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Materials Matter: The Cases of Thomas Herzog and Ove Arup

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ABSTRACT

An interest in the expanding field of building materials has resurfaced in architectural practice. And the frequency with which new materials are invented, produced and deployed has prompted a re-evaluation of the role played by building skins in the development of innovative architectural projects. The work of Thomas Herzog and Ove Arup will be reviewed in this regard and their collaborations with the building industry, research institutes and affiliated non-profits will be also be highlighted. For each has participated in the search for innovative materials and contributed to the construction of ecologically determined buildings.

1. INTRODUCTION

Architecture, as a modern phenomenon, is a theoretical and historical trope most visibly manifest in the technological innovations which have, over the past two centuries, drastically reconfigured building processes and their techniques. In this regard, central has been the role played by new materials in altering the very nature of architectural practice. The history of modern architecture can, in part, be written as the invention and unprecedented use of novel materials in the service of alternative building types, forms and procedures.

We need only recall the watershed development of an entirely new language at the turn of the twentieth century which registered significant transformations in the production and consumption of building materials. The metaphor of the 'machine aesthetic' with its instrumentality and technological determinism underpinned a theoretical shift in the nature of construction and the triad of materials then charged with making manifest this transformation was that of glass, iron and reinforced concrete.

In 1928, Siegfried Giedion identified the iconic role which iron was to play in his book *Building in France, Building in Iron, Building in Ferro Concrete*; "Industry completes the transition from handicraft to machine production. The introduction of iron into architecture signifies the change from craftsmanship to industrial building production."⁵⁷ And with the introduction of iron in the making of concrete an entirely new material was developed precipitating the rise of the even more radical ideology espoused by Futurists Antonio Sant' Elia and Filippo Marinetti, who stated; "...the calculation of the strength of materials, the use of reinforced concrete, rule out 'architecture' in the ... traditional sense...the *Futurist* house must be like an enormous machine..."⁵⁸ "... the new architecture is the architecture ... of reinforced concrete, iron, glass ... and all those replacements for wood, stone and brick that make for the attainment in maximum elasticity and lightness."⁵⁹

⁵⁷ Siegfried Giedion, *Building in France, Building in Iron, Building in Ferro Concrete* (Getty Center for the History of Art and the Humanities, 1995), p. 88.

⁵⁸ Ulrich Conrads, Antonio Sant'Elia/Filippo Tommaso Marinetti, "Futurist architecture" in *Programs and manifestoes on 20th century architecture* (Cambridge, Mass.:The MIT Press, 1970), pp. 34-38.

⁵⁹ Reyner Banham, "Sant'Elia and Futurist Architecture," *Theory and Design in the First Machine Age* (Cambridge, Mass.: The MIT Press, 1967), p. 129.

Notwithstanding the never realized social, political and aesthetic revolution these new materials hoped to engender, unveiled in the unbridled optimism which Giedion and the Futurists had for their deployment, was the rhetorical dimension of architectural technologies. Indeed, by the 20th century, one contributed to the articulation of an architectural paradigm merely in the choice of a building's materials and in the modes of construction they occasioned.

It is the aim of this paper to advance that, a full century later, a form of material determinism has once again motivated a considerable radicalization of the architectural project. The altering of our contemporary landscapes, street-scapes and buildings is in large part the result of sweeping transformations in the nature of materials. And examining the manner in which these changes have redefined the age old relationship between architectural design and the building industry is of direct interest.

The structure and composition of recently developed building materials are vastly other than those customarily identified with modernism. The configuration and organizing parameters of metal meshes, fiber optics and polymers of all kinds, are in excess of existing modes of material thinking and in so being are incommensurate with the structure of either Gottfried Semper's 19th century four fold material cosmography or Kenneth Frampton's development of the 'Tectonic' a hundred years later.⁶⁰ Carpentry, stereotomy, earthworks and the art of weaving were undoubtedly productive building archetypes within which to organize the world of matter at the origins of the industrial revolution. However, in the context of developments in nanotechnology, electro-technology and digital technologies, this particular structuring of matter no longer suffices. Moreover, notwithstanding the enlightened and rigorous theory postulated by Frampton in his seminal book *Studies in Tectonic Culture*, his interpretation of the building arts as conceptualized through the architecture of modern masters Louis Kahn, Mies van der Rohe, Carlo Scarpa and Jorge Utzon only reconfirms conventional building processes predicated on a craft tradition.⁶¹

But a decade following Frampton's publication, material inventions have fundamentally transformed building products and modes of architectural practice. Their expanded uses now condition a more complex terrain within which architecture is constructed and construed. And disciplines outside of architecture - such as medicine, aeronautics, and engineering - have contributed to this development in two ways. On the one hand, entirely new materials have been created in laboratory settings which investigate the workings of matter at a level beyond nature's reproductive agenda. On the other, as in the example of translucent concrete and structural glass, atomic properties have been manipulated radically transforming the corporeal nature of existing materials.

Recently, the most compelling technology transfers have taken place in the area of sustainable design. The appeal for ecologically sound objects, buildings and landscapes has precipitated the greatest number of innovative material solutions. And two design practices which have been highly exemplary in this regard are the German architectural firm of Thomas Herzog + Partner and the international engineering firm of Ove Arup. Their world wide professional and academic success can be measured in dozens of ground-breaking projects in their respective areas of building technology. And while both have invested substantially in the development of energy conscious projects, they have done so by concentrating on the design and construction of building enclosures. For decades, Thomas Herzog and Ove Arup have been at the vanguard of advances in architectural skins and facades and it is to these particular inventions that this paper is addressed.

2. THOMAS HERZOG

Thomas Herzog's designs and inventions are now legendary. In the span of thirty years no architect has more carefully re-imagined the relationship between a building's structure, its mechanical environment, and the circulatory systems to which it owes its state of balance. Indeed, no other designer has more

⁶⁰ Gottfried Semper, *The four elements of architecture and other writings* (Cambridge; New York: Cambridge University Press, c1989).

⁶¹ Kenneth Frampton, *Studies in Tectonic Culture, The Poetics of Construction in Nineteenth and Twentieth Century Architecture*, (Cambridge, Mass.: The MIT Press, 1995).

convincingly deployed the tools of *'ingenium'* to resolve some of the most pressing issues confronting the building industry today.

As educator, building technologist, architect, and activist, Herzog has promoted the unconventional use of emerging materials along with their alternative modes of construction. Desirous to substitute unskilled building crafts with highly engineered prefabricated systems, his architectural projects have encouraged the use of components constructed in highly controlled environments. And concerned with responding to the increased demands placed upon the performance of materials, assemblies, and operating systems, Herzog has dedicated a substantial portion of his career to actively conducting research in various areas of building technology. To this end, the architectural component most highly favored by his investigations is that of the building's surface; the skin and physical interface which most acutely registers atmospheric and thermal conditions. Time and again, Herzog has returned to this material threshold separating a building's interior from its exterior in the hope of advancing not only its operational functions but equally in attending to its representational role.

"The highly complex subject of the building "skin", its adaptability and manipulation, using the appropriate techniques, is something I regard as mainly the prerogative of the architect. Inevitably, the question of an adequate design form is also involved. Architects who tackle this subject, however, will need to understand something about construction, technology, materials and physics – at least so much that they can confidently discuss these matters with specialists."⁶²

So stating, it should be of no surprise that Herzog's success is directly related to his embrace of a collaborative methodology wherein highly productive networks are developed amongst engineers, the building industry, academia and research institutes. Even in the early years of his career, Herzog initiated highly productive ventures with manufacturers and suppliers of building facades. In 1973, he worked extensively with *Petrocarbona* a manufacturer of external load bearing wall panels made of rigid and flexible foam. He helped the company develop prototypes and marketable products and, along with his then partner Vladimir Nikolic, invented a highly customizable panel system which incorporated both the structure and skin of the facade in one tectonic member.⁶³ But a few years later, in cooperation with Helmut Muller, Herzog extended his interests to metal skins and collaborated with the *Fischer Unit Construction Facade System*. He conceived of an early 'double-skin system' which was lightweight yet capable of passively stimulating the flow of air in its two layered section; a building principle Herzog has returned to on numerous occasions throughout his career.⁶⁴

His fascination with building skins of all kinds has prompted further investigations with materials such wood and glass, clay, air and Aerogel. Following a decade of experience building housing projects conceived to maximize solar heat gain, in 1984 Herzog co-authored a book with Julius Natterer on the construction of wood and glass skins.⁶⁵ Most recently, turning his attention to the benefits of clay tiles, Herzog has devised the "*Modinger* facade system" in collaboration with Max Gerharer. Incorporating a variety of clay sections suspended from an aluminum structure, the system maximizes the material's innate thermal capacity and integrates heat gain into a ventilated wall system, furthermore advancing the operational potential of architectural skins. Projects which have incorporated the *Modinger* system include a public housing development in Linz, a spa in Kassel and a high rise tower in the city of Hanover. Herzog's interests have also involved the study of architecture's lightest material, air. As early as the completion of his doctoral thesis in 1972 at the University of Rome, Herzog admired the material possibilities of pneumatic structures. Publishing his book (*Pneumatische Konstruktionen, Bauten aus Membranen und Luft*) *Pneumatic Construction* in 1976, he demonstrated vast knowledge of both the science and art of deployable structures.⁶⁶ And albeit, in a manner far different from the large scale balloon structures dotting the science fiction landscape of his publication, decades later in 1997 he employed the material characteristics natural to air to the benefit of his corporate client, Siemens. In the decision to refurbish a 1930's steel and brick industrial storage shed into a contemporary office

⁶² Thomas Herzog, *Architecture + Technology* (Munich, London, New York: Prestel, 2001), p. 37.

⁶³ Ibid., "Career and Background Interview with Thomas Herzog," p. 27, and "*Petrocarbona* External Wall System," p.155.

⁶⁴ Ibid., "Fischer Unit Construction Company," p. 157.

⁶⁵ Thomas Herzog & Julius Natterer, *Habiller de verre et de bois/ Gebaudehullen aus Glas und Holz* (Lausanne, 1984).

⁶⁶ Thomas Herzog, *Pneumatische Konstruktionen, Bauten aus Membranen und Luft*, (Stuttgart: Verlag Gerd Hatje, 1976).

space for the company's design department, Herzog actualized the potential of plastic skins in a manner ingenious and complex.⁶⁷ By collaborating with José-Luis Moro and the Bavarian membrane manufacturer *Koch Hightex*,⁶⁸ Herzog inserted a two layer translucent membrane within the existing building section, carefully controlling the quantity and temperature of insulating air caught between the plastic film and the existing exterior wall. In so doing, the team had not only rendered thermally viable a 60 year old building whose obsolescence would have otherwise greatly contributed to the problem of landfill, but in having subverted the relationship between interior and exterior skins, constructed a highly ethereal environment whose poetic dimension transcended its technologically determined details.

Another material of early interest to Herzog, and whose further integration into the building arts promises substantial architectural innovation, is that of 'Aerogel'.⁶⁹ In collaboration with the *Fraunhofer Institute for Solar Energy Systems* (ISE), Herzog designed and built an exterior facade system for a private residence using this space age product employed extensively in the aeronautics industry. Its highly porous structure exists at the scale of nanometers and made up of 99% air insulates at a rate 40 times that of fiberglass. Herzog adapted the material's thermal capacities in the design of a 16 mm silicate infill sandwiched between two layers of glass and in so doing achieved thermal comfort without a correspondent loss in transmitted light.

In the end, regardless to which architectural material Herzog directs his attention, an essential component of his design method involves radicalizing accepted building paradigms. In this regard, his collaborations with research institutes, both private and public, have been vital. Laboratory facilities and technical expertise offered by agencies such as the *Fraunhofer Institute for Solar Energy Systems* (ISE), the *Center for Applied Energy Research* (ZAE) and the *Bartenbach Lighting Laboratory* have been productive venues for the testing of his inventions. And without their assistance many a sketch and idea would have remained just that. In one example, Herzog successfully designed the "Daylight Grid System" in collaboration with Christian Bartenbach and the Fraunhofer Institute.⁷⁰ As a result of his access to computer simulations measuring the thermal and energy transmission of various sky light prototypes, a number of laminated glass and aluminum sections were selected for world wide production; not before, however, having featured the grid-shaped device designed to reflect and diffuse large quantities of light in the structure of his curved glass roof spanning the Linz Exhibition Hall.

His academic work at the Universities of Kassel and Munich has also contributed to an expanded repertoire of material inventions. In collaboration with doctoral students, Herzog has continued to challenge the frontiers of facade design and in one case in particular, the research work of Waldemar Jaensch (1977-1980) resulted in the development of an ingenious kinetic sunscreen directly responsive to light and energy.⁷¹ In the ability to modulate the device's solid to void ratio, a method was developed to attain desired thermal levels and energy conservation. And in excess of its sun shading benefits, the patterns and configurations which resulted from the kinetic modulations offered an extraordinarily poetic language of surface articulations.⁷²

Herzog's commitment to the design of sustainable buildings is three decades old and as we have seen encompasses all aspects of his career. The development of new materials and their accompanying construction processes situate the conservation of energy at the center of his practice, making ecologically sensitive decisions the rule and not the exception. And a project which acknowledged this

⁶⁷ See Layla Dawson, "Eco Membrane" in *Architectural Review*, Vol. 204 (August, 1998), pp. 24 -25, Rossella Mombelli, "Un intervento leggero -Siemens Design Department" in *Arca* n. 123 (February 1998), pp. 74-77, and *Thomas Herzog, Architecture + Technology* (Munich, London, New York: Prestel, 2001), pp. 102-103.

⁶⁸ Herzog had collaborated with the manufacturer Koch years earlier when working with membrane structures at the University of Kassel. See *Thomas Herzog, Architecture + Technology*, p. 29.

⁶⁹ See Layla Dawson, "Light Spirited" in *Architectural Review*, Vol. 197, n. 1175 (January 1995), pp. 20-21, Witte, Chen, Faircloth, Hodge, Kim and Lee, "98% nothing: Transparency by degrees" in *Journal of Architectural Education*, Vol. 56, n. 4 (May 2003), pp. 27-29, and *Thomas Herzog, Architecture + Technology*, pp. 170-171.

⁷⁰ *Thomas Herzog, Architecture + Technology*, pp. 80-87 and 168-169.

⁷¹ *Ibid*, "Changeable Surfaces - Processes for Assessing Kinetic Manipulators in the Skins of Buildings as a means of Regulating the Indoor Climate," pp. 180-181.

⁷² *Thomas Herzog, Architecture + Technology*, pp. 180-181.

goal at an architectonic scale is the Administration Building for the Hanover World Fair completed in 1999.⁷³ All aspects of this high-rise building are exemplary and for the purposes of this paper it will suffice to highlight but one. The building's facade was conceived as a double skin system incorporating the latest technological innovations in matters of air transfer with the goal of securing large scale energy savings. Running the perimeter of each floor is a ventilated air chamber, roughly four feet wide which separates the interior surface of the building from its exterior. In this section are orchestrated all temperature adjustments necessary in maintaining the inside of the building at a constant air temperature. Shading devices are installed on both surfaces and the ability to re-circulate the heat generated within the cavity increases thermal comfort and decreases the need for additional sources of energy. All building details and mechanical systems were devised to further support the facade's operations.

Detailing further the myriad of ways Thomas Herzog has developed an exemplary career in his innovative approaches to the use of materials and to the rehabilitation of art of building would be an arduous task, however fruitful. Suffice it to conclude that he has offered the architectural profession the example of a most virtuous building activity, and one that we would do well to study in the hope of devising more sustainable approaches to our own buildings.

3. OVE ARUP

At a scale far different is the work of the Engineering Consortium Ove Arup whose world wide recognition situates this practice at the forefront of building innovations. Scant are the international building sites, irrespective of project type or size, which have not been in some measure affected by its expertise in matters of structural design, environmental systems or sustainability. Founded as a construction company by Sir Arup (1895-1988) in post World War II London, it has grown into a global firm of design and engineering consultants with thousands of employees and commissions on all five continents.

Of particular interest to this paper is the continued attention Arup has conferred upon the design of building facades, upon the innovative use of materials, and upon their unconditional commitment to developing ecologically sound environments. To begin with, noteworthy is the presence of 'The Building Facade Engineering Department', a division exclusively dedicated to advancements in architectural skins. Whether concerned with structural glass, traditional masonry or ventilated double-skin facades, the group's expertise has been of consequence in the development of numerous projects in the city of London including Cesar Pelli's Bank Street Buildings, Sir Norman Foster's City Hall,⁷⁴ and Kohn Pederson Fox's AIG European Headquarters. Indeed, the very presence within the company's structure of design services entirely dedicated to architectural enclosures signals, more generally, the increasing complexity of contemporary skins, particularly when conceived in conjunction with a building's heating, lighting and ventilation systems.

Secondly, Arup's commitment to the study of materials is equally remarkable. The 'Material consulting' division facilitates the selection of building materials, offers an assessment of their measure of sustainability, and evaluates their performance in a number of different contexts.⁷⁵ To their efforts must be connected the ground-breaking project designed by Future Systems for Selfbridges Department Store in Birmingham, England. Material investigations made possible the construction and attachment of 15, 000 spun anodized aluminum discs which were structurally tested against the weight of adventurous humans who might one day desire to climb its surface.⁷⁶

⁷³ See Layla Dawson, "Systems Analysis – Trade Fair Administration Building, Hanover Germany" in *Architectural Review*, Vol. 209, n. 1247 (January 2001), pp. 46-50, and *Thomas Herzog, Architecture + Technology*, pp. 122-129.

⁷⁴ Sara Hart, "Technology and ingenuity contribute to energy-efficient performance," in *Architectural Record*, Vol. 191 (February 2003), p. 116, Malcolm Turpin, "Great Hall" in *Civil Engineering* (August 2003), pp. 36 -45.

⁷⁵ As claimed on the Arup webpage; <http://www.arup.com/skill.cfm?pageid=486> .

⁷⁶ As described on the Arup webpage; <http://www.arup.com/facadeengineering/project.cfm?pageid=1784> See Catherine Seron-Pierre, "Future Systems Grand Magasin en Centre Ville Birmingham" in *AMC*, n.137 (October 200), p. 54-58.

And finally, in what concerns Arup's greater commitment to issues of sustainability, the firm's charter identifies amongst its priorities a commitment to sound environmental practices. As inventors of the 'Vertical-Axis Wind Turbine Extractor (VAWTEX)' used to maximize wind power at the Harare International School in Zimbabwe,⁷⁷ as consultants with the non profit group based in the Netherlands - Global Reporting Initiative, and as inventors of their trademarked sustainability tool, SPeAR®: Product overview, Arup's division of 'Sustainability Services' has repeatedly demonstrated vanguard approaches to the design of ecologically determined environments.

By way of these examples, therefore, it is apparent that within the very structure of Arup as a professional organization is recognition of the firm's commitment to the design of enhanced facades, emerging materials and the promotion of a sustainable consciousness. These are the targets around which Arup continues to expand and intensify its terrains of investigation and in the review of two recent projects this paper seeks to demonstrate how so.

To being with, throughout the years, Arup designers have maintained a close association with the world of art, often collaborating with spatial and material visionaries.⁷⁸ This was in fact the case when in the year 2002 structural engineer Cecil Balmond⁷⁹ worked alongside artist Anish Kapoor charged with installing a larger than life sculptural figure in the Turbine Hall of the Tate Modern. Kapoor enlisted the help of Arup to engineer all aspects of the project he entitled, *Marysas*. Even the most cursory of looks at the final installation reveals the artist's inspiration; the mythological Greek figure who in losing a musical challenge with the god Apollo was destined to being skinned alive. To this end, Kapoor devised the construction of an enormous steel structure sonorous in profile and 140 meters (roughly 450 feet) in length. Covered in 3500m² of an alarming red PVC-coated polyester membrane, also supplied by the contractor 'Hightex', the carefully constructed figure achieved its mathematical precision by way of wax models, Real Time software and a computer program used for non linear form derivations called, 'Fabwin'.⁸⁰ And setting aside the spectacular quality of this architectonic installation, many lessons were learnt throughout the project's various stages of design, construction and material selection; all of which will undoubtedly contribute to the expanding dimension of Arup's knowledge base. It is often precisely in collaborations with members outside of a strictly defined building economy that many of the most innovative results are intuited. And it is to Arup's credit that projects such as these will soon bear fruit within the traditional building arts. Indeed, their experiments with innovative membranes have already facilitated significant transformations in the nature of architectural surfaces and they have helped us better understand the symbiotic relationship which exists between the design of a building's skin and the design of its heating, lighting and ventilation systems.

One material which has most recently contributed to this dialogue and pioneered a particular approach in sustainable design is the recyclable film known as ETFE, Ethyltetrafluoroethylene; a highly transparent foil, trade named Teflon, with a weight of one percent that of glass and whose structure and insulation value is achieved by the addition of forced air.⁸¹ Lighter and more thermally resistant than glass, it is a material perfectly suited to greenhouse enclosures.⁸² And this is precisely how it was used by Arup in collaboration with architect Nicholas Grimshaw in the construction of a botanical garden in Cornwall England for a non-profit group called 'The Eden Project'. In the construction of eight quasi-geodesic domes termed 'biomes,' the use of Teflon 'pillows' organized in a series of structural hexagonal frames gave rise to a veritable landscape of pneumatic structures. Their physical measures

⁷⁷ As reported on the Arup webpage; <http://www.arup.com/environment/feature.cfm?pageid=1658> .

⁷⁸ Arup collaborated with James Carpenter in the design of a glass skin, see James S. Russell, "Bring Form to Light" in *Architectural Record*, Vol. 178 (November 1990), pp. 108-111. They also collaborated with Jenny Holzer at the Berlin Reichstag, see "Engineering the Reichstag sign" in *The Arup Journal*, (1999), p. 21.

⁷⁹ Cecil Balmond is a deputy chairman of Arup and has most recently collaborated with Oscar Neimeyer in the construction of the Serpentine Gallery, a temporary building installed in Hyde Park, London, Summer 2003.

⁸⁰ Cecil Balmond et al. "Marsyas at Tate Modern" in *The Arup Journal* (January 2003), pp. 40- 45.

⁸¹ As claimed on the Arup webpage, <http://www.arup.com/europe/project.cfm?pageid=187>. See also Isabel Allen, "A taste of Eden," in *The Architect's Journal*, (February 22, 2001), pp.30 -37.

⁸² "Pillow Talk" in *The Architect's Journal* (April 15, 1999), p. 42.

defy reality, with some cushions measuring 30 feet in diameter and others six feet in depth. The great genius of Arup's involvement was to have integrated the design of this air filled plastic surface within the building's system of energy recovery and distribution; the challenge of which was enormous given that beneath the domes rainforests and moonscapes were simulated.

And if 'The Eden Project' had not been challenging enough, using the same system in the design of an aquatic environment will certainly test this material to its very limits. In collaboration with the Australian architectural firm PTW, Arup has been commissioned by the People's Republic of China to engineer the construction of its 2008 Olympic Pool. Using the same material and structural logic, the project identified as the 'Water Cube' will use ETFE - Teflon air inflated cushions for both the inner and outer skins of the building.

The practices of which I have presented but mere samplings of their work occupy at present the forefront of innovations in building technology as they continue to offer architects profoundly different possibilities for the conceptualization of space and for the manipulation of matter. In many ways this is a time no different than that first recognized by Giedion and Marinetti who saw in the use of iron and reinforced concrete a potential far different than ever imagined. We would do well, however, to remember that the social and political transformations which they dreamed to be the natural outcome of material innovation never materialized. Therefore, in the practices of Herzog + Partners and in that of Ove Arup, we are all the more fortunate to have as models a deeply humanitarian belief that building technology and new materials are distinctly suited to the creation of sustainable environments of all kinds.