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Structural Intuition and Creative Play: An Architectural Perspective to Shell Pedagogies

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Abstract

The notions of structural intuition and creative play had been raised by particular structural artists (Billington, 1983 [1]). Professor Pier Luigi Nervi expressed the importance of Structural Intuition in his 1965 Elliot Norton Lectures at Harvard University (Nervi, 1965 [3]) whilst Professor Heinz Isler described and drew attention to the idea of creative play in his shell practice through a child-like and non-preconceived observations of nature. Illustrated by past experience of working with architecture students in hands-on design/ construction workshops, as well as from explorations in a design studio environment, this paper presents and shares learning and teaching practices by the author, with a specificity to architectural education, in hope of opening up discussions on the pedagogies of shell teaching with creative experimental research.

Keywords: teaching, architectural design, architects, learning, lightweight structures, shells, intuitive understanding

1. Shell and light-weight spatial structures in the context of architectural education

> *An architect, who does not dismiss shells and spatial structures from their architectural vocabulary or design offering, allows shells and spatial structures to live. An architect who proposes shell solutions in their design work; breathes life to them.*

Architectural education is a domain of many functions. It demands the student much of both artistic and scientific sensibilities, requiring an aesthetic yet mathematical understanding; be cultured, yet practical; be creatively atmospheric, yet technologically aware and technically competent. An architect is an artist, and a scientist all at once - a true *Renaissance man* or woman.

The importance of an architect with structural creativity and structural understanding cannot be underestimated. This understanding is especially important to ensure the longevity of shells and spatial structures and is one way of promoting this vocabulary of architectural expression.

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Figure 1: The unusual cavernous spaces of Taichung Metropolitan Opera House [www.DesignBoom.com]

The synergies between an architect who understands structure and an engineer who understands architectural design can result in great feats of engineering, very often forming a project key theme or concept. Toyo Ito's recent Metropolitan Opera House, at Taichung, Taiwan stands as a proud testament to the collaboration between the two disciplines – a notion previously discussed by Popovic Larsen and Tyas, 2003 [4]. The result is a piece of architecture engineered with formal elegance and organised with spatial complexity, an epitome of successful collaboration between architects Toyo Ito Architects and ARUPs.

If architecture only results from a mutual understanding, then the challenge of architectural educators of shells and spatial structures is how to inculcate this appreciation in the next generation of architects - professionals open-minded to and inspired by the offerings of such form-active structures, and not just restricted to conventional post and beam construction.

An understanding of the context of how building projects are commissioned is important. In a construction project, an architect is often commissioned at the first instance. Structural engineers are then enlisted to verify and resolve structural issues. Issues of structural uncertainties can be eliminated at the outset should the architect have a realistic appreciation of structural possibilities. Having said that, however, by not having a preconceived idea of structure, one could also result in impossibilities that could test, challenge and extend structural norms resulting in structural innovations.

The issue of a creative approach to the teaching of structures is noted famously by Pier Luigi Nervi, a dedicated teacher of structures. He lamented the death of structural creativity and formal expression by a mathematical approach to learning about structures, writing in 1956, "Mathematics and drawing are means to be used in engineering and architecture, but they are not the whole of these disciplines, and if used incorrectly may even impair the clarity of a technical idea or the correctness of an architectural inspiration…..". He expressed this as he observed that the most admired engineering student was usually the one most adept in mathematical theory (Nervi, 1956 [2]).

In a similar vein, Heinz Isler's approach of *creative play* rests on his child-like perspective of viewing natural forms such as flowers and leaves. Particularly, observations of geometries in nature sparked much conceptual ideas to the prolific shell designer - a trait shared by the great architect Antoni Gaudi whose imagination often stemmed from his quest for a naturally inspired geometrical rationale, resulting in funicular vaulted masterpieces such as the Sagrada Fagmilia and other structures with strong geometrical bases of formal expression.

Form active structures involve both an understanding of structural principles, as well as an understanding of architectural spaces, the important challenge is what we, as a community interested in shells and spatial structures, can do to promote innovation and collaboration between the two complementary disciplines.

To induce and develop structural intuition in architects, the teaching of structures non-mathematically to architecture students is especially important to enable them to demystify the complexities involving structural and spatial planning.

Lightweight structures education remains a great way of letting students experiment. It allows them to handle materials in a physical and architectural manner. By being able to deal with materials physically, they are able to understand and develop an innate, cognitive understanding of material behaviour. Additionally, the joints, connections and material articulation can also help them develop a sense of tectonics, material articulation and interfacing that adds to the overall architectural resolution. For instance, concrete shells take on a very different material expression from a timber gridshell and by construction exercises, these future architects can develop meaningful understanding of construction and learn what could good structures.

Lightweight-structures, such as reciprocal or tensigrity structures, are conducive to create not just "non-heavy" structures, but structures which are light and often temporary. Their see-through and transparent nature makes them attractive in the understanding of physical structures and material behaviour and assembly. Logistically, their ability to be stored away, taking up minimal space in their dissembled form is also very attractive as an educational tool.

Shells are complex to analyse. With forces closely related to morphology, especially for the architecture student, scaled models and physical modelmaking are good ways of developing this innate structural intuition or "feel" for these structures and understand them. Efficient structures as they usually are, there may be a right (or wrong) way of designing. Apart from aesthetic reasons, their application in an architectural project is also appropriate to their architectural context such as neighbouring buildings, material availabilities, cost, cultural and social settings. Through constructing these structures, students of architecture can begin to understand forces of compression, tension and bending as well as experience what forces can do - such as deflection and movement, from a very practical point of view and in a very visible way.

To inspire and encourage these application as suitable solutions, architects, or future architects, need to understand shells and lightweight structures and appreciate what form changes may effect structural action change.

Clients commission architects to design buildings. Any early proposal from an architect is important to the way the project develops. The ability to not discount curves and doubly curved forms from an architectural point of view is key to giving any possible chances to promote shells and spatial structures.

Due to their geometrical complexities, physical models and digital form-making are very useful tools to interrogate form and plan match and to co-ordinate spatial functions and structure. This is especially useful in working out junctions and details between walls and floors.

Modelmaking and hands-on life-scale construction enables thinking and simulation of construction thereby creating a realistic environment for the architect to understand form-active structures so they may not be daunted by their unfamiliarity in the future. Although digital formfinding can be explored, the definition and finiteness of design at an early stage may dissuade architecture students from proposing shells in their future career.

2. Student Workshops

The following section describes some workshop and initiatives where architecture and architectural technology students were involved in as part of this move to educate and experiment to develop structural intuition and creative play. It describes the activities carried out by the author at Sheffield Hallam University, UK in his work as an architectural design tutor specialising in shells and lightweight structures.

2.1 Timber gridshell workshop (2008)

Figure 2: Bamboo gridshell construction workshop held in 2008 demonstrates the deformation of a flat mat to result in a anticlastic dome. [credit: Gabriel Tang]

In December 2008, Edward Cullinan Architects, London, designers of the Weald and Downland Jerwood gridshell were approached to conduct some construction workshops at Sheffield Hallam University to explore the design and construction of lightweight structures such as deployable gridshells. 10 mm diameter bamboo canes were rudimentarily spliced together using cable ties and formed a circular gridmat with a diameter of three metres on the ground with loose intersection points. With students holding each end of the bamboo laths, as they moved towards the middle of the circular mat, a synclastic dome was created. This was a very direct and instant way of instructing students on how such lightweight materials can become instrumental in demonstrating and learning about forces in a doubly-curved skin.

2.2 The Swells (2011)

Figure 3: Physical models of timber gridshells were made from paper card strips (top left). The Swell timber gridshell (top right) on display for 2 weeks in Sheffield City Centre in 2011. Students create the shells together to learn and understand timber as a material in bending and deformational behavior arising from forces applied. (Bottom) [credit: Gabriel Tang]

This project built on the ideas of the initial gridshell 2008 workshop. During this weeklong workshop, the students, in groups, designed the shells collectively using physical card models constructed from 5 mm thin strips of pastecards. The designs were translated into two life-size timber structures installed in Sheffield City Centre for a fortnight. The understanding of structural behaviour was very quickly absorbed and the students quickly saw how pronounced double curvatures induced in the shell forms could help stabilise a shell structure to achieve rigidity.

2.3 Material Connections – Concrete Canvas Workshop (2013)

Figure 4: Group design presentations of shell proposals taking place (left). Concrete Canvas is draped onto the timber gridshell below acting as a temporary formwork (right). [credit: Gabriel Tang]

In 2013, a student workshop *Material Connections* was devised to invite material thinking using an innovative material called concrete canvas. A fabric, in which a matrix of cement is embedded which upon hydration forms a rigid shell. During this workshop, students from both architecture and architectural technology courses created a timber gridshell. Following that, the timber gridshell which was used as timber formwork, removed from below to create a rigid gridshell.

3 Design Studio Work

Building exercises covered by the construction workshop described in the above section allows students to explore and experiment with construction architecturally. The teaching of tectonics and construction of such form-active structures introduces students to shell forms to allow form ideas to infiltrate their design studio work so as to enhance their creative outputs. These continue the architectural and construction thinking associated with their studio design work.

In a charrette-style session with final year architecture students, Rich proposed multiple and repeated shells that projected forwards and lifted skywards as shown in figure 5, forming an exhibition facility envisaged to provide multi-functional/ flexible community spaces for the inner-city residents of Ancoats in Manchester, England.

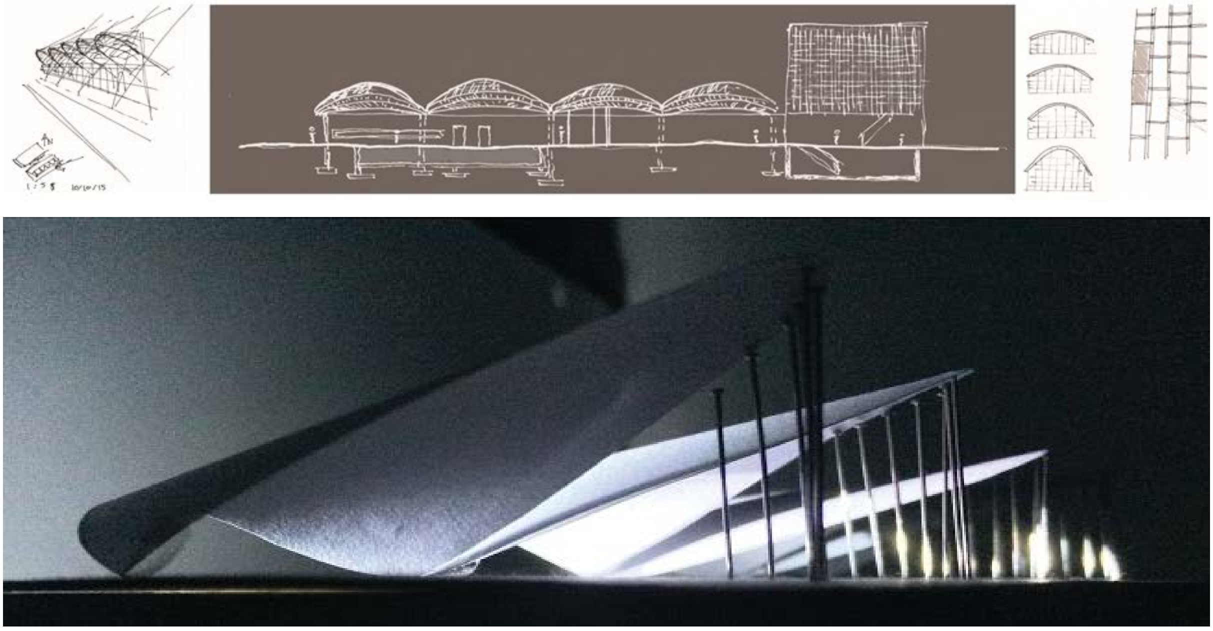

Figure 5: Initial sketches and sketch models by undergraduate architecture student Adam Rich in his initial an urban proposal for Ancoats, Manchester, UK [credit: Adam Rich]

In another design project also for Ancoats, Manchester, Jackson proposed a folded shell for a dance studio that celebrated movement and dance. Using physical models, she explored the use of a hypar as an expressive roof form for her community proposal as shown in figure 5. She considered ventilation and thermal airflow through this highly expressive structure, important aspects that such structures offered, apart from the usual structural efficiency, material economy and architectural aesthetics.

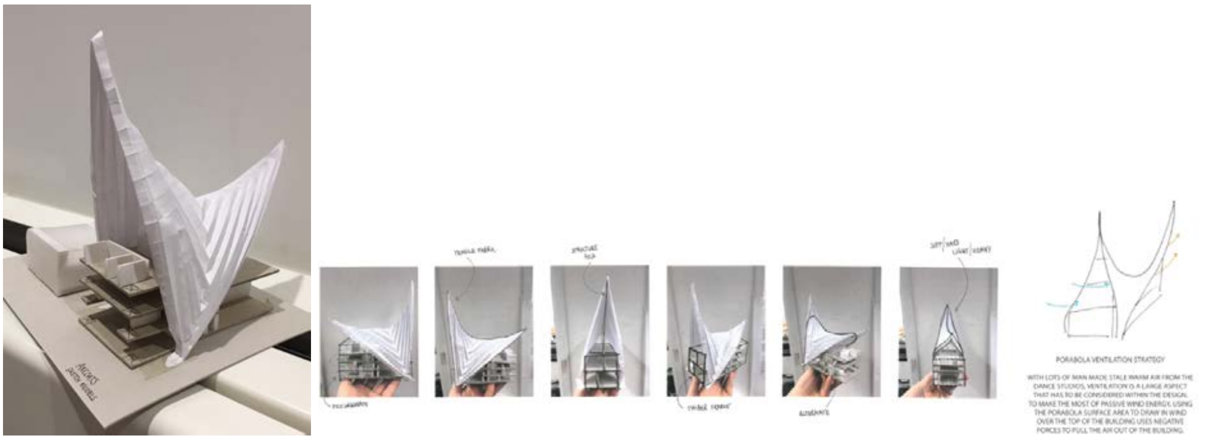

Figure 6: A dance studio in Ancoats, Manchester with a hypar roof proposed by Gemma Jackson [credit: Gemma Jackson]

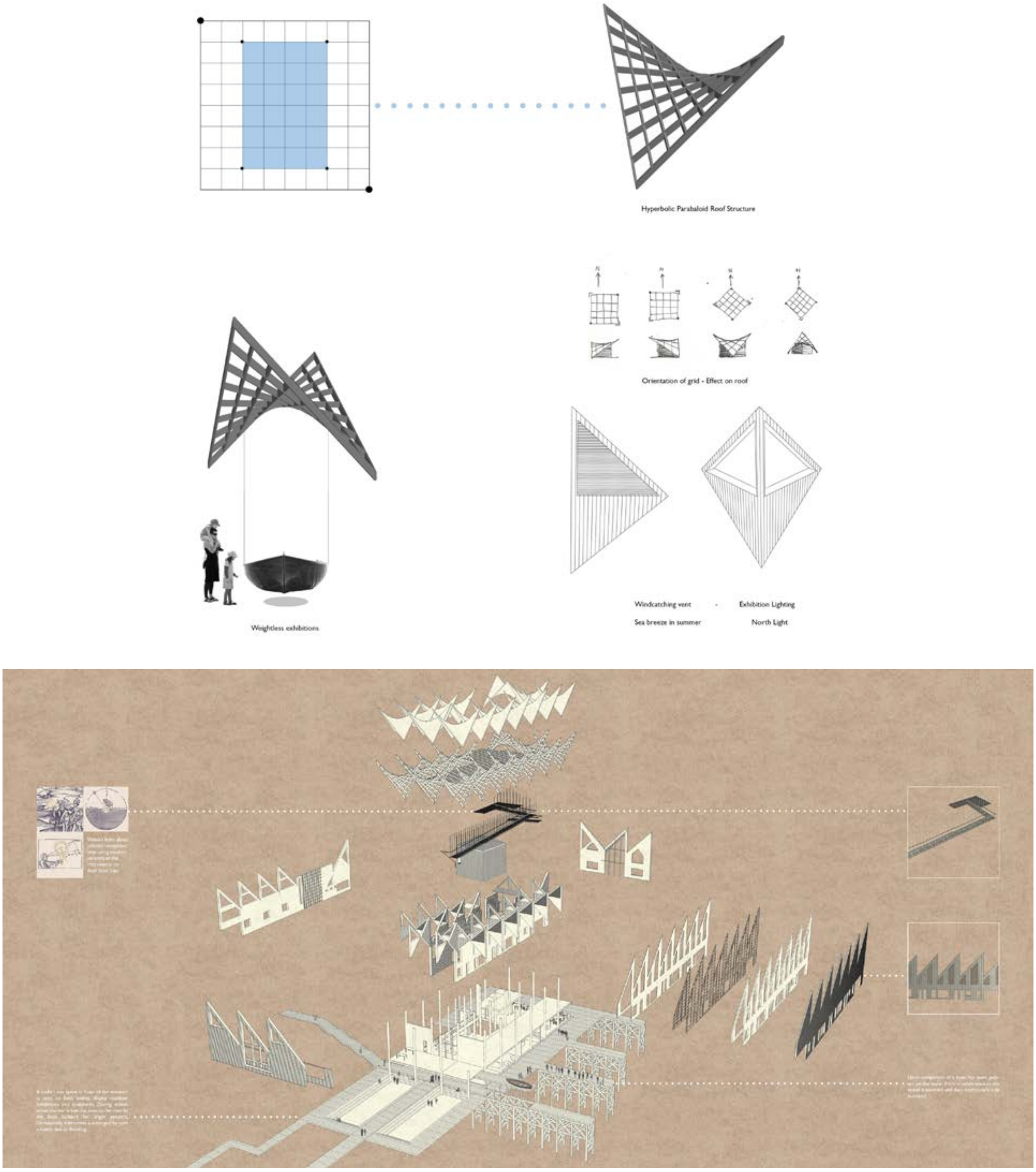

Figure 7: Construction of a hypar timber roof (top). An exploded axonometric drawing of the different building components of a new market proposal in Berwick-Upon-Tweed, England, UK. [credits: Sam Walters]

Based in a small Northumbrian town of Berwick-Upon-Tweed, England, in a design project entitled *A Question of Identity*, Walters proposed the repeated use of timber hyperbolic parabolas as a roofing system. Initially, Walters proposed to use a single hypar structure to cover the entire building. However, it was not until making a physical model did he encounter the dimensional restrictions posed by a single hypar shell. To retain his original idea of using the hypar, Walters reduced the single hypar to an array of smaller timber shells. Supported by columns, they formed an expressive roof strata based on strong architectural and structural rationale, but lets natural daylight penetrate and bounce back into the spaces below. The modularization also meant that in theory, this discretized system could extend and be plugged into the existing structure for future expansion. This solution bore similarities to the Cayoacan Market Hypar shells in Mexico City designed by Felix Candela in collaboration with Pedro Ramirez Vazquez in 1955. The series of images presented below (fig. 8) gives an impression of the roof surfaces and material to great effect. Knowingly these architecture students do not have the support of engineers to produce these schemes. However, in real life, should design professionals or clients become informed and educated about the application of these forms, engineers could then become involved in their engineering to realise their potential.

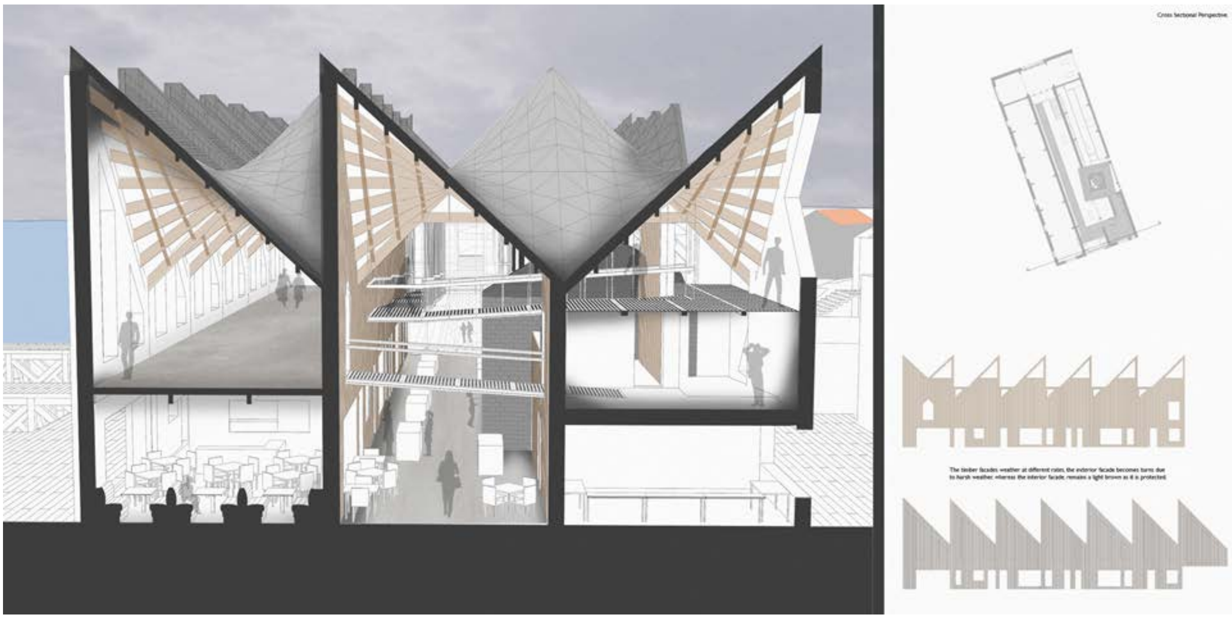

Figure 8: A sectional perspective of the new Berwick-Upon-Tweed market [credit: Sam Walters]

In 2015, for a thesis project at Masters of Technical Architecture, Leonhart proposed a demountable pavilion that touches on ideas of strength and aesthetics of a doubly curved roofing system. Central to the project is portability, where this pavilion is viewed as a travelling pavilion which could be packed up, crated and set up at concourses at railway stations or airports. The design considered components and mechanical joints.

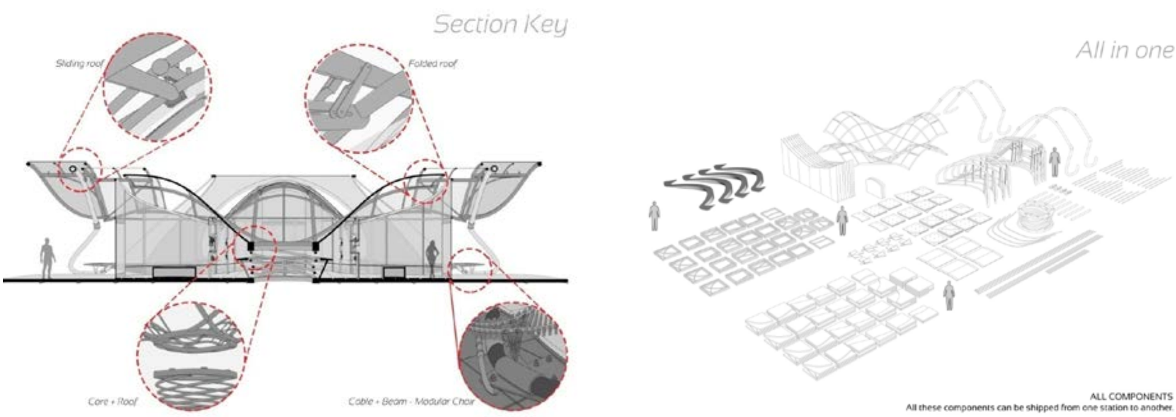

Figure 9: Component design of a travelling pavilion [credit: Raymond Leonhart]

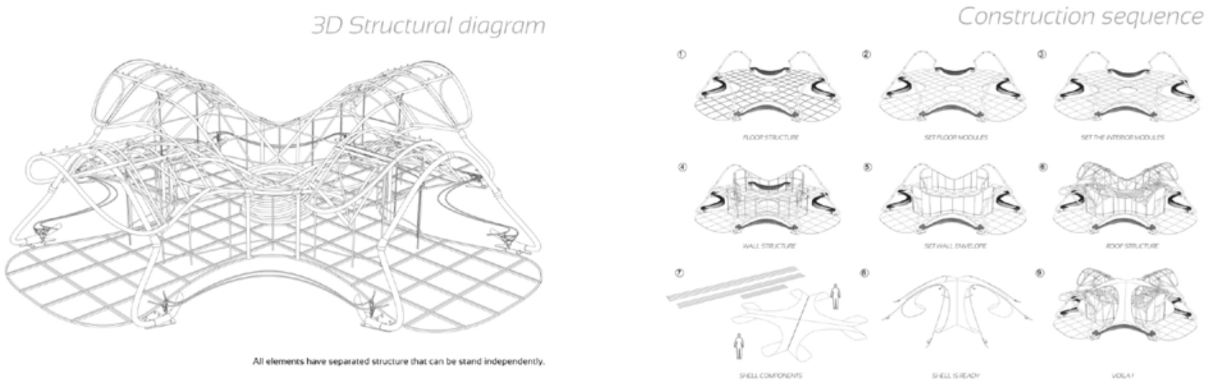

Figure 10: The structural elements of a travelling pavilion, 2015 [credit: Raymond Leonhart]

4. Conclusion:

The paper discussed firstly the rationale and reasons why the education of shell structures to architectural students is important. As we can see from the commissioning process, the openness and suggestions of the architect bears an important relevance. Therefore, this makes the structural understanding of such form active structures especially important to ensure the appropriate and continued application of such structural types. The teaching of shell structures need to be linked into the design studio for architecture students to explore and integrate what they have learnt experientially during construction workshops into their design work.

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References

[1] Billington, D. 1983. The Tower and The Bridge. The New Art of Structural Engineering. Princeton University Press, 1983.

[2] Nervi, P. L., 1956. *Structures F.W. Dodge Corporation*, 1956.

[3] Nervi P.L., 1965, Aesthetics and Technology in Building, Harvard, 1965

[4] Popovic, O and Tyas, A, 2003. Conceptual Structural Design: Bridging the Gap between Engineers and Architects, Thomas Telford Books, London,