Something Borrowed: Defining an Emerging Covenant between Architecture and Materials

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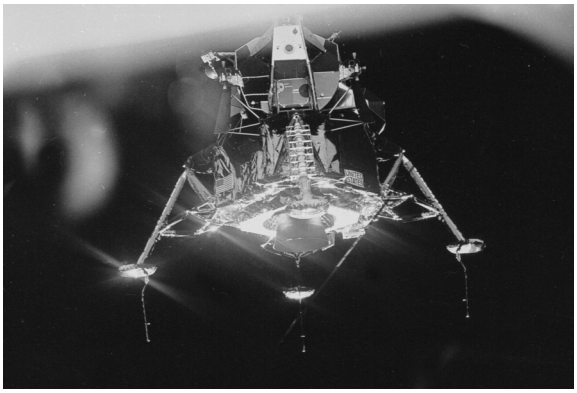
Abstract

This essay will examine the historical precedent of borrowed material technologies in order to interrogate the role of research in stimulating the development and use of new materials within architecture. Architecture today is constructed in a world characterized by a rising influx of material inventions available within the global marketplace. As such, the selection of materials available is in a state of perpetual change. Although a precise explanation for this increase in materials is complex as the development is dependent upon economic, scientific, technological, and design-based factors, it is certain that the profession must adapt to this change. Material science advancements are becoming increasingly complex, while most products are made for other disciplines prior to their use in architecture.

Rather than providing a synopsis of new materials, this paper will scrutinize the possibilities for architectural materials research to contribute to a collective knowledge base that extends beyond the confines of traditional professional boundaries. As such, it will interrogate the latent potential of contemporary research-based design to stimulate sustained material and technological innovation within architecture and the constructed world by addressing this central question: what is the role of research within architecture of perpetual innovation?

Introduction

Recent advancements in material science have introduced an innumerable range of new materials that continue to redefine our environs. Paralleling this increasing quantity of new materials is a renewed interest in the appropriation of material technologies from different disciplines into the realm of architecture, as even now most nascent material innovations are initially developed and utilized in applications other than buildings. As architects, we are inspired by the sensory properties of new materials and encouraged by their performance characteristics. Materials discovered by NASA's space program such as aerogel, a foamed glass product, and phase change material, a thermal storage wax, are promising alternatives to traditional technologies due to both their technical and experiential attributes. Stimulated by the environmental mandate for sustainable materials, construction processes, and building technologies, much research is currently being devoted to the modification of these and other borrowed material technologies. The emerging covenant between architecture and materials calls for a new paradigm of interdisciplinary and collaborative research towards a future of sustained technological innovation within the profession.



NASA research for space exploration continues to stimulate material innovations.[1]

Achieving and sustaining technical advancements may prove to be a challenging endeavor as innovation within architecture is often depicted as a slow and protracted process obstructed by an attachment to tradition, custom and convention that routinely define the construction industry. Almost a century after architects such as Mies van der Rohe and his contemporaries embraced industrialization and the use of new materials and processes with bold declarations of a revolution on the immediate horizon, the rapid transformation of the construction of buildings exhibits characteristically slow change. Notwithstanding this banal history of material innovation, contemporary architecture is yet again

[1] "Earth's Moon – Apollo 11," nssdc.nasa.gov, 24 January 2004, <http://nssdc.gsfc.nasa.gov/imgcat/html/object_page/a 11_h_44_6574.html> (15 March 2010).

increasingly directed by the vast influx of newly developed materials and processes that are entering the global marketplace at a rapid and unprecedented pace.[2] Similar to many of the "new" materials developed in the Industrial Revolution, today's emerging material technologies and processes are largely engineered within other knowledge areas, prior to their use in architecture. A detailed analysis of this historical precedent of appropriating technologies can be used to interrogate the current state of technological research on emerging materials, and to critique the future trajectory of architecture's relationship with technology.

Historical Precedents

Though largely discounted by the historical and theoretical discourse surrounding materiality in architecture, it is notable that architecture has procured material innovations from other disciplines for centuries.[3] This process, often coined as 'technology transfer' is characterized by the re-appropriation of materials and techniques from one discipline into another.[4]

The practice of technology transfer dates back over 5,000 years and has hastened the use of a multitude of materials that are now commonplace within the profession, including kiln-dried bricks, reinforced concrete and plywood. The method of firing bricks within a kiln was derived from the ancient process used in Mesopotamia to produce ceramic pottery.[5] Although developed and refined in our industrial world, the benefits of a controlled curing process to harden clay into bricks is still valued by modern day society as bricks are one of the most ubiquitous materials used for construction today. Similarly, the invention of reinforced concrete can also be traced to the gardening industry. Beginning with the inclusion of a metal mesh to improve the strength of concrete flowerpots, Joseph Monier, a French gardener, is credited with the innovation ultimately leading to the development of reinforced concrete. Following soon thereafter, François Hennebique, an engineer and builder, extended this idea into buildings through the addition of bent reinforcement bars within floor slabs in the late nineteenth century. However, widespread use of this newly developed 'liquid stone' was not possible until the engineering methods to evaluate and predict the behavior of reinforced concrete systems was discovered in Germany in the early 1900s.[6]

The aforementioned precedent of the entry of reinforced concrete into the construction industry persuasively illustrates the need for a comprehensive knowledge base initiated by interrelated advancements in material composites, engineering technologies, as well as material science. Comprehensive understanding of both quantitative and qualitative aspects of emerging materials is required in order to realize innovative applications for the use of these new materials within architecture. This example is of consequence due to the technical merits and superior tensile performance of reinforced concrete as its invention signified a critical moment in architectural history that spawned an era of experimentation and formal investigations. Furthermore as reinforced concrete was widely heralded as a revolutionary invention within the profession, it quickly assumed a central role in the theory, technologies, and design put forth in the Modern Movement. In the decades that followed, the profession devoted itself wholeheartedly to the complete and honest consideration of the use of this new material, exploring the aesthetic aspects of the material in pursuit of formal perfection, while neglecting to keep pace with the subsequent material advancements that followed.

The aircraft and boating industries offered similar imported material technologies, including plywood and aluminum, both of which were produced in large quantities following the end of the Second World War. Modern plywood originated in The Havilland Mosquito, a British aircraft made entirely of wood that was used extensively in combat missions during the war. As the use of plywood in the Havilland was considered experimental, production of the plane was initially halted during the war in order to focus on existing and more conventional designs. Permission to build the planes was later reinstated owed to the fact that it utilized molded plywood, a "non-strategic" material that was

[2] Sara Hart, "New Technologies Create New Challenges," Architectural Record, 1 February 2006, Lexis-Nexis. (10 March 2010).

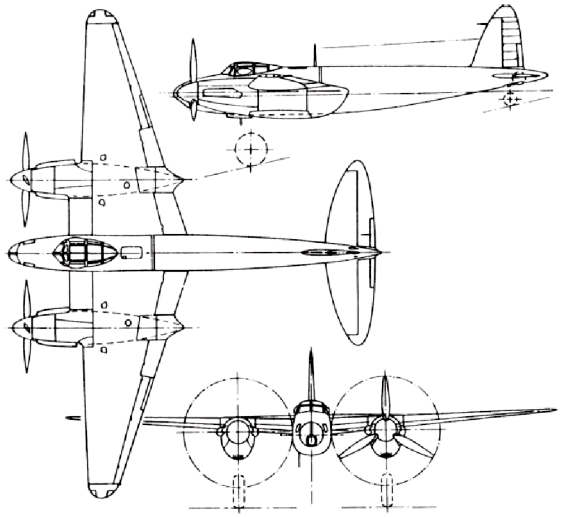
[3] Martin Pawley, "Technology Transfer," in Rethinking Technology, ed. William W. Braham and Jonathan A. Hale (New York: Routledge, 2007), 298.

[4] Ibid, 297.

[5] Richard Weston, *Materials, Form and Architecture* (New Haven: Yale University Press, 2003), 20.

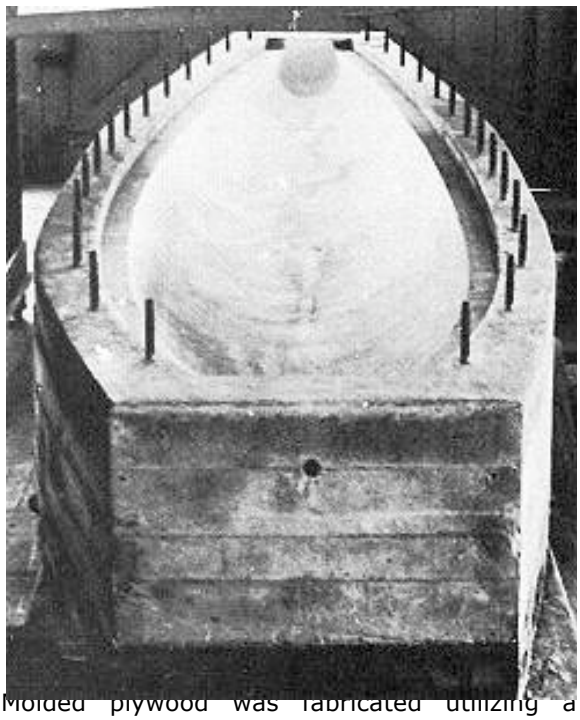
[6] Ibid, 34.

available in sufficient quantity during the war.[7] The production of molded plywood monocoque shells utilized wood veneers alternatively laid with casein glue into a reinforced concrete mold. The molds were filled with an inflated rubber bag exerting pressure as the wood dried for 24 hours.[8]



Plywood can be traced to the Second World War aviation technology.[9]

After the war ended, the new material of plywood came into mainstream use in the buildings of the 1950s. Similarly aluminum, which first appeared as foil for candy wrappers in 1912, was confined to the structural uses within aircraft until post war times. Similarly, the manufacturing infrastructure of aluminum boomed after the war, with the number of smelters increasing by seven fold, as aluminum was introduced to the building sector in cladding and curtain wall systems. Yet, the use of aluminum within these products fell short of fundamentally altering the building industry as a whole.



Molded plywood was fabricated utilizing a reinforced concrete mold.[10]

Research and Innovation

Despite the arrival of a considerable post war manufacturing and production industry, architecture largely experimented with materials invented in the late nineteenth century in relative isolation from the continual advancement of scientific and technological research that was embraced by other industries. Buckminster Fuller, one of few notable defectors from this modern trend towards "formalism and illusionism," proposed to keep pace with the advancement of material technologies at that time. His well-known 1927 proposition for the Dymaxion House, a radial plan that utilized a metal cladding system adapted from aircraft technologies of his era, utilized many of the emerging technologies of his era.[11] Though two prototypes were constructed, Fuller's plan to build the house in mass was never realized. Even after the arrival of a substantial

[7] "De Havilland DH 98 Mosquito," aviastar.org, <http://www.aviastar.org/air/england/havilland_mosquito.php> (15 March 2010).

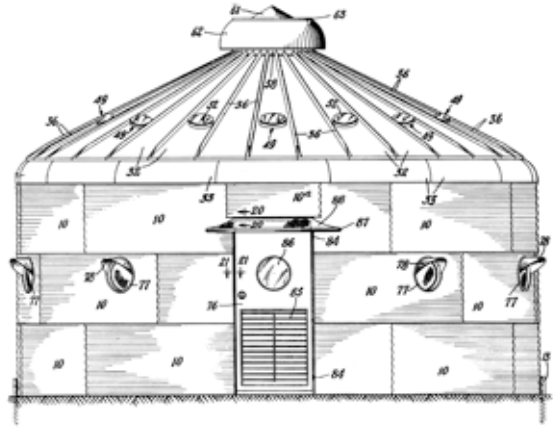
[8] "Molded Plywood Construction," aviation-history.org, < http://www.aviation-history.com/theory/plywood.htm> (12 March 2010).

[9] "De Havilland DH 98 Mosquito," aviastar.org, <http://www.aviastar.org/air/england/havilland_mosquito.php> (15 March 2010).

[10] "Molded Plywood Construction," aviation-history.org, < http://www.aviation-history.com/theory/plywood.htm> (12 March 2010).

[11] Peter Reyner Banham, *Theory and Design in the First Machine Age* (New York: Frederick A. Praeger, 1960), 326.

engineering and manufacturing infrastructure following the war, the light frame and monocoque enclosures from the aircraft industry failed to introduce the level of sustained innovation that was technically feasible.



Buckminster Fuller's Dymaxion House utilized aircraft technologies and new materials.[12]

"Despite the spectacular output of synthetic materials and new structural technologies that marked the post-war period, [Modern architects'] palette remained limited, as did that of their immediate successors…It was precisely because the sons of the pioneers concentrated on formal inventiveness rather than exploring the process of technology transfer that had given them new ways to build, that Modern architecture died of ignorance while new information was exploding all around it."[13]

In the quote above, Martin Pawley is unambiguously critical of Modern architecture for failing to keep tempo with the rate of technological material advancements of the mid-twentieth century. In this 1987 essay, he writes with disappointment of the missed opportunity for sustained material innovation during this time, while simultaneously acknowledging the immensity of such a task. Admittedly at the turn of the twentieth century, few architects could have predicted the ensuing inundation of technological advancement that followed and continues to accelerate through today. In consideration of two seemingly irreconcilable trajectories of innovation, one belonging to technology and the other belonging to architecture, it might seem fair to conclude as Banham asserted that, "what we have hitherto understood as architecture, and what we are beginning to understand of technology are incompatible disciplines."[14] Yet, evidence of the coincident encounters between the two knowledge realms bears much evidence in dispute of this theory.[15] Although architecture and technology have at times experienced periods of ambiguity and uncertainty, the interdependence of the two is certain.

Sustained Technological Growth

Due to the lack of attention given the phenomenon of borrowed technologies within architecture, evidence of the relationships between the complex set of the factors that produce periods of technological growth as compared to periods of technological stagnation is scarce. Pawley summarizes the motives for technology transfer as the resultant of "serendipitous curiosity on the part of individuals" or "serious marketing effort by corporations intent on developing new outlets for materials or techniques."[16] In acknowledgement of the mounting importance of shared technologies, Martin Pawley called for a complete history and documentation of this "technological and methodological" trend.[17] Absent this account, the most comprehensive study of this can be found in economist Marian Bowley's 1960 analysis, in which she examined the forces of technology transfer that create material innovations within the building sector.

Though completed half a century ago, Bowley's research still offers relevant empirical evidence of the factors that serve to stimulate innovation today. In addition, the fact that this account of the architectural profession is written through the voice of an outsider, the observations and conclusions included seem unbiased and without underlying prejudice or motive. In this study Bowley defines four rationales for the introduction of material

[12] "The Dymaxion Dwelling Machine," bfi.org < http://www.bfi.org/our_programs/who_is_buckminster_fuller/design_science/dymaxion_designs/the_dymaxion_dwelling_machine_by_j_baldwin> (15 March 2010).

[13] Martin Pawley, "Technology Transfer," in Rethinking Technology, ed. William W. Braham and Jonathan A. Hale (New York: Routledge, 2007), 299.

[14] Peter Reyner Banham, *Theory and Design in the First Machine Age* (New York: Frederick A. Praeger, 1960), 329.

[15] Martin Pawley, "Technology Transfer," in Rethinking Technology, ed. William W. Braham and Jonathan A. Hale (New York: Routledge, 2007), 300.

[16] Ibid, 297.

[17] Ibid, 304.

innovation into the built environment: newly defined market requirements, an increased desire or need for a variety of choices, routine and incremental product developments and finally, an aspiration for material substitutions.[18] This study offers much to our understanding of the outside commercial forces that serve to encourage sustained innovation within the building sector. Today, the requirement for more sustainable construction processes remains a primary stimulus for innovation as considerable funding is directed towards this area of materials research.

Architecture has enjoyed a complex - and dubious - history with technology as the schism between art and science has historically instigated a competition, each battling for greater significance within the profession. Yet presently, theoreticians and technologists agree that the profession is facing a grand challenge of unprecedented magnitude as the social and environmental consequences of our buildings is called into question. As buildings today account for almost half of all energy consumption worldwide.[19] Therefore the time has come to elucidate the relationship between architecture and its technologies in response to the critical task at hand.

Although the complexity of today's materials and fabrication processes have increased exponentially as compared to the issues brought about by the adoption of aluminum and reinforced concrete, the environmental stakes are higher as well. The immensity of today's issues of sustainability and ecological design demand advanced performance of buildings that rise to the technological challenges dictated by this grand environmental challenge. As such, it is no longer advisable – or possible – for architecture to sit idly on the sidelines as the pace of technological change races by. Indeed, the global mandate for a sustainable approach to the use of natural resources in buildings requires a persistent commitment to technological innovation.

Innovation and creativity, in thought, process, form, material, and system, is central to achieving the goals set forth by the movement for more sustainable built environments. As such, the historical phenomenon of borrowed material technologies provides a central link to the creation of a shared knowledge base that is created across multiple professions and areas of expertise. The pressure for environmentally sustainable architecture reaffirms the need for interdisciplinary fundamental research by engineers, ecologists, economists, entrepreneurs, scientists, and architects. In order to fundamentally change the way we build buildings, we must fundamentally alter the means by which we create knowledge within the profession towards the creation of a new paradigm of constructing the built environment. Embracing the forces that encourage the importation of external technologies and the processes through which they are adapted within the profession will provide a means of sustaining technological growth.

Contemporary Challenges

"Indeed, when one evaluates the diverse and fantastic range of materials available today, one realizes the extent of humanity's unwavering pursuit of innovation. Rather than a fixed catalog of products, one sees a constantly shifting array of materials, which offer continual improvements upon known standards or render those standards obsolete."[20]

As avowed by this quote by architect Blaine Brownell, architecture today is constructed in a material world that can be characterized most simply by its continual expansion. The material influx that began after the Second World War has only increased in its intensity through the first decade of the twenty-first century. Although a precise explanation for this increase in materials is complex, industry experts estimate that "more new products have been developed in the last twenty years than in the prior history of materials science."[21]

Therefore, in addition to the need for more interdisciplinary research, this explosion of materials also warrants the development of a more flexible organizational system. As a result of the influx of new materials, there is the growing sense that our traditions of cataloguing, organizing, and conceptualizing material products within architecture and design-related fields is no longer adequate, or even capable of keeping pace with the material innovations that

[18] Marian Bowley, *Innovations in Building Materials* (London: Gerald Duckworth & Co. Ltd., 1960), 400-406.

[19] "The Building Sector: A Hidden Culprit," architecture 2030.org, <http://www.architecture2030.org/ current_ situation/building_sector.html> (12 March 2010).

[20] Blaine Brownell, ed., *Transmaterial: A Catalog of Materials that Redefine Our Physical Environment* (New York: Princeton Architectural Press, 2006), 6.

[21] Ibid.

have occurred of late. New material technologies have evolved from static entities, which can be catalogued by a simple system such as the Construction Standards Institute classification system, into dynamic units with responsive, intelligent, and dynamic properties, so-called 'smart materials.' The inherent difficulties in classifying smart materials are echoed in the complexities of constructing a comprehensive definition of these nascent technologies. Smart materials and technologies can be defined as "a molecule, a material, a composite, an assembly or a system." Yet regardless of scale they are defined through their distinctive behavioral properties characterized as time-based, self-actuated, selective, direct, and transient.[22]

This entire field represents contemporary technology transfer as the invention of smart materials is attributed to two chemists, Jacques and Pierre Curie, while current research in these areas is shared primarily by mechanical and electrical engineering disciplines.[23] But, this contemporary example of technology transfer demonstrates critical evolutionary maturity as compared to the technologies borrowed a century ago. In direct contrast to the invention of molded plywood and reinforced concrete, the technological knowledge base of smart materials is being developed simultaneously, often even collaboratively, with architectural applications. This time-based shift towards the concurrent creation of a collective knowledge base marks a key advancement in the relationship of architecture and its technologies. Information-age advancements, including the Internet and other computerized technologies facilitate this type of coincident research.

Applied Design Research

Other computerized innovations, including digital design and fabrication equipment, have radically altered the relationship between architects and materials. As described by architect and educator Lisa Iwamoto, "Digital fabrication…has spurred a design revolution, yielding a wealth of architectural invention and innovation" in which "the architectural project is a form of applied design research."[24] These pioneering processes have allowed architects to reduce the knowledge gap between the virtual and the physical, allowing for iterative experimentation and prototyping of material constructs at full scale in direct translation from architectural representation to physical artifact. These current prototyping processes are rapidly evolving and shaping the manufacturing processes of the future. Similar to contemporary research on smart materials, the transfer of fabrication and manufacturing technologies occurs simultaneously and incrementally, for small and large-scale projects. The digital interface supports the exchange and cross-pollination of multiple disciplines in an increasingly seamless process of virtual exchange and design refinement.

In contrast to the large-scale manufacturing research put forth by progress in digital fabrication, nanotechnology operates at atomic and molecular scales. These modern advancements in science promise to facilitate innovations in material properties that begin where traditional materials approach their basic limitations. To that end, this newly emerged discipline is inherently cross-disciplinary through its origins in biology, physics, and materials engineering. Although a newly arrived discipline, nanotechnology poses a great opportunity to invoke a paradigm shift in the ways materials are conceived and engineered in response to the critical need for sustainable technologies in the future.[25] Despite the inherent invisible nature of nanotechnology as the scale of nanoparticles is too small to scatter light, these micro innovations promise to evoke great change in the built environment as this emerging area provides a new place for architectural research in the immediate future.

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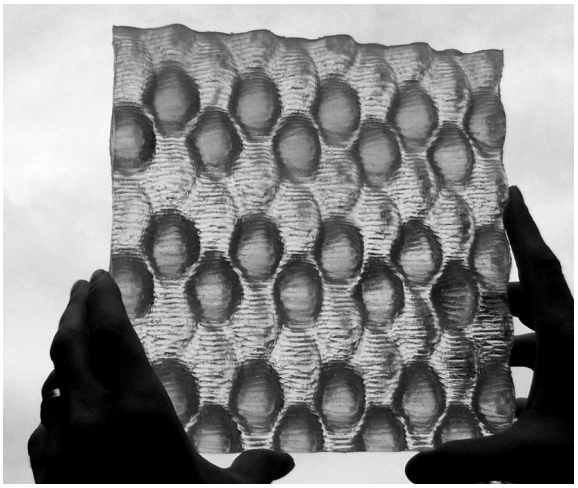
[22] Michelle Addington and Daniel Schodek, *Smart Materials and Technologies for the Building Construction Industry,* (Oxford: Architectural Press, 2005), 10-11.

[23] Ibid.

[24] Lisa Iwamoto, *Digital Fabrications: Architectural and Material Techniques*, (New York: Princeton Architectural Press, 2009), 4.

[25] Sylvia Leydecker, *Nanomaterials in Architecture, Interior Architecture and Design*, (Basel: Birkhauser, 2008), 8.



Energy storage daylighting panel utilizing phase change material, a NASA technology.[26]

Conclusion

Contemporary issues related to the transfer of new material technologies reveal the pivotal prospect for research to stimulate architecture of sustained innovation. It is imperative that the profession recognizes the essential role of fundamental, applied, and design research as an embedded share of its pedagogical, academic, and practice-based approaches to architecture. At present, the exemplars of architectural research remain loosely defined without clearly specified technological and methodological objectives. Absent these goals, the discipline of architecture runs the risk of history repeating itself with present day architects being one day condemned for a missed opportunity to embrace technological innovation.

Since material knowledge simultaneously resides in multiple industries, the process of information exchange between the boundaries of individual disciplines is loosely defined and at times, indistinguishable. In direct contrast to the technology transfer of the last century, today's technologies are shared as multiple disciplines simultaneously consider the influence of a collective knowledge base, rather than those bound by strictly defined professional boundaries. Collaborative practices and academic research environments must recognize that contemporary innovations will occur in disciplinary overlaps, rather than within isolated professions. The place for research for architects is at once scientific, experiential, ecological, material, built, and imagined. Future architects bear a responsibility to participate within the larger discourse surrounding material innovation and to contribute to research that forwards the creation of a future global knowledge base of shared information.

[26] Rashida Ng, Sneha Patel and Amy Fleischer, "Responsive Daylighting Panel Integrating Phase Change Material," sponsored by the Green Building Alliance, 2009.

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