Pass me the mixing bucket:
The Ribbed Catalan studio as a design/research case study

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Abstract:
The Ribbed Catalan, a large scale ribbed tile vault, was the result of a collaborative, award winning design/build/research studio involving students enrolled in the M.Arch. program at the University of Technology Sydney, guided by masterclass instructors Dr Philippe Block (ETH Zurich / Block Research Group), Melonie Bayl-Smith (UTS / Bijl Architecture) and David Pigram (UTS / Supermanoeuvre).

The studio provided an opportunity for the M.Arch. students to undertake an experimental design/build intensive workshop that also straddled the instructors' intersecting research interests, being masonry vaulting, digital/analogue relationships and innovative teaching. By harnessing these research interests, the studio brief delivered direct, high level learning outcomes through not only the physical process of building, but also via the reflection tasks undertaken at the studio conclusion.

After an introductory session, the students pursued a parallel design and research process, directly engaging with a sophisticated digital software interface utilised for formal explorations. Alongside the design process the students experimented with a variety of construction techniques, necessitated in part by the use of standardised Australian building materials that performed well beyond their usual application. These vault materials were donated or provided at cost, creating broader industry interest in the studio and establishing relationships for future collaborations.

The premise for the brief and studio structure tested outcomes from the author's *BuildAbility* research project (2011), which asserted that design/build and material/making studios provide opportunities for expanding design and integration skills in students, and engendering learning that transcends the specifics of the studio brief, including deep peer-to-peer learning, developing investigative intelligence, and enhancing students' appreciation for material and form.

This case study will present an overview of the Ribbed Catalan studio intent and execution, unpacking the decisions and outcomes behind the research inputs and outputs, as well as providing commentary on how design/build studios can successfully provide a platform for diverse learning and research outcomes.

Design/Build studios, similarly known as 'Learning by Making' studios, have continued to proliferate in architecture schools, as evidenced at the recent TU Berlin DesignBuild-Symposium which brought together educators, students and practitioners from around the world.[1] As demonstrated by the speakers and projects presented at the Symposium, there exists a strong belief amongst invested educators, students and practitioners alike that design/build studios are highly

effective, offering an integrated teaching platform that delivers intensive learning opportunities. This conviction is underpinned by the manner in which the very nature and format of design/build studios swiftly moves students out of their comfort zone into challenging experiences, with a potency and immediacy that engenders humility and respect within the individual for the process of building and what is required to realise a design, particularly if more complex geometries, junctions and forms are pursued.

As a recent and relevant reference point, the DesignBuild-Symposium content revealed that a significant number of the studios presented were related to socially conscious community or humanitarian projects. Whilst these studios are valuable with respect to their material community contributions, potentially innovative pedagogies and experiential learning opportunities, the influence and transferability of any design research outcomes (intentional or otherwise) can be readily diminished by the specificity of the site, community or country in which the studio takes place.

In contrast, whilst there is a temptation to rest on the laurels of novel formalism and material effects, design/build studios concerned with making, materials, construction methodologies and structural innovation have a greater opportunity to produce universally interesting and transferable research outcomes, even when coupled with a real brief and site. So rather than attempt to endow upon architecture students a certain level of mastery in order to realise a 'knowable' and usually normative design, the core focus of these exploratory design/build studios emerges not as the actual built outcome - however impressive this might be given time, material and skill restraints - but instead as the development of an investigative intelligence in the participants. As a result, this broad-based, high level learning outcome reinforces the enormous capacity of design/build studios to sit within ongoing or discrete research projects, and to be fruitful with respect to speculative outputs and stimulating the imaginations of students.

To further explore the methods and frameworks inherent to a productive design/build studio underpinned by a research project intent, this paper will focus on the Ribbed Catalan vault studio. The Ribbed Catalan vault was the built outcome of an award-winning[2] collaborative design/build/research masterclass involving a team of thirteen M.Arch. students at the University of Technology, Sydney. This two week studio was held in October 2012 and was led by Dr Philippe Block (ETH Zurich/Block Research Group), with Melonie Bayl-Smith (UTS / Bijl Architecture) and David Pigram (UTS / Supermanoeuvre) as instructors.

Traditional Catalan vaulting techniques and the structural form finding principles inherent to vault construction have regained interest in recent years (Fig.1) with the advent of new stone and masonry cutting technologies as well as the development of software tools enabling the creation and virtual testing of complex vaulted structures.

The conception and building of freeform masonry vaults such as the timbrel vault[3] (Fig. 2) built in 2011 by Lara Davis (formerly of Block Research Group) has been enabled with the advent of software such as RhinoVAULT (rV), a Rhino software plug-in developed by Matthias Rippmann, a current member of the Block Research Group. In the case of Davis' timbrel vault, the capabilities of

rV were tested, as was the marrying of CNC fabrication with low tech, readily available and recyclable scaffolding materials such as cardboard boxes and wooden pallets.

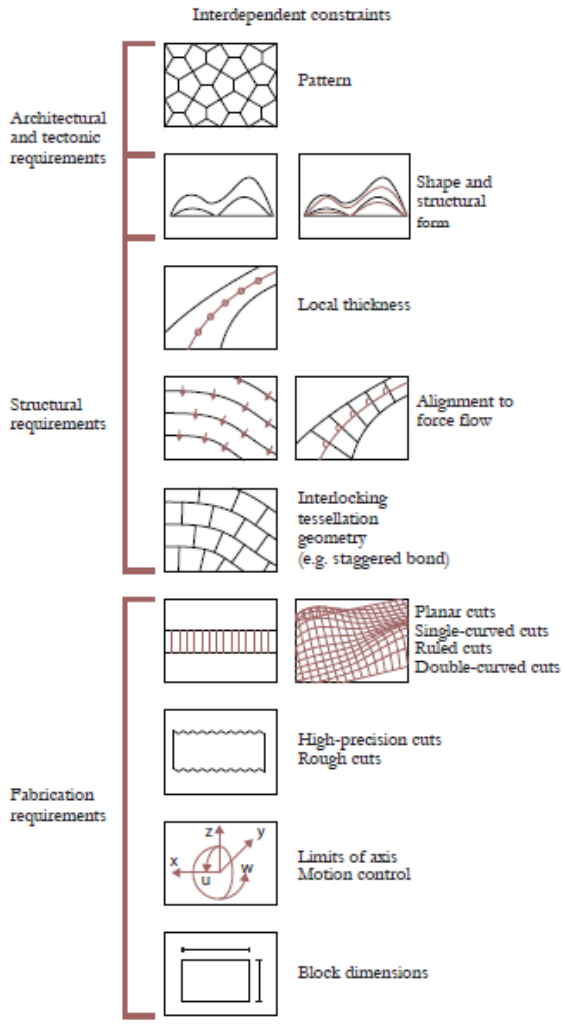

Figure 1. Diagram of the key parameters of structural masonry, particularly unreinforced cut stone shells, Block Research Group, ETHZ, 2012. Image: Dr Philippe Block and Matthias Rippmann.

Figure 2. Freeform tiled vault built by Lara Davis (PhD research project) undertaken with the Block Research Group, ETHZ, 2011. Photo: Lara Davis.

This intermingling of digital/analogue and high/low relationships, exemplified by the use of simple materials and powerful parametric design/testing software, became the key driver for the inception and research incentives of the Ribbed Catalan studio. This was not only due to the compelling intersection of the instructors' ongoing individual and joint research interests, but also because of the potential learning outcomes for the students with respect to designing, testing and building a novel and geometrically challenging vault.

From the very beginning, significant consideration was given to the teaching and research methods that would stimulate and eventually inform the success of the masterclass. While on first appearance the studio structure may not seem particularly open ended, the deployment of an easily learned construction method allowed extensive freedom to be given over to the design modelling and testing of the designs in RhinoVAULT.

In turn, giving this freedom over to such a highly flexible software tool as rV opened up design research opportunities for geometrically complex construction that would have been literally impossible to consider or test prior to the advent of rV. It is at this juncture that it becomes clear that the studio intent allowed an opportunity for otherwise impenetrable and highly speculative structural engineering research to become manifestly tangible to the architecture student, the practitioner and the academic alike.

Moving from these research intentions, the desired student activities and learning outcomes encompassed the following: engendering an understanding of the innate value of structural form finding techniques through research, architectural design processes and the translation of these into a material assembly via prototyping processes; challenging the utilisation of traditional construction techniques and standardised Australian building materials to open up new ways of thinking about the act of building; and cultivating an understanding of the potential and limitations

of working with few and simple materials, in conjunction with appreciating the complexity and challenges of building.

From this springing point, the Ribbed Catalan studio was formulated so as to contribute to Dr Block's larger ongoing research project of masonry vaulting, as well provide an opportunity to examine how students deal with the challenges of moving between digital and analogue design and representation tools, particularly when dealing with these modes at 1:1 scale. To commence the workshop, the students undertook an initial exploration of traditional Catalan vaulting techniques and structural form finding principles, through some basic arch building exercises as well as reviewing historical precedents.

After moving through this preliminary phase, the students were issued the studio brief, which was to pursue a Catalan masonry vault design that investigated the opportunities and limitations of fully three-dimensional networks of structural ribs in tiled vaulting, and explored the boundaries of the traditional construction techniques. In answering this brief, the students were given the opportunity to actively pursue a parallel design and research process, engaging in both digital and analogue technologies and explorations to realise the geometrically and structurally complex form (Fig. 3).

Figure 3. Initial prototypes produced to understand capacity and opportunities of ribbing with the available concrete tiles, Ribbed Catalan Masterclass, UTS, 2012. Photo: Melonie Bayl-Smith.

As identified in this student reflection statement quote, the specific construction method enabled the studio intent rather than suffocating it, creating parameters which the students quickly recognised and were then able to challenge in a clear and focused prototyping process:

"The design-build studio helps students to consider the structure of the form, allowing them to understand the real challenge of creating building forms, especially the process of translating the design into the 1-to-1 scale of construction."[4]

Alongside the digital modelling and design process, the students experimented with construction techniques, necessitated in part by the use of the Monier concrete roofing tiles that were cut down and radically reconsidered, performing well beyond their usual application. The potential interactions and design outcomes that lead to the final built form involved the deployment of three key approaches and situations: direct engagement with RhinoVAULT for formal explorations and structural form finding (Fig 4.); inductive hands-on prototyping and testing (Fig. 5) to quickly and intuitively research the necessary construction methods and details; and investigating and trialling a series of construction management processes.

The methods and processes tested and utilised included lightweight and readily adjustable low tech cardboard and polystyrene foam box guidework and scaffolding (Figs. 6, 8), mortar mixing in hand-held pliable plastic buckets to enable an ease and flexibility in the mortaring process (Figs. 7, 8), and undertaking detailed tiling cuts and setouts (Fig. 8) - to understand the manner in which the vault would be both built in accordance with the documented final design (Fig. 12) and then tested to failure (Fig. 13).

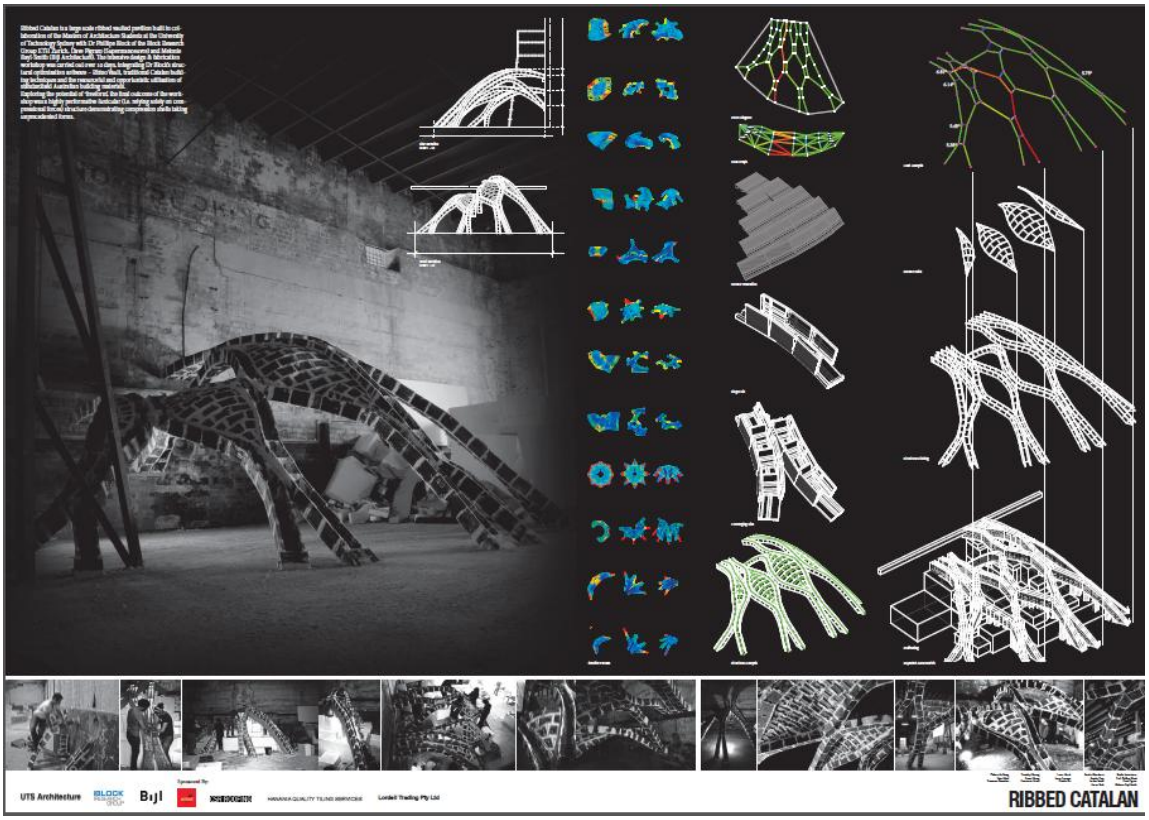

Figure 4. Poster documenting the process and design of the 'Ribbed Catalan' tiled vault, demonstrating the origin and close development of the iterative design testing in RhinoVAULT alongside prototyping and resolution of the scaffolding and construction methods for the actual build. Image: James Lauman and Jordan Soriot using documentation by the Masterclass students.

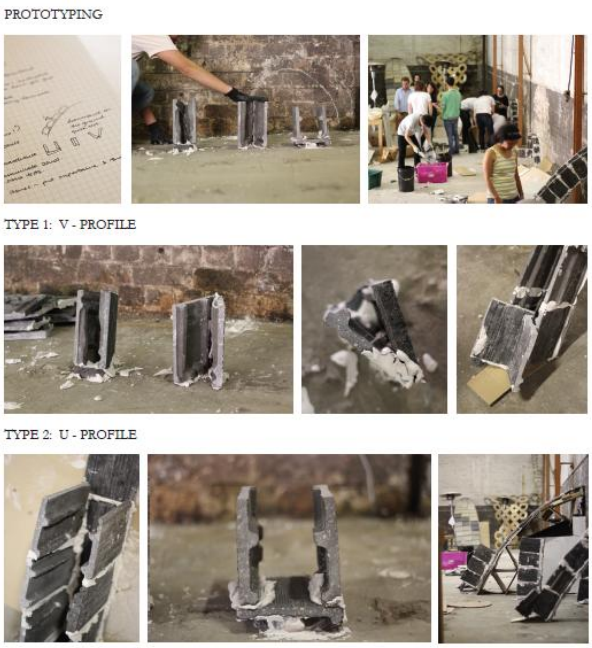

Figure 5. Prototyping for the ribbing elements. Photos: Natalie Ma and Sandra Mendonca

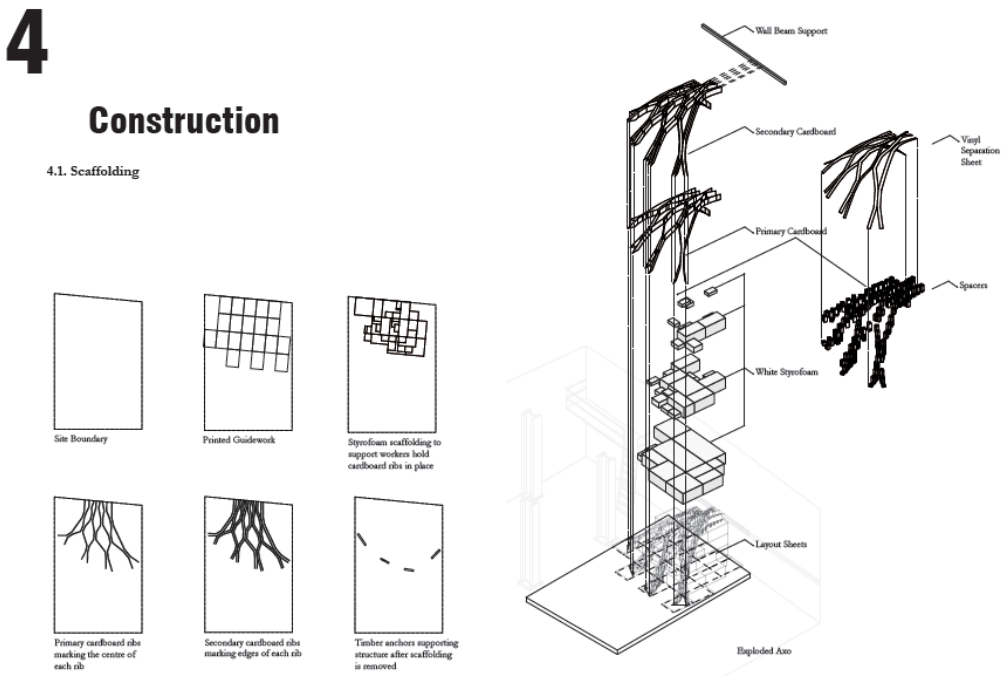

Figure 6. Scaffolding and guidework axonometric and layout diagrams which arose from the intersection of the scaffolding prototyping process and the vault design development testing in RhinoVAULT. Image: Aaron Yeoh and Philena Au Yeung

Figure 7. The vault in progress – by commencing the construction of each of the eight individual ribs at the start of the build process, an ongoing prototyping process was allowed to take place, with some demolition and rebuilding of the ribs occurring early in the build process after the geometries of several specific ribs revealed a range of construction challenges. Photo: Michael Ford_studio

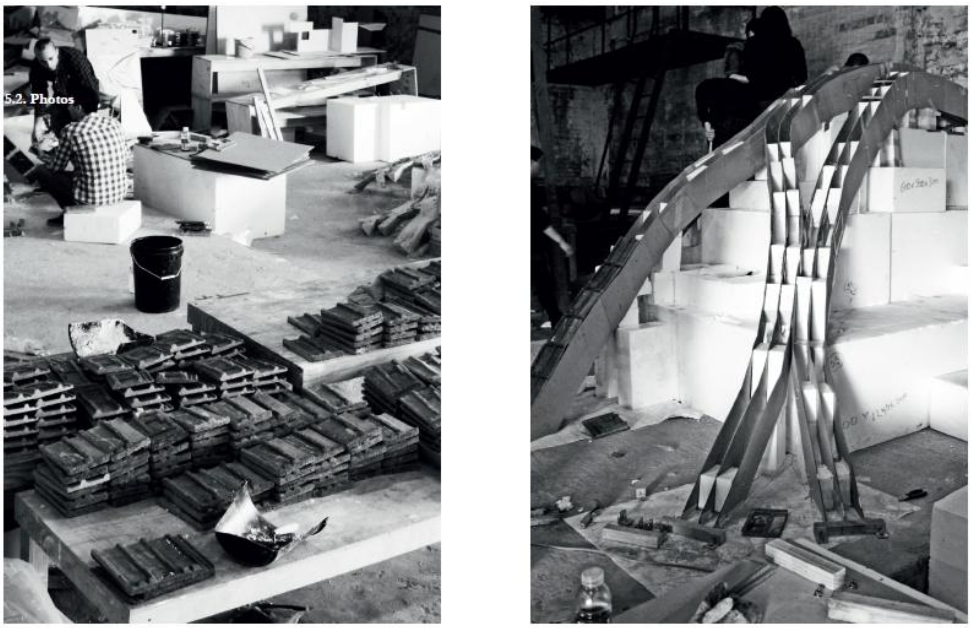

Figure 8. As the mortaring materials and method required a high level of efficiency, the construction management methods were also tested and refined to suit the build process. This included a rigorous tile cutting, numbering and stacking system, with one team mixing mortar whilst another placed and mortared the tiles. Photos: Sandra Mendonca and Natalie Ma

This experimentation was supported by the instructors' own ongoing discussions around this physical extrapolation and integration of their overlapping research interests. These interconnecting conversations and processes allowed a high level of feedback flow between the instructors and

students, opening up the research pathways and developing them within the fluid prototyping, designing and building processes. An example of this is the bracing and reinforcing of the ribs – after various structural appraisals and physical tests, the ribs came to rely on perpendicular tile placement at centres over a standard cement fill with geotextile mesh inlay reinforcement placed along the base of each rib (Fig. 9).

Key to the eventual structural success of the vault, this solution only came about by a testing process jointly informed by the structural expertise of Dr Block, the extensive construction knowledge of the co-Instructors, and the empirical prototyping and building experiences of the students (Fig. 10). Here, the feedback flow supports peer to peer learning and what emerges are interactions and working relationships that could potentially be applied to the innovation of architectural practice, as might be concluded from this student reflection statement extract:

"In architectural practice, a design is developed and then construction begins. I thought, however, that the constant transition between digital design and hands on construction and prototyping, especially in the earlier stages of the studio, was extremely beneficial and allowed us to further understand the different ways design can be used to push material boundaries, and vice versa. I believe that if the design and construction processes were kept separate our overall vault design would not only have been less innovative in its design but potentially would not have 'stood up'." [5]

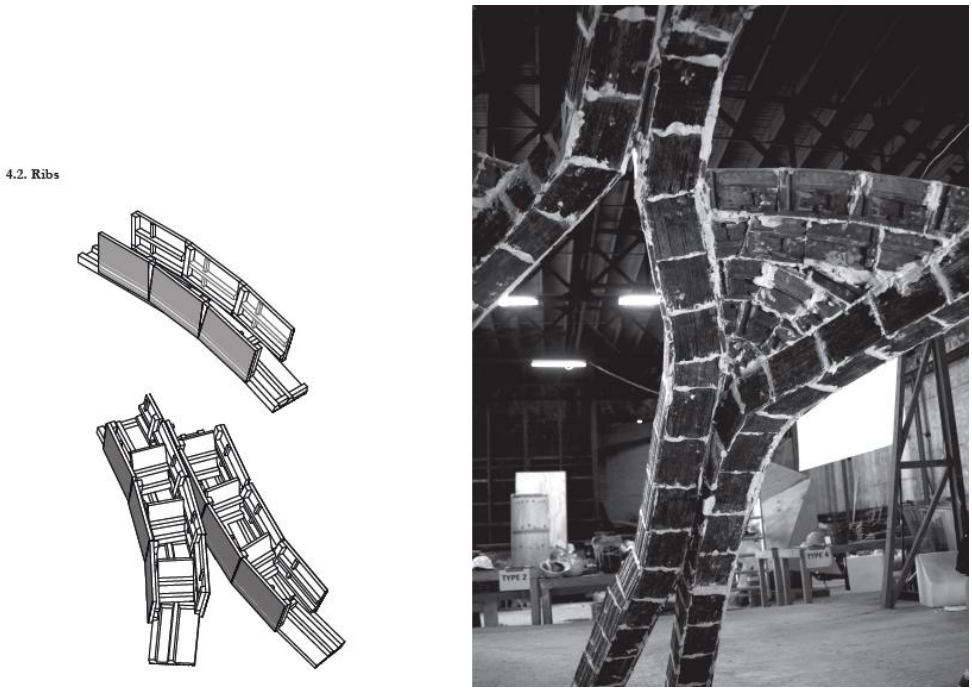

Figure 9. Rib construction and reinforcement / bracing details were developed and refined during the prototyping process that occurred concurrent to the vault building. Image shows commencement of the 'patching' or 'infill' to the ribs. Image: Masterclass students, Photo: Aaron Yeoh

Figure 10. Aerial view of construction process for the ribs, demonstrating the laying of the tiles over the guidework. Photo: Jordan Soriot

The masterclass ran for a total of thirteen days, within which the Ribbed Catalan vault was conceived, designed, prototyped, built and completed (Fig. 11). The tightness of the time program, whilst lamented by some students in their reflection writings, pushed rather than hindered the level of experimentation contained in the studio because of the immediate need to find the best solution.

As the students were confronted with the realities of their design decisions, which seemed insurmountable at first, the impending deadline engendered a deep and necessarily effective learning culture in the overall group, quickly engaging them with the research intent for the studio. In actively refining the tacit and explicit knowledge gained through their experimentation, the students usually remained motivated and quickly become capable of providing efficacy and transparency on the various successes and failures of the experimentation.

Once identified and properly harnessed, this design/research feedback loop allows the accumulating information to flow into tangible outcomes, either by informing and influencing the prototyping activities of the other teams, or in binding the teams together to execute the building of the final design.

Figure 11. The completed ‘Ribbed Catalan’ tiled vault. Photo by Michael Ford_studio

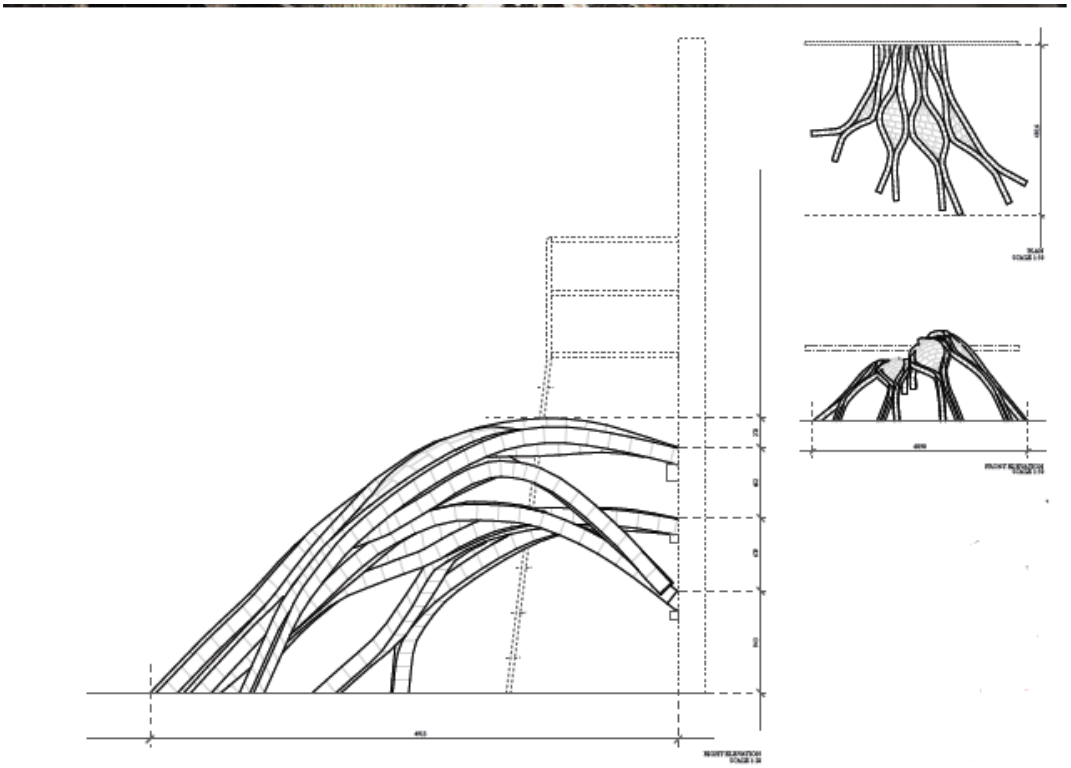

Figure 12. Orthographic drawings of the final vault design. Images: Jordan Soriot and James Lauman.

This further demonstrated that the pursuit of a well considered and focused design research intent can be realised in the design/build studio format because of the open platform given over to the experimental making activities that usually characterise these types of studios. Further, apart from allowing the students the possibility to align a part of their studies with established, innovative research, key to the success of research via design/build workshops is the capacity to harness the deep peer-to-peer learning that emerges, particularly through dividing the larger student group into small teams. Typically, these small teams develop an investigative intelligence specific to their assigned specialty under the overall studio intent, and, by virtue of their scale, generally increase communication flows and maintain accountability between participants.

In conclusion, the innate suitability of the design-build studio platform for informing and undertaking research projects is perhaps best summarised in this student quote:

'There is a lot of potential in the structure and content of a design / build studio—particularly if it presents advancement of any innovative architectural technologies. Even if the resulting work of these kinds of studios often fails, in certain respects, as design that can be directly translated into highly-finished and practical pieces of architectural componentry, the work is still able to hold its place as a materialised idea that can inspire further progress and refinement as a prototype.' [6]

From this reflection, it is evident that clearly identified learning outcomes significantly influence the success of research activities in the design studio, because of the momentum provided by a focused, curious and somewhat restless group of investigators, and also by the drive to seek tangible results irrespective of apparent failure or obvious success.
At this nexus, the act of designing is at its most potent, its most affecting - and surely this is the least that should be proffered to the students of today and the architects of tomorrow.

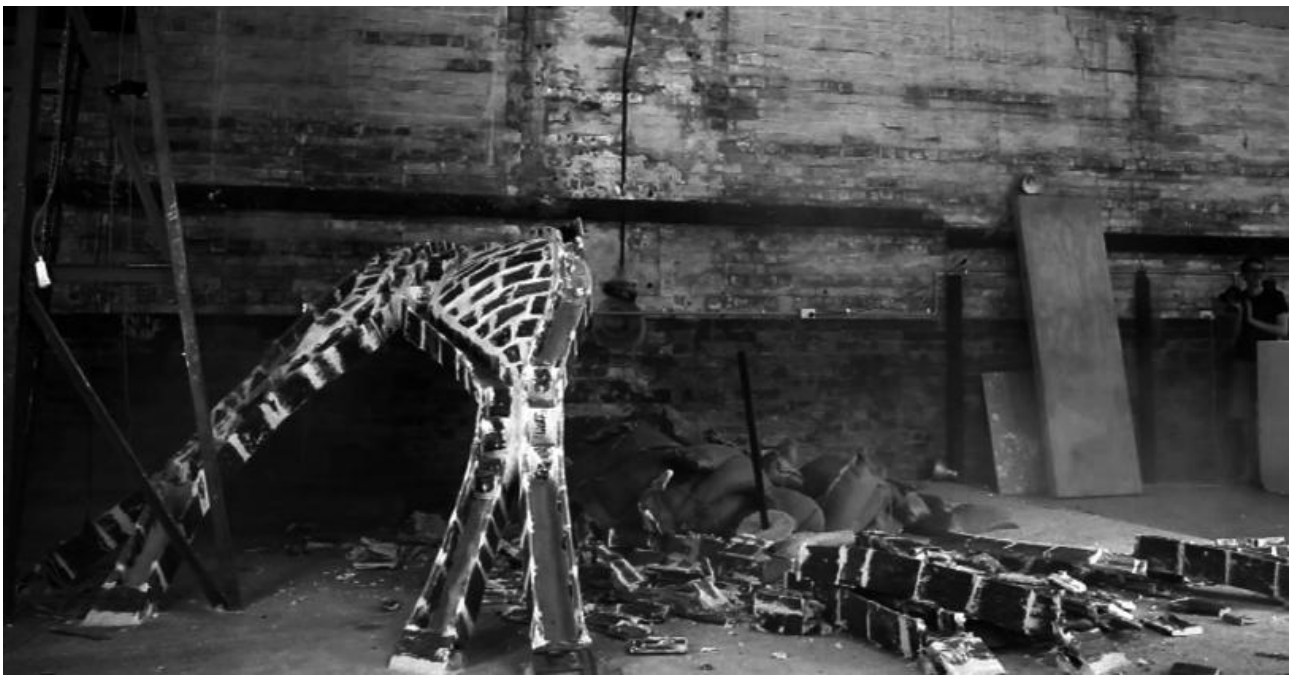

Figure 13. The Ribbed Catalan vault was subsequently tested, with no evidence of movement or failure at a point load of more than 1.5 tons. One of the ribs was then demolished in order to destabilise the structural integrity of the vault, after which the point load caused the failure of the vault. Photos: James Lauman.

[1] TU Berlin, Co-Coon DesignBuild–Symposium webpage http://www.a.tu-berlin.de/cocoon/php/symposium.php (accessed 14 August 2013)

[2] 2013 Graduate & Student Awards of the Australian Institute of Architects State Chapter: Structural Innovation in Architecture Prize - Winner; Digital Innovation in Architecture Prize – Commendation

[3] The research intent and process of building the freeform timbrel vault is documented in Davis L., Rippmann M., Pawlofsky T. and Block P. Efficient and Expressive Thin-tile Vaulting using Cardboard Formwork, Proceedings of the IABSE-IASS Symposium 2011, London, UK.

[4] Extract from Reflection statement submitted for the design/build studio 11524 MASTERCLASS: DESIGN TECHNOLOGIES 2 by UTS M.Arch. student James Lauman (2012)

[5] Extract from Reflection statement submitted for the design/build studio 11524 MASTERCLASS: DESIGN TECHNOLOGIES 2 by UTS M.Arch. student Laura Hinds (2012)

[6] Extract from Reflection statement submitted for the design/build studio 11524 MASTERCLASS: DESIGN TECHNOLOGIES 2 by UTS M.Arch. student Jordan Soriot (2012)