A New Kind Of Laboratory For Building Technology Research

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The first part of this paper describes a new research facility and its operating methods. The second part outlines our current research program as an example of how these methods have produced a specific set of research projects.

In the fall of 1998, the Canadian Foundation for Innovations (CFI), an independent corporation established by the federal government of Canada to strengthen Canadian capability for research, granted the University of Manitoba sufficient funds to construct and equip a new research facility dedicated to research in fabric-formed reinforced concrete structures. This represents a turning point for this research, which until now has been done without significant institutional support over the course of the last nine or ten years.

Our new facility will bring together people, tools, and techniques from a wide cross section of industrial sectors and academic disciplines. Our work together will advance both basic and applied research in flexible membrane formwork technology. The goal of this work is to industrialize what have been, until now, largely artisanal techniques developed through the production of various prototypical formworks and fabric-formed concrete structures. This work holds the promise of a new sculptural "language" for reinforced concrete construction, and simultaneously affords new levels of structural and constructional efficiency unimaginable with the use of traditional rigid panel formwork.

There is, however, another agenda at work here that does not explicitly show up in any grant application or "official" research description. What we are aiming to do, as a normal part of our research and teaching, is to advance a "technology" of education designed to stimulate invention and play between several professional cultures that do not often get a chance to study together.

The building that will house this research unit will be a 4,000 to 5,000 square foot pre-engineered metal building with a 20 foot ceiling height, providing a studio space on a mezzanine level above the production tools. The studio space will place students of engineering, architecture and sculpture/fine arts in the same place at the same time along with a variety of materials and equipment. Their basic task will be to "fool around with stuff" in a recombinant manner until something sufficiently interesting is found. These particular findings will then become candidates for research funding, and eventual graduation to the official research floor below.

The ideas generated in this environment need no particular pedigree; they may constitute the basis for research projects in architecture, industrial design, landscape architecture, interior design, civil or mechanical engineering, or any other discipline that may find value in the work at hand. The searching that takes place in this studio space, in other words, is emphatically open-ended.

Work among these students will synthesize techniques of investigation and production from engineering, architecture, and fine arts. The two putative "extremes" in this synthetic equation, of course, are fine arts and engineering, which to most observers resemble oil and water in their lack of affinity. The architectural venue of this research will play the role of catalyst (or Cupid) between these two rather distant cultures. This invokes the old cliché about architecture combining art and engineering, the arts and science, the rational and the aesthetic, etc., etc. Although we, as architects and educators, often fall short of this idealized description, aphorisms and clichés don't come from nothing, and this one is taken here very seriously indeed.

The part of this equation that is most easily jettisoned, and most convenient to pay lip service to, are the traditions of artistic production. We commonly hear "the arts" being lauded in terms of cultural values, etc., however, when one gets down to business these "fine" sensibilities can easily be left behind as unnecessary (or worse). Indeed, the concerns of an artistic sensibility very often have a nasty habit of gumming up the works and muddling up the directives of "serious" research and production. I will therefore first address what I believe to be the real instrumental value of some of these art practice traditions, as well as the more obvious pitfalls to be avoided.

Our current research in fabric-formed reinforced concrete structures has its origins in a method of research that might be called "irresponsible" play. This play, done with various combinations of materials, is irresponsible in that it has no obligations or requirements other than those it sets for itself. This kind of self-referentiality is well known and well accepted in artistic practice, but is considered out of bounds in both architectural and engineering research traditions. It represents an epistemological tradition quite unlike anything else, and recommends itself not only by providing diversity in the generation of knowledge, but by its extremely long and glorious track record for innovation.

The instrumental value of this kind of "irresponsible" play lies in its ability to originate new lines of fruitful work. Work/play that is responsible only to its own desires and unexpected branchings, provides a necessary general condition of speculative freedom that is difficult or impossible to establish in other, more restrained, environments.

Beyond merely providing the atmospheric conditions for the imagination to flourish, there are also specific research/production techniques our research methods appropriate from art practices. These fall generally under the heading of collage (or montage). This is a technique of recombinant making, that simultaneously sees everything as both fragment and as a portion of some other possible whole. Through this technique, everything known and recognizable is subject to fragmentation and reorientation for the purpose of rendering that thing more fecund than its previous undisturbed incarnation would allow. The modern world is loaded with examples of the generative power of this basic creative strategy. The Twentieth Century in particular has made extensive use of fragmentation/recombination; from Kurt Shwitters to gene splicing, the fecundity of the collage method is beyond dispute.

To use it effectively as a tool for generating useful ideas, however, requires some training. It is not so easy to break away from what one already knows, and see something familiar as a body of fragments, each charged with its own potential, awaiting unexpected orientations and contexts for a new synthetic "completion." An artist trained in this method of investigation/production will find this discussion both elementary and obvious, whereas someone trained in more rational (and "responsible") pursuits, such as an engineer, may simply find this confusing, or at best, very hard to do. But the doing of it is what matters, and if the engineer (not to mention the architect) can gather these techniques of discovery and synthesis through the activities of the studio setting, and learn about their appropriate use and timely deployment in the creative process, they can acquire a powerful tool for generating new ideas from existing materials and techniques.

In this method nothing can ever be said to be precisely what it is; everything is always contingent on its context, always suggesting something else as well, and as well, and as well. So, a sewing machine takes on a different meaning when placed next to a concrete mixer (and visa versa); structural testing equipment can be reversed to act as a press used for production purposes (and reversed again to test the structure it produced). The building that will house our fabric formwork research will itself be used for full scale building experiments. A pre-engineered metal "shed" was chosen not simply because it is the most inexpensive way to contain our workspace, it also provides a suitably "blank canvas" on and through which students can make full scale alterations and interventions —an armature for architectural experiments carried out through actual building materials and practice.

The biologist Stephen Vogel in his book *Life in Moving Fluids,*[1] describes his research method as equivalent to shooting a shotgun against a wall, and then drawing bulls-eyes around all the holes. On the other hand, the usual test of marksmanship, aiming a rifle at a pre-existing bulls eye, models what we usually refer to as "practice" (praxis), i.e., a test of mastery over one's discipline in practical applications. Vogel's method is emphatically not about praxis, but is purely about research.

Our own appropriation of Vogel's model invokes an acute curiosity about things that actually happen, the extraordinary and astounding specificity of this thing happening exactly here in exactly this way, and the mysteries each actuality holds. This approach emphatically embraces both planned and unplanned events, each one deserving of its own particular bulls-eye. The invitation of chance and the unexpected is necessarily a crucial part of the research methodology used. Notice that the "goal" of the work is not established before starting, but tends to precipitate, or otherwise jump out of the work itself in unexpected ways.

The generation of original ideas has its own set of requirements and research techniques, and in this realm traditions of artistic production are primary and without equal. After new collaged artifacts and techniques have been "discovered" through play, however, another mentality is also required in order to "mine" these initial findings for use. Here hard-headed critical judgments based on specific practical knowledge is brought into play; initial wanderings and findings are interviewed for usefulness (this might make an interesting heat radiator; this might model or lend itself to pultrusion technology; this might be a way of solving an air or fluid distribution problem; etc.).

This is an opportunistic mentality that searches through the artifacts and detritus of "playtime" in search of something recognizable. It requires a kind of composite methodology that maintains the "collage-head" willingness to forget the name of the thing one sees, while simultaneously subjecting that thing to a rigorous anological examination (this shape looks like an efficient cantilever; this is reminiscent of a certain manufacturing process, etc.). Through this composite state of mind, wheat is separated from chaff by manifesting a potential for usefulness; ideas are found, brought out, dusted off, and subjected to the focused considerations of rational thought. It is important to note that "wheat" and "chaff" in this case are not absolute terms. Different observers will see different things as valuable or useless, depending on the specific knowledge they bring to bear in their seeing, and on the subtlety of their own perceptions. This demands that different people from a wide variety of disciplines should be invited to the party, that imaginative academics, business people, workers, and professionals all be part of this particular phase of the work.

After this process of winnowing for usefulness, particular research disciplines can proceed according to their own focused research traditions and agendas, as further investigation and development may require. This is the final layer of research, which may take the form of basic or applied work in a number of different fields.

Our research uses an existing industrial base of materials, production equipment, and techniques as a "pallet" of available collage elements. We appropriate artifacts of our industrial and post-industrial culture, while seeking to advance the material and instrumental possibilities that are locked within the established boundaries of discipline and areas of expertise. The flexible membrane formwork project is a specific example of new possibilities being "unlocked" through the collaging and "mis-use" of existing industrial artifacts and equipment.

Our fabric formwork research finds itself, at present, leaving behind its original research methodologies of speculative play. We have recently reached the point where we can begin transferring a series of findings to specifically focused engineering and industrial research agendas.

On an academic research front, Dr. Sami Rizkalla President of ISIS Canada (Intelligent Sensing For Innovative Structures) and Professor of Civil Engineering at the University of Manitoba, will be partnering with us in a research project using carbon and glass fibre textiles as both formwork and primary tension reinforcement. Our partners in the Department of Applied Mathematics will be building a new software tool to predict and model the complex geometries this technology allows us to produce. This tool will eventually serve to link architectural and structural design to formwork production through computer controlled production technologies already in place in the apparel industry. This will require the expertise of our colleagues in the Department of Clothing and Textiles in conjunction with our partners in the apparel and textile industries.

On an industrial and applied research front, We are working with LaFarge Canada Inc., and Conforce Structures, Ltd., who both operate large precast plants locally and internationally, and with the LaFarge Cement Group and Inland Cement to develop specific industrial applications for fabric-formed concrete structures.

This research provides more than the promise of a new building technology. It also serves as a working model for a method of research (or methods of research) that combine different areas of expertise, states of mind, and research techniques. The building we are building here in Winnipeg will be dedicated to testing the method itself, as well as the specific fruits that method has currently produced.

FABRIC FORMWORK TECHNOLOGY

We have found ways of forming reinforced concrete columns, beams, walls, and slabs in both cast-in-place and precast applications. The results range from highly efficient variable section structural geometries, to the emphatically sculptural. More importantly, this work provides for both conditions to exist at the same time. These sophisticated and often complex curved geometries are formed as effortlessly by a flexible membrane as uniform rectangular sections are produced by flat rigid panels. The geometries we build with flexible formworks literally "fall" into place through the mutual

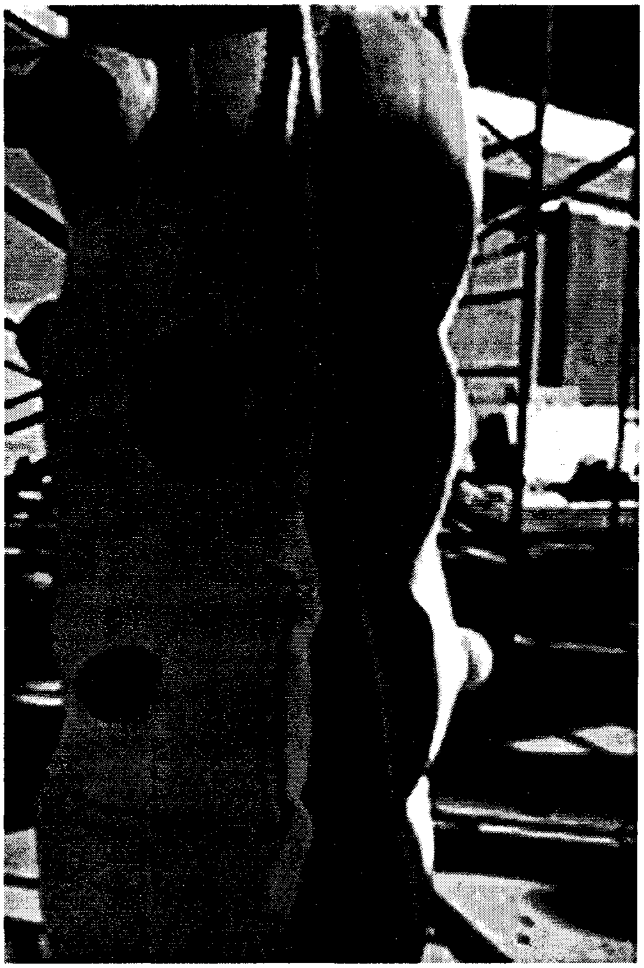

Fig. 1. Column formwork

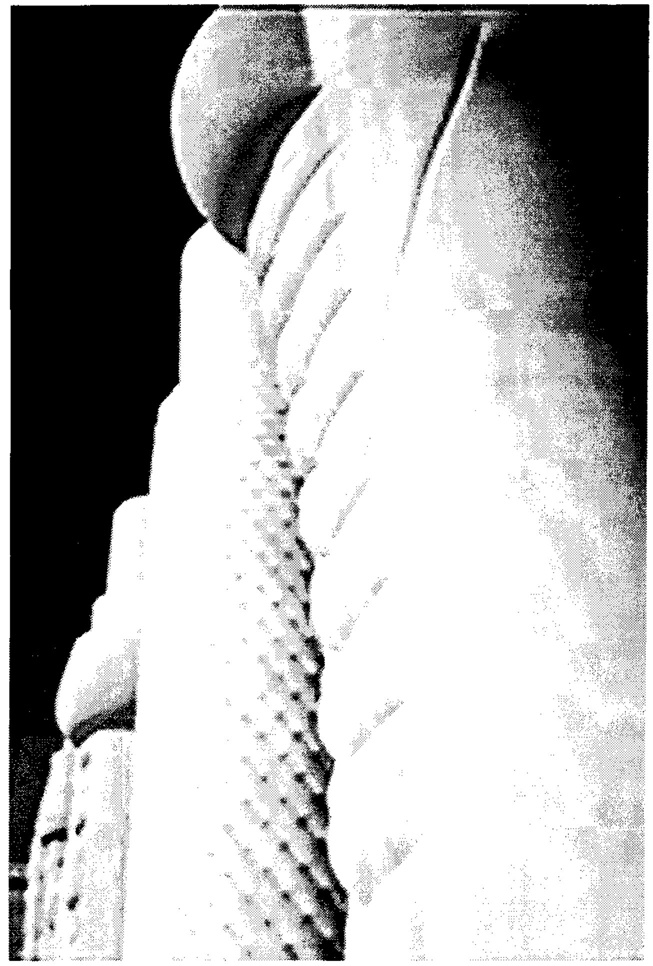

Fig. 2. Fabric-formed columns

negotiation of the materials themselves. The wet fluidy concrete and its tension membrane container naturally fall into the precise geometries that produce the exact strain energies required to achieve stasis.

The architectural applications and implications of this technology are great. Our methods provide a new kind of architectural language that is produced directly from a material and constructional basis. This means that the design and its method of construction are not separated; in this method they are, in fact, indistinguishable from each other. Through the use of flexible formworks, the "fluidy" nature of concrete is allowed to blossom into a new and unexpected formal and structural life that offers associative links to vegetal and animal forms on the one hand, and extraordinarily elegant and structurally efficient stressed skin geometries on the other. The constructions produced by our methods do not look or "feel" anything like traditional concrete architecture.

Surface finish, and increased strength:

Of particular note is the way in which permeable membranes, such as woven and knitted textiles, cause the formworks to act as a filter, allowing air bubbles and excess mix water to bleed through, leaving an immaculate cement-rich paste at the surface. Stunning finishes are achievable without vibration or additional surface treatments such as sand blasting, acid etching, etc. This filtering action simultaneously improves the water-cement ratio of the surface concrete, producing what is effectively a case-hardened structural member (with an immaculate finish).

This results in several simultaneous advantages: The concrete is beautiful, it does not require expensive finishes or veneers to make itself palatable; it is more resistant to water infiltration and abrasion, and this surface finish can be achieved without special skills, or the need for vibration.

Efficient Geometries

The practice of forming concrete in rigid wooden boxes belongs to the 19th Century (i.e. concurrent with the development of steel-reinforced concrete). It is fair to say that the last significant advance in wooden formwork was the introduction of plywood panels after World War II.

Because it is difficult to build anything except rectilinear molds using flat rigid panels, and because formwork costs largely determine the overall cost of building a reinforced concrete structure, the vast majority of reinforced concrete structures are naturally composed of rectangular solids. Planar geometries, however, rarely provide a high level of structural efficiency. Furthermore, it is very difficult to hold a plastic material like wet concrete in flat, planar geometries, forcing traditional rigid formwork to deploy substantial amounts of structure simply to limit deflection. Traditional methods, therefore, require significant excess costs: first to hold everything flat, and second for the geometric inefficiencies associated with rectangular solids. These severe limitations are currently imposed by a formwork technology suitable to a time that relied upon the strength and *rigidity* of traditional building materials.

By replacing rigid panels with a flexible tension membrane, advantage can be taken of the natural deflection geometries these membranes assume under load, thus providing new efficiencies impossible to achieve using traditional formwork methods. Not only is the formwork many times lighter, but the concrete structure itself can be made substantially lighter as well by using these deflection geometries to produce highly efficient variable section members.

Our Research Program

Our work to date has included Full scale tests and demonstration projects done in Ottawa Ontario, Bar Harbor Maine, Tallahassee Florida, New York City, and includes columns, column capitals, beams, slabs, a facade renovation, and a public art sound-sculpture. The first structural and industrial use of fabric-formed columns is in Winnipeg Manitoba where fabric-formed precast columns have been installed in a new theatre building.

Future applied research will concentrate on industrializing several previously artisanal techniques for use in the precast and prestressed concrete industry. Future Basic research includes the use of formwork membranes made of fibre reinforced polymer (FRP) textiles, that will not only hold the wet concrete, but will form it into highly efficient structural shapes, and then serve as the primary tension reinforcement for that member. This method, should it prove practicable, holds the promise of stronger, lighter, structures with a longer service life due to the absence of steel reinforcing. This combines the pioneering work of our civil engineering partner Professor Rizkalla in the use of external FRP reinforcing textiles, and our own work with fabric-formed concrete structures.

This work will produce and test concrete column, slab, and beam designs using FRP continuous fibre tension reinforcing textiles acting as both formwork and reinforcement for precast structural members. In each case the structural behaviour of various designs will be tested, and bonding performance between concrete and reinforcement textiles will be investigated.

The sophisticated geometries produced by tension membrane formworks require a computer program that can predict and describe the three-dimensional shapes produced by specific formwork designs. We will be developing this computer-based design and production tool under the supervision of the applied mathematicians Dr. William Hoskins and Dr. James Peters. This tool will provide a crucial interface between the activities of design, and the requirements of industrialized formwork production. These 3-D modeling and animation capabilities will give architectural and structural designers the ability to adjust and optimize the geometry of a structure. An "unfold" function will then allow their final design to be rationalized into a two-dimensional CAD file describing the precise shape of the flat fabric panels needed to produce the desired geometries. This digitized information will allow computer-controlled apparel manufacturing machinery to automatically produce the required formwork.

General Comments

This work requires fundamental conceptual changes in traditional thinking about construction. For example, deflection and deformation have long been considered "bad" things to be assiduously avoided. In our approach, these events are embraced as highly efficient form-givers, rather than "de-formers". This simple premise has multiple repercussions with regard to how architects and engineers collectively think about reinforced concrete structures. This work requires a combination of the imaginations and expertise held by these two fields, along with contributions from the fields of textiles, computing, mathematics, construction, and manufacturing. The methods and knowledge of each field have their own role to play in this synergetic enterprise, each having the opportunity to enrich and expand the field of knowledge in other areas.

The methods of play and collage that produced our current research program will continue be used to produce and incubate new ideas within our new research facility. This method of work is based on an abiding faith in the irreplaceable efficacy of "irresponsible" play and the value of nurturing a free creative spirit in the midst of a rational discipline. It is based on the knowledge that the rational and irrational capacities of the human mind do not displace each other, but rather make themselves felt most completely in their simultaneous and parallel existence.

NOTES

[1] Vogel Steven, *Life in moving fluids : The physical biology of Flow* (Boston: W. Grant Press, 1981).