Risky Matter

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Most research in the material industry has ambition to improve their material and develop new products that expand the range of the material's performance. But typically, the focus is on increasing performance of the materials in relationship to current benchmarks driven by policy or economics. Therefore, more speculative or risky applications are often prevented from advancing by either building code or inertia of the industry. By taking agency early in a material's conception, design can play a critical role in helping to reduce this risk, when given the opportunity to speculate into the future.

For designers to forge unknown territory for an alternative mode of practice, risk is inevitably in the equation. Today, designers are taking more agency in the design process and rather than waiting for a client, they are seeking out collaborators and stakeholders in pursuit of their own agenda. Since any building material is a reflection of the status quo of architectural production, experiments with materials, methods, or technologies require designers to start at the level of 'matter', before a material is yet to be materialized. Similar to the work of the Spanish artist Lara Almarcegui that consists of piles and stacks of raw materials that are void of idealization, or in other words, focusing on 'matter' as an approach, aims to revoke premeditated formal or ideological agendas. Therefore, in order to question the status quo of how we design with materials, designers can take risks by reinterpreting 'matter', before it even becomes a material.

Based on this premise, the paper discusses a design research collaboration between an architecture firm and the material industry that uses design speculation as a method by which innovation emerges from working with the conceptual principles of a material, or, in other words, its matter. In this collaboration, the design process foregrounds the conceptual logic of the material over a metric to avoid premeditated outcomes, specifically leaving the formal and programmatic outcome of the research open-ended. For example, the perception of concrete as a heavy material was replaced by the reality that concrete can be lighter than water and float. And the precise strength and structural capacity is not foregrounded but rather the concrete mix's ability to conceptually be as thin and light as paper and still maintain structural strength. From this knowledge, a prototype emerged that alters the perception of concrete as a solid, heavy material, from the conception of its matter, to become a light, floatable, porous material. This, in turn, defines a new type of resilient shoreline infrastructure that floats and continually adapts to rising sea levels. The paper will use the project to exemplify a design research process that starts with matter and requires design to take agency in material research and take risks that can lead to unchartered territories.

INTRODUCTION

Most research in the material industry has ambition to improve their material and develop new products and applications that expand the range of the material performance. But typically, the focus is on increasing performance of the materials in relationship to current benchmarks that are driven by policy or economics. Also, the mate-rial industry is often not trained to consider a material's function in a larger context; hindering speculation and innovation with new technology, especially when it comes to design. Which suggests that more speculative applications for a material are often prevented from advancing by either building code, inertia, or simply lack of foresight. Therefore, designers and engineers, the team developed new knowledge and experimental methods of form-making by reversing the design approach and collaborating at the research and development phase of a material. This partnership offers architects, as facilitators, an opportunity to achieve novel approaches to design that question norms and perceptions of materials that lead to unforeseen possibilities for design that otherwise would never have been discovered.

COLLABORATION AS PROCESS FOR INVENTION

The material industry is interested in new applications for their materials, but realize they lack the platform necessary for conceptualizing beyond the technical and per-formative capacity of the materials. But in order to bring innovation to architectural de-sign with new materials, the process of design needs to be reversed from fixed systems of material and construction to an open-ended system where materials are critically explored. To do so, the design team has equal roles and has to be free from pre-conceptions of the material in order to explore emergent ideas, how new forms can be constructed and what the potential applications are if we examine the properties of a material.

To start the discussion, CEMEX outlined the conceptual principles of their materials but did not provide a specific metric to avoid hindering architectural potential of the materials. For example, the precise strength and structural capacity of their

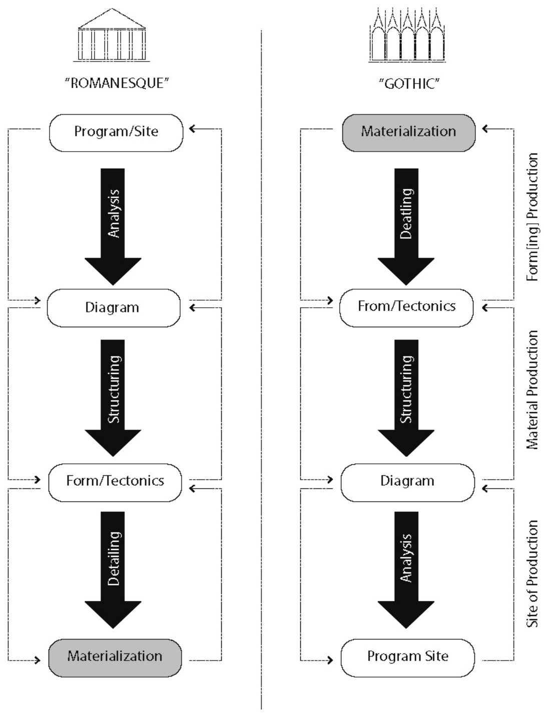

Figure 1: 'Reversed Design Process' diagram (drawing by author).

Resilia® mix was not foregrounded but rather its ability to conceptually be as thin as paper and still maintain structural strength. Or in other cases, intentional contradictions were prompts to questions of current mixes and their capabilities. For example, could the high strength mix also be light and buoyant? Could a high-density mix let in light? Or how does a pervious mix slowly release water? These critical questions led to new approaches for architectural design by not designing for the material, but designing beyond it.

THE ROLE OF CONCRETE IN DESIGN

Typically, many projects are developed from either 'program' or 'site' with form, mate-riality and construction coming later in the process. With this approach, most materials are developed as a response to social, environmental or economic factors rather than as speculations. And even though the technological advancement of concrete had a direct influence on architectural form that went beyond the traditional architect / con-tractor relationship, it was still used to fulfill pre-existing needs or aesthetic desires. One example is the patenting and licensing of early reinforced concrete systems by Francois Hennebique, a Belgian contractor who gave up contracting in 1892 to concentrate on licensing the patents he developed[1]. His licensing system made him instrumental in an unprecedented amount of reinforced concrete structures. But Hennebique promoted his system not as an opportunity for design innovation; rather as a structure that was safe from potentially disastrous fires, and ideally strong "for supporting the exuberant, decorative surfaces,"[2] that were desired by the architectural fashion of his time.

It is rare that materials and construction methods take center stage in a broader argu-ment for design intentions. Even in the case of Giedion's proclamation in his seminal 1928 publication, 'Building in France, building in iron, building in ferroconcrete,'[3] he saw new materials as the key ingredient for a new architecture but only to serve a modernist aesthetic. His approach originated more from a fascination with the forms created by new concrete applications for industrial buildings, rather than the actual opportunities of the material itself. And despite Giedion's assertion, it was not a mod-ern design vision that made cement one of the most proliferate building materials on the planet[4], but rather the material's capacity, with its technical advantages, to create larger spans and faster construction processes.

Italian architect and engineer, Pier Luigi Nervi, invented his own version of concrete called 'ferrocemento'[5] that allowed him to create both lightness and strength with half inch-thick concrete. It was Nervi's innovation in the development of his concrete's structural properties, in combination with careful structural observations, that led to his expressive designs. The design of a complex corrugated cylindrical arches and great spans in the 1949 Turin Exhibition, for example, was only achievable because of ferrocemento. It is this type of innovation of prefabricated concrete, that determined the shift towards lightness within architecture.

Similar to Nervi's approach, the following case studies aimed to use materials as the initial design criteria that forms the basis for design innovation. Each of the projects aim to rebuke the perception of concrete as a heavy and massive material and rethink beyond the material itself when it becomes extremely thin and light. Sheila Kennedy's argument in Material Misuse that, 'the perception of qualities attributed to materials, and our multiple understandings of what it means to be material, are all integral parts of media culture,'[6] was the departure for investigating the materials in full scale prototypes to find new programmatic and formal potential of the material. This intentionally questions cultural perceptions that typically shape the form and expression of the architecture.

DESIGNING MATERIAL INNOVATION

In order to innovate with material as a new medium, and not using it for a particular form, program or site, the methodology needed to reverse the order by which conceptual ideas emerge. To avoid the material being in response to other design criteria, materiality is foregrounded as the critical component to the process. The three projects that will be discussed reflect on this reversed process of design where ideas emerge from a material's properties. In the 'reversed design process' diagram (figure 1), the left side is the typical process that starts with 'program' and 'site' as design initiators with

Figure 2: Element of Rhizolith Island (Photo by author).

Figure 3: Pop-up Surfaces. Top: concrete still in ‘pop-up’ molds,
Bottom: Final folded forms (Photo by author).

Figure 4: Pop-up technique for Rhizolith Island element comprised of a composite of different concrete mixes in one form to make element light enough to float. The formwork uses the 'pop-up' technique that folds a simple flat formwork into a complex geometry (Photo by CEMEX).

material and construction strategies applied later. On the right is the reversal of the process where material and fabrication techniques are the design initiators of form, program and site. This is seen as an 'emergent tectonic' approach similar to the one described by Deleuze and Félix Guattari in relation to gothic architecture as '...inseparable from a will to build churches longer and taller than the Romanesque churches… But this difference is not simply quantitative; it marks a qualitative change: the static relation, form-matter, tends to fade into the background in favor of a dynamic relation, material-forces.[7] While a dynamic relation between material and force can be seen as the core condition of any tectonic approach, a more contemporary reading of the term 'force' requires one to react to many dynamic conditions.

This 'reversed design process' can be described in three phases: Material Invention, Formal Invention, and Sites of Invention. Material Invention is the phase by which mixes, fabrication techniques, and assembly methods are questioned as key drivers for formal and programmatic innovation. Formal Invention is the second phase and tests the potential and limits of the material and conceptually ties the mate-rial investigation to a new performance, program or site constraint. Finally, Prototyping Invention is the stage where formal and material ideas are tested through physical prototypes. At this stage, a prototype may need multiple revisions to successfully achieve the desired formal outcome or to resolve design problems with the fabrication techniques.

The described projects serve to demonstrate this reversed design process: Rhizolith Island (figure 2), Pop-Up (figure 3), and Thinness (figure 5), all exemplify a novel formal or programmatic approach to using advanced concrete technology and question concrete as a heavy, massive material as a point of departure. Respectively, the projects either see concrete as not mass but a plane, not mass but a composite, and not mass but hollow. And it was through either the formwork, the mix, or the optimization of sur-face that the projects demonstrate how rethinking concrete as thin and light rather than heavy and massive can lead to design innovation.

MATERIAL INVENTION

The origin of any of the projects is a fascination for material characteristics that lie beyond the normative applications that are typically associated with it. The technical possibilities to cast ultra-thin yet strong sheets of concrete or the capacity for concrete to float due to extremely low density mixes become points of departure for design inquiries.

With Pop-Up, the team questioned the properties of the concrete as not mass but a plane. Concrete structures are typically perceived as heavy, massive forms but the Pop-Up strategies attempt to flip that perception to create thin and light folded casts. The mix is poured into a flat formwork and folded or 'popped' into a final three-dimensional position. This new method uses a singular formwork comprised of thin planes that fold the concrete into thin and complex, geometrical forms.

The goal of APTUM was to challenge the formal potential of the varied angles while CGRD tested the ability of the mix to not slump or sag when rotated up to 90 degrees. The innovation in the material is the ability of CGRDs Resilia® mix to be thin and light enough to cast the concrete in formwork that is folded up after only a few hours of curing and create refined and geometrically sophisticated forms with just a few folds of one formwork.

In Rhizolith Island, the intention was to showcase contradictory terms; concrete that can be strong and durable yet buoyant and fragile. The perception of concrete as a massive and indestructible material is counter to the argument of this next project, Rhizolith Island, where the team conceptualized the concrete not as homogeneous mass but as a composite of different performative mixes (Figure 4). To achieve this, APTUM was interested in adapting the high strength, lightweight concrete as a floating surface that would be strong enough to withstand heavy storms, similar to XBlocks or tetrapods[8], but light enough to float on water. In this phase,

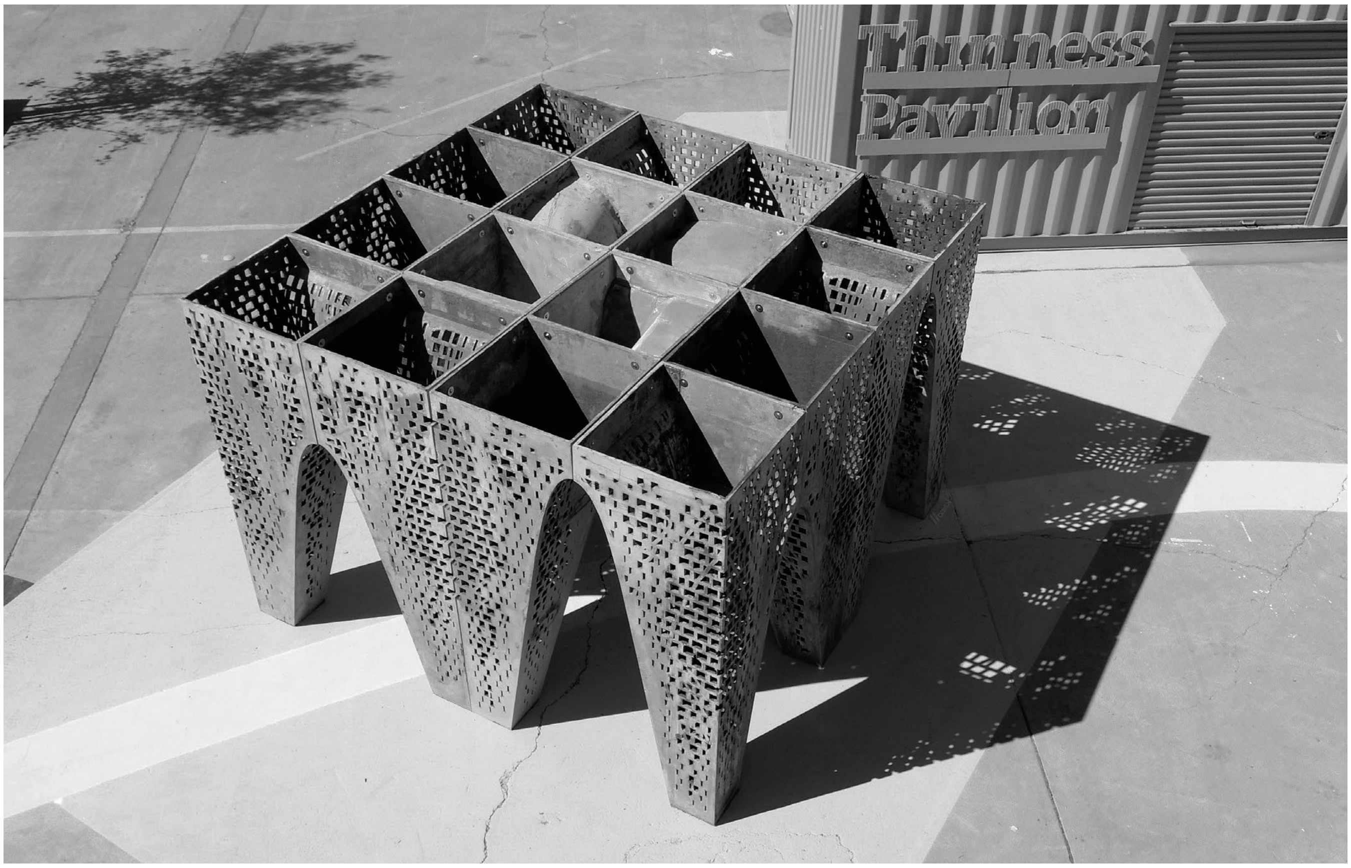

Figure 5: Thinness Pavilion (Photo by Mike Campos of AerialShotz)

CGRD composited a new combination of CGRDs Pervia® and Resilia® concrete mixes for a composited to create a structural, protective shell on the exterior and a light floating volume on the interior. As a goal for the team, the innovation was in creating a composite of two materials with vastly different properties, high strength together with light and brittle, to form a ‘third’ material type that could be used for new programs latent in the material properties.

In Thinness, the goal was to alter the perception of concrete as thick poche, and create thin and hollow elements. Thinness is situated within the tension of a thin veneer and a volumetric poche to create a novel approach to being thin and light through optimization of the concrete surface. The team began with CRGs Resilia® mix with the aim to go as thin, light and as tall as possible without needing traditional steel reinforcement. The elements were made of only 3 meter tall and 2 cm thick walls with only 15mm steel reinforcement fibers to showcase the high strength of the material as well as the design of very light and thin elements. APTUM designed a strategy to use digital optimization to thin out the surface with voids that puncture the surface, while CGRD designed a mix that could keep the structural integrity of the volume.

FORMAL INVENTION

Once new techniques of fabrication and systems of assemblies are established for a particular mix, the system’s formal possibilities and potential applications are explored with the intent to exemplify the system’s idiosyncratic qualities. In this phase, the capacity of architects to use design as a speculative tool becomes a valuable asset.

Taking advantage of concrete now as a foldable material, Pop-Up studied how a plane could be folded into various three-dimensional forms. This strategy, in turn, created an infinite number of forms with varied shapes and angles from only one formwork. The formal innovations of APTUM were driven by a combination of digital models of three dimensional folded geometries that provided the CGRD technicians geometries to test as unfolded and folded formwork. The benefits to the Pop-Up strategy was the structural integrity of the folded elements, and the rich architectural history of folded structures. The Pop-Up geometries allowed the team to envision applications for hollow concrete vessels as well as vertical and horizontal structural elements.

In this phase, the collaboration of Rhizolith Island began with material that is durable yet buoyant. This led to creating a strong yet light composite structure that is designed to float on water. The team took cues from Erwin Hauer’s modular studies to investigate repetitive elements aggregating into larger surfaces. First, the team developed the program of the floating elements as a buoyant breakwater. Second, the goal was for the breakwater to perform as a floating surface that supported new mangrove growth in vulnerable sites susceptible to storm damage. The elements needed to float above water to grow and protect mangrove seedlings until the roots grew to maturity. As the team developed the elements, the intention was for mangroves to eventually break the elements and moor into the seabed. This became an innovative design asset because water infrastructure is typically indestructible and does not allow nature to return as the main source of protection for shorelines. Since lightweight concrete is a weaker mixture, CGRD designed the mix to allow the roots of mangroves to break and grow through the concrete over time. The design innovation is in the performative and programmatic hybridity of the composite of mixes as 'mass' that is both simultaneously strong and weak. The speculative design of the larger, aggregated public surface provides shelter for mangroves, but then provides a much larger shelter - the breakwater - for urban space.

The goals of Thinness were to achieve a formally complex geometry that becomes a hybridic cross-vault that works both as a hollowed-out volume and a thin veneer. To challenge the mix further, a digital technique similar to 'diffusion-limited aggregation', was used to create a dense pattern of voids in the surface of the volumes. Different patterns were designed[9] to comprise a thin and visually light surface. The arc of the structural diagram informed the density of the digital pattern to reduce stresses and ensure ideal load distribution. The pattern on the skin, with a dense distribution of voids, highlights the high strength of the concrete because there is little concrete comprising the surface to maintain structural integrity. The collaboration between the architects and engineers generated a series of iterations to test the ability of the elements to maintain structural strength as more voids and shapes were altered.

PROTOTYPING INVENTION

The production of large scale prototypes was used to further develop the projects. When working with more normative material systems, models and drawings might be enough to develop a project, but this material is at the center of the process of design innovation, which makes these prototypes indispensable. Working collaboratively, these prototypes improve the projects from a formal and technical point of view, but more importantly they test the limits of the material and how to adapt it to design ambitions.

In Pop-Up, the goal of the prototypes was to construct them as flat planes and fold them into various configurations. The forms were poured with an adoption of CGRDs Resilia® concrete as a thin, flat plane. Once the consistency of the mix was fixed, the elements were able to fold up to the 90-degree limit without the concrete slumping. Without the prototype phase, the design of the formwork may have been limited to more obtuse angles which would have resulted in far less formal possibilities. It was only through making the prototypes that the team discovered how far the edges could fold up and offer more formal variety with one formwork.

The formal and programmatic innovation of Rhizolith Island is in the asymmetrical plan and section of the elements to create a formally varied surface area above water and a slender section with voids puncturing a surface for marine habitat below water. The challenge during the fabrication process was to calibrate the composite ratio of high strength Resilia® exterior shells impregnated with lightweight Pervia® concrete to ensure the design of the asymmetrical element could float. A hole was left in the center of each element for more porous concrete, to plant and grow mangroves. To accommodate the asymmetrical plan, the CGRD team needed a material composite that would ensure equilibrium between the top and bottom of the element. APTUM designed the narrow 'fin' extending into the water to offset the asymmetry of the top. This was achieved through iterative prototypes between the designers and the engineers to ensure the elements would float but could still configure into different surface patterns.

The development of the prototypes in Thinness derived from the dichotomy of using low tech and high-tech methods for constructing the formwork. The formwork is a combination of new digital fabrication techniques with water jet cut silicone; alongside prehistoric techniques of 'lost wax molds' that are melted and reused after each pour. During this phase, there was extreme difficulty to create a consistent mix with steel fibers that would easily flow around tight edges in the silicon formwork. Through collaboration, the team realized in order to achieve the quantity and quality of the voids in the surface, the pattern needed to change to a larger scale to accommodate the current 17 mm steel fibers or maintain the scale of the voids and make the fibers smaller. It was at this point, that the team decided it was the pattern composition that superseded the current scale of the the fibers. The CGRD team decided to use smaller fibers in the mix to accommodate the lighter pattern of voids. Without the early prototypes, the innovation in the density of the voids to create a very ephemeral and light surface would not have been achieved.

CONCLUSION

Material methods as a catalyst for design invention is both an experimental process of making with advanced materials and fabrication as well as an actual site of collaboration where new partnerships are fostered between designers and industry. The three projects were test-beds to explore different design strategies through prototyping that continually expand knowledge and untapped capabilities of the material. The new approach of collaboration with industry reverses the design process to stretch disciplinary habits, from engineering to material science to design. The flipped process questions the normative protocols of materials to expose what is possible when productively combining new technologies with design.

Rather than exploring material innovations or construction techniques to find the best way to construct a premeditated form; innovation in material and construction are driven by design itself. As Sheila Kennedy states, "It may seem counter-intuitive for a critical practice of material research to examine the material predicaments inherent in the culture of production as a source of inspiration. But it is precisely here that the greatest challenges to the imagination lie."[10] And it is this challenge that provokes designers to uncover the relationship between material as a medium and the methods that can lead to discovery of novel architectural forms and programs. As a methodology, partnering with industry provides architects the agency to bring criticality and imaginative skill to the rapid development of new materials.

ENDNOTES

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8. Xblocks and tetrapods are interlocking concrete blocks (or "armour units") designed to protect shores, harbour walls, seawalls, breakwaters and other coastal structures from the impact of waves.
9. The surfaces were designed using Rhino 3D digital computing with the Grasshopper plug-in. Structural analysis was completed using SAP2000
10. Grunenberg, Christoph, and Sheila Kennedy. "Material Presence." *Material Misuse: Kennedy & Violich Architecture, Architectural Association*, 2001, p. 21.