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Alan Chandler | **Building walls**

Experiments with an innovative in situ casting technique question assumptions about the nature of concrete, the workmanship of risk, and the familiar relationship between design and making.

Building walls – a philosophy of engagement

Alan Chandler

> *'Then a mouse-grey liquid is poured into the empty speculative counter forms to give them permanent life on earth, an undeniable reality, especially after the signs of the initial madness – the shuttering – have been removed.'* (Koolhaas, 1994)

Wall One is part of a series of 1:1 construction workshops involving collaborations between architecture and engineering students at the University of East London (UEL), teachers at Edinburgh University School of Architecture, and CAST at the University of Manitoba, Canada. The workshop forum is valuable in developing a philosophy of engagement between architectural teaching and practice, treating materials research and design as facets of one activity. Taking students through the process of following a theoretical construct into physical construction at 1:1 makes public their innovative material investigations, and within the School of Architecture develops an archive of test pieces that contribute to the visual culture of the studio *[2, 3]*.

Building Wall One was an exercise in rethinking the practice of *in situ* concrete casting, aiming to establish new techniques using innovative shuttering. Innovation can be defined as a purposeful radicalism, which responds to or redefines an existing need or opportunity. It allows architectural teaching to remain relevant, and to use its position outside the standardised context of practice to critically examine how and why we build. Concrete is crucial for both structural and thermal performance, but issues of embodied energy and the resource-intensive casting process affect its environmental credentials. Allied to these financial and energy concerns, there are inseparable visual and theoretical implications to the use of concrete that any research into the material must address. This is particularly true with non-orthogonal geometry, which the plastic nature of concrete is ideally suited to, if only the means of shuttering can be achieved economically and expediently.

Depending upon how a material is worked, its expression, significance and status is capable of radical variation. This is true of all materials, however with concrete, it is expressive only when its primary quality – that of being liquid – has been lost. The pleasure of working with concrete comes primarily from its ability to retain a history of its former state, of bringing opposing qualities of fluidity and solidity together – akin to appreciating the potential of fine figurative sculpture to render soft human form in marble. It is the method by which the material is worked that largely determines its aesthetic significance, and not the material itself.

In considering the innate plasticity of concrete, the means of allowing that state to inform the final result of the operation led logically to working with a responsive shuttering medium, with the technical challenge of restraining a fabric against the hydrostatic pressure of concrete the focus of experiment. Allowing flexibility with regard to arranging restraints enabled the form of the wall to emerge as it was being made, the inverse of traditional shuttering, where the entire final form has to be fully described in watertight negative, often using expendable materials and resources. Minimising shuttering time and materials use was a key requirement of Wall One.

The Wall One project also sought to address the embodied energy issue of the concrete itself through the specification of recycled, manufactured aggregate. A partner in the workshop research programme at UEL is the MARC programme, based in the School of Computing and Technology and funded by the ENTRUST Landfill Tax Credit Scheme. Under the direction of Darryl Newport, the MARC programme recycles waste industrial granular material and organic sewage residues to create aggregates with specifiable size, density and colour. This 'smart' aggregate uses selected and metered dry powder resource material which is mixed at 1450rpm, then mechanically pelletised using minimal water content. As with the constituent mix, the size of pellets is also specifiable. Following the drying of the green pellets, they are heated in a trefoil kiln to vitrify the pellet surface, using the combustible potential of the organic matter within the blend to generate an internal honeycomb within each pellet: the greater the internal void, the lighter

1 Wall One: the final lift, with an enhanced surface definition through the use of high dust content sand in the mix

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the aggregate. Because Wall One was situated within the main AVA building at UEL, cast onto the existing floor slab, the lightest specification, containing waste paper sludge, was chosen. Further recycled materials were incorporated within the Wall in the form of shredded recycled plastic to act as an anti-crack reinforcement that has the capacity to flow around the dynamic curved interior of the formwork.

Technique and form

Materials are linked to a resultant form via technique. The choice of technique is therefore decisive, and can potentially allow the dialogue between the maker and the cycle of making to register individual actions within the final built piece. Geotextile casting is provocative at a number of levels: in its material economy as ultra-lightweight, inexpensive containment for concrete; and in the formal dynamic which redefines presuppositions about concrete and its shuttering, allowing the inherent flexibility of the geotextile to provide an expressive combination with the hydrostatic pressure of the liquid. The need for restraint in containing that internal pressure opens up possibilities for the constructor to enter into a creative dialogue with the textile concrete. Work by Kenzo Unno in Japan, for example, has taken the mass production potential of a technique with fabric to a flawless level, while Mark West at CAST in Canada has developed fabric formworks to make structurally and materially efficient beams and slabs.

The work of Unno on casting fabric-shuttered walls expresses with beautiful clarity the formal and surface potential of textile concrete, the technical means by which the concrete is cast being hauntingly absent from the finished pieces. Wall One is complementary to this work, and its purpose lay in determining a process by which the active participation of the maker is registered within the finished piece, exploiting the material's natural behaviour to create an architectural language of detail. To do this effectively, the shuttering needs to be rethought not only in detail, but also conceptually.

The frame that supported the textile during the casting of Wall One was conceived as a jig, a device for

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2 'To be an architect means, of course, the desire to build' (Prouvé, 1971)

3 'When the [student] has made his choice, he must build immediately at the college, which will have been transformed into a factory or a practice' (Prouvé, 1971)

holding a piece to be worked, rather than a means of pre-determining the piece exactly, as with conventional shuttering. This is an important distinction if the relationship between the constructor and the material is to yield an element of the unforeseen, to become a means of determining a systematic construction that retains the tactility of a craft process. A jig is a conceptually looser and more open-ended mechanism, its precision lying in the clarity with which it enables a range of operations.

To make concrete, water is required for both chemical change to achieve a solid, and for workability to enable the flow into its containment. The presence of water in excess of that required for chemical reaction creates minute voids, which propagate crazing and create visual defects. Manufactured as an inexpensive subsoil woven geotextile by the Don and Low Company in Scotland, Lotrak 300GT is an engineered polypropylene weave with a bleed potential of approximately 160 litres per metre square per minute. This permeability is useful to leach excess water and entrapped air, delivering a concrete with low excess water content at the point of cure. This 'sweating' allows a migration of cement fines and sand dust to the inner surface of the textile, giving the concrete enhanced definition and strength at the face of the cast with a quality almost unachievable with rigid formwork.

The shuttering fabric has inherent properties of high tear resistance and elasticity, with a grab tensile strength of 1.35kN, and more importantly an elongation capacity of around 15% in both warp and weft, which allows the fabric to respond three-dimensionally to the significant hydrostatic pressure of the pour. The geometry of the textile is utilised orthogonally with lateral fibres acting in tension. The vertical fibres of the weave act as a jig themselves to restrain the lateral threads in place. The tear resistance allows for simple bolt through fixings without the risk of the openings in the fabric spreading under load. One of the many details developed by Mark West involves using a marlinspike to force apart the weave, allowing the insertion of fixings through the material. The weave thus remains unbroken, allowing it to retain its integrity and to be fully re-usable.

According to Gottfried Semper, the geometry inherent in materials is the basis for an architectural language, with the original *wand*-maker as the proto-architect organising woven fabrics to define a third skin beyond the second skin of clothing as elemental protection. The weave, for Semper, through historic development came to generate order, pattern and scale for defining the wall as a tectonic element (Semper, 1989). The consequence of a textile-based casting medium is directly analogous to Semper's

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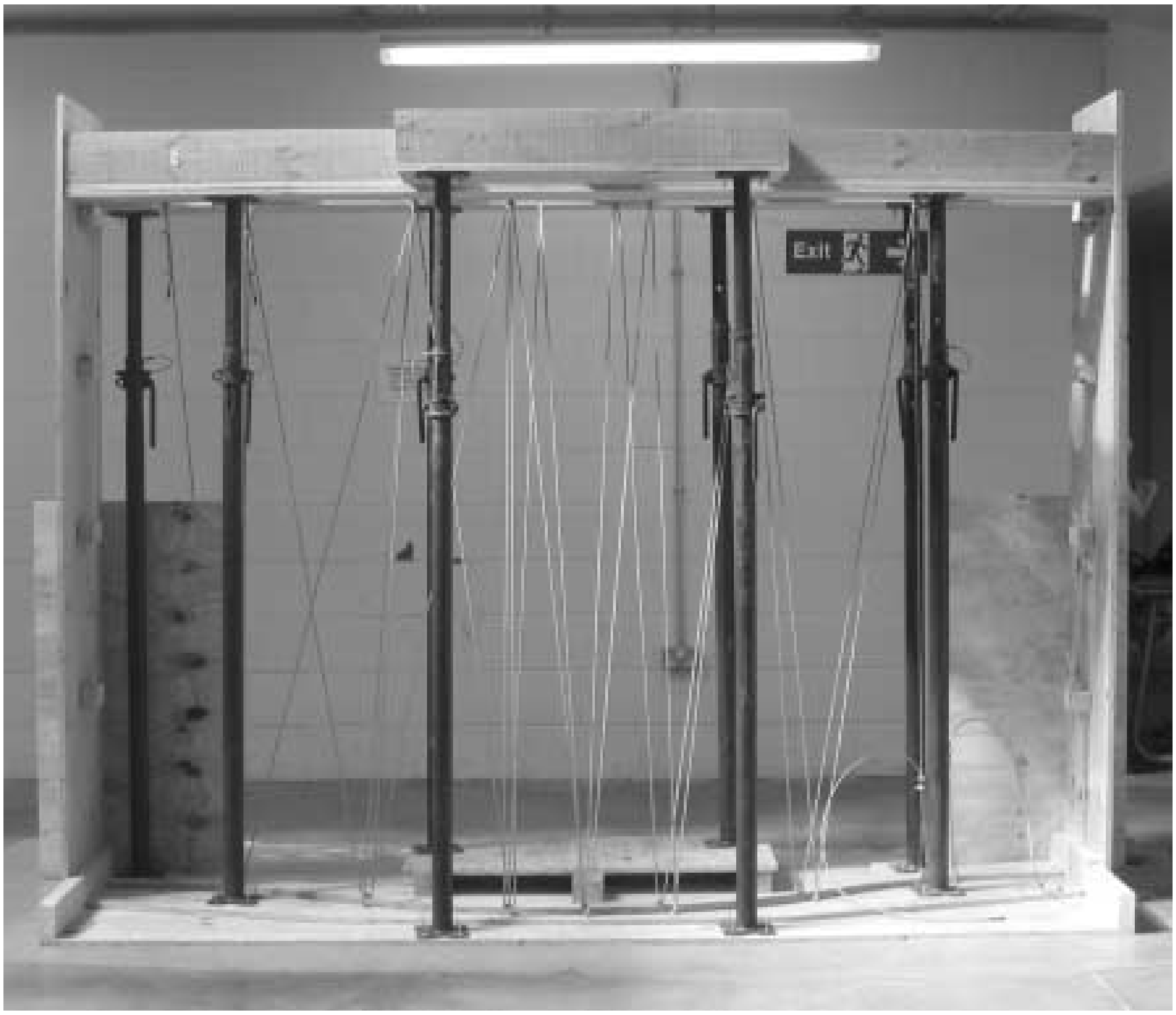
idea, engaging the structural potential of a fabric material to create deflections and pressure points, transitions and connections which constitute an architectural presence. The expanded geometry that becomes available using fabric erodes the pre-eminence of the extruded plan and a modern reliance on the manufactured panel as a measure and dictator of constructed form. Textile casting implies, and allows for, non-linear spatial form to develop as a consequence of the constructive process itself.

Forming the jig

The jig to hold the textile and to allow it to remain responsive was designed to minimise material use primarily through sustainable concerns, and with a view to applications in situations with a severely restricted economy of means. An interest in Buckminster Fuller's notion of 'tensegrity' as the resolution of forces within the structure itself, converting dynamic loads into dead weight, informed the opposition of cables and tension props resisting the fluid concrete weight and fabric deformation *[4]*.

The top rig was designed as a re-usable joisted deck, the base rig being ply with the curved plan form of the wall described with a cut-out. The curved base plan afforded self-stability, and allowed successive casts to form, with 180 degree rotations of the formwork jig, a sine-wave wall, taking inspiration from work by the Uruguayan engineer Eladio Dieste. The props are 'readymades', providing the energy for the tension without the necessity for elaborate reinvention. Bespoke containment of the fabric was devised using ply discs, set out across the surface of the cast to define the geometry for the eventual surface, and control sectional variation. The specification of the setting-out would give, we imagined, the ability to contain randomness within the process. Given the high puncture resistance of the fabric, the circular ply form was chosen less to avoid corners and pressure points, more to allow the anticipated curvature of the fabric under pressure to be unhampered by orthogonal geometries *[5a, b]*.

In encompassing the steel cable which connected top to base rig, the paired ply discs acted as post-tensioning devices when tightened together, augmenting the work of the props. The cables later became part of the formwork imprint due to the wide offsets between the discs. This ability to modulate the tension field was the mechanism for both control and lack of control of the surface topography and section. A range of section thickness between 100mm and zero was determined by the student team, as was the final spacing of the discs across the surface. In places, this allowed the concrete thickness to reach over 200mm *[6]*.



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4 The completed formwork

5 a/b The robust top rig transfers the downward pull of the concrete onto the upward thrust of the acro props. The side panels define precise vertical edges to the cast, notionally to allow the wall to be continued in sections, rotated 180 degrees each time, to create a sine wave wall. The top rig slides up as the prop tension is increased through slotted connections. The steel cable restraints are visible, which in conjunction with paired ply discs on threaded ties restrain the concrete

Casting

The initial pour was limited to a 500mm lift, both to minimise the pressure at the base of the fabric, and to deliberately set up a 'day-work' joint. The legibility of the concrete within the fabric was a revelation, with free water sweating through as the concrete level rose within the formwork. The water content within the mix was increased once the behaviour of the fabric was noted. The ability to respond to the demands of such a construction would be inconceivable without doing a test at 1:1. The increased flow now available enhanced the ability to manipulate the spacing between the ply discs, making the variation in cross section more extreme than originally envisaged, with the responsiveness of the fabric encouraging a sense of play with the material. Larger discs were made during the pour to vary the scale of the detail *[7, 8]*.

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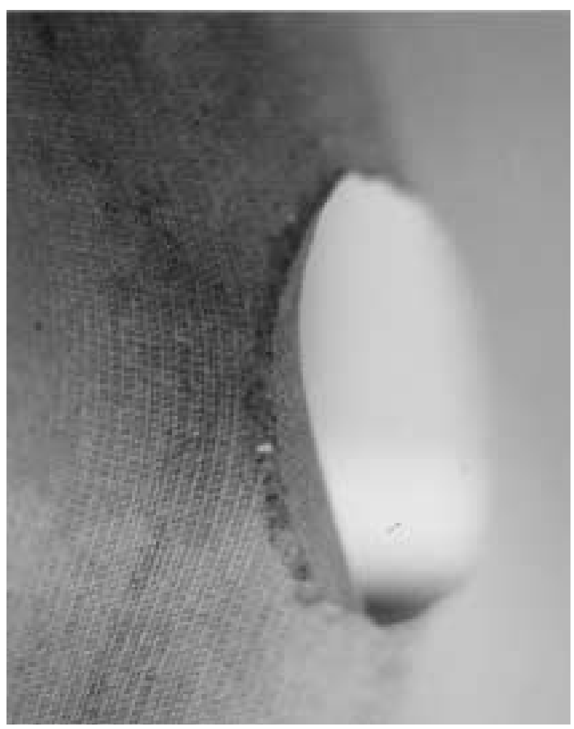

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Towards the end of the casting sequence, the initiative to create a window within the wall spurred the creation of an aperture frame, complete with spacers and rebates, which was made and inserted into the fabric as the concrete was being poured. This window made for a surreal presence in the finished cast, with the pressure on the fabric so tangibly present, having an opening with 25mm thick edges defied expectations. The overt expression of pressure and mass was overturned by the actual thinness of the wall and fineness of the window edges.

The role of play within research became a question as a consequence of our experience – the enjoyment of a creative interaction with materials providing new areas of invention as the Wall progressed. The sand specification was changed during the second lift, sharp sand being replaced by Leighton Buzzard sand, to assess how the sweating properties of the fabric affected the sand's ability to influence the colour of the final cast, in this case yielding a faint pink hue.

The final lift provided a further opportunity to change sand, to one with high dust content *[1]*. The dust is finer than the cement fines that are conventionally the smallest element of the matrix, so with the sweating bringing the fines to the surface, the dust radically affected the colour of the cast and the surface definition. As a side effect of the sweating, the concrete achieves a striking capability within 24 hours, enabling the entire 3 by 2 metre wall to be completed from unloading supplies to striking the formwork within five days. The enthusiastic support offered by Allan Haines of the Concrete Centre means that the advantages discovered with this technique have a potentially useful future, with the speed of formwork erection; short pour to strike time; high-strength, low water content matrix; and blowhole-free surface giving distinct advantages to construction projects.

Process, form and risk

An architectural prototype acts as both an anticipation of the end of a process of thought and as an enactment of that process. A prototype's power lies in its ability to embody a field of ideas and the means of testing the interrelationship of those ideas in a single moment: making a prototype accelerates the proposition. The task for Wall One was to conceive of a prototype construction process which was both a practical, repeatable technique, yet within its own operation allowed for and encouraged the constructors actively to manipulate that process. The exact placement of restraints, their size and degree of constriction, could be manipulated even as the concrete was poured, questioning the need for the extensive pre-determination required of conventional concrete work. The casting technique of Wall One showed that from a coherent technique, unpredictable, even incoherent, detail might emerge – an architectural equivalent of the Surrealist game of the 'Exquisite Corpse'. This subversive intention was at the heart of the Wall One exercise, and formed a critique of industrialised building processes by addressing the very aspect of construction that causes most difficulty – risk.

In his book *The Nature and Art of Workmanship*, David Pye distinguishes between the 'workmanship of risk' and the 'workmanship of certainty'. He clarifies the role of the individual maker with regard to either being involved with the determination of the result, or being placed outside of a pre-determined mechanical or digital process. He asks us to look at means and ends. The 'workmanship of risk' reflects the ambiguities surrounding the reality of architectural practice: 'In the workmanship of risk, the result of every operation during production is determined by the workman as he works and its outcome depends wholly or largely on his care, judgement and dexterity' (Pye, 1968). In other words, can one determine the accuracy of a built result more confidently by using techniques which do not prescribe the outcome entirely, but rather incorporate adjustment and judgement within their operation?

With much of architectural production focused on one-off buildings for particular users and locations, it is vital to address the issues surrounding bespoke production, of equipping architects to exercise judgement and dexterity both at the design *and* production stages of building. The issue for education is to equip students to actively manage the practice of risk, and to define a means of operating that enhances the potential within any given situation. But how can one teach the management of risk when increasingly the framework of teaching itself is becoming risk averse? Essentially, risk needs to become a focus of activity, not a pariah to be avoided. Building at 1:1 using innovative techniques places a responsibility upon the participants to use intuition and lateral thought to re-think both processes and material languages, and to define new and safe working practices in the process.

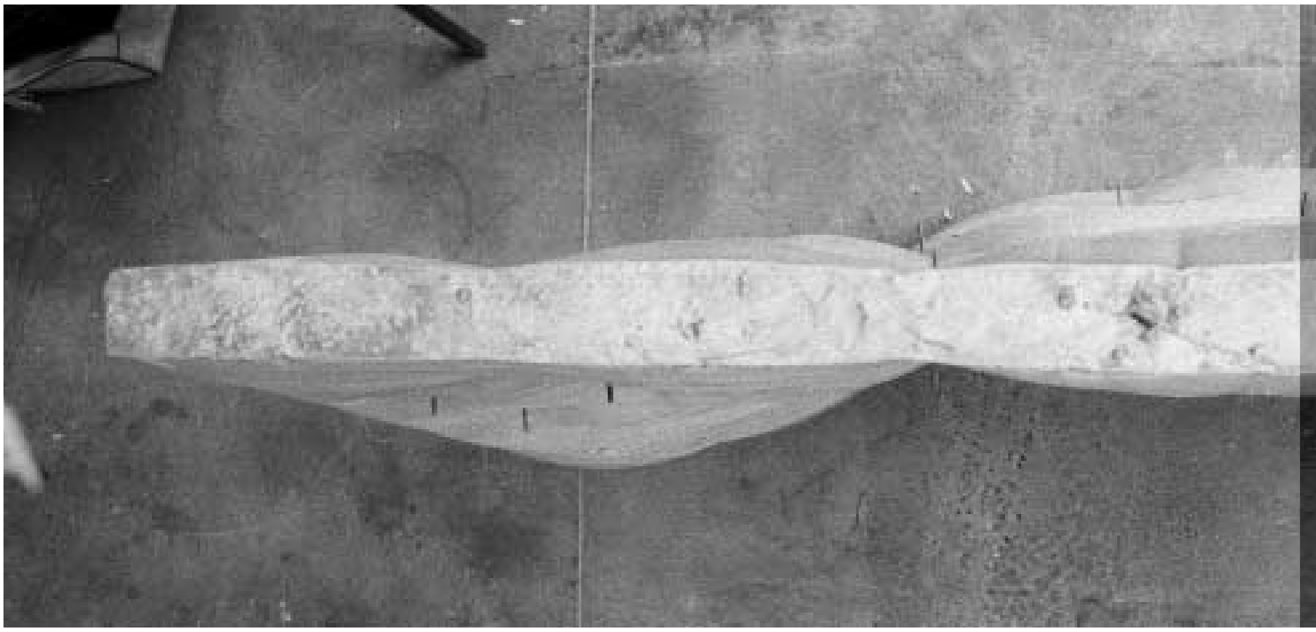
The drawing, with its inherent abstraction, normally precedes the making of structures with material. Within the Workshop this need not be so, and the line loses its pre-eminence. Workshops rely on both verbal and manual exchange in order to generate the constructed situation between the participants and their task. The student is taught never to assume that the mastery of matter is always the responsibility of others. In the very conception of a design the qualities and properties of materials must be grasped and understood in order to make.

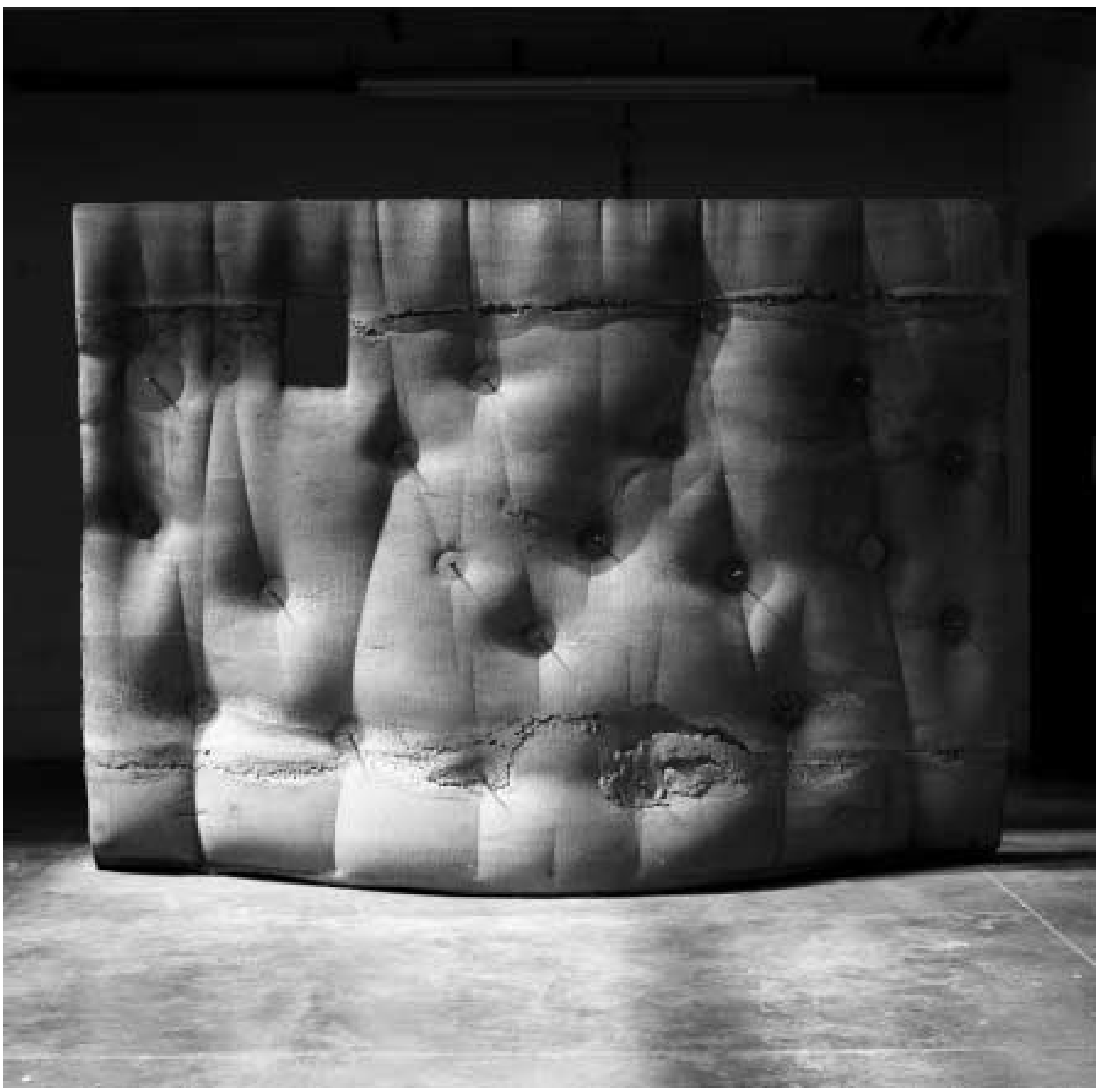
The practice of prototyping is a proper domain for architectural research. Constructive processes and material inertia need to be thought of not as impediments to formal invention, but rather as active participants in innovation. As educators and as

6 **Deflection**

7 **The pressure of the concrete around the retaining discs, held together/apart via threaded studding, forces the geotextile to respond. With a grab tensile resistance of 135 kN, and an elastic potential of 15%, safe deformations are possible, and depending on the spacing of the discs, suppressed or encouraged**

8 **When the ply discs were tightened until they touched**





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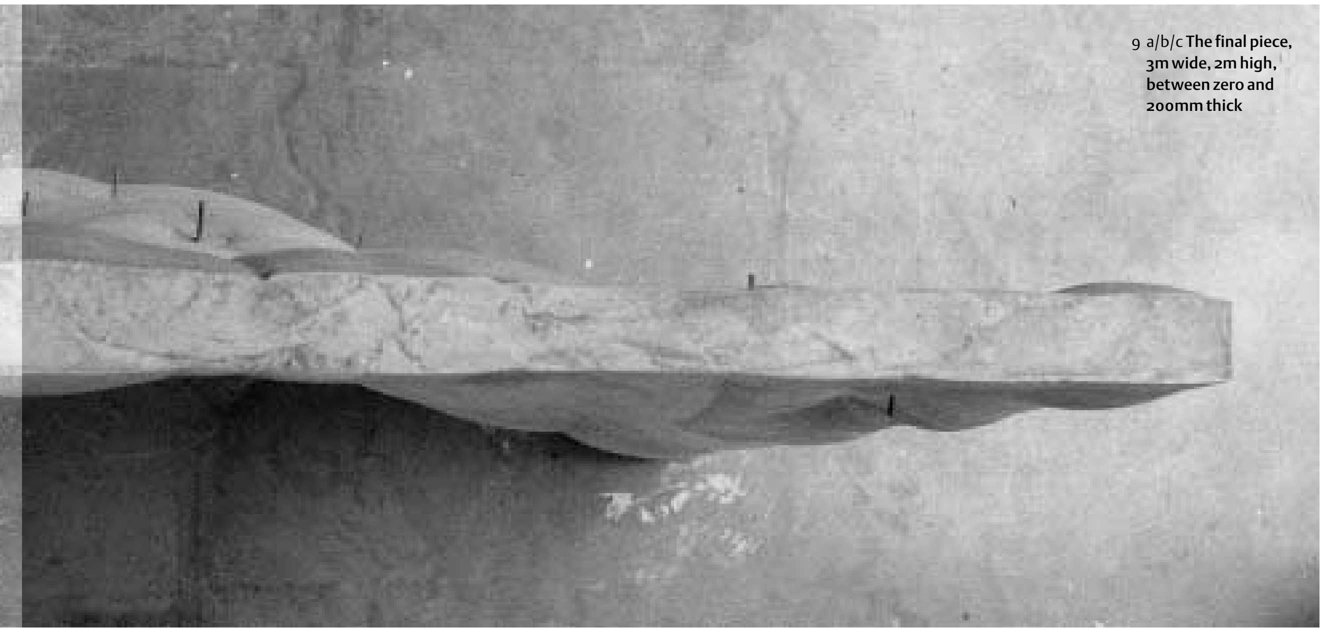

9 a/b/c **The final piece, 3m wide, 2m high, between zero and 200mm thick**

9b

9c

architects, the compulsion should be to build, learn and build again, a mode of operations at odds with traditional (non-architectural yet dominant) research practice. Conventionally, a discrete series of operations would be defined which, through systematic and linear processes, became understood and evaluated according to pre-set criteria. Building at 1:1, informed with a limited but effective body of intuition and understanding, provides a broad platform from which significant areas of study – of materiality, process and technique – can be tested simultaneously. It is only after the prototype is built that the linear model of analysis becomes vital in refining the opportunities that full-size making has generated. The prototype tests the interaction of materials and events, not merely their constituent parts. In making a prototype, one discovers how to build, and where to focus the activity of risk, the value of team consciousness, and the consequences of theoretical decision making [9a, b, c].

Walls Two and Three have already been constructed, pushing further the geometric, technical and material possibilities using both concrete and unstabilised rammed earth. With the effective tensile restraint of fabric used as permanent formwork, tensile weak rammed earth could gain new structural possibilities, and will form the next area of 'Wall' investigation. The engagement with materials makes innovation both possible and purposeful: within architectural education, producing only an image of architecture is not enough.

References

The Architects' Journal Information Library (1968). 'In Situ Finishes', 14 February.

Gage, M. (1969). *Guide to Exposed Concrete Finishes*, The Architectural Press, London.

CAST (2005). *The Centre for Architectural Structures and Technology*, see: www.umanitoba.ca/cast_building/.

Koolhaas, R. (1994). *Delirious New York*, 010 Publishers, Rotterdam.

MARC (2005). *Manufactured Aggregate Research Centre,* see: www.uel.ac.uk/marc/.

Pedreschi, R. (2000). *Eladio Dieste*, Thomas Telford, London.

Prouvé, J. (1971). *Prefabrication: Structures and Elements*, Praeger Publishers Inc, New York; London.

Pye, D. (1968). *The Nature and Art of Workmanship*, Cambridge University Press, Cambridge.

Semper, G. (1989). *The Four Elements of Architecture and Other Writings,* Cambridge University Press, Cambridge.

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Biography

An architect and teacher, Alan Chandler developed an interest in manipulating casting processes and in using flexible formworks while studying at the AA in the early 1990s. He is now leading Technical Studies at the University of East London, where construction and innovation in thermally massive materials has developed into a teaching and research practice.

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