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Casting concrete with fabric formwork: Active learning methodologies in architectural education

Fabricando hormigón con encofrados textiles: Metodologías de aprendizaje activo en educación arquitectónica

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HIGHLIGHTS

- This paper examines the ways students hone their understanding of materials research by following learning through making methodologies when working with concrete.
- Este artículo examina las maneras en las que los estudiantes desarrollan su entendimiento de materiales siguiendo metodologías de aprendizaje activo experimentando con hormigón.
- A hands-on approach working with materials plays an important role in the student learning process.
- El trabajo manual directo con materiales juega un papel fundamental en el proceso de aprendizaje de los alumnos.

RESUMEN

Basándose en el material producido por dos grupos de estudiantes del Máster de Arquitectura dirigidos por el autor y otros académicos en la Universidad de Newcastle (Reino Unido), este artículo examina las diferentes maneras en las que estudiantes de arquitectura desarrollan su entendimiento de la investigación de materiales siguiendo metodologías de aprendizaje activo experimentando con hormigón. En el material analizado, los estudiantes exploraron el potencial de innovadores métodos de encofrado, centrándose en el uso de materiales textiles como encofrado de paneles y columnas a pequeña escala. Los trabajos se basaron en el trabajo pionero con encofrados flexibles desarrollado por el arquitecto español Miguel Fisac en el siglo veinte, proponiendo a los alumnos una serie de ejercicios de fabricación de hormigón gradualmente más complejos. El análisis comparativo de los trabajos aboga por una diferente aproximación pedagógica a la educación arquitectónica, en la que el trabajo manual directo con materiales juega un papel fundamental en el proceso de aprendizaje de los alumnos.

Palabras clave: *Hormigón, encofrado textil, Miguel Fisac*

ABSTRACT

Based on the material from a couple of Master of Architecture studios taught by the author with other colleagues at Newcastle University, this paper examines the ways higher education students in architecture hone their critical and creative understanding of materials research by following specific learning through making methodologies when working with concrete. The studios explored the potential of innovative methods of shuttering for concrete construction, focusing on the use of fabric as formwork for the creation of small columns and panels. They built upon the work with fabric formwork developed by Spanish architect Miguel Fisac in the twentieth century, asking students to engage with casting concrete in a series of exercises that became progressively more complex. The comparative examination of these projects argues about a more holistic pedagogical attitude to architectural design, in which a hands-on approach working with materials plays an important role in the student learning process.

Keywords: *Concrete, fabric formwork, Miguel Fisac*

1. INTRODUCTION

"Liquid rock, concrete is born under a sign of paradox and does not care. […] Only give it a place to lie down, a place of any shape, and concrete will do your bidding. Let concrete set, however, and sense the difference. Concrete hardens in the shape of whatever container received its flow, its momentary sensual abandon in thoughtless submission to half-loved gravity." [1]

Fabric formwork is a construction technology that utilises membranes as facing materials in concrete shuttering. Unlike traditional rigid formwork, fabrics are flexible and deflect under the pressure of freshly poured concrete. This makes the resulting forms exhibit a degree of curvature and surface finishes that are generally not associated with concrete structures. Although the origins of fabric formwork can be traced back to the Industrial Revolution, and even with some parallelisms in ancient Roman

engineering, the first person to truly acknowledge the architectural and aesthetic possibilities of fabric formwork beyond the mere utilitarian applications was the Spanish architect Miguel Fisac (1913-2006) [2].

Fig. 1: *Newcastle University Master of Architecture studios (Images by Emma Burles & Brandon Few)*

Fisac became a renowned architect in Spain in the 1940s and 1950s and developed innovative structural uses of concrete since the beginning of the 1960s. However, at the very end of that decade, Fisac started to experiment with concrete in a different way: "I thought, in the end, after studying it in detail that, perhaps, the most distinctive characteristic, the most exclusive one of concrete is that it is the only material that arrives at the site, or to its prior fabrication, in a doughy state, which then solidifies. So, I thought that possibly its most genuine artistic impression might be of that of recording, like a genetic print, that it had been a soft material, poured into a mould. And as a characteristic of this doughy, soft state, it should not have sharp edges and should present a rounded aspect, typical of all soft materials." [3]

Fig. 2: *Miguel Fisac photographed in front of one of his fabric formwork walls, and Miguel Fisac's first project using that technique: the MUPAG building in Madrid, 1969 (Images by Fundación Miguel Fisac)*

Fisac developed and patented in the 1970s a very simple system that relied on the use of cheap materials for the formwork and without the necessity of any skilled craftmanship. A rigid softwood or steel framework, a flexible polyethylene plastic sheet and chicken wire were the only elements required for the formwork. This system was used repeatedly by Fisac throughout all his projects for nearly 35 years until his death [4]. One unique characteristic of fabric formwork is its responsive nature, which allows the behaviour of material to engage with and influence the construction process itself, causing the entire decision-making process within the building sequence to come under scrutiny [5]. This is something inherent to the work of Miguel Fisac, and something we wanted our Master of Architecture students at Newcastle University to engage with.

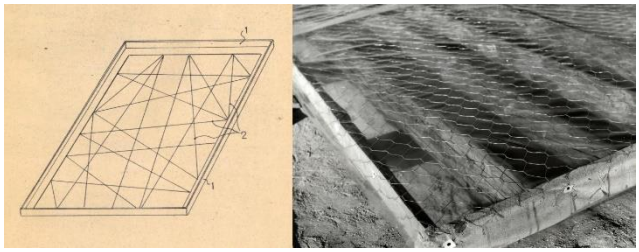

Fig. 3: *Drawing of one of Miguel Fisac's fabric formwork patents, and photograph of a formwork with timber framework and chicken wire (Images by Fundación Miguel Fisac)*

Two separate studios were subject of study for this paper. The first one (studio A) carried out explorations casting concrete with fabric formwork in academic year 2018/2019, whereas the second one (studio B) developed their work in 2021/2022. Studio A set their target on making short concrete columns, whereas studio B worked towards casting small concrete panels. Each studio took place over a period of under six weeks. Students spent most of their time experimenting with designing and making different fabric formworks, as well as improving the concrete mixtures and testing a variety of textures and finishes.

2. METHODOLOGY

2.1 Studio A (concrete columns)

Nine students took part in studio A, working on different casting exercises for a period of four consecutive weeks. A regular pattern of work was followed, involving the preparation of the fabric formworks and casting of the columns taking place on Mondays, and the striking and evaluation of the results on Thursdays, leaving about 72h for curing.

Fig. 4: *Studio A working methods (from left to right): stitching the fabric formwork with a sewing machine; fabricating the timber rigs; mixing the concrete on a tray; pouring the concrete into the fabric formwork clamped to the rig (Images by Emma Burles)*

A standard Portland type I cement was used, together with sharp sand and fine aggregates. Different proportions were tried every week when mixing the concrete. In particular, the cement-sand-aggregates proportions were 6-4-2 (week 1) and 4-4-2 (weeks 2 to 4). The water to cement ratio was initially established at 0.25; however, as it will be further elaborated when overviewing the results, the amount of water was gradually increased as the exercises advanced to account for the water that was getting absorbed by the fabric.

In week 1, students started fabricating the timber rigs that were used in every casting iteration. Each rig was manufactured with a couple of 400x400 mm OSB boards at top and bottom, joined by four legs of 50x50 mm timber battens. Each rig had a different shape and dimension opening at the top OSB board for the fabric formwork to sit in and allow for different columns shapes. The height of each rig was 600mm to give a common parameter to each iteration. Students sourced different types of fabric and used a sewing machine to stitch the formworks. They clamped the fabric formworks to the timber rigs, so that the fabric got stretched between base and top, preventing any sagging in the textile. Once the concrete was poured, it was compacted with a metal rod to remove any trapped air, with particular care to avoid the fabric formwork being torn. After a curing period lasting about 3 days, students stroke the columns cutting the fabric formwork.

2.2 Studio B (concrete panels)

Thirteen students took part in studio B, working on different casting exercises for a period of five consecutive weeks. Students started their work in week 1 manufacturing the rigs that would be used to cast all panels. These were 300mm x 300mm squares made from a perimeter of softwood offcuts screwed together. The timber rigs were easily reusable, disassembled and reassembled after a typical 72h curing period of

the concrete, facilitating in turn the process of striking the moulds and limiting the risk of damaging the panels.

A standard Portland type I cement was used, together with different types of sand and fine aggregates. Students experimented with different mix ratios, such as 1:2 cement: coarse sand; 1:2:1.5 cement: fine sand: Styrofoam; 1:2:1.5 cement: fine sand: aggregate; 1:2 cement: fine sand.

Fig. 5: *Studio B working methods (from left to right): drawing showing the design of the timber rigs for the panels; concrete mixes with varying components and colour pigmentations; fabric formwork including plastic, reeds, and grasses; pouring the concrete mixes into the formwork (Images by Brandon Few)*

After casting a small number of test panels to experiment with a variety of ratios of concrete mixes, the studio was subdivided into smaller working groups that would focus on three specific studies: Material Re-use, Colour Pigmentation and Natural Materials. Students investigated re-using locally sourced materials to create the formwork including different types of fabric, pursuing a high variety of different concrete surfaces.

They also looked at incorporating natural materials as formwork, such as crushing up mussel shells to add to the concrete mix to create a pseudo-Roman concrete or collecting reeds to use as the formwork for the concrete panels. Students also experimented with different processes that could vary the textures and finishes, such as burning and vacuum moulding.

3. RESULTS AND DISCUSSION

3.1 Studio A (concrete columns)

Four columns were casted during the first week of the work, using four different fabrics. Experiment 1 (satin fabric) generated an unsuccessful column, as the aggregate used was excessively large and the resulting concrete mix was overly dry, meaning the exterior of the column fell out at the time of striking the formwork. Experiment 2 (bin bag) also offered a disappointing outcome, as the concrete mix was again too dry, which resulted in the twisted fabric not being printed into the concrete. Despite this, the smaller size aggregate used created a more consistent mix.

Experiment 3 (corduroy) was unsuccessful too. This time the design of the fabric formwork was at fault, leaving the middle of the column too narrow to support the volume of concrete above. Upon evaluation of the three unsatisfactory exercises, students learned they should use smaller aggregates in subsequent iterations as well as more water, or at least a fabric that would not let water drain out during the curing process. They also learned they should be more judicious when designing the layout of the formworks, as well as better compacting the concrete mixes to remove air gaps and create a smoother finish.

The final attempt that week, experiment 4 (felt lined tablecloth) resulted in a very successful column. Although the concrete mix seemed to be excessively wet when poured, this facilitated the surface of the concrete taking the pattern of the fabric with an excellent level of detail. The fabric was quite impermeable, so it retained the water much better than the other three experiments.

Fig. 6: *Some of the concrete columns produced by Studio A (Images by Emma Burles)*

Another four columns were casted during the second week, using four other fabrics. Experiment 1 (linen fabric with chicken wire) produced an unsuccessful column. Although the concrete mix was sufficiently wet, the fabric did not bulge through the wire as expected. The mixture had not been compacted sufficiently, and the wire had far too small holes, which did not allow the concrete to penetrate properly. In experiment 2 (plastic sheet with rope), the writing on the plastic formwork printed onto the concrete very clearly. However, the column showed two different strains as the concrete mix had not been compacted enough.

Experiment 3 (cotton jeans) provided a column that took the grain of the fabric in a very interesting way. The cotton fabric absorbed much of this moisture and dried out the concrete, which partially dusted. The final experiment 4 (wool) was very successful. The wool fabric adhered well to the surface of the concrete, creating a beautiful texture. However, the fabric bulged more than expected and the column ended up being wider than anticipated.

Upon evaluation of the four experiments, students learned the following: that a different type of wire should be used in further iterations; that they should ensure proper compacting to avoid the stratification of different mixes; that they needed to keep fabric regularly wet during the curing process, to avoid the columns getting too dry; and that the choice of wool as a fabric had proved to most successful so far in terms of pattern, but a less bulging alternative could be sourced in future iterations.

Three columns were casted in the third week of work. Experiment 1 (Felt lined tablecloth) produced a very good column. The combination of a well-proportioned concrete mix, together with a good retention of water thanks to the plastic formwork, it all contributed to form a beautiful pattern onto the surface of the concrete. Experiment 2 (Plastic backed tablecloth) became very successful as well, with a very detailed pattern appearing on the surface. Experiment 3 (Red jeans) produced a surprisingly pleasing column, as the column took the red pigmentation on its surface.

Upon reflection of the three columns, this was probably the most successful week since the work began. The evaluation showed that this plastic back tablecloth was successful in retaining water and obtaining high detail in the concrete surface. However, it also required caution when compacting using the metal rod, as the fabric could easily get torn. They also learned that covering the jeans fabric in a bin bag was a very good solution to ensure the concrete mix was kept sufficiently wet during the curing process.

In the final week of work, students took a different direction and decided to cast a single column but double the height than the previous ones (i.e., from 600mm rigs to a 1200mm rig). For the fabric formwork, they used a plastic-backed tablecloth that provided an excellent finish with plenty of detail on the surface of the concrete. Due to the increased height of the column, students tied rope around different parts to allow the column to properly bulge. The biggest struggle was compacting the mix with the metal rod while not tearing the fabric as a result. Upon evaluation and reflection, students

concluded it was a very successful exercise which could have been perfected if too narrow parts had been avoided, just so the compacting could have been carried out without tearing the fabric.

3.2 Studio B (concrete panels)

In a similar way to what happened to studio A's columns, some of studio B's concrete panels offered more successful results than others, in some cases influenced by the type of thematic research developed by students. For example, the panels produced by the group studying Material Re-use investigated re-using locally sourced materials for concrete formwork. In doing so, students manufactured a variety of panels using materials such as denim and jut bags for formwork. These resulted in very detailed textural qualities being imbued onto the concrete. This group was formed of students who found their projects were situated in incredibly urban settings where the sorts of materials used as form work could be found in abundance.

Fig. 7: *Some of the concrete panels produced by Studio B (Images by Brandon Few)*

The group focused on Colour Pigmentation worked on manipulating the colour of the concrete mix to achieve a variety of different chromatic finishes. A wide range of panels was casted, in some cases inspired by the type of programmes students considered these panels could be used in. For example, a range of playful coloured panels was created having in mind their use in a building programme of a school for young children. Some other attempts experimented with creating panels that incorporated glowing elements in the mix, for their use in underground projects.

The final group worked with Natural Materials into the formwork. Three of the panels provided very interesting outcomes on the surface finishes, thanks to the addition of reeds and grasses to the formwork. Pouring the concrete onto a bed of grasses and reeds left those embedded into the concrete, creating a very rich texture on the surface of the concrete panels. Once the concrete was set, the grass was burnt off in one of the panels with a heat gun, which provided the surface of the concrete a beautiful, charred quality.

On the second panel, cling film was used to prevent the reeds becoming rooted into the concrete mix. This method made the concrete pick the texture of the cling film, rather than the natural materials. On the third panel, a vacuum former was used to create a plastic mould of the reeds onto which the concrete was poured. This created a neatly defined texture on the surface.

4. CONCLUSIONS

This paper presented two case studies of active learning methodologies in architectural education, in which Master of Architecture students at Newcastle University carried out different experiments casting concrete with fabric formwork using similar methods than those developed by Spanish architect Miguel Fisac last century. The two studios were implemented just before and after the Covid-19 pandemic (in 2019 and 2022 respectively), when the absence of lockdowns allowed students to physically work hands-on with the material in the workshop. These opportunities for learning through making offered a more holistic pedagogical approach to architectural design,

which contrasted with the limited means available to students during the pandemic years.

Students were able to manufacture a broad range of concrete columns and panels, with different degrees of success in their results depending on the materials used and sourced, either for the concrete mixes or the formworks. Nevertheless, the working methodology constituted the biggest success of the studios, as students were able to experience practical ways of approaching material design. Working in groups, thinking with their hands, and learning through trial and error, it all became an invaluable learning experience for students, emphasising the indivisible relationship between designing and making.

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6. REFERENCES

[1] Schjeldahl, P. (1994) Columns & Catalogues, Great Barrington, MA: The Figures, pp.196-200.

[2] Veenendaal, D., West, M., Block, P. (2011) History and overview of fabric formwork: using fabrics for concrete casting, Structural Concrete, vol. 12, pp. 164-177. https://doi.org/10.1002/suco.201100014

[3] Fisac, M. (2007) Carta a mis sobrinos (estudiantes de arquitectura), Ciudad Real: Fundación Miguel Fisac , pp.44-45

[4] Peris López, D., Peris Sánchez, D. (2020) Los hormigones con encofrados flexibles de Miguel Fisac, Cuadernos de Estudios Manchegos, vol. 45 pp. 405-446

[5] Chandler, A. (2007) Concrete as Equipment, in: Chandler, A., Pedreschi, R. (Eds.), Fabric Formwork, London: RIBA Publishing, pp. 5-19.