. As Wortham notes:

"The public nature of these investigations allows knowledge to be disseminated, challenged, and developed in a collective and comprehensive way. Studio, then, is an opportunity for architectural faculty to engage in public and collective research."[27]

When a prototyping activity emphasises iterative processes and reflection upon each stage, students learn a method of producing creative outcomes through a research-based process. It is imperative that students be made aware that prototyping is fundamentally a research-based activity and that it is just one of many research activities common to the discipline of architecture.

(Endnotes)

1 Simons, M. &Elen, J. (2007). The 'research-teaching nexus' and 'education through research': an exploration of ambivalences. *Studies in Higher Education*, *32* (5), p. 618.

2 Griffiths, R. (2004). Research production and the research-teaching nexus: the case of the built environment disciplines. *Studies in Higher Education*, *29* (6), pp. 715-717.

3 Wortham, B. D. (2007). The way we think about the way we think: architecture is a paradigm for reconsidering research. *Journal of Architectural Education*, *61* (1), 44-53.

4 Maloney, J. (2000). Studio based research in architecture: the legacy and new horizons offered by digital technology. *Working Papers in Art and Design*, *1*. URL: http://sitem.herts.ac.uk/artdes_research/papers/wpades/vol1/moloney2.html.

5 Varnelis, K. (2007). Is there research in the studio?. *Journal of Architectural Education*, *61* (1), p. 13.

6 Wortham, op cit, p. 46.

7 Griffiths, op cit.

8 Brew, A. & Boud, D. (1995). Teaching and research: establishing the vital link with learning. *Higher Education*, *29* (3), 261-273.

9 Boud, D., Cohen, R. & Walker, D. (1993). Introduction: understanding learning from experience. In Boud, D., Cohen, R. & Walker, D. *Using Experience for Learning*. Buckingham: Society for Research into Higher Education and Open University. p. 1-17; Deignan, T. (2009). Enquiry-based learning: perspectives on practice. *Teaching in Higher Education*, *14* (1), 13-28; Kahn, P. & O'Rourke, K. (2005). Understanding enquiry-based learning. In Barrett, T., Mac Labhrainn, I. & Fallon, H. *Handbook of Enquiry and Problem Based Learning: Irish case studies and international perspectives*. Galway: CELT. URL: http://www.aishe.org/readings/2005-2/contents.html

10 Dewey, J. (1933). *How we think: a restatement of the relation of reflective thinking to the educative process.* Boston: D. C. Heath.

11 Schön, D. A. (1987). *Educating the reflective practitioner: toward a new design for teaching and learning in the professions*. San Francisco: Jossey-Bass Publishers.

12 Cavanagh, T. (2004). Introduction: architecture, technology, education. *Journal of Architectural Education*, *58* (1), 3.

13 Hinson, D. (2007). Design as research: learning and doing in the design-build studio. *Journal of Architectural Education*, *61* (1), 23-26.

14 Architectural Association (2006). *ExperimentAAtion: AA projects review 05/06*. London: Architectural Association; Hensel, M. & Menges, A. (Eds.). (2006). *Morpho-ecologies.* London: Architectural Association; Dempsey, A. & Obuchi, Y. (Eds.). (2010). *AA Agendas 8: nine problems in the form of a pavilion*. London: Architectural Association; Self, M. & Walker, C. (Eds.). (2011). *AA Agendas 9: making pavilions*. London: Architectural Association.

15 Iwamoto, L. (2004). Translations: fabricating space. *Journal of Architectural Education*, *58* (1), 35-38; Scheurer, F. (2005). From design to production: three complex structures materialized in wood. In: Soddu, C. *Generative Art 2005: proceedings of the 6th international conference*. Milan. URL: http://www.designtoproduction.ch/content/view/28/15/; Larsen, K. E. & Stori, S. (2006). 1-2-TRE: 6 camera obscura project. URL: http://www.ntnu.no/1-2-tre/06/

16 Schroepfer, T. & Margolis, L. (2006). Integrating material culture. *Journal of Architectural Education*, *60* (2), 43-48.

17 Tisi, R. (2008). B+S+P+T+PL+M: six ways to approach architecture through the lens of performance. *Journal of Architectural Education*, *61* (4), 69-75.

18 Spronken-Smith, R. and Walker, R. (2010). Can inquiry-based learning strengthen the links between teaching and disciplinary research?. *Studies in Higher Education*, *35* (6), p. 727.

19 Ibid, p. 726.

20 Spronken-Smith and Walker, op cit, p. 735.

21 Brew, A. (2003). Teaching and research: new relationships and their implications for inquiry-based teaching and learning in higher education. *Higher Education Research and Development*, *22* (1), p. 3.

22 Ibid, p. 12.

23 Wareham, T. (2008). *Creative graduates: enhancing teaching-research links in the creative arts: briefing paper*. Higher Education Academy/Palantine. URL: http://www.palatine.ac.uk/files/Publications/1224.pdf

24 Wortham, op cit, p. 46.

25 Spronken-Smith and Walker, op cit, p. 736.

26 Ibid, p. 734.

27 Wortham, op cit, p. 49.

Investigation

Scale: One to Twenty

We begin with the big picture: the generation of form and the holistic set of processes used to derive form. Often in architecture, form is where one begins and will dictate the detail to follow.

This studio sought to encourage and engage with a constant evolution of architectural form. The ambition of achieving a final built outcome at 1:1 meant that testing analogue models was as crucial as developing digital models.

The oscillation between the analogue and digital investigations allowed an exploration of space through both form and sensory experience. While digital models investigated the pattern and shape of the surface, each iteration of analogue models revealed the physical quality of space and the subtleties of the geometry. The information derived from the analogue models was continually fed back into the parallel process of digital modelling, contributing to a regeneration and improvement of the script to approximate the desired effects of the analogue models. With each iteration, the structure and form were refined, and both the analogue and digital models began to more closely resemble each other.

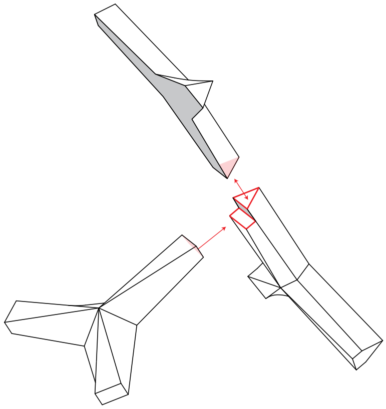
What resulted from this dual process was a design-rich, highly efficient structure that recognised the spatial qualities of an overall design, achieved through intelligent and parametric manipulation of digitally customised components.

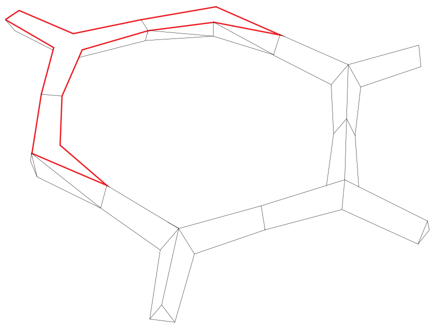
Analogue Explorations of Form

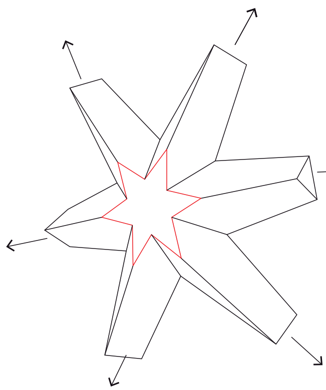
Physical model making was a critical component of the studio's practice-based research, and was paramount in the early stages of designing the overall form of the structure.

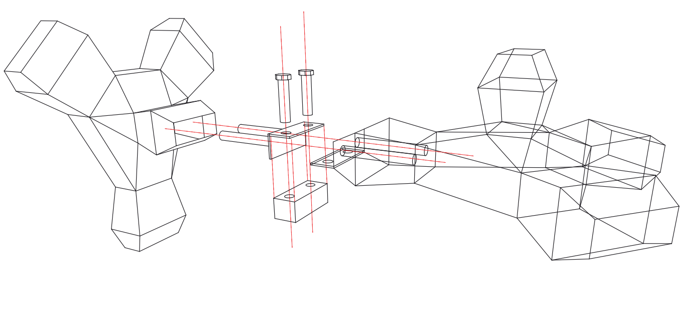
The use of analogue models to explore the form and shape of the gateway structure was paramount to the derivation of design intent and structural logic. Each student conducted their own investigations, pursuing their own desires and designs for what might constitute a parametric, mass-customised structure.

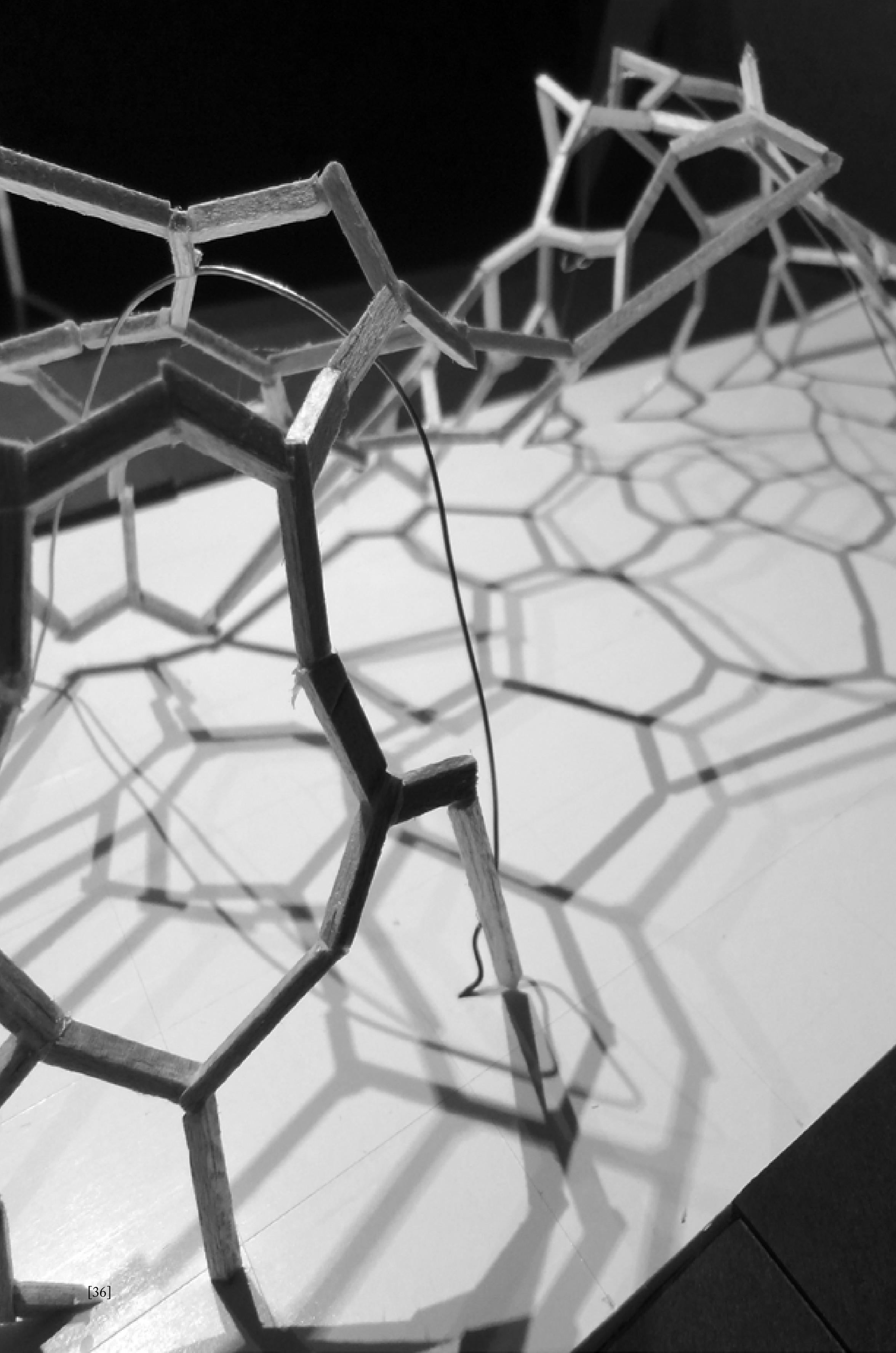
Students tested their ideas through a range of materials and scales, which gave them the scope to experiment with differing component shapes, patterns, and structural systems. The range of materials used to create the models gave the students a deeper understanding of the quality of space and the structural performance of materials in weight, span and load transfer. This process produced a diverse range of ideas to critique and iterate. The plethora of designs explored concepts of 'gateway' and architectural issues of place, form, continuity, connections and detail to attempt the most efficient and visually dynamic possibilities. Not only was there diversity in the students' formal propositions for the gateway structure, but the design of their individual concrete components varied markedly in geometry, scale, permeability and complexity.

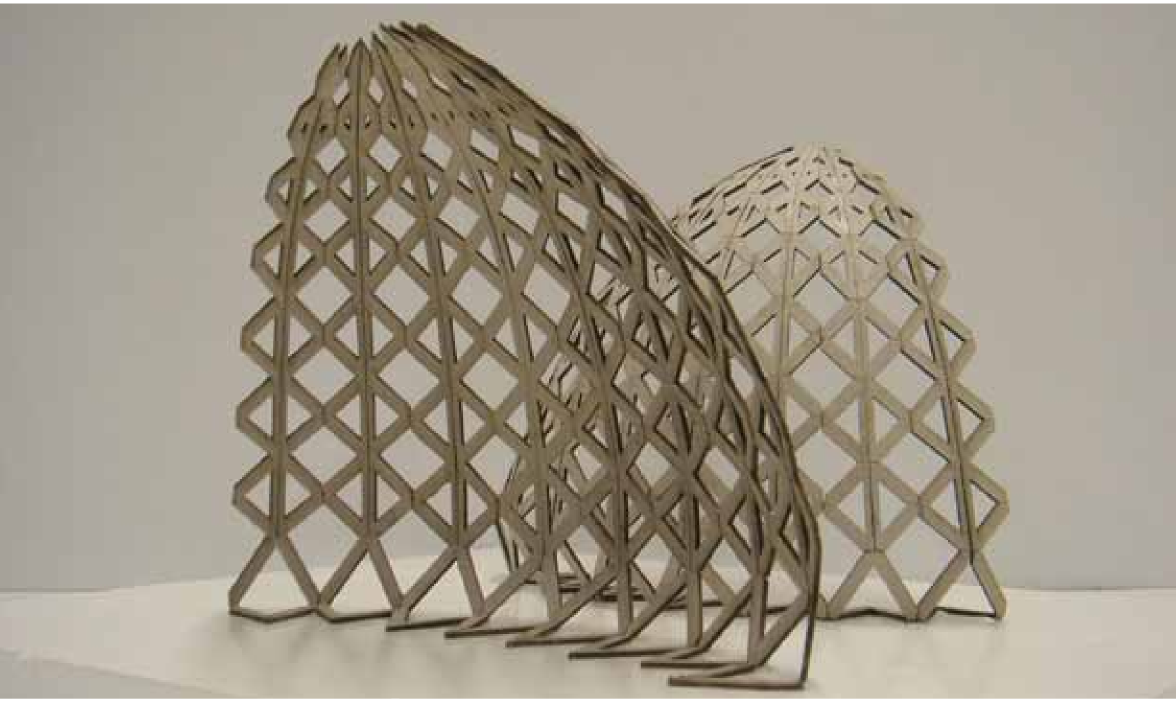


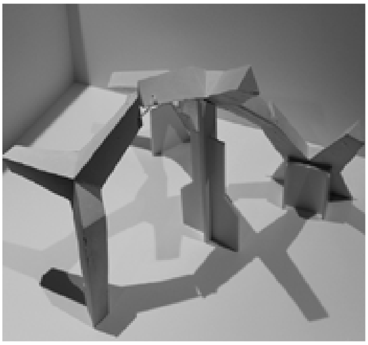


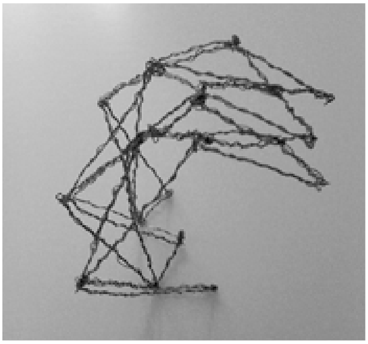


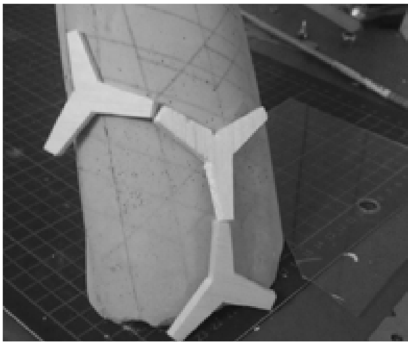


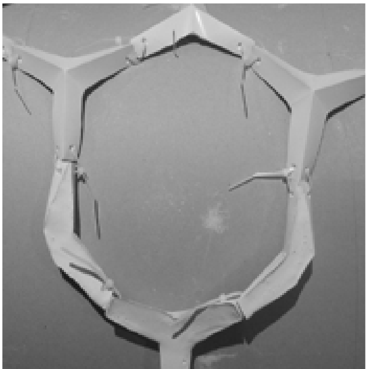


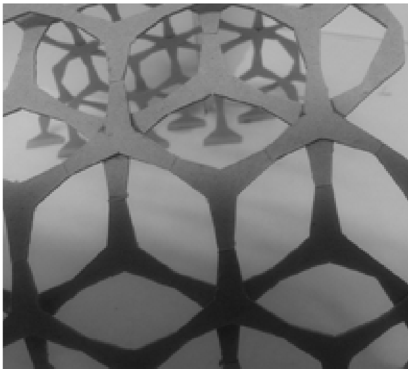


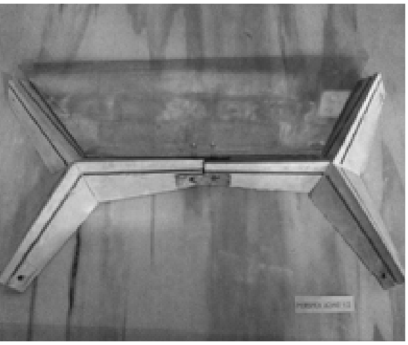


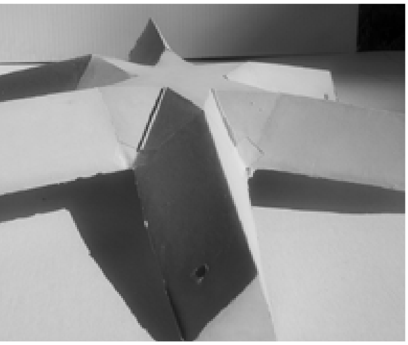
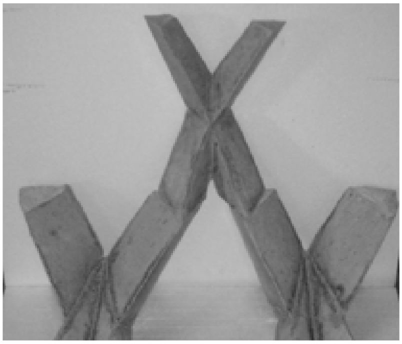
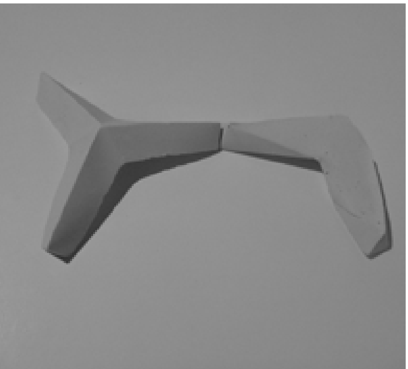


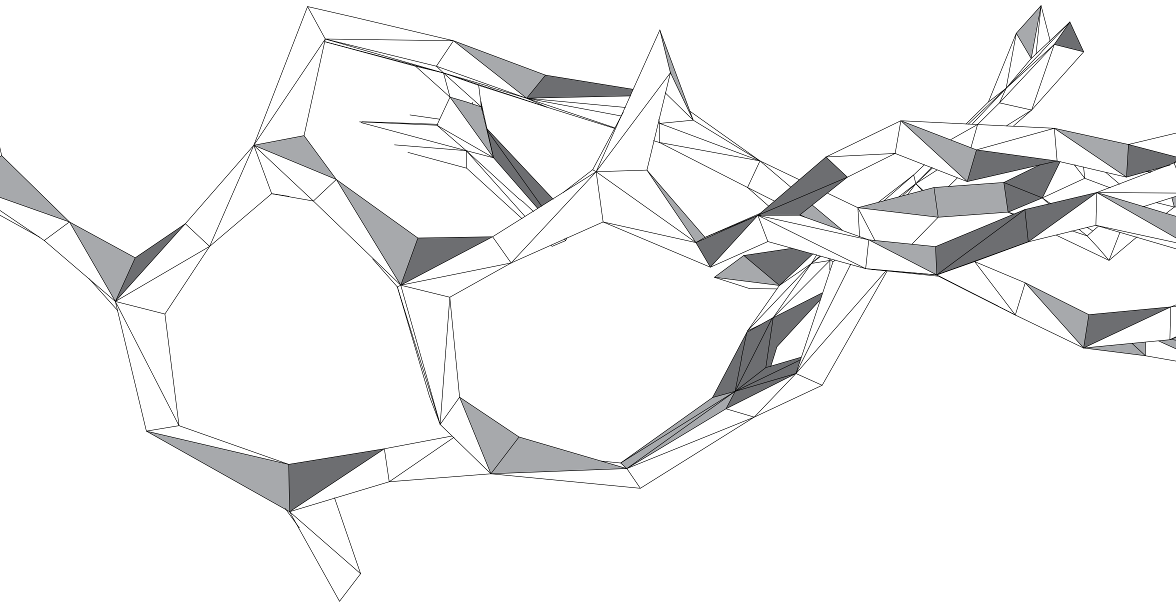


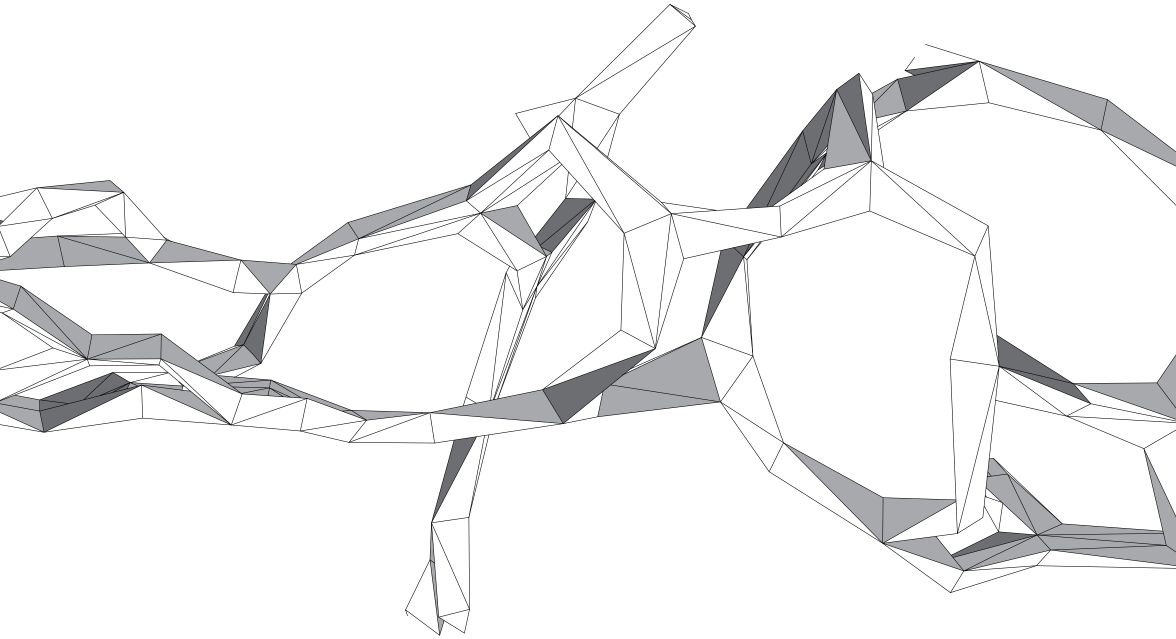








Parametric Investigations

The form was dictated by the rules governing parabolic arches and catenary curves. The digital scripting process developed by *Supermanoeuvre* made it possible for the design to change and adapt at any given moment.

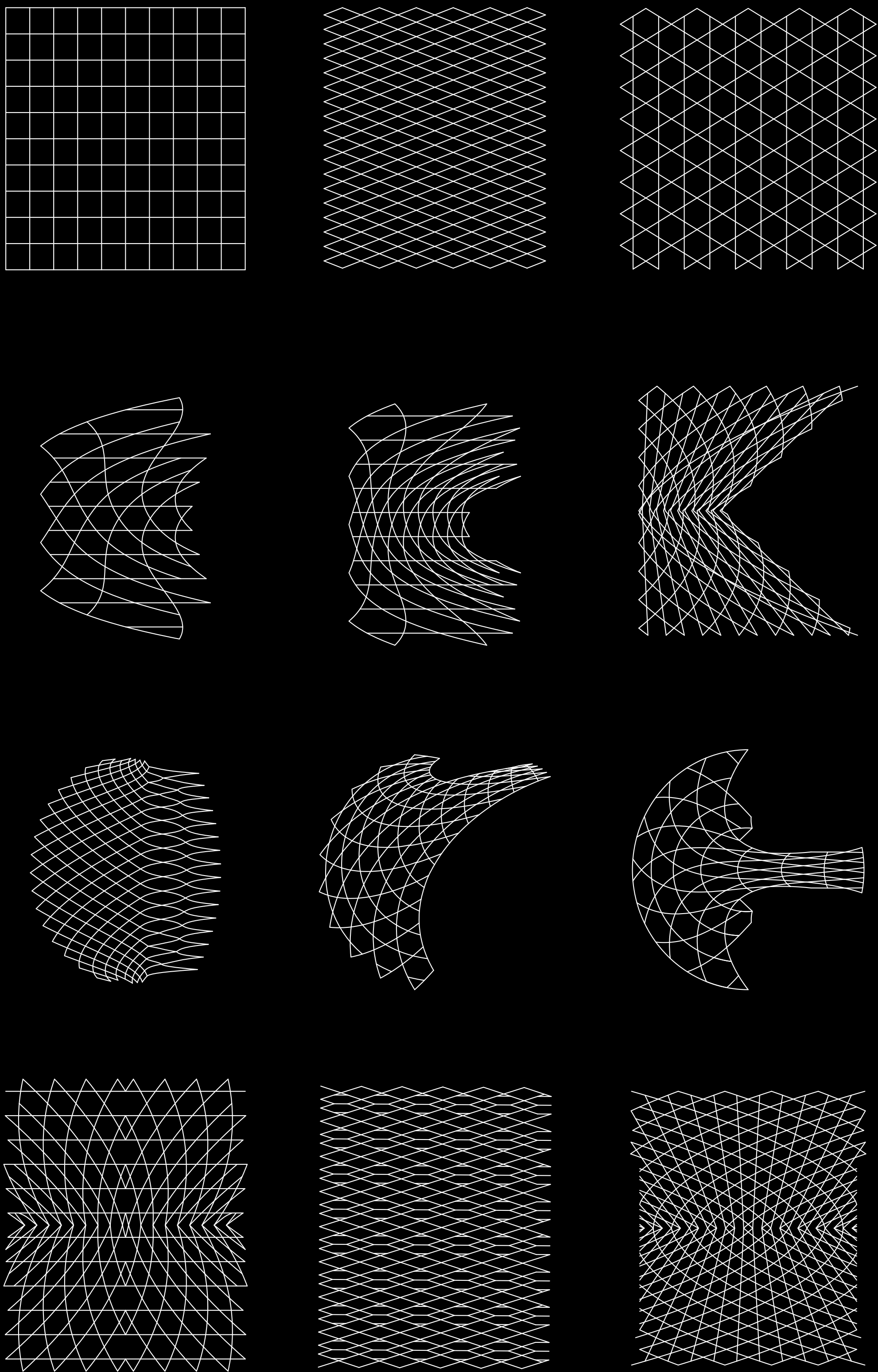
The script emulated the method of Gaudi's hanging chain model, using catenary arches to ensure that the structure would be entirely compressive and self supporting. The script was applied alongside the analogue models being produced by the students. It controlled the effect of curvature, size and angle of the overall structure and was pushed to its limits in trying to achieve the students' ambition to construct an arched structure with twisted surface geometry.

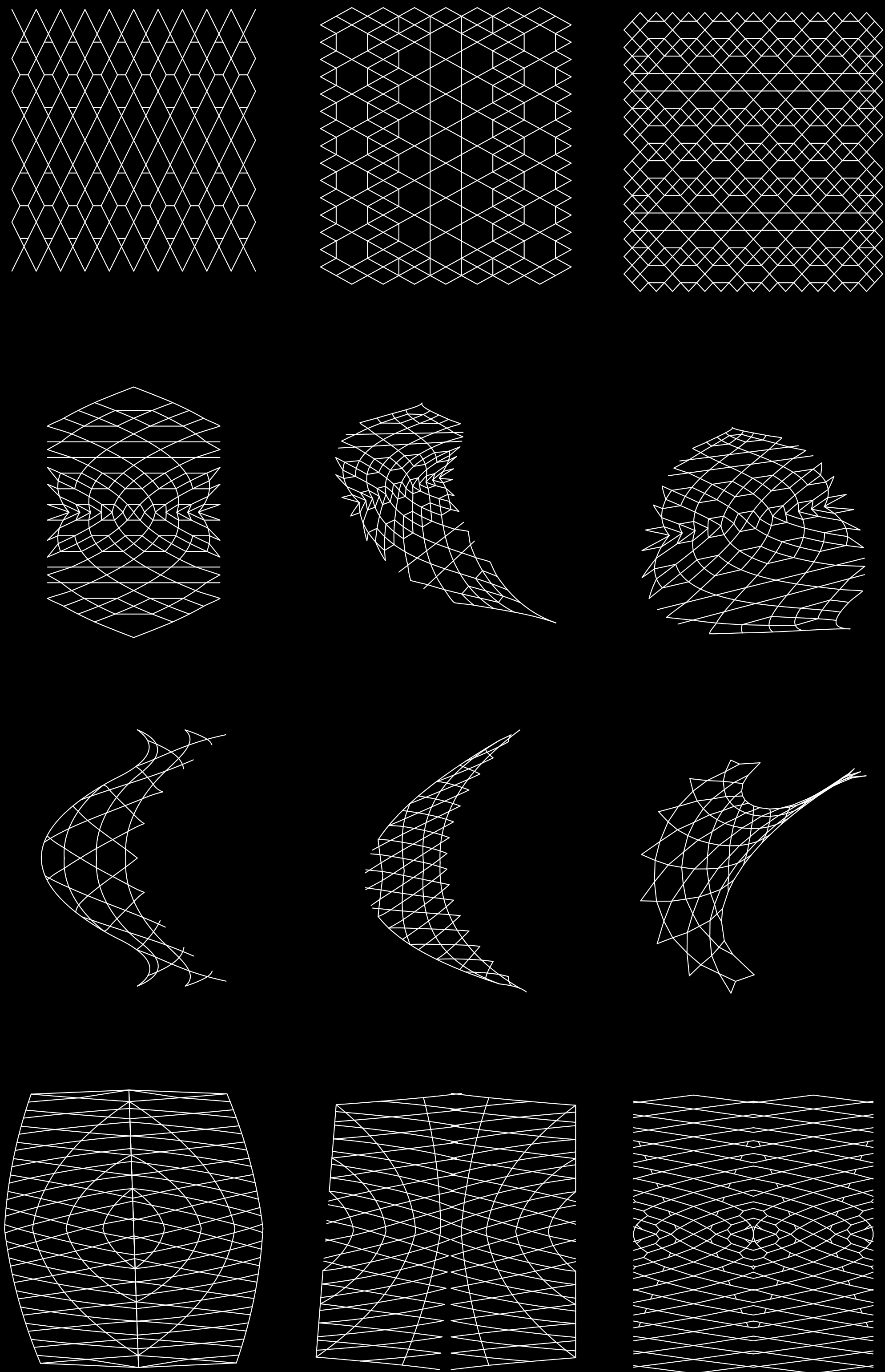
Built-in parametric indices allowed instant changes to the structural grid, surface pattern and distance between ground connections. This allowed for a rapid and limitless number of iterations that could be constantly manipulated digitally as the design evolved in the analogue realm.

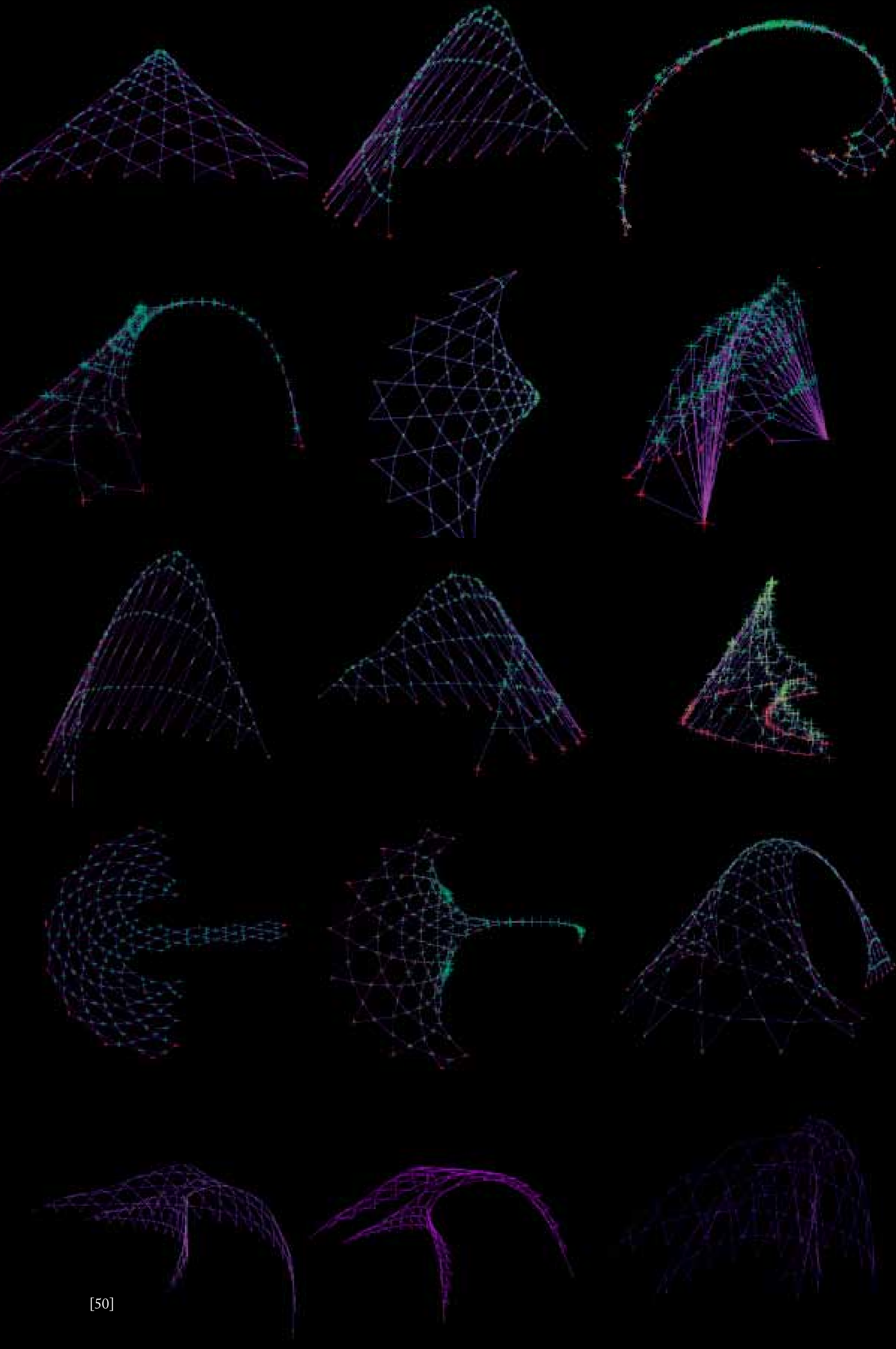
The use of customised algorithms to generate the components allowed for infinite permutations in pattern, size, geometry, surface and profile, meaning that the structural shape and individual concrete components were perpetually being regenerated in new formal outcomes.

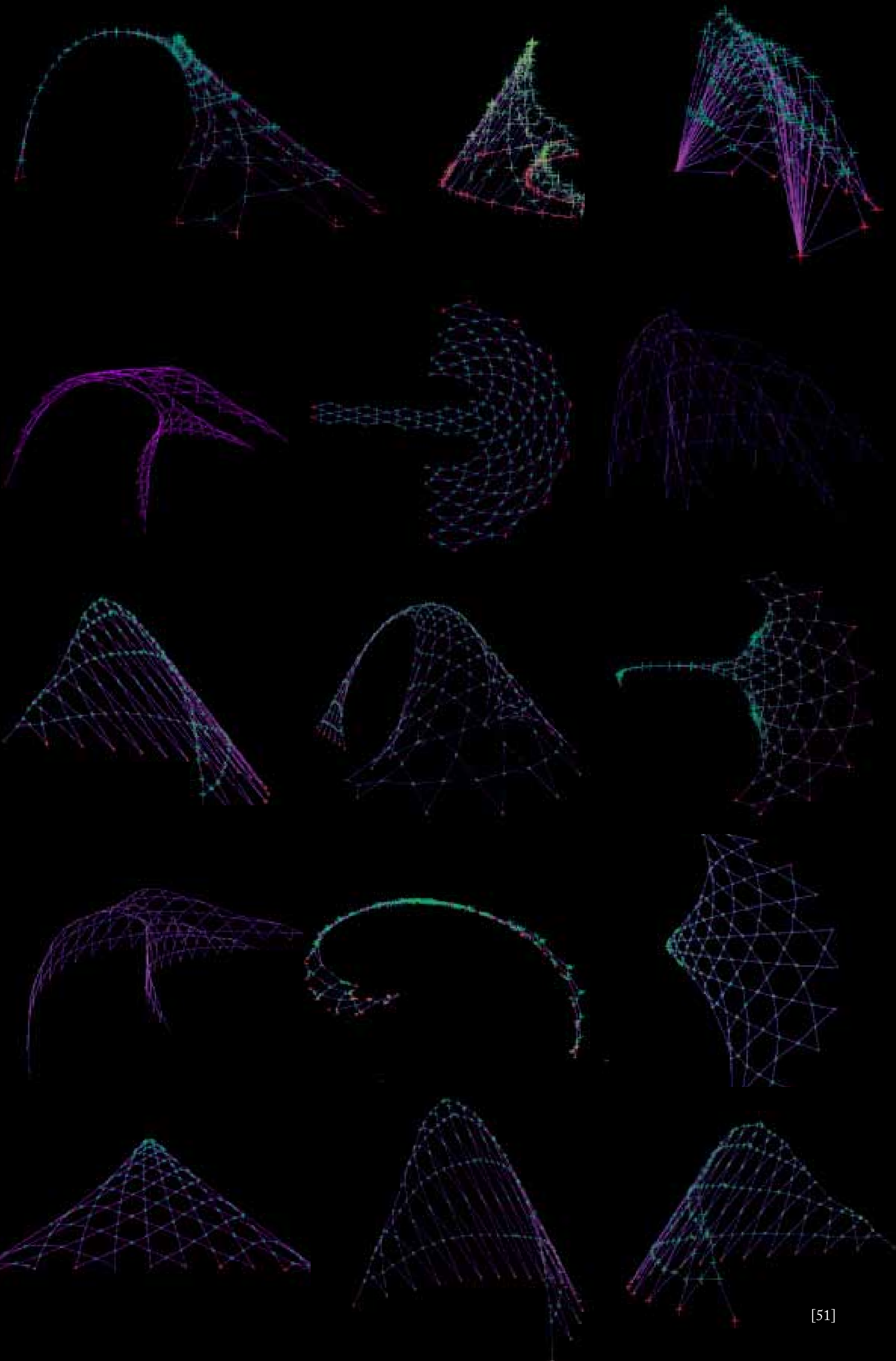
While this digital tool equipped students with unlimited design options, what remained important throughout the process was that the digital models should not overwhelm the analogue investigations occurring in parallel. While the digital sphere could process the complex mathematics of a self-supporting structure, the analogue sphere could capture the atmospheric and material potential of the design. A meaningful balance was achieved between the two so that, rather than competing, they were complementary to each other.

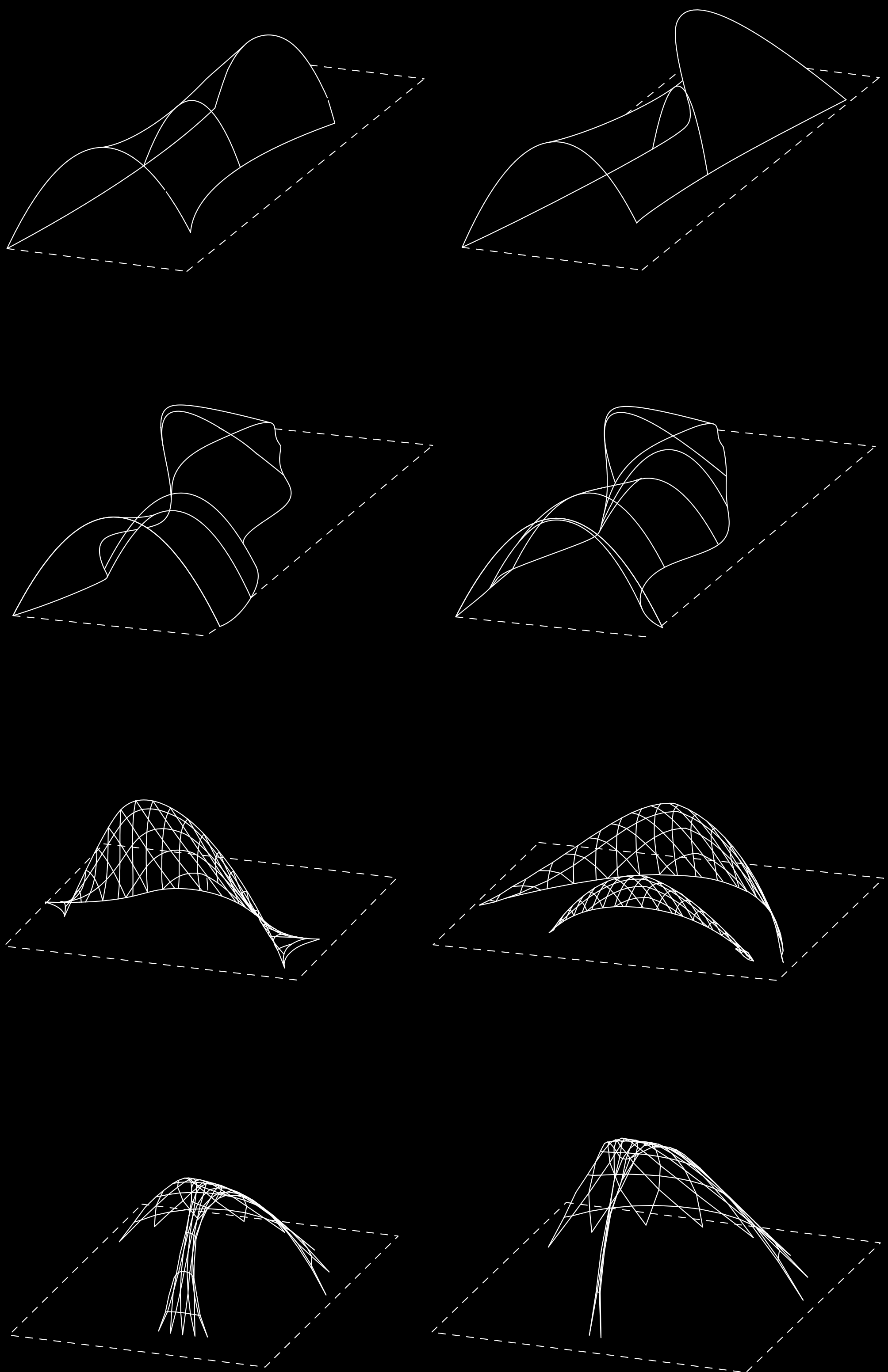
The fluidity achieved in the studio process highlights the possibilities of parametric design as both a proactive agent and a reactive one in the architectural design process.

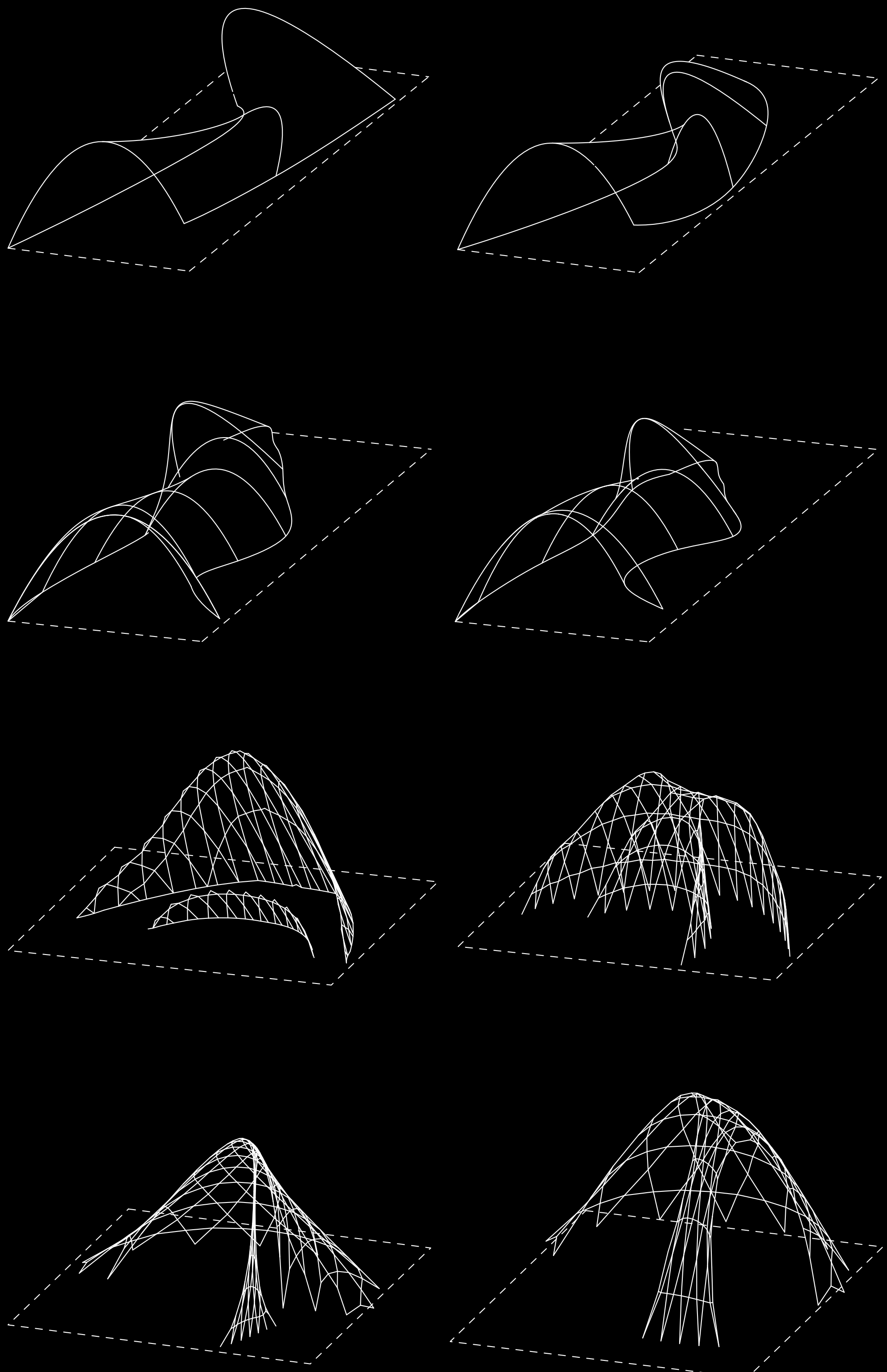


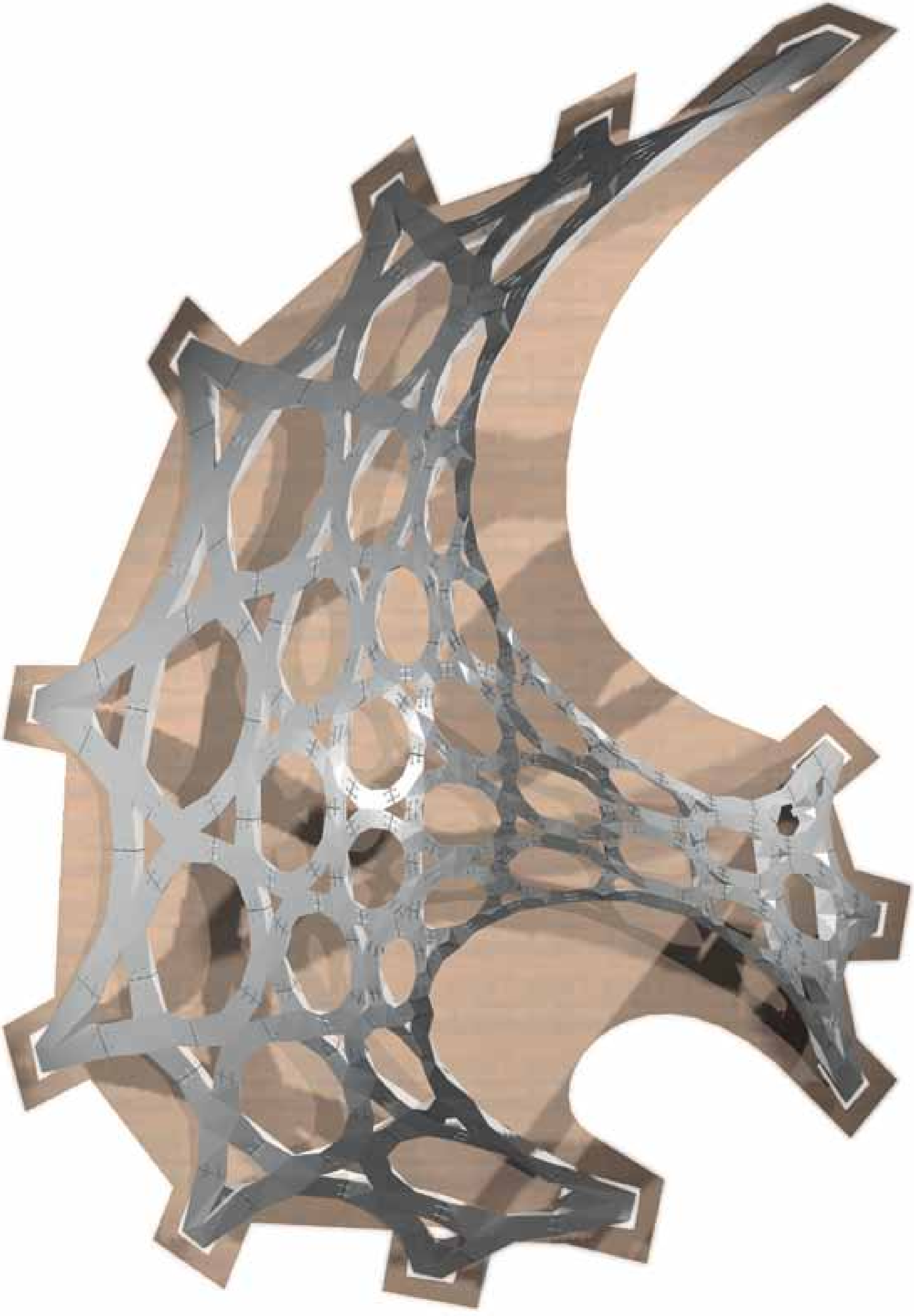


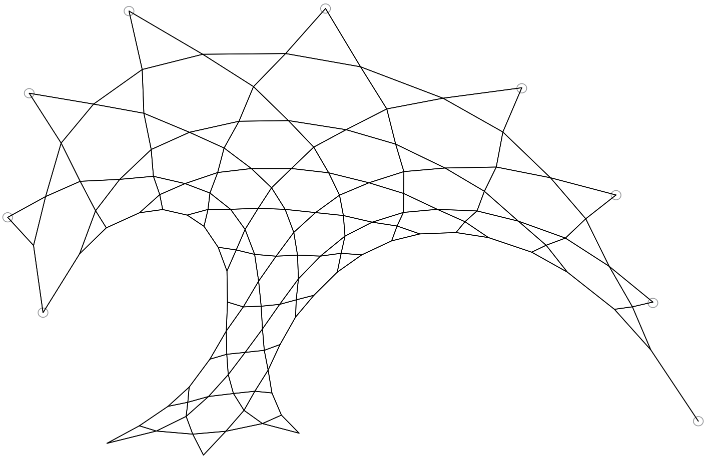


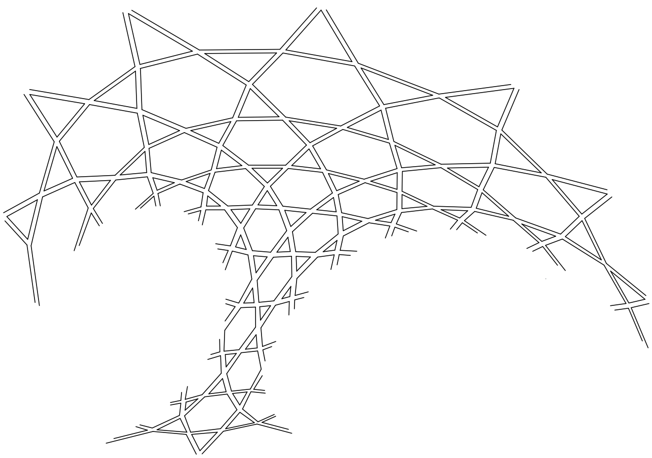


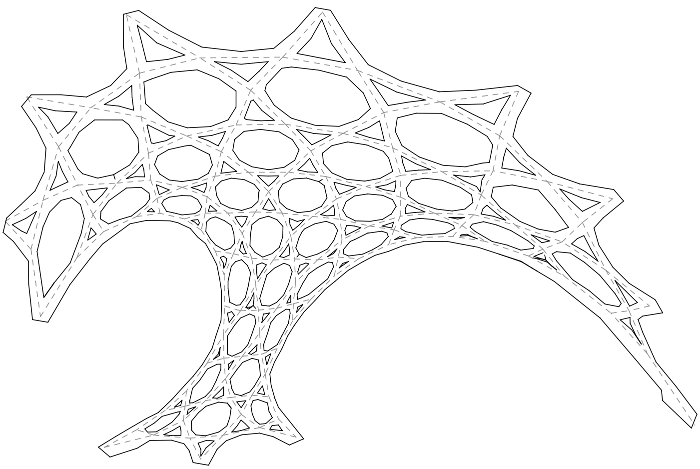


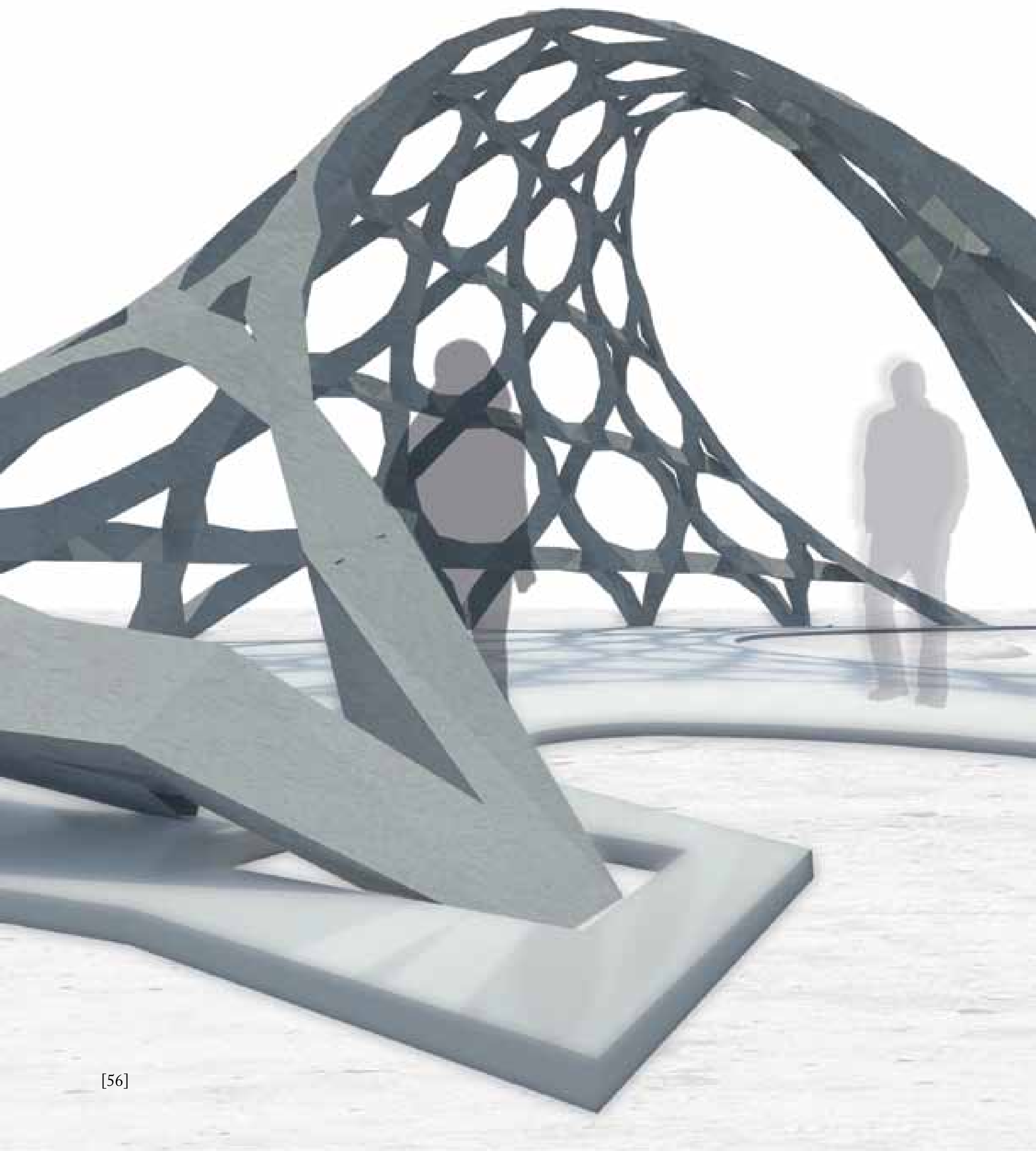












Scale: One to Ten

In conjunction with the development of the overall form at 1:20, the studio required that consideration be given to how the structure would actually be constructed. Thus, it was crucial to understand, and develop a solution for, how the structure would meet the ground. It was also essential to develop a strategy for the design of scaffolding that was necessary to support the structure during construction.

It was at 1:10 that the studio began to explore elements of design that are crucial to the construction process but often omitted from the university architecture curriculum. While considering construction methodology and the consequent impact on the design of the structure, students were required to think more laterally about their approach to the design solution.

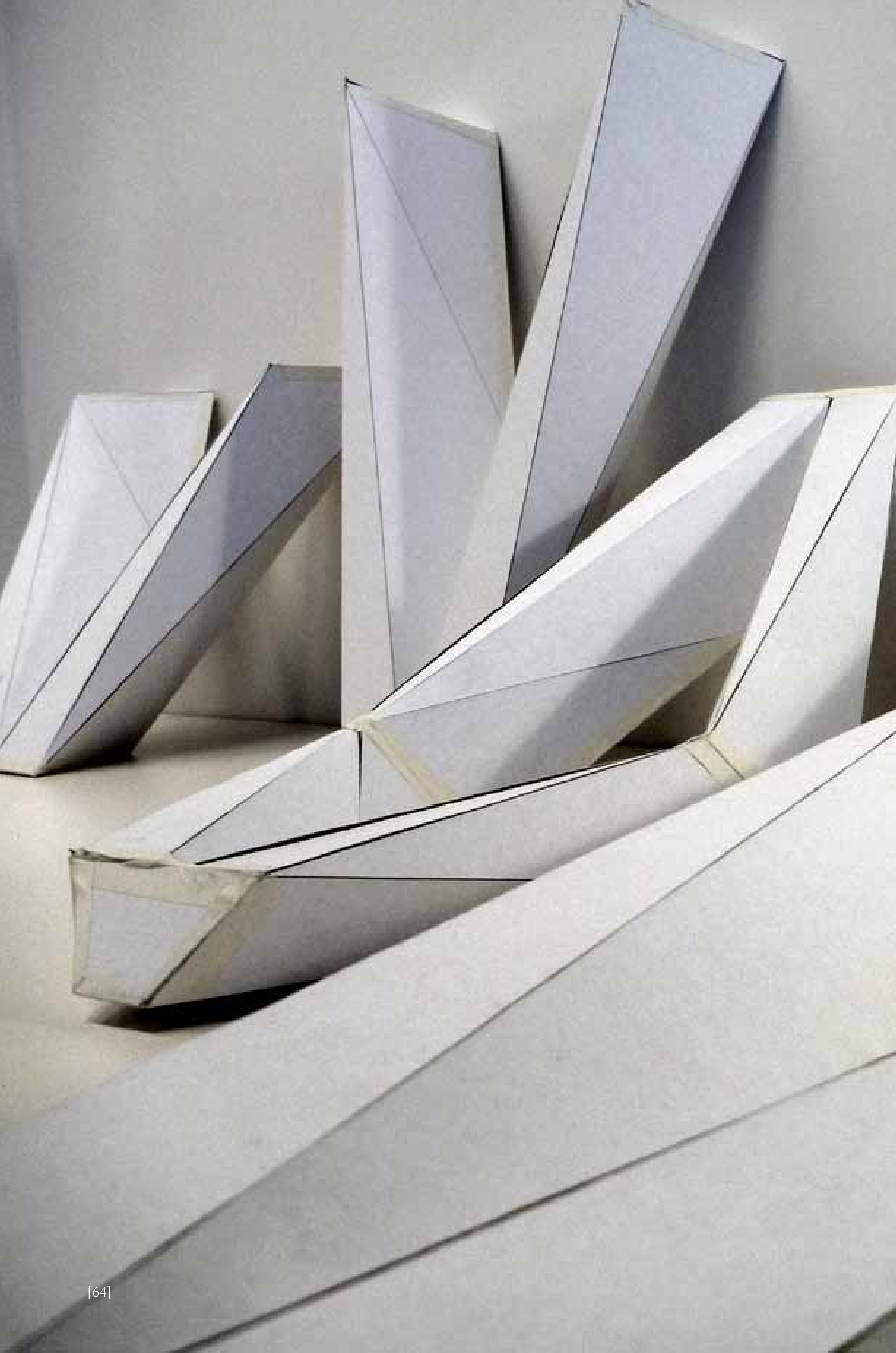
With structural advice from engineer Peter Standen of *Partridge*, students were able to understand the complexities involved in building the structure whilst also acknowledging the crucial involvement of consultants during the design process to achieve the most successful and appropriate result.

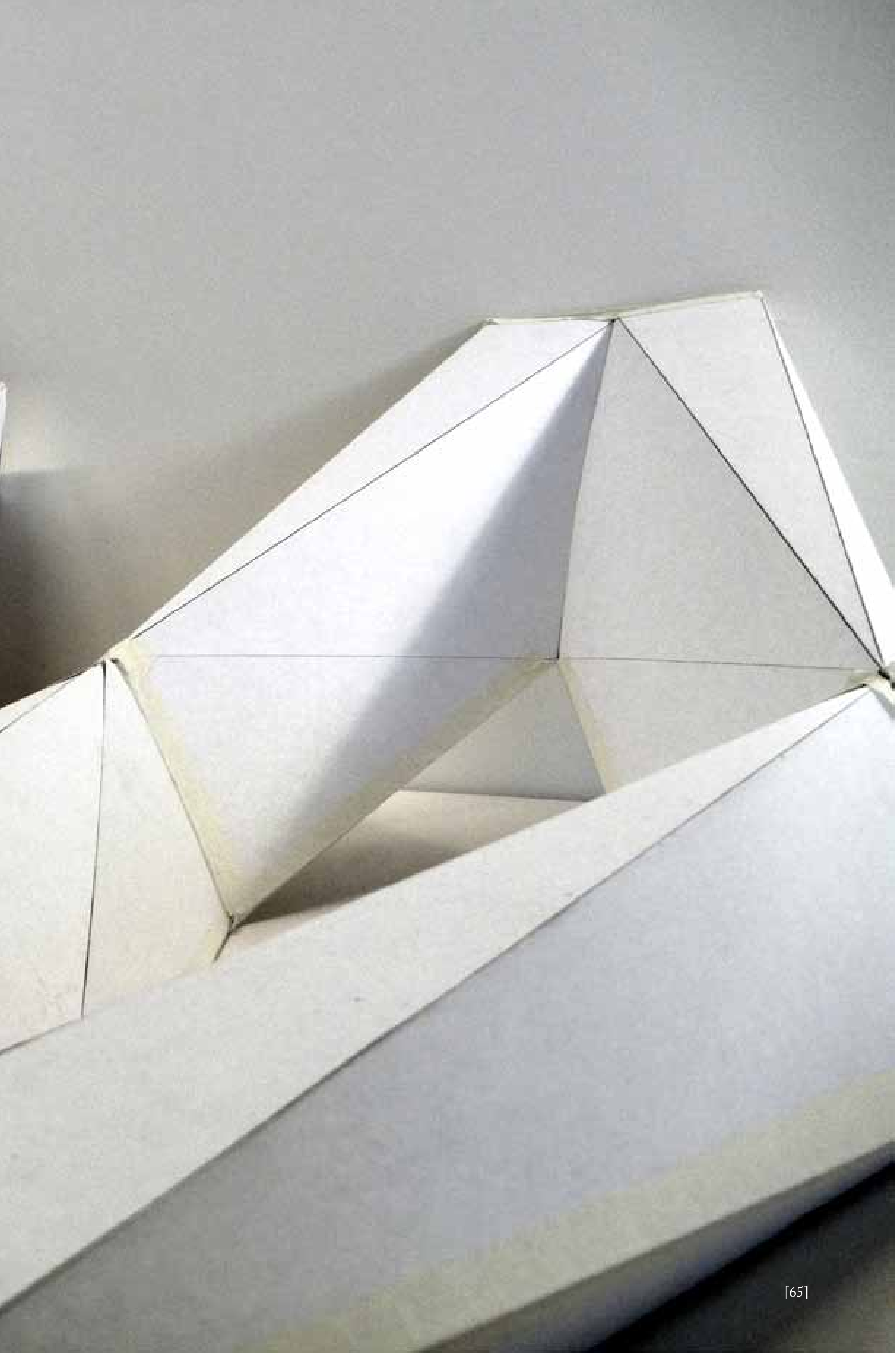
Ground Plane

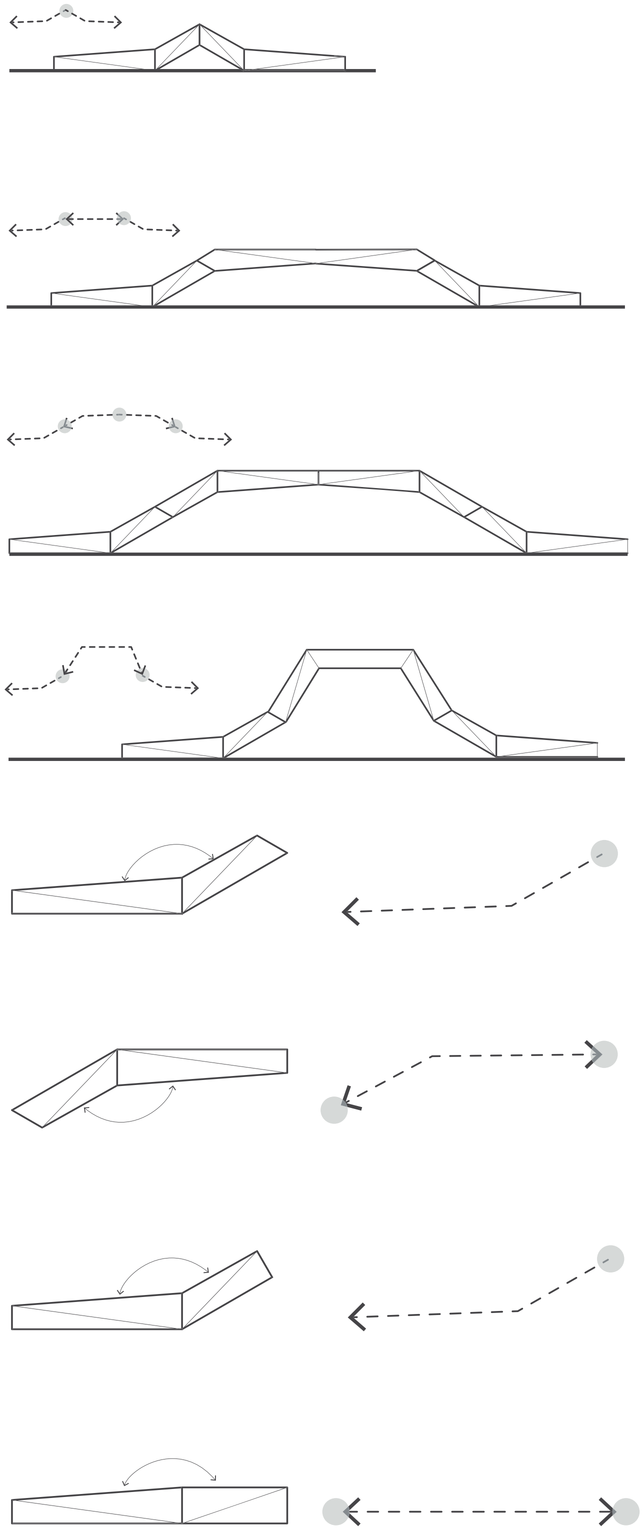
The design of the ground plane was crucial to the overall success of the structure, both aesthetically and structurally. The ground plane comprised two primary components: the 12 individual concrete footings and the plywood diaphragm base design, essential to tie the footings together and prevent them from spreading. The design of the footings and plywood base were inextricably linked and reliant upon one another.

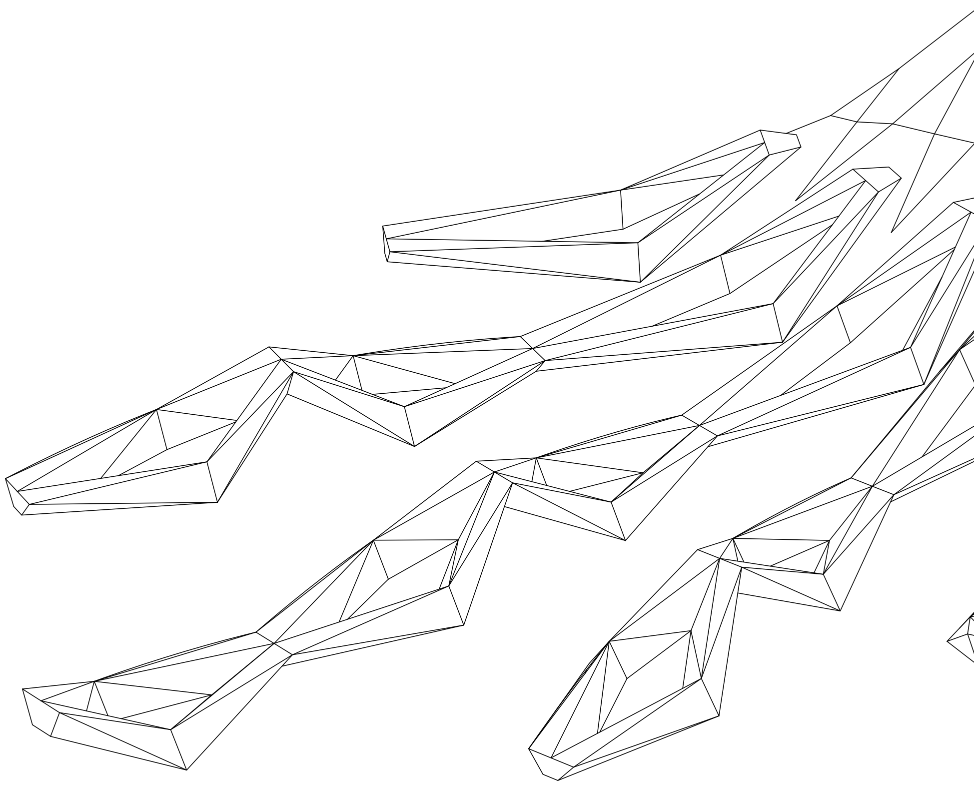
There was a strong desire to create a folding ground plane of concrete components to make the structure appear as though seamlessly growing from the ground. The development of footing pieces that could adequately support the forces of the structure and achieve the fluidity of a folding aesthetic was achieved through continuous oscillation between both digital and physical prototyping in designing an elegant and simple footing design. Ultimately, the footing design resulted in a simplified version of the folding ground plane due to the time constraints of the studio and the ever-changing process of the overall digital design development.

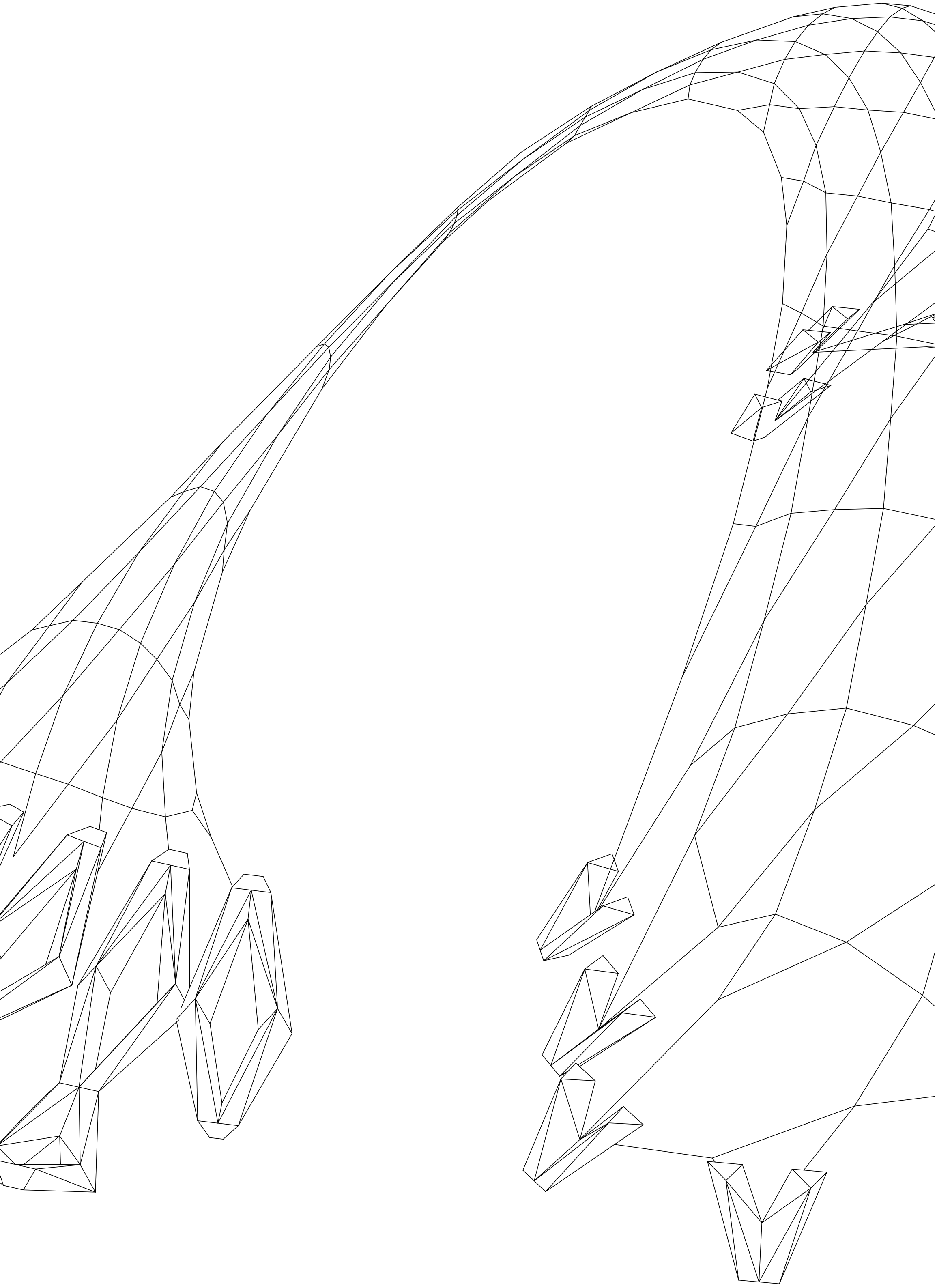
The development of the plywood base was more fraught than the students had expected. Structural advice from the engineer resulted in the double-layering of the plywood base to achieve the required cross-bracing. The overall shape of the base was designed digitally; however the physical construction added a degree of complexity and consideration in achieving an accurate result.

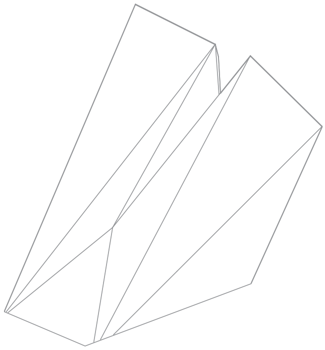


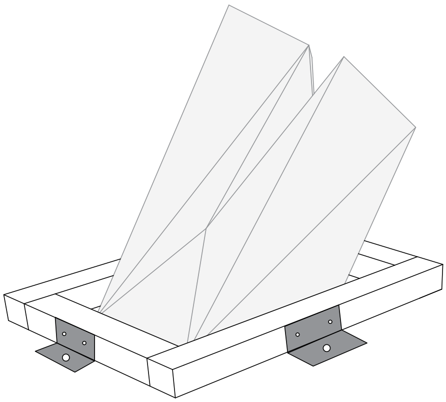


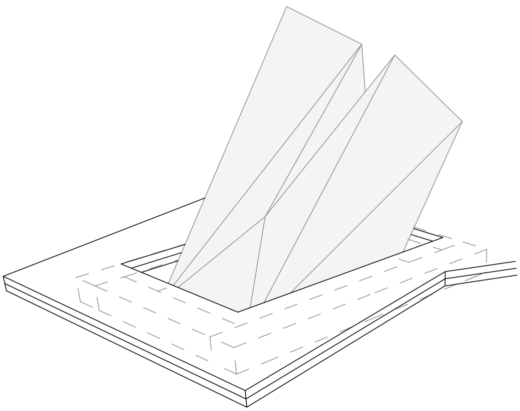


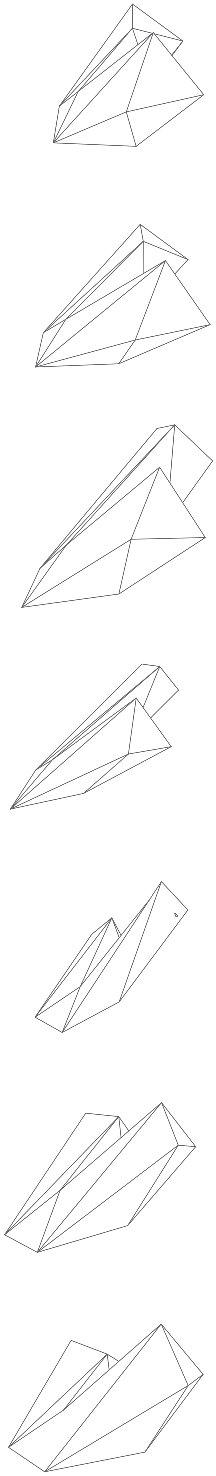










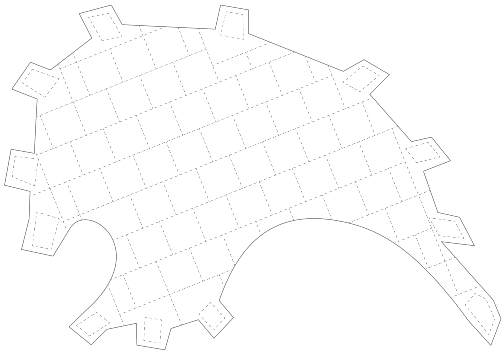


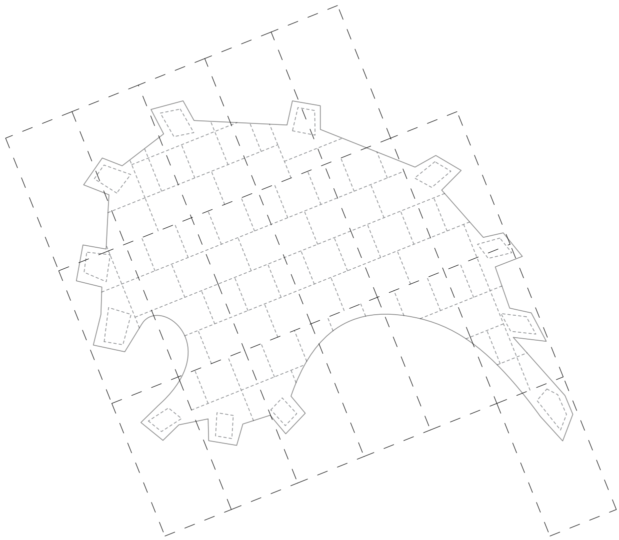


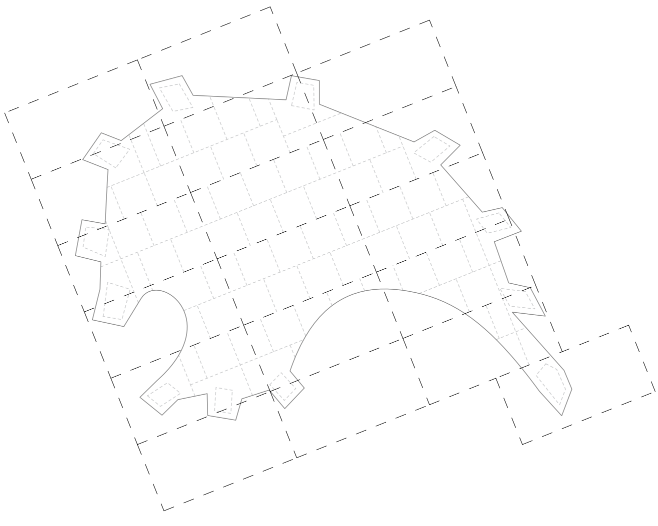










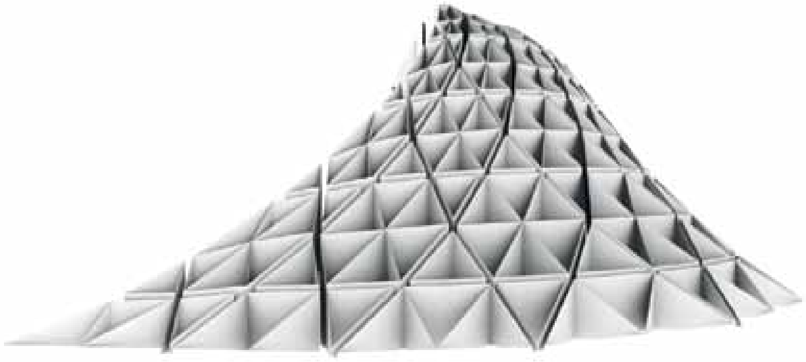


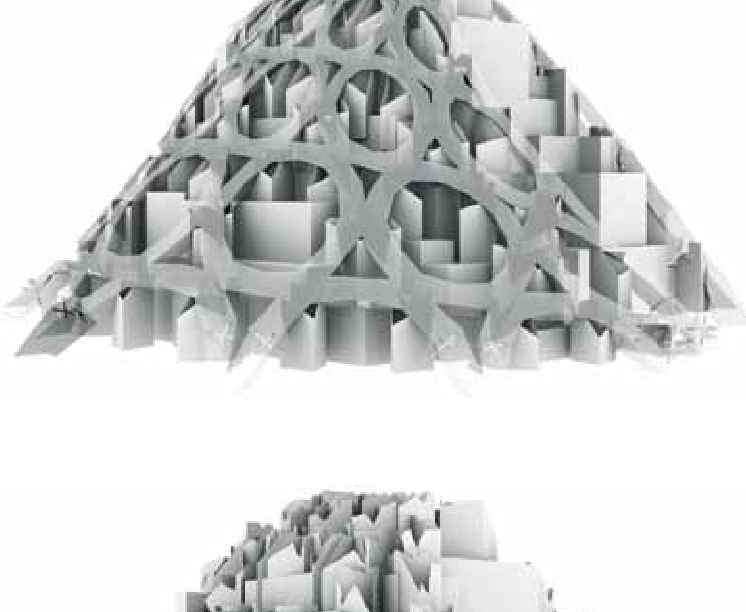
Scaffolding

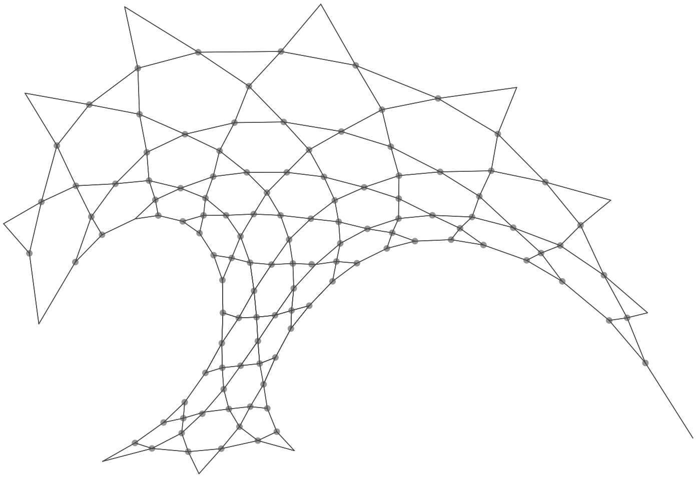
The scaffolding design and development needed to ensure the successful erection of the structure. The nature of the parametric design of the concrete structure required minimal tolerances in the order of ±1mm in the positioning of the components relative to one another. This demanded that the scaffolding be carefully designed to enable accurate positioning of the concrete components.

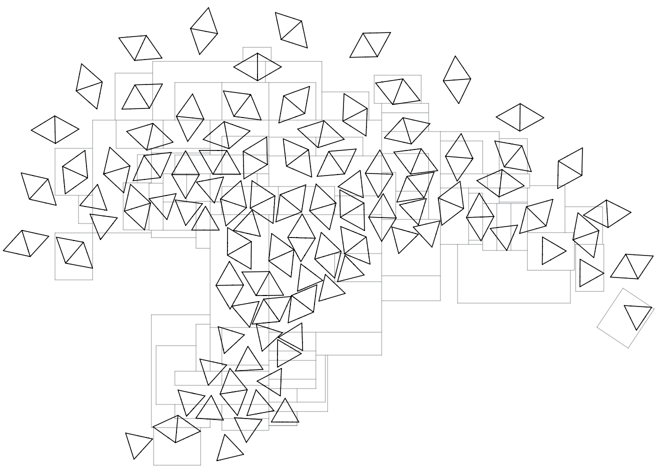
The scaffolding needed to be sturdy enough to support the enormous weight of the entire three metre height at the peak of the structure. It also needed to be intricate to provide a cradling system that was accurate and strong enough to support the concrete components in place. Large polystyrene blocks were stacked to approximate the geometry of the overall concrete structure and provided a stable foundation and a cost efficient solution, requiring no custom cut pieces. A grid of laser cut corrugated cardboard fins was laid over the polystyrene mountain. The hollow triangular prisms of cardboard acted as a cradling system to support and accurately locate the profiles of the individual concrete components. The cardboard scaffold was scripted through the same parametric software as was used to generate the overall concrete structure form. This ensured accuracy in the scaffolding design.

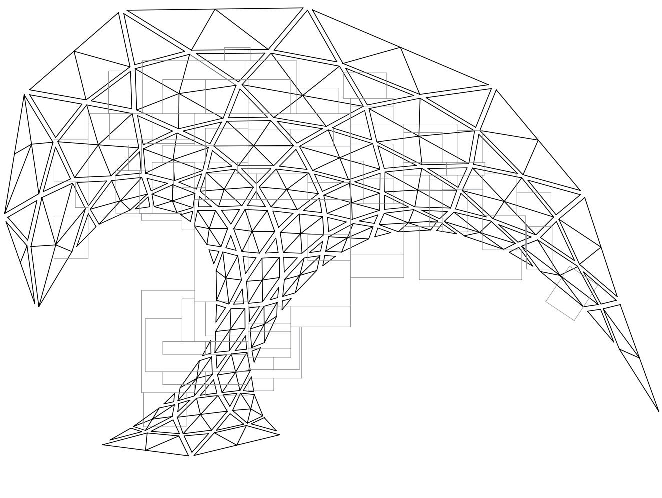

600x625
P118











Scale: One to Five

In parallel with the 1:20 investigation of form and 1:10 investigation of ground plane was an investigation focussed on developing strategies for the mass-customisation of the individual concrete components.

Mass-customisation is rare in precast concrete because it is so costly and therefore unrealistic for most architectural projects. More generally within the construction industry, opportunities for mass-customisation are limited by a fear of the uncontrollable. This studio exerted control over the potential anarchy of mass-customisation through careful investigation in both analogue and digital realms. The pursuit of innovation to push precast concrete to new limits meant that the students were constantly re-designing in the digital sphere and immediately testing these designs in physical prototypes.

To understand the rules governing the parametric customisation, components were assembled in paper, plaster, and most importantly concrete. They were then digitally iterated to create maximum visual impact with minimum added complexity. This was accompanied by a thorough investigation into the casting process of individual components using laser cut PET moulds. The testing of different shaped components and different casting methods enabled the students to synthesise outcomes to arrive at the casting process they found most efficient and effective and with the highest degree of accuracy.

While this was a time consuming activity, the prototyping and testing throughout the design process meant that there was a much greater understanding in the possibilities and constraints of mass-customising components.

Concrete Component Design

While there appears to be great variety in the scale and form of individual concrete components, the casting mould for each component is a derivative from the original geometrical "X" form.

Negotiation between the overall form and the components it generated meant that mass-customisation of components could only be achieved through parametric variables. What was key to this investigation was to harness the power of mass-customisation and maximise visual impact with controlled and measurable changes.

The final structure is composed of 130 components, each unique in its overall size, cross-sectional depth and geometry. There are three primary components used throughout the structure, each with its own purpose. The "X" shape is used throughout the body of the structure, becoming thicker towards the base where structural loads are transferred to the ground. The "V" footing component is located at the base, with a flat bearing surface that can be fixed to the ground. The "Y" components are those that negotiate the edge of the form, creating closed geometries and smooth arches to the entry-ways.

Simple parametric changes to the angle of rotation, the length of arms and the number of arms, give each component a unique geometry and size. This allows for a variety in the scale and shape of components, and creates the ability for components to change as they negotiate around the structure.

The broad spectrum of unique components creates a diverse cell structure and typological variation, resulting in a more complex and intricate form than if all the components were identical.

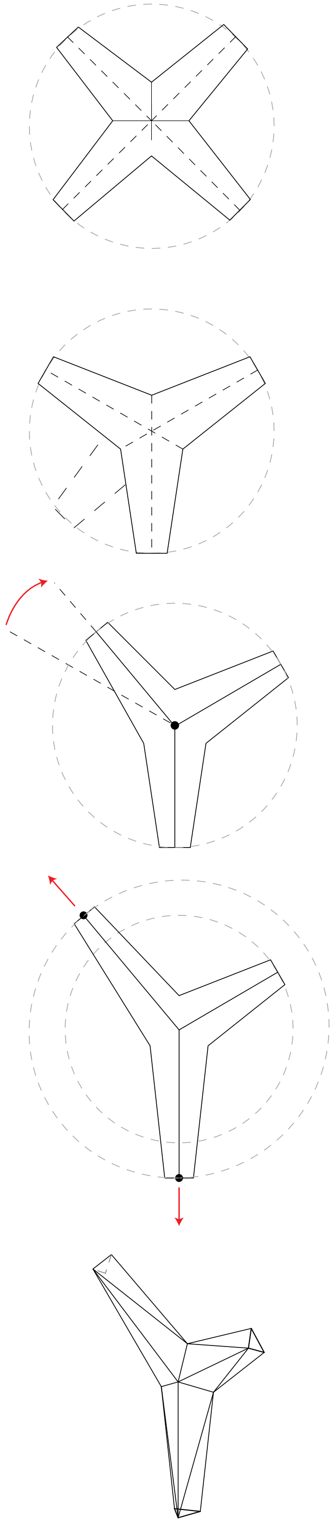

MANGOES

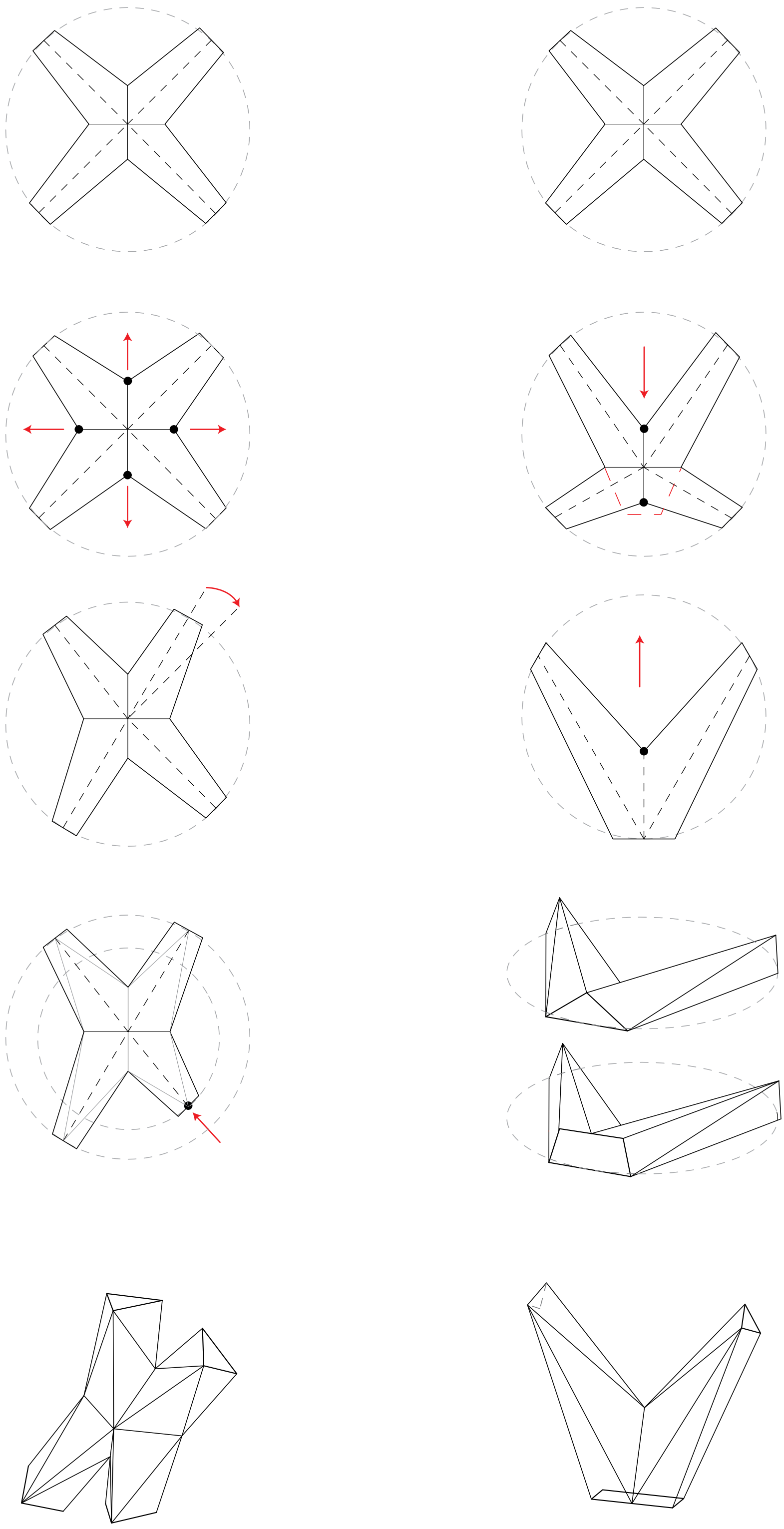


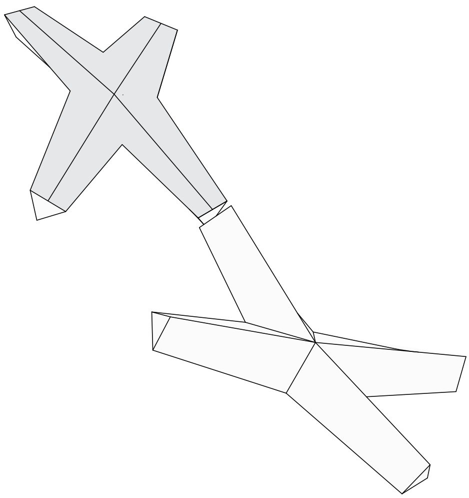


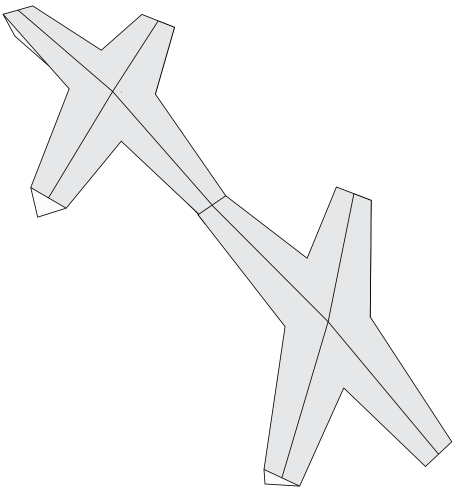


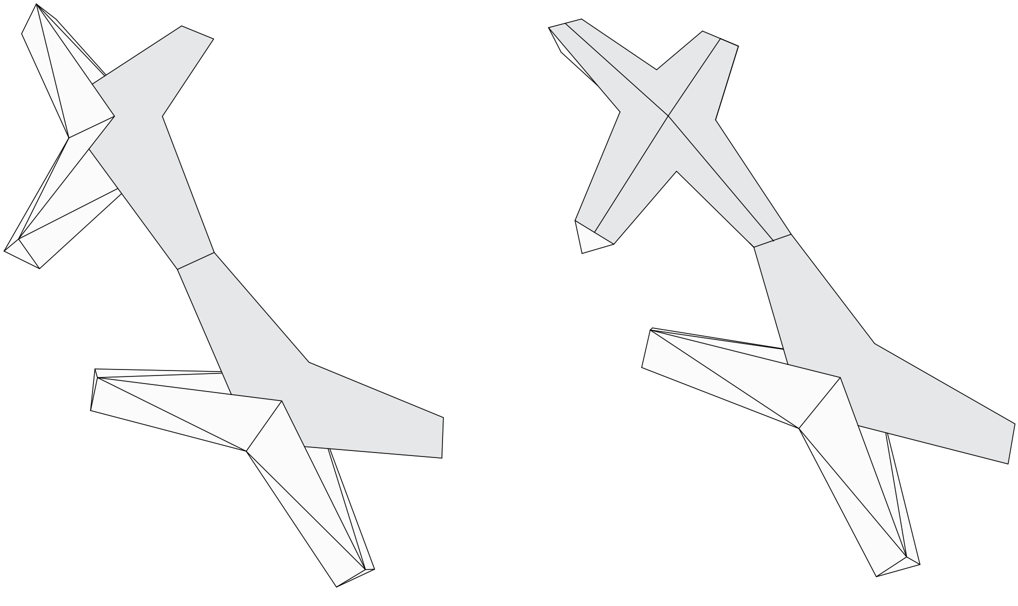


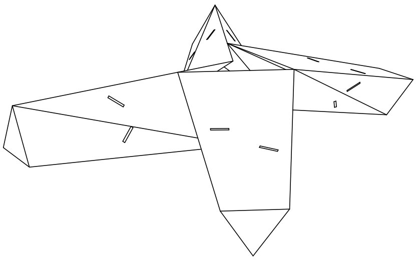
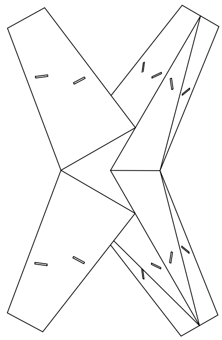
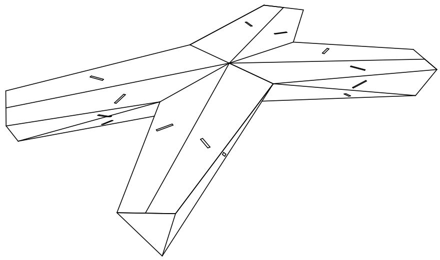
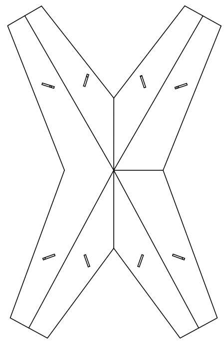
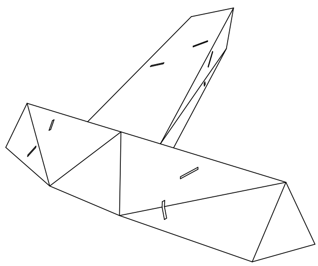
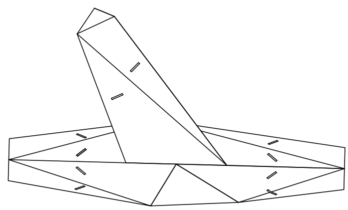
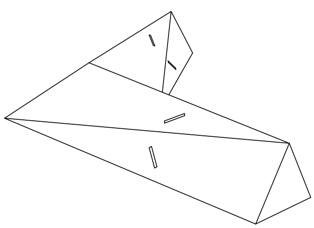
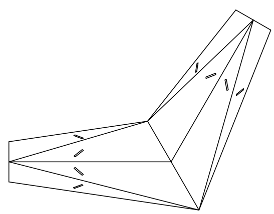












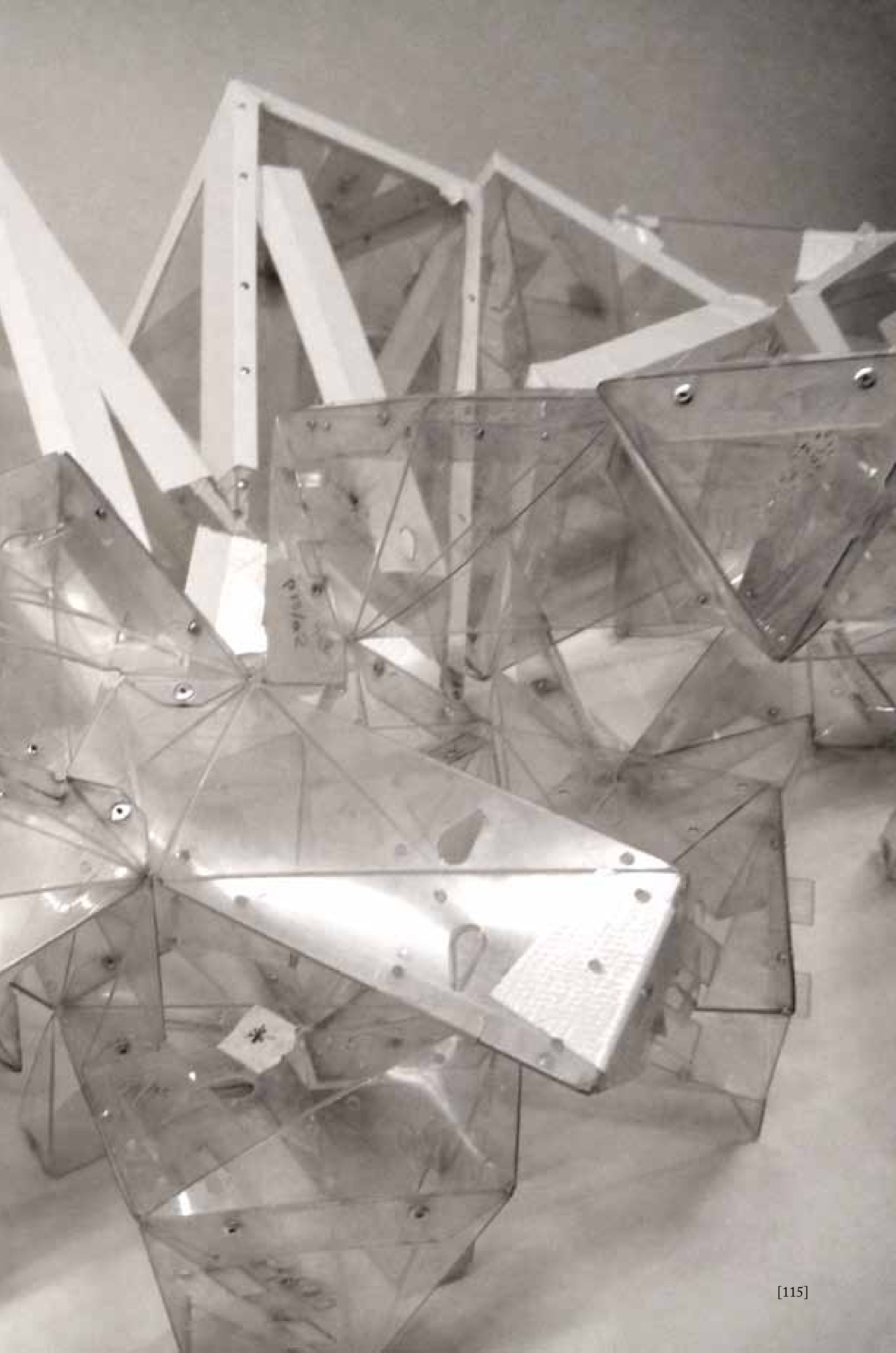
Casting Experimentation

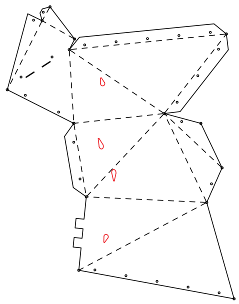
Perhaps the most important investigation carried out was the 1:1 prototyping that was undertaken to perfect the casting method and geometrical outcomes. Over thirteen weeks the students produced more than one hundred test components and prototypes in order to achieve a final outcome that satisfied all tolerances and design issues.

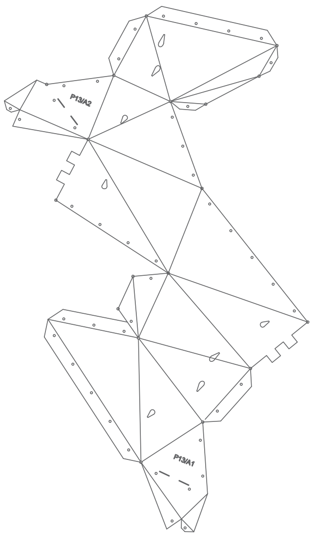
This studio was determined to realise the potential of mass-customising concrete components through an innovative process of casting in laser cut PET moulds. The casting experimentations explored variations in mould design, concrete mixture and overall casting techniques. Exploring differentiations in the fold lines, tabs, geometry and PET thickness, the students were able to devise an optimum mould design. By testing sand beds, cradles and other supports, the ideal casting method was also devised.

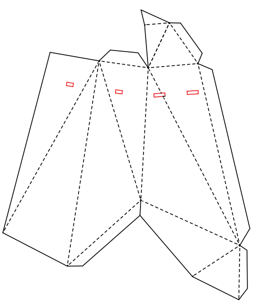
These variables also needed to consider and accommodate the changes that would be experienced in each unique component. The constant negotiation between the digitally designed components and their physical realisation meant that a constant process of modelling and casting was needed to best understand the parametric changes in components.

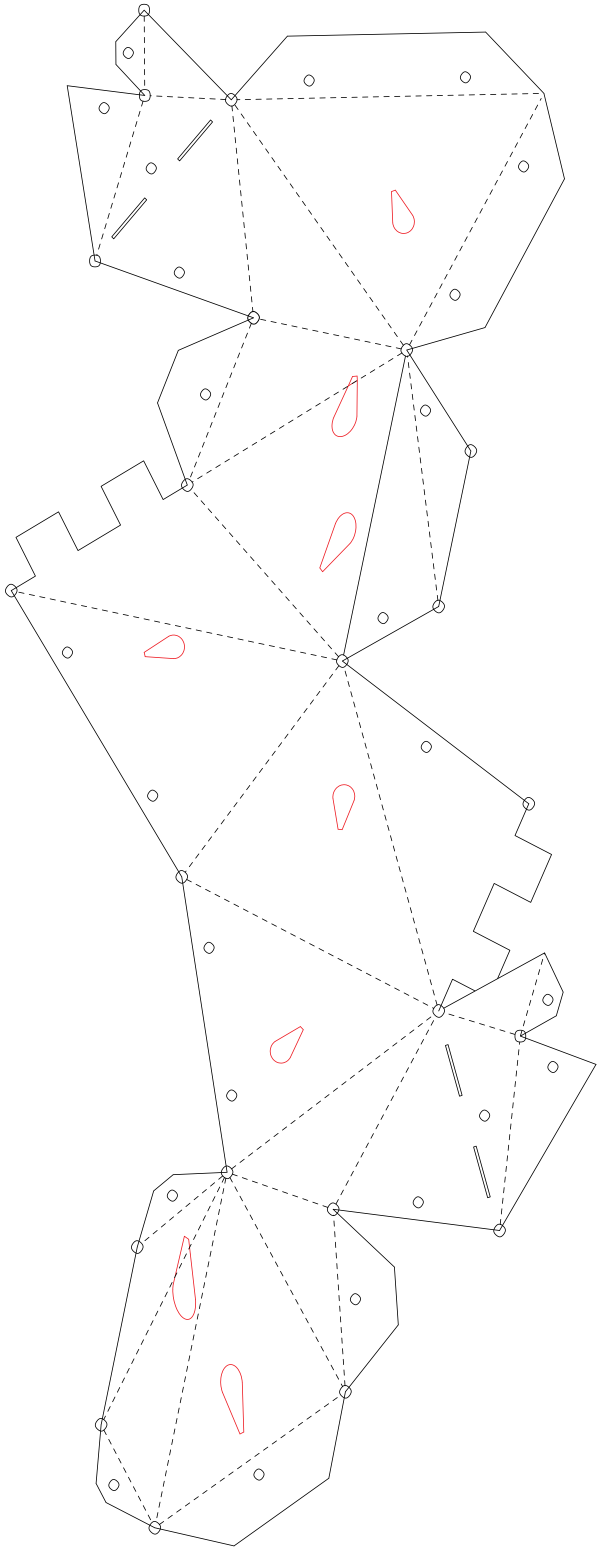
As a result, the students became quite precise and expert in their ability to fold, pour and cast the concrete components to achieve accurate and high-quality results. This became crucial for creating the final components, where the perfected process was to be repeated 130 times to produce all the components needed for the structure.






P13/A2
P13/A1

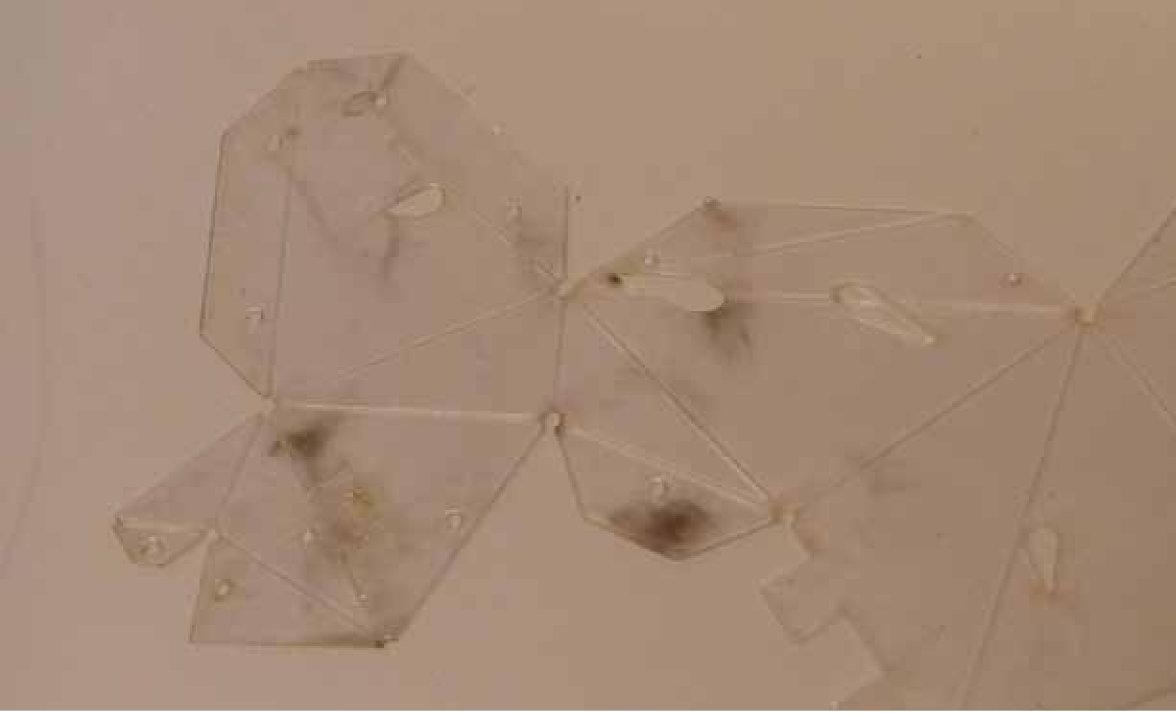




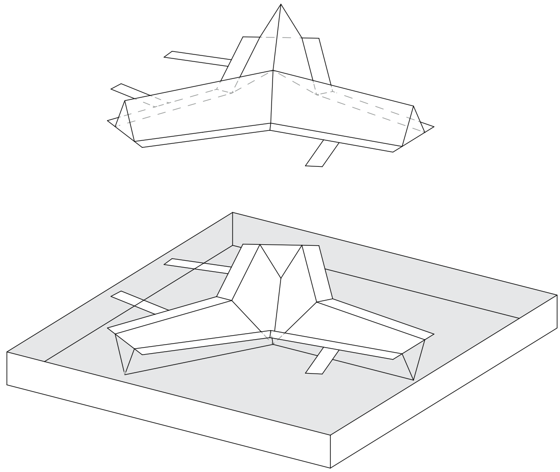


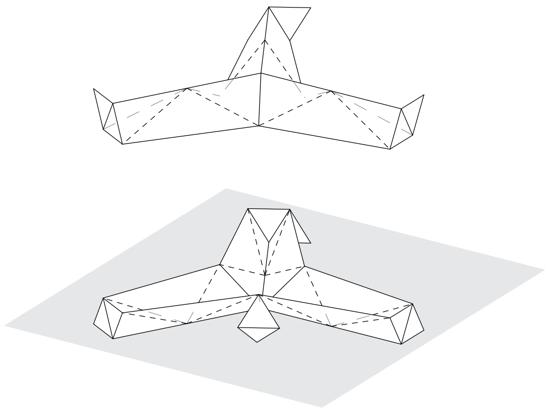


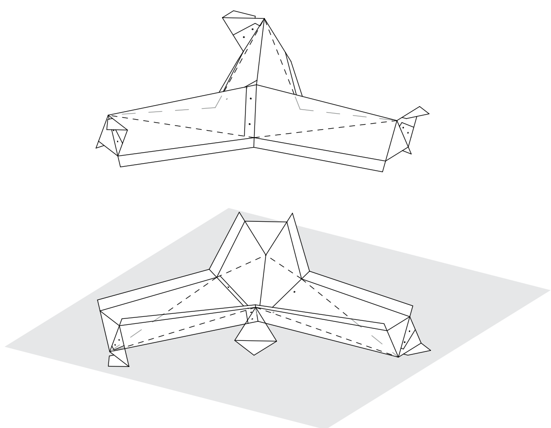

DREMEL




P5







Scale: One to Two

Most evident in the studio processes was the demand for students to think concurrently about the whole and its smaller parts. As the details of componentry began to question materiality, joints and lighting, a deeper investigation into the structure and design of the individual components was needed.

At the scale of 1:2, human interaction and perception through the senses began to surface. Perhaps the most important aspect of the users' understanding and appreciation of the overall structure is through the joints and textured finish of the concrete.

Cohesion between design and practicality becomes very important when assessing the studio outcomes at the scale of 1:2. The brief was to achieve maximum visual impact with minimum use of materials. Through copious amounts of testing and prototyping, many different options were produced for both joint systems, materiality and lighting techniques. The constant battle between achieving an elegant joint at the same time as a clean compressive load transfer between components saw a true collaboration between the students and engineer. In a similar way, the negotiation between a beautifully textured finish and an efficient casting method resulted in a refined and simple material solution.

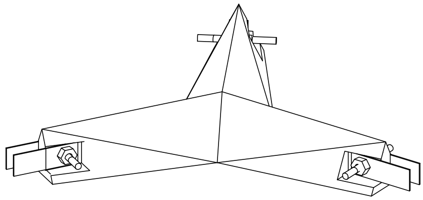
Apparent at this scale is that the beauty of the detail is just as important as the design of the whole. What resulted from this thinking was a desire to express the sophistication of the design in both the simplest and most elegant manner.

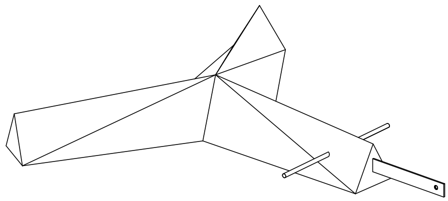
Joints & Reinforcement

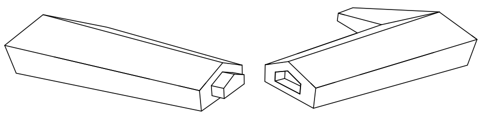
The jointing system was perhaps the most critical detail to the design of the entire structure. While the overall structure is in compression, a post-tensioning joint system was required as a placement mechanism to ensure that the components sat flush and that tight tolerances were achieved. This joint system worked congruently with the mass-customisation of components, as it demanded a constant end-to-end connection that could be varied in angle in order to achieve the curvilinear form. While the stainless steel cable ties achieve the desired industrial aesthetic, it was only upon the approval of the engineer that the students could finally proceed with this system.

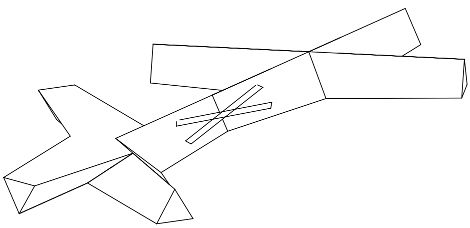
The steel reinforcement of the individual concrete components was also crucial to meet safety standards and address possible lateral loads that might place the components in tension. The placement of the reinforcement inside the moulds to allow for sufficient coverage of the concrete proved to be a challenging task. Time constraints meant there was no testing of the insertion of the reinforcing steel because it was believed that the same technique as had been used in Aarhus in 2011 would be sufficient. However, this proved not to be the case and a new method of tying the reinforcement to the moulds with wire was required – a time consuming and fiddly task.

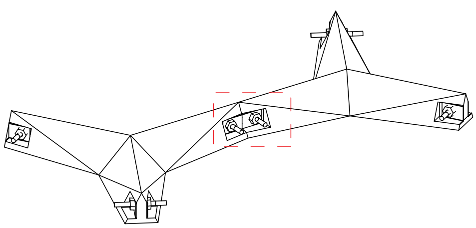
This highlights the importance of collaborative efforts in innovative practices to achieve efficient and customised structural solutions. It was the structural analysis of the digital form that dictated the ultimate built outcome, and it was a constant negotiation between the analogue and the digital that continued to permeate outcomes over the course of the studio.

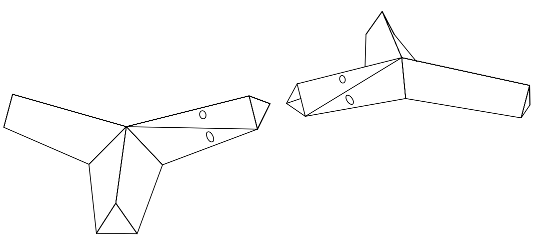


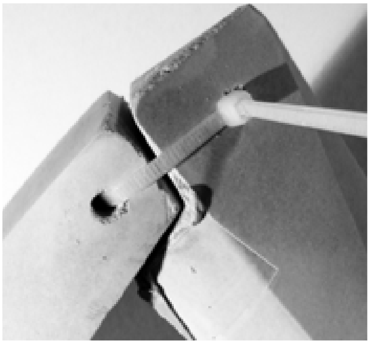


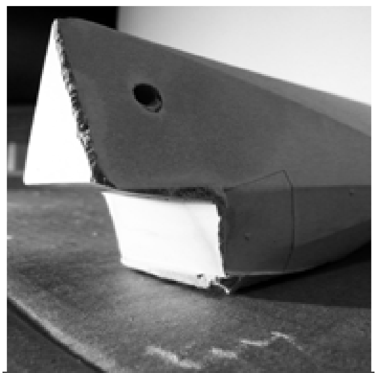


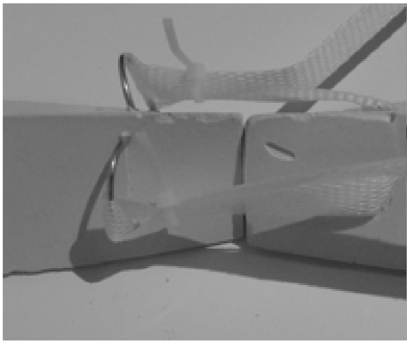


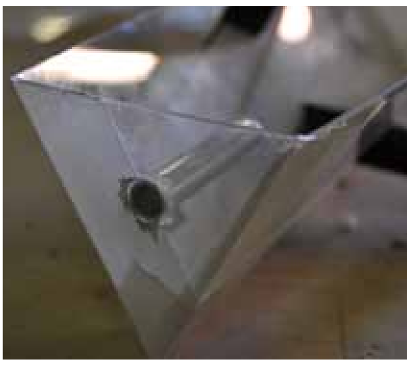






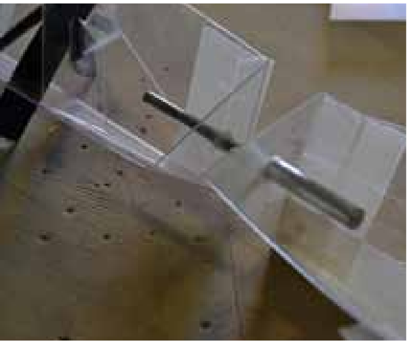


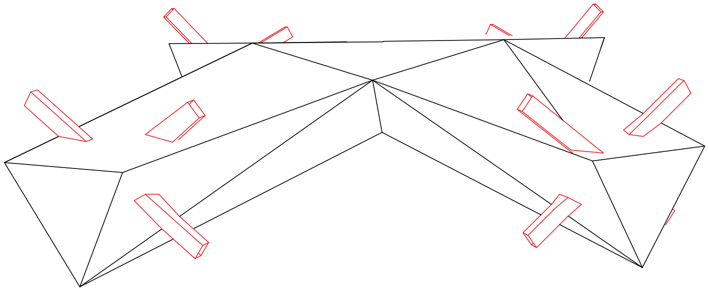


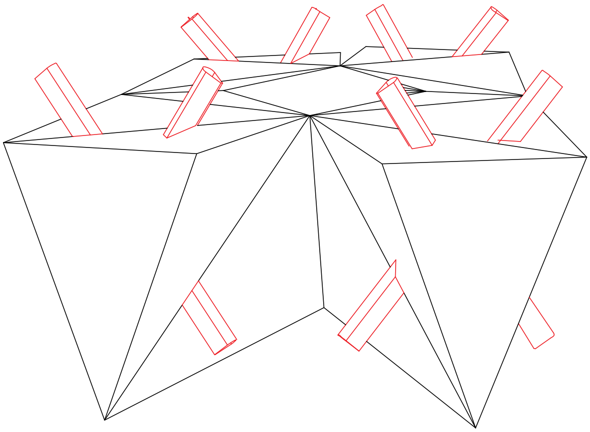


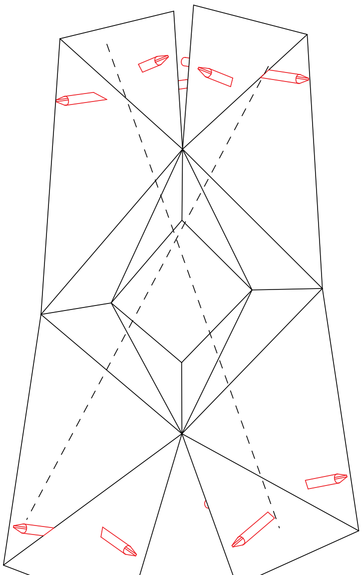










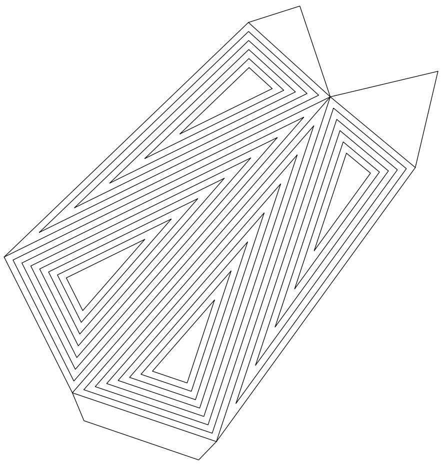
Materiality & Lighting

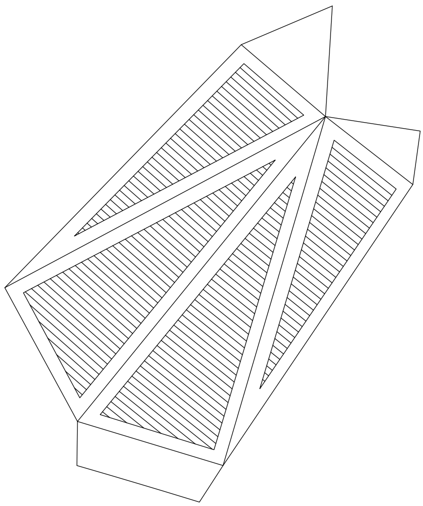
This studio sought to push concrete in both a structural and aesthetic sense. Many prototypes were made to explore possible changes to the surface finishes of the components through the introduction of foreign agents, other materials, a retarder, or etching of the PET to create surface patterning. In the end, it was a distinctly modernistic choice to retain the purity of the off-form concrete finish. While the PET gave an attractive mirror finish to the faceted surfaces, the expression of the oxidised front face of the components was enhanced and controlled through a series of perforations and a centre-piece diamond pour hole in the mould.

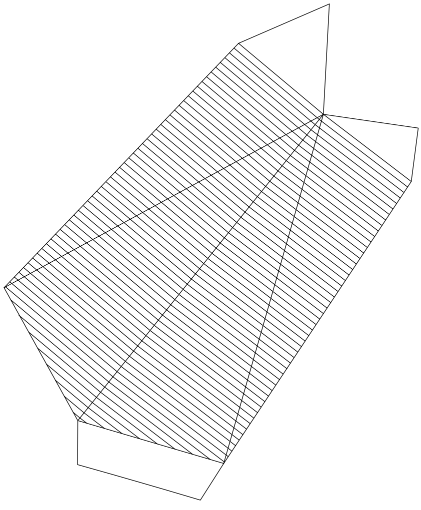
Tension between the two opposing surface qualities – one, smooth and mirror-like; the other, oxidised and pitted with small craters – questions how concrete in architecture is understood and experienced. In this gateway structure, the ubiquitous raw and dull off-form grey slab is replaced by the seductive surfaces off PET, reflecting light onto the porous and grainy underside.

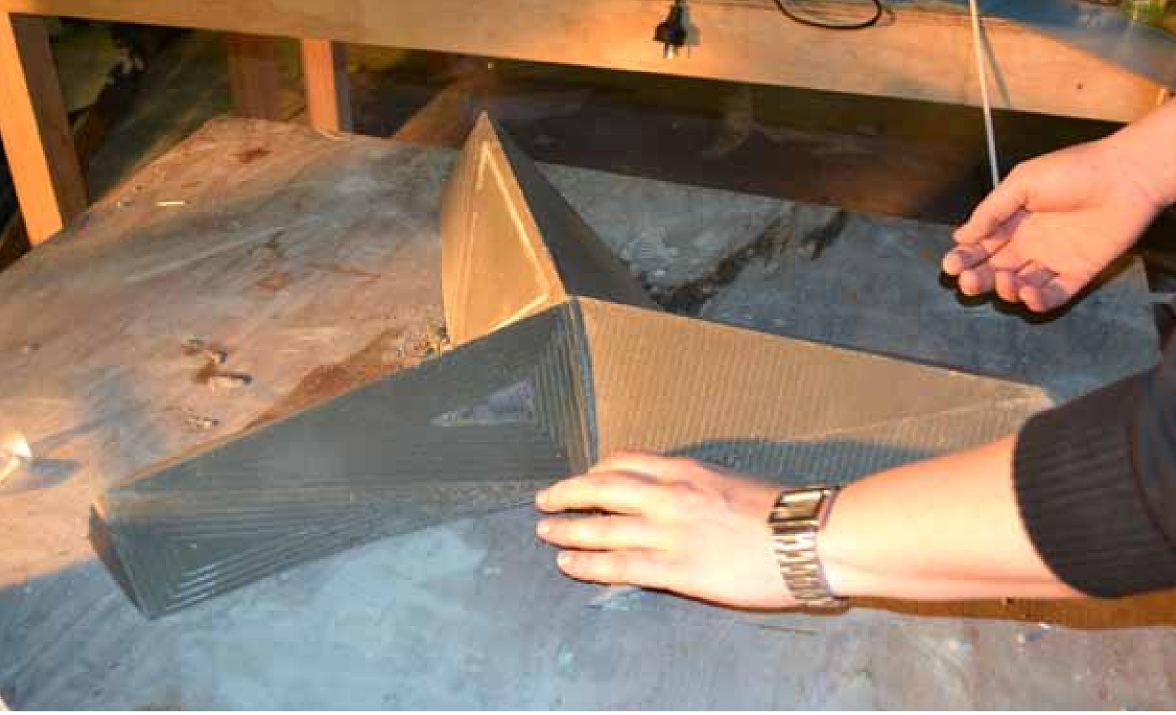
The lighting design needed to complement the textural qualities of the surface finish. It was designed holistically to be seamlessly integrated into the design of single components, with continuous cabling running through the structure. The investigation included the testing of embedded materials and shadow lines to create the desired effect. The proposed lighting scheme proposed to integrate the lighting into the concrete structure and allow light to pass through from the centre of the component to create a sense of lightness and porosity in the solid concrete components. Unfortunately the lighting system was ultimately abandoned due to cost overruns.

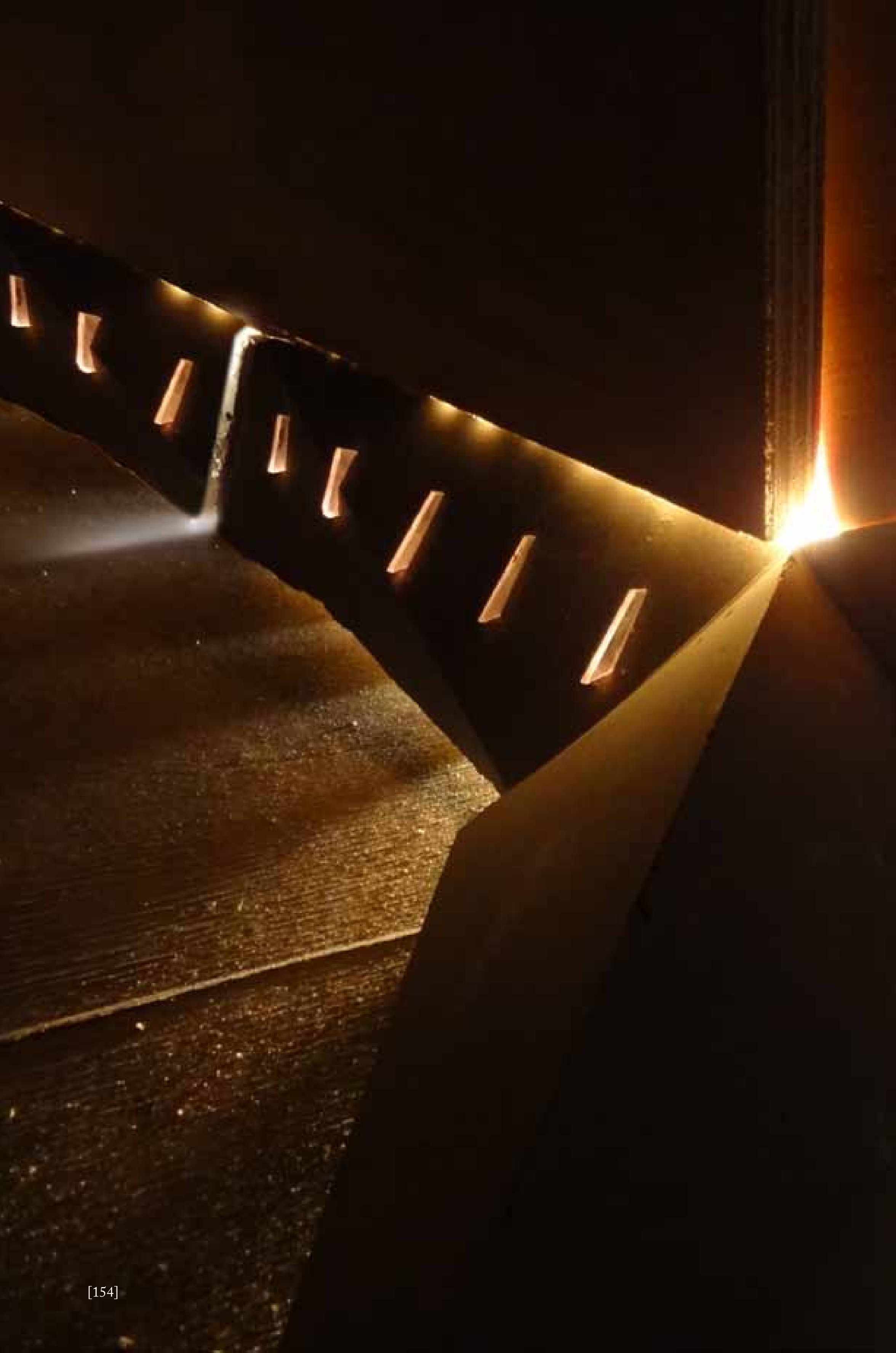
While this is somewhat disappointing, it is indicative of the way in which the original design proposal and final built outcome are often two quite different things, and highlights the importance of a strong design intent that does not rest solely on one visual aspect.

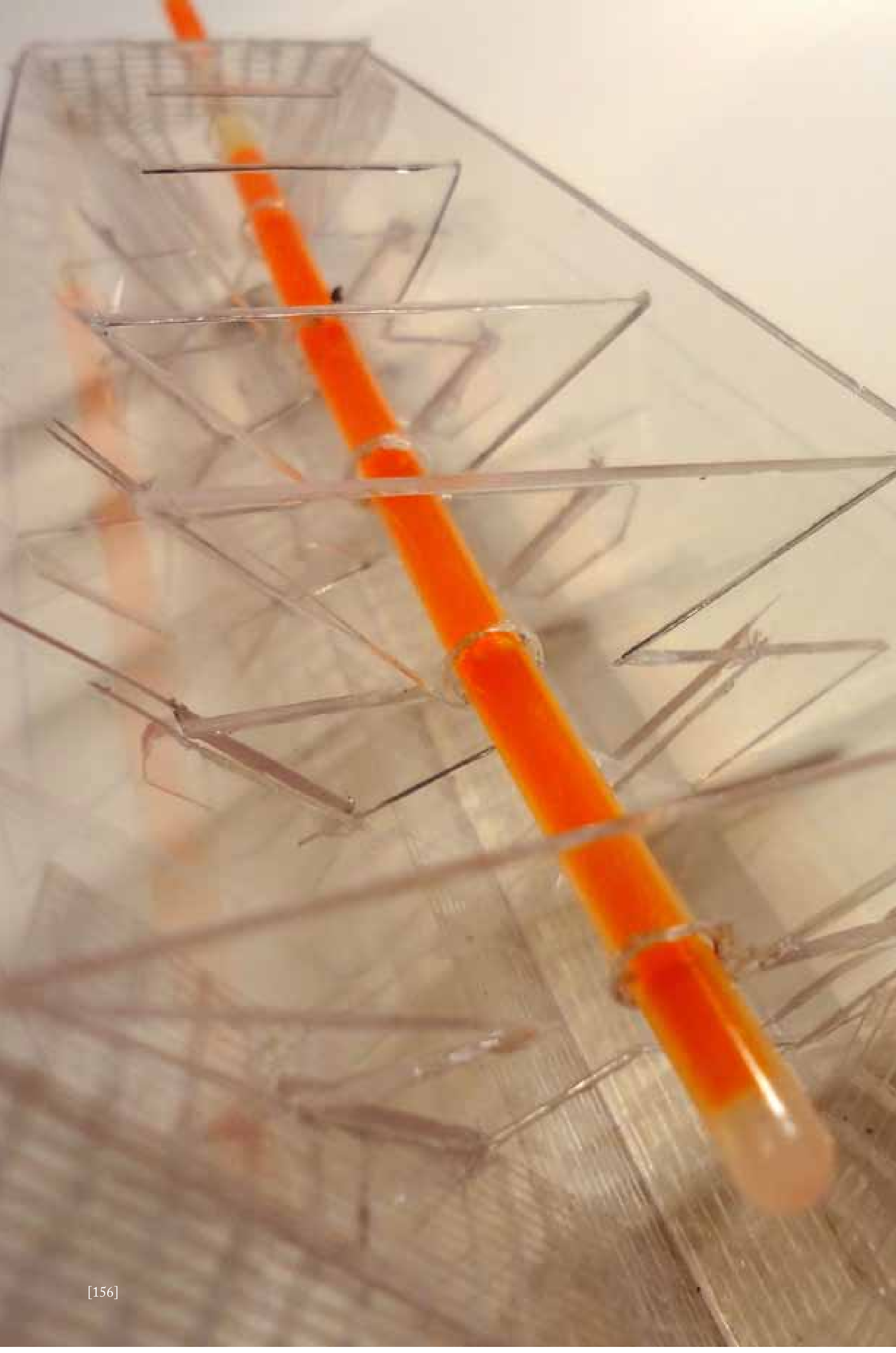


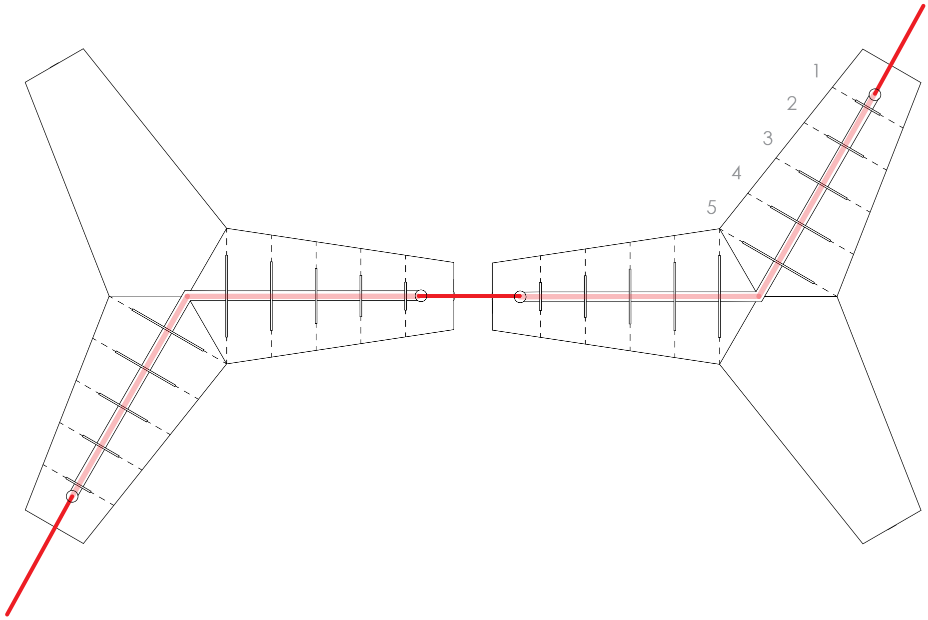


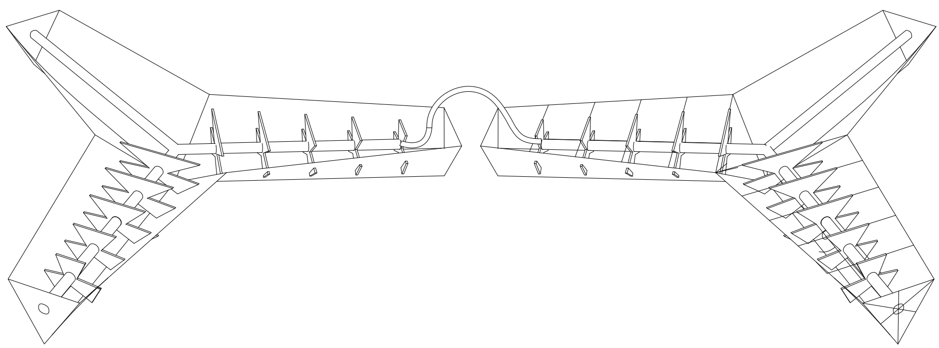


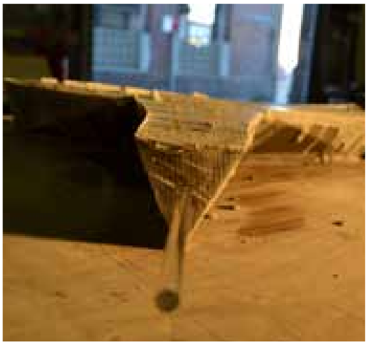


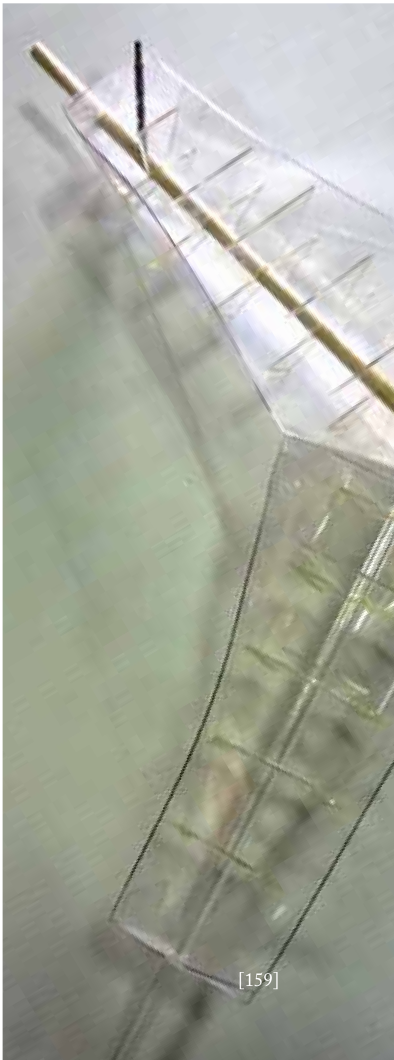





1
2
3
4
5







Scale: One to One

The final scale, 1:1, is arguably the most important. It is where the findings of the previous investigations at other scales are brought together to achieve the final result. Through each of the different scales there were predominant areas of focus however it is through the final, full-size erection and construction that the strengths and weaknesses of the overall design can be appreciated.

It is also through the construction of full-scale prototypes that the cyclical nature of the design process is best understood. The students were able to experience first-hand the successes and failures of their work and then to collaborate to resolve practical solutions that could be fed back into the design process and consequently resolved into a more successful result.

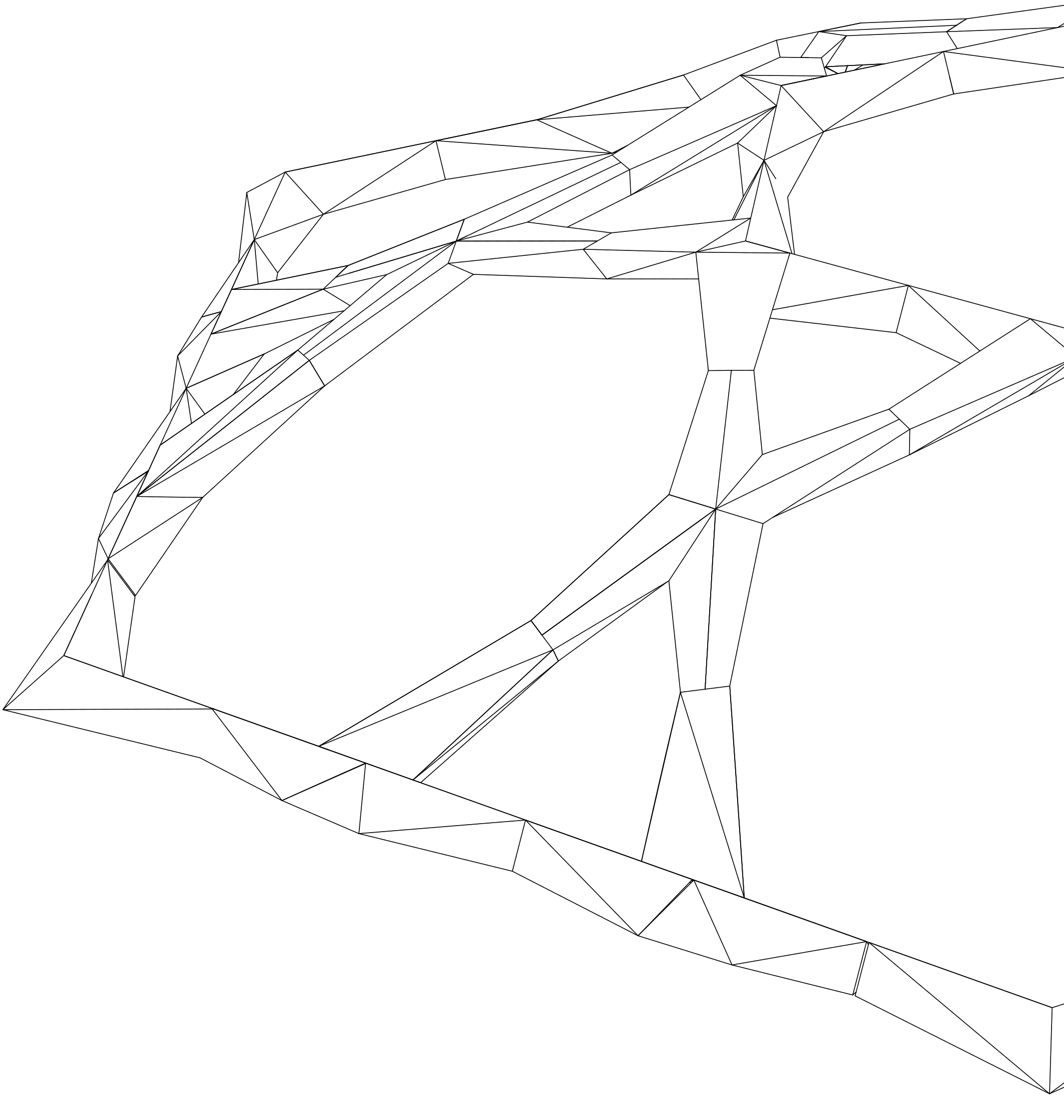
Through the exploration of the structure at 1:1 the students were also able to develop an understanding of the flow-on impact that individual and seemingly insignificant decisions can make on the final built outcome.

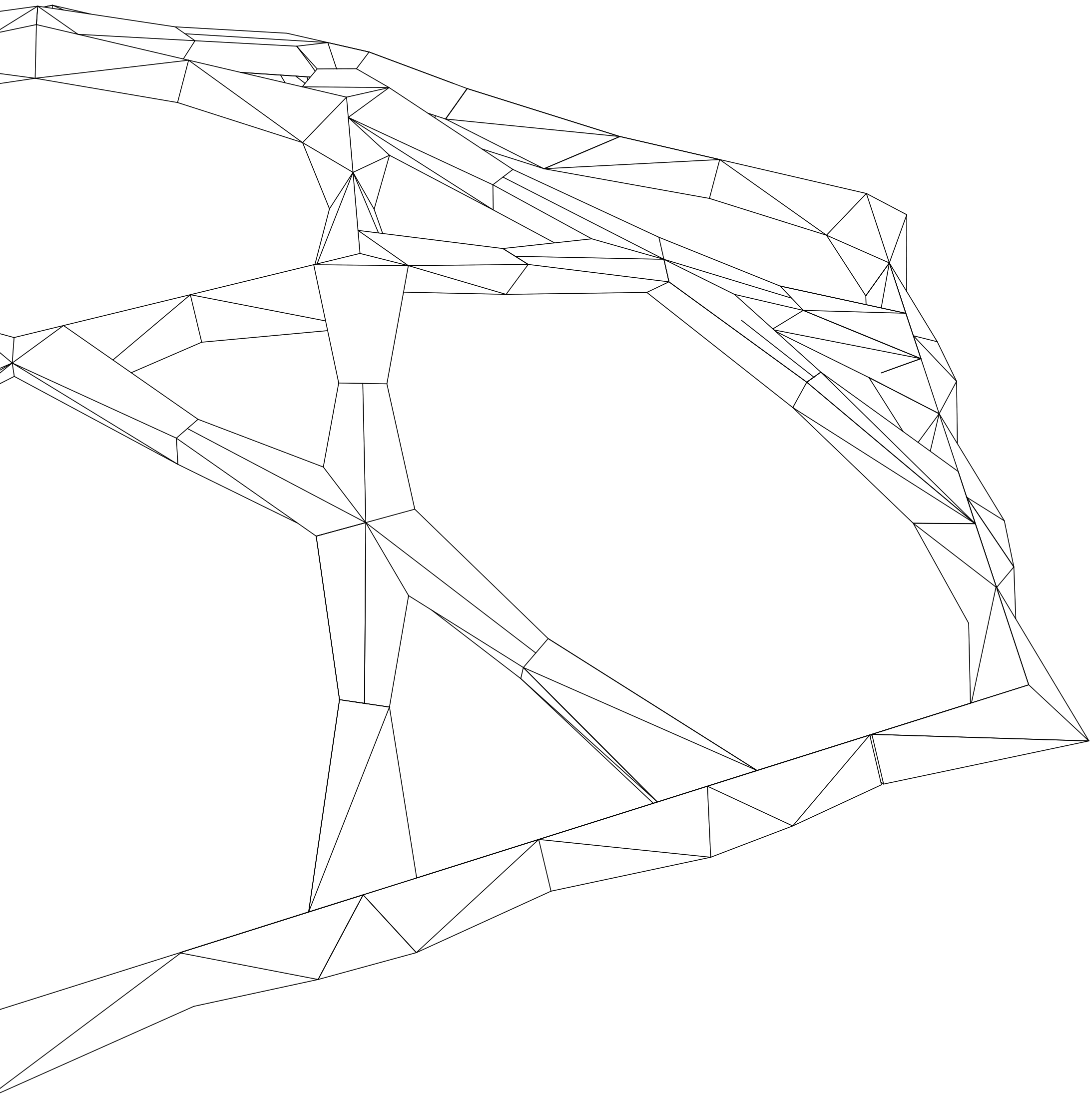
Prototype

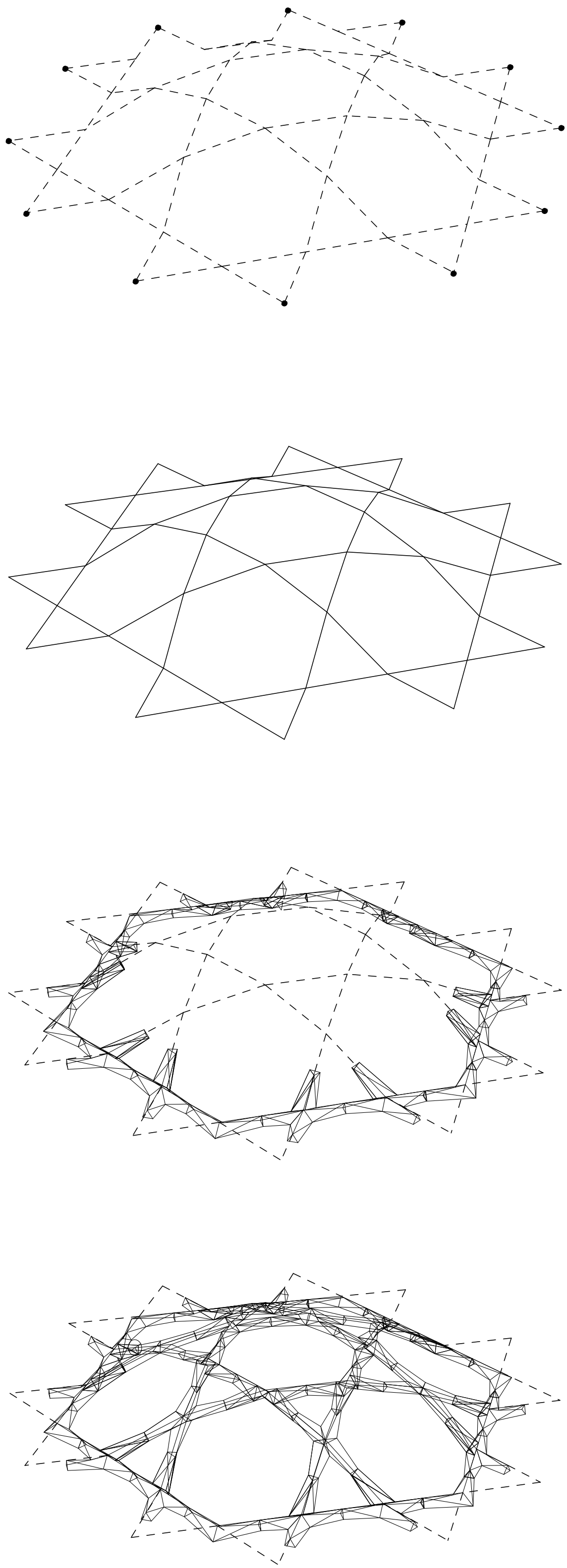
As explored through various scales, physical prototyping was crucial in developing a holistic understanding of the components. Much the same, a full-size prototype of an assembled structure was required to test the coming together of the various components involved in the assemblage. An initial 'dome' prototype was designed comprising five unique components that were repeated to total thirty components in all. This 'dome' prototype was designed to fail.

It was the first test of the mass-produced PET moulds, assemblage and casting, all of which resulted in a huge learning opportunity for the final structure in achieving the most efficient method. At all previous scales, components had been tested on a one-off basis ensuring a more accurate result, however producing components en masse gave more room for error and mistake. Thus the implementation of a quality control method was crucial to ensure a more precise result.

Understanding the weight, tolerances, scaffolding design and joint techniques all provided insights to possible improvements for the final structure. The main challenge of the prototype was ensuring that components were correctly assembled in their proper locations while still allowing for post-tensioning the stainless steel cable tie joints to ensure minimal tolerances were met. Assembling the prototype proved to be an invaluable learning experience for all involved in the studio and resulted in consequent alterations across all scales for the design of the final structure.








LOAD NOT TO

Final Assemblage

The final assemblage was not as successful as hoped and is yet to be erected in full. However, areas of the structure have been threaded together in order to demonstrate the parametric lattice emerging from the assembly of mass-customised components. With the benefit of hindsight, the failure of the final assembly arose from a lack of understanding of the complex flow on effects incurred when the original decision was made to change to the 'X' component from the original 'Y' shape, which had been successful in 2011. The addition of a fourth leg to each component greatly complicated the casting method because each component required an internal curvature such that all legs were inclined at different angles from the horizontal. This added an unforseen degree of complexity to the casting process and consequently resulted in many of the components exceeding the tolerances allowed for in the scripted design.

The portions of the structure that were successfully assembled, however, clearly demonstrate the advances made from the earlier prototype in relation to the joint techniques, PET mould assemblage and materiality. These begin to show the innovation of the structure and the scripting software and the possibilities that can arise from a student-led process that is committed to engaging deeply with both the analogue and digital realms and a cycle of design and prototyping.

Conclusion

Conclusion

Associate Professor Kirsten Orr, Natalie Nicholas and Jessica Tringali

What is clear from the processes of the *Concrete Tectonics Studio* 2012 is that complex problem solving in digital design can only be realised through an intricate relationship between analogue and digital realms. This process of design evolution is as innovative as the precast concrete experimentations that the studio pursued. While there are niche groups in the industry that are beginning to bridge the gap between these two realms, the architectural profession continues to be relatively conservative in its experimentation with complex digital forms and processes.

This studio was deliberately positioned to work at the frontier of the profession, to engage with innovative practices and tackle the associated complexity. Its diverse research into the material possibilities of precast concrete has produced an extensive database of knowledge about the tectonics of concrete design and fabrication. Such knowledge needs to be carried forward and into the architectural profession and broader construction industry as a strategic willingness to research, experiment, and take risks that might possibly fail.

As the students involved in this studio graduate and become the next generation of architects they should be embraced by industry for their skills in experimentation and complex problem solving. They are the keepers of a diverse body of knowledge and a method of innovation that begins to challenge the notions of purely digital architecture, and equips them with the skills needed in the future to achieve complex built outcomes.

Subject Co-ordinator

Associate Professor Kirsten Orr

Tutors

Dr Kirsten Orr

David Pigram

Nicky Choi

Students

Mark Alves

Domenico Ciccio

Kimberley Cooper

Olga Georgitsis

Alexander Herran

John Holland

Aleksandar Kotaran

Andrew Maszluch

Natalie Nicholas

Joshua Seeto

Miguel Silva-Santisteban

Danilo Astudillo Silva

Kim Willoughby-Thomas

Jessica Tringali

Huan Xiao

Salima Youssef

Acknowledgements

The UTS Concrete Tectonics Studio 2012 would not have been possible without financial and material support from the following:

UTS Vice-Chancellor's Learning and Teaching Grant

UTS School of Architecture

www.utsarchitecture.net

UTS Centre for Contemporary Design Practices

www.ccdpresearch.com

Supermanoeuvre

www.supermanoeuvre.com

Partridge - Engineering

www.partridge.com.au

Artist Damien Butler

www.assemblage.org.au