

The Nature of Tectonic Architecture and Structural Design

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ABSTRACT: Since earliest times mankind has sought inspiration from nature for our built structures. However until the dawn of the modern era in architecture and design, the true structural character of a building was invariably fully or partially encased in an ornamented cladding, of often stylised motifs of nature. The modern emphasis on honest structural expression has resulted in more sincere and innovative interpretations of nature in spatial structures. With reference particularly to the exemplary nature inspired tectonic architecture of Jørn Utzon, together with comparisons to the works of amongst others; Gaudi, Candela, Frei Otto, Nervi, Calatrava and Foreign Office Architects and the writings particularly of Kenneth Frampton, this paper will argue that the direct inspiration of nature and the increasing use of advanced parametric digital design tools that replicate virtually instantaneously evolutionary processes results in structures that are not only elegant tectonically and in terms of economy of means, but also aesthetically pleasing, profoundly satisfying experientially and often culturally significant.

1 INTRODUCTION

“A desire for well-being must be fundamental to all architecture if we are to achieve harmony between the spaces we create and the activities to be undertaken in them. This is quite simple and reasonable. It requires an ability to create harmony from all the demands made by the undertaking, an ability to persuade them to grow together to form a new whole – as in nature; nature know of no compromise, it accepts all difficulties, not as difficulties but merely as new factors which with no sign of conflict evolve into a whole.”

Jørn Utzon, (Weston, 2002: p11)

Since the very beginning of human civilisation, nature has provided our most profound source of understanding and reference to the world. The earliest civilisations found both literal and metaphoric inspiration and significance in the natural world around them. Certainly nature, that is the human body and the biological and physical world, were the original fertile sources of the development of our own technology and culture. However with the advent of Euclidean geometry and widespread understanding of mathematics, the works of man began to take on an abstract character and significance in their own right, in opposition to nature, leading to the apotheosis of the machine itself as the source of reference early in the 20th century. However, with our more recent understanding of the actual complexity of mathematics, as expressed in chaos theory and fractals, increasing understanding of complex natural systems, and the evolution of computer technology into a web of neural networks, our perception of the world has progressed from a purely mechanistic perspective towards a more organic understanding of existence, and once more, both literal and metaphoric references to nature are gaining pre-eminence

1.1 *The significance of nature in the classical tradition.*

Historically, literal and metaphoric evocations of nature have played a significant role in the conception and appreciation of architecture. The most primitive of man-made structures, evoked an ancient understanding of the cosmos, recreated at human scale, as evidenced for example by the evolution of simple dome structures amongst many ancient cultures. While the earliest antecedents of classical architecture of Mesopotamia, Egypt and Greece evolved through interpretation of nature, most clearly evident in the analogy between classical columns and the forms of reeds and trees. In the hypostyle hall of the temple of El-Karnak, the analogy to reeds is reflected not only in the form of the 122 columns, but also in their close proximity to each other; it being fundamental to Egyptian culture to recreate the essence of the natural world, which was considered to be a gift of the gods. In contrast to the Egyptian arrangement of columns, within a walled structure, the later Greek temples consist of a sanctuary surrounded by columns that thereby articulated the exterior space and established the importance of the external appearance of architecture. Through many centuries the Greeks refined their architecture, striving for perfection in the articulation of the individual building parts; that came to be known as the orders of architecture, which were defined as stylobate, base, shaft, capital, architrave, frieze, cornice and pediment, that each in their own way metaphorically expressed nature and simultaneously represented a specific structural purpose.

1.2 *Early Modernism and the International Style.*

Throughout the evolution of the classical tradition and its many subsequent re-interpretations these original motifs were constantly redefined and re-utilised, often though in a merely mannerist, stylistic or literally figurative manner. With the dawn of the twentieth century, came a distinctive break with the classical tradition. The emerging Modern Movement, broke with the past and the perceived romantic attachment to inspiration in the natural world. Modernism saw the machine as the metaphor for a modern world and thus by inference, modern architecture. Though espousing a rejection of classical tradition, the early modernists were nevertheless well versed in the architecture of the classical world and were not only heavily indebted to it in terms of their sense of proportion, but more importantly as a source of inspiration. The white-washed houses of the Greek islands and sun-bleached columns of classical ruins, served as a reference for Le Corbusier's white architecture and his use of piloti. This pure, unadorned architecture being combined with allusions to the great passenger liners that crossed the Atlantic, which for Le Corbusier and other modernists epitomised the forward progress of modern technology. Similarly the Russian Constructivists and Italian Futurists sought to embody in their architecture, the dynamic energy and sense of movement of the new machine age, which they saw as the driving force for a dynamic new society.

This unquestioning fascination with technology and somewhat naive belief in its potential for enabling the realisation of a universally more ideal society, led to an increasing interest in industrialisation and mass-production within architecture. The ideals of the modern movement were exemplified by the Bauhaus, where a belief in industrialisation and increasing abstraction of design, was nevertheless informed by artistic endeavour and craft tradition. The Nazi's not only closed the Bauhaus, but also effectively curtailed the idealism of the Modern Movement reverting to the techniques of classical form and motifs given expression in the work of Albert Speer. By the end of the 1930's, many of the leading members of the modern movement had emigrated to the New World; most particularly the United States. Led by Mies van der Rohe, whose earliest designs for a skyscraper had originally shared the earlier Expressionist vision of a crystalline architecture, the Modern Movement evolved into the International Style, whose vacuous desire for homogeneity has since dictated the appearance of the central business district of almost every major city around the world. The bareness of the ubiquitous curtain-wall, denied all potential allusions, to all other analogies than that of an all enclosing skin, which even today we are technologically as yet incapable of truly replicating in a fully functioning, flexible and unbroken form. A modern architecture thus emerged that was largely devoid of reference to nature and thus remote from human experience.

1.3 *Critical alternatives to the International Style: A Nordic approach.*

'Nordic architecture had a strong clear and specific architectural context based on three important factors, which were understood and accepted by the population of the region: climatic conditions, potential of place and a common definition of social consciousness.'

Per Olaf Fjeld (Olaf Fjeld 2009: p.10)

Despite an overwhelming tendency towards a technology-driven and nature-devoid architecture, there were a number of notable exceptions. The later more expressively sculptural and highly narrative works of Le Corbusier, the idealised landscapes of America in the late works of Frank Lloyd Wright, the sublime abstractions of nature in the work of Luis Barragan and Louis Kahn's poetic re-interpretations of archetypal architectural elements and the inspiration of the ruins of antiquity. Perhaps the most significant alternative to the otherwise banal conformity to the International Style, was the work of Alvar Aalto. In the intervening years, Aalto's work has been constantly re-evaluated, re-assessed and his contribution to modern architecture has been elevated. Far from being merely an inspired, but idiosyncratic and eclectic regional architect, Colin St John Wilson in his revisionist thesis on the influential leaders of modern architecture published in 1995, argues that Aalto was the leading pioneer of what he calls "the other tradition of modern architecture" which he considers to be "the uncompleted project" (St John Wilson, 1995). Optimistically suggesting an alternative continuing tradition of the modern, a poetic modern architecture of materiality, which is tectonic and is inspired by, as well as being analogous to nature.

As the Norwegian architect, Per Olaf Fjeld has noted *'In the North, architecture was always responding to or acting on or in nature.'* (Olaf Fjeld 2009: p.11) Aalto moderated and humanised modern architecture, through the extensive use of principles and forms found in nature, most particularly the indigenous nature of his native Finland. While Aalto not only created a significant legacy of work, that firmly established an organic identity for Nordic architecture, his inspiration and approach found subsequent expression in the work of many Nordic and International architects, notably Reima Pietilä, Sverre Fehn and perhaps most significantly, Jørn Utzon.

Within Finnish architecture, Reima Pietilä was the most outstanding successor to Aalto, who selected Pietilä the winner of the competition for the Student Union Building at Dipoli, opposite the University Campus he had himself designed. In the overtly expressive and fragmented forms of Pietilä's Dipoli building, which evoked rock formations, the Finnish forest, shards of ice and cave-like interiors, Pietilä was both continuing the Finnish organic tradition, based on National Romantic themes, at the same time anticipating future directions in architecture, that are only now becoming more widely manifest in the works of such architects as Frank Gehry, Zaha Hadid and Steven Holl. According to Pietilä Euclidean geometry was merely a cultural invention, an incidental and passing phase in history and that one could achieve greater architectural significance and authenticity through the use of the timeless inspiration to be found in nature. On this basis Pietilä re-interpreted the Christian symbolism of the fish, in this instance as a fossilised fish, in the plan form for the dramatic structure of the Kaleva Church in Tampere. He went on to recreate the undulating snow covered Finnish landscape and its underlying geological structure in the Finnish Embassy in New Delhi and later the Finnish President's Residence, as well as developing what he referred to as Zooamorphic architecture, based on the forms of animals as in the Tampere Library, where the formal and structural idea of the building was inspired by the image of the native wild grouse ruffling its plumage in a mating call. While Pietilä's work has exasperated architectural purists, the unique personality and narrative of his architecture, greatly endeared it to the wider public.

The legacy of Aalto is also clearly apparent, but perhaps more subtle, in the work of Jørn Utzon. An architecture that is equally poetic, but a more abstract and rational evocation of nature, that still today provides an exemplary paradigm for the potential of using nature as a source of inspiration, metaphor and understanding.

2 UTZON'S PARADIGM – NATURE AS A SOURCE OF INSPIRATION

Analysing most specifically the Sydney Opera House, as one of the most original, technically innovative and iconic buildings of the twentieth century, this section examines its influences and sources of inspiration from nature combined with other sources, as an explanation of its iconic status and basis for a paradigm for Utzon's architecture.

2.1 *The Nature of Utzon's Architecture*

In 1946, the young Jørn Utzon, together with Tobias Faber and Mogens Irming participated in the major international competition for the redevelopment of the Crystal Palace site in London. The project, which was praised at the time, proposed a massive stepped platform, above which the exhibition spaces were contained within horizontal levels of floors and ceilings at differing heights. The impressive spatial organisation of the project owed much to Utzon's powerful metaphorical use of nature as inspiration. The character of the spaces between the columns intentionally evokes the feeling of walking through a beech forest, with this analogy reinforced by an accompanying image. The archetypal image of the beech forest was to remain with Utzon, in gestation however until many years later, when it was to serve as the catalyst for his design of the Paustian furniture showroom on the waterfront in the Nordhavn docks of Copenhagen, which opened in 1987. The metaphorical evocation of the birch trees, not only provides the spatial organisation, but also clarity of tectonic structural expression, with triangular gussets between the columns and beams providing lateral stability.

The theme of nature as a source of inspiration was very much to the fore, when Utzon and Faber presented their thinking on architecture at a lecture in Copenhagen. This became the basis for an illustrated article in *Arkitekten* in 1947, entitled '*Tendenser i Nutidens Arkitektur*' - Trends in the Architecture of Today, a manifesto, presenting the themes and interests that would become increasingly apparent in later work.

Utzon's understanding pre-empted the much more recent interest in theories of Emergence and in particular 'Emergent Architecture' that see clear and direct corollaries between processes and forms in the natural world and human cultural developments. Utzon, like Louis Kahn, who Frampton states was "*preoccupied with the latent order of nature as this had been revealed through scientific research*" (Frampton, 1996: p. 216) and many other architects then and subsequently, were greatly inspired by the book *On Growth and Form* by D'Arcy Thompson, first published in 1917, which has had a profound and lasting influence. The significance of Thompson's work was that he so clearly demonstrated that within the natural world all organic structures are the result of a few constructional principles and proportional geometries. According to Thompson, the evolution of form in nature was purely a direct response to functional requirements, physical context and economy of means.

According to his own personal architectural credo "The Innermost Being of Architecture" written in 1948, Utzon states that, "*The true innermost being of architecture can be compared with that of nature's seed, and something of the inevitability of nature's principle of growth ought to be a fundamental concept in architecture*" (Weston, 2002: p.10). The idea of organic growth is further evoked by Utzon's highly original design a few years later for the Langelinie Pavilion competition, for a restaurant on the Copenhagen waterfront, close to the site of the famous Little Mermaid statue. Utzon had realised, by climbing up a ship's mast, that a tower at this location would provide panoramic views of the city's skyline and most important landmarks. A central 'trunk' provided an access and service core, from which floors cantilevered out like leaves. By stepping intermediate floors back as narrower mezzanine levels, Utzon proposed spacious double-height spaces which provided the diners with unimpeded views of the water and city.

Utzon's Langelinie Pavilion, as with much of his architecture, was inspired by forms in nature, in this case trees and fungi, in terms of underlying principles of structure, organisation and services, while refraining from any overt literal representation. For Utzon as with many of his contemporaries, the fascination with natural form also encouraged an interest in original primitive and vernacular architecture, long before the subject was widely popularised by Bernard Rudofsky's pioneering classic *Architecture without Architects* more than a decade later. Vernacular architecture, like structure in nature, having invariably been developed and refined

through a continual process of evolution driven by need and context and within ancient cultures, an economy of means.

Fired by images of Islamic architecture and the enthusiasm for North Africa he shared with Sverre Fehn, Utzon set off for Morocco in 1947. In Morocco, Utzon was greatly impressed by the cohesion and architectural integrity of the mountain villages of courtyard houses built entirely with local clay, unifying them with the surrounding landscape. As he recalled *'I went on a very long walk in Morocco, from Ourzazate around the Southern side of the Atlas Mountains, and there I experienced a building tradition that was completely in harmony with the place and materials. They built – now and then – and they sang while they built, stamped out mud houses, you know, in many storeys from clay and grass.* (Holm, M, Kjeldsen, K. and Marcus, M (ed.) 2004: p.10). Such a unity of material and landscape was what Utzon had in mind when he later designed the Kingo houses and housing at Fredensborg, north of Copenhagen. These housing schemes still more than fifty years later, remain one of the most outstanding examples of high-density low rise suburban housing. However it the iconic Sydney Opera House that Jørn Utzon is most famous for and perhaps the work architecture that most exemplifies just what can be achieved through reference to nature. .

2.2 *The inspiration from nature and the iconic legacy of the Sydney Opera House*

Few buildings create such a frisson of excitement and sense of *genius loci*, as the Sydney Opera House; whether viewed from the air or fleetingly glimpsed between tall buildings or emerging from behind coastal bush as the Manly Ferry sails into Circular Quay; in its shimmering whiteness it as mesmerising an experience as seeing that most romantic and exotic of monuments the Taj Mahal, to which the Opera House once completed, was quickly compared. It was Utzon's vision, that recognised that this unique site needed to be understood in terms of its surrounding landscape and required a sculptural solution, rather than conventional orthogonal design as was the norm among the majority of other entries. Without having visited Sydney, Utzon realised from the study of topographic maritime charts and photographs that Bennelong Point could be seen from many high vantage points around the harbour and therefore the design of the roof, the 'fifth facade' was of supreme significance.

Utzon's appreciation of the context of the site was far more profound than merely the creation of a prominently located, expressive artistic statement, "a magnificent doodle" as described by Australian art critic Robert Hughes (Murray, 2003: p. 10). With an expertise gained through his passion for sailing, Utzon was able to appreciate the particular morphology of the Sydney harbour basin, through his reading of maritime charts. The special character of the headlands and promontories that define the Sydney harbour, which due to geological uplift, rise up just prior to falling into the sea, is emulated in the forming of the podium. Originally it was even intended that the podium would be clad with the local sandstone, of which the site was largely composed, an intention that would have further emphasized its character as an artificial landform, but was later abandoned for technical reasons. The podium, with its origins in the ancient architectural idea of the raised platform, becomes in Sydney a continuation and evocation of the local natural terrain, building as landscape, in a manner similar in intention to that of other Nordic architects, notably Asplund, Aalto and Pietilä.

The sense of a continuous landscape is also maintained within the interior, with the grand processional movement of the audience up the podium and around the concert halls, providing at the same time stunning elevated views of the harbour and its famous bridge. This approach effectively raised the experience from that of the everyday, creating a sense of a festive event upon what has become Sydney's Acropolis. To achieve this effect Utzon, alone among the competition entrants, made the brilliant, but site overreaching decision to place the two halls side by side, rather than end to end. Contained within the podium of Utzon's original design for the Opera House was what was intended to be a central pedestrian passage between the halls, with an intended character reminiscent of an Arab bazaar. This passage led to a sheltered exterior plaza at the end of Bennelong Point, where the full horizontal panorama of the Sydney harbour would suddenly, dramatically become apparent.

The elegance of Utzon's plan was further complimented by the simple organizational clarity of Utzon's section. In a manner similar to Kahn's principle of served and servant spaces, Utzon located all of the normally rear-of-house functions below the auditoria within the mass of the

podium, leaving the space under the ethereal billowing sails entirely free for the performance and needs of the audience. As with the earlier Langelinie Pavilion, this separation was serviced by means of lifts, which in the context of the Sydney Opera House made use of sophisticated stage machinery and large lifts capable of raising stage sets from below, but eliminated the space usually required for side-stages. The designs for two main auditoria, the major and minor halls, which were perfected during Utzon's time in Sydney, were rigorously formed according to acoustic principles. Initially the Major Hall was to have had a multi-faceted ceiling, akin to Islamic *musqarnas* (Weston, 2002: p. 164) the crystalline-like "stalactite vaults", that Utzon had admired at the 'Friday Mosque' in Isafahan. As a result of rationalisation imposed by the needs of industrialisation, the acoustic ceilings were finally proposed, but not realised, as circular wave-like forms that had been developed from an analogy between the movement of sound and waves. The resulting articulation of the halls as seemingly independent structures free of the exterior shells and with their own architectural expression rejected the prevailing dogma that the inner form should be as one with the outer; this offended architectural purists at the time. Utzon explained the differences in the character of the two forms, by using the analogy of the walnut and its shell. This differentiating of the inside and the outside of a building, was later to be proposed by Robert Venturi in *Complexity and Contradiction* as appropriate means to once again achieve an urbanist approach to architecture (Weston, 2002: p. 184) and certainly can now be seen to be a guiding principle of many of the most innovative architects practicing today.

Seemingly floating above the podium, the Opera House's signature sail-like roof shells were expressed by Utzon in his conceptual sketches as being like clouds, both as experienced in nature and the abstract representation of Chinese temple roofs. The shimmering, ever-changing appearance of the shells is one of the most evocative architectural surfaces ever created, which justifies the comparison as the other Taj Mahal (Yeomans, 1973). Early on in the design process, Utzon had realised that a roof of white tiles would emphasise the sculptural character of the building, particularly at night and his aim was to achieve an effect similar to that of the "combination of matt snow and shining ice" (Frampton, 1996: p. 275) through the use of two different types of glazed ceramic tile. Such tiles of the character and the demanding quality that Utzon required did not at that time exist and it was to take three years of technical development in collaboration with Utzon before the Swedish manufacturer Högånäs were able to produce tiles that were suitable. This was one of the many technical achievements that were made during the development of the Sydney Opera House, that were fundamental to its successful realisation. The greatest, almost insurmountable challenge was however the determination of structural geometry and construction of the shells themselves.

As Yuzo Mikami, the Japanese architect who first worked with Utzon and then subsequently with Ove Arup on the design of the Opera House, writes in '*Utzon's Sphere*', his own account of the project "*The cluster of curved white roofs in the competition scheme were undoubtedly the most striking feature of Utzon's design. He wanted them to be constructed in a thin concrete membrane structure, this technology being very popular at the time*" (Mikami, 2001: p.32)

Certainly the earlier work of Robert Maillart, Felix Candela and Pier Luigi Nervi played a role in opening Utzon's imagination to the new technical and aesthetic possibilities of large parabolic reinforced concrete roof spans, as did the recently designed Radiohuset concert hall in Copenhagen by Wilhelm Lauritzen, which informed his competition proposal. While it was the participation in the jury of Eero Saarinen, who had previous experience of designing a thin concrete membrane structure with the Kresge Auditorium at MIT and was later to design a highly sculptural bird-like free-from concrete structure TWA Terminal at New York's Kennedy Airport, who convinced the rest of the jury of the quality and feasibility of the project. It is interesting to note that Saarinen's own perspective sketches of the Opera House made to help persuade the jury, suggest a more vertical and spherical form to the roofs, as if he perhaps intuitively foresaw the difficulties that Utzon would encounter with the scale of the parabolic forms and how it would eventually be resolved. As Mikami notes "*Saarinen started from a strictly geometrical design for his shell roofs and proceeded to the free form, in other words from a purely architectural to a more sculptural approach*" (Mikami, 2001: p.32), while Utzon, initially convinced of the potential capabilities of thin membrane structures based on the recent

pioneering examples, was to move away from the free sculptural approach to a spherical geometry, as he became aware of the inherent limitations. As Mikami comments, “*on the competition entry drawing, the shapes of the roof vault had no geometrical definition at all. It was a fanciful and sculptural form drawn by free-hand. Many people felt the shapes of the roofs reminded them of fully blown sails of large sailing boats. The impression it gave was of a lightweight, almost semi-transparent curved membrane floating in the air.*” (Mikami, 2001: p.33)

Originally Utzon had conceived of the Opera House roofs as being like egg shells that were structurally uniform and non-directional, with smooth continuous surfaces. This desired smoothness, being the reason that Utzon rejected Nervi’s solution of using diagonally crossing ribs to supporting the roof. After more than three years of intense investigations in collaboration with Ove Arup and his engineers, including advanced model simulations at Southampton University, Utzon had still not been able to achieve a satisfactory solution to the realisation of the paraboloid egg-like roof structures, until he made the breakthrough decision to adopt a spherical geometry, the most effective way in nature to contain the greatest volume with the least surface area. Per Olaf Fjeld evokes the poetic cultural dimension of this decision, by suggesting that ‘*When Utzon was to realise his Sydney Opera House, he went to the geometry of the ball. By cutting sections from the ball he found the exact shape for his shells. It was as if he moved into the past, destroyed the dome of the cathedral, and by gathering the pieces left on the ground, he suddenly had the tools to realise the poetic dream of the present.*’ (Olaf Fjeld, 2009: p.180)

In a more direct and practical approach, Utzon explained his use of spherical geometry to produce all the different sized roofs with the same curvature, with reference to segments of an orange and emphasised the benefits of producing a more limited number of differently dimensioned roofing components. While the structure of palm fronds, provided models for resolving the complex construction challenges of realising the fan-like ribs that supported the roofs. Beneath the roofs Utzon proposed uniquely innovative design solutions for the interiors of the halls, corridors, built-in seating and most remarkably the structural mullions of the glass walls, all using bent plywood. The plywood mullions were to have been elegantly articulated like wings of a bird in flight, with the external depth of the mullions creating a seemingly kinetic striated screen of light and shade, effectively eliminating the reflections on the glass walls that make the more angular and protruding post-Utson solution seem so aggressive and distracting from the harmony between the podium and the shells. A hint of the character Utzon’s glass walls would have had can be seen in the design, by Jan and Jørn Utzon, of an undulating roof canopy over the service area of a petrol station in Herning, which was intended as the prototype for a chain of service stations in the region.

That the Sydney Opera House without doubt remains the most widely recognised and popularly appreciated building of the twentieth century, which is due to its poetic metaphoric imagery and tectonic integrity with its origins in nature. Utzon’s belief in a nature inspired organic architecture gives it a harmonious sculptural integrity and timeless quality that transcends the two-dimensional, overtly literal and historic symbolism that subsequently emerged in the work of later post-modern architects or inhumane exaltation of modern technology of high-tech architecture, with its unnatural external structural frames and cross-bracing.

3 THE NEW ORGANIC TRADITION

Utzon himself rather had admiration for the work of Gaudi, the underlying structure of whose architecture is remarkably elegant and daring in terms of its engineering, based upon a profound understanding of how forces operate in nature, analogies to natural forms, particularly the bee-hive and the use of weighted string models. Similarly Utzon saw continuity from Gaudi, through his own work to that of Santiago Caltrava.

Certainly one can clearly contrast coldly mechanical high-tech architecture, with the sensual, often highly poetic structural expressions of the Spanish architect and engineer, Santiago Calatrava, that have in recent years come to represent highly identifiable symbols of civic pride in many aspiring European cities . Though his work is sometimes marred by an overtly expressive use of natural form, he demonstrates the incredible resource for structural inspiration that is to be found in the highly evolved natural structures of plants and animal skeletons. The use of

analogies to nature as a basis for innovation and creativity within architecture and engineering dates back to antiquity, but did not come back to the fore until the mid-nineteenth century, with important advancements in the study of natural history and the form characteristics of natural structures, noticeably the prevalence of curving and spiraling forms. It came to be more fully realised that in nature there was no such thing as a straight line and that curvature was a feature of all living organisms, which not only created structural integrity, but could also be considered to create unity and harmony in the same sense as aesthetic composition; an understanding which was to inspire artists and architects of the Art Nouveau, such as Viollet-le-Duc, Horta and Gaudí, and more recently in the architectural structures of Frei Otto and Calatrava. Whose work draws parallels to that of the most outstanding engineers of the Twentieth Century, such as Robert Maillart, Pier Luigi Nervi, Eduardo Torroja and Felix Candela, who have transcended merely solving technical problems and have rather created, poetically expressive and daring structures, that have captured the imagination.

While more recent avant-garde architects exploring the creative possibilities made possible by the latest technical advances in the era of computer-aided design, includes Toyo Ito whose work continues in the spirit of Utzon's poetic striving for an architectural synthesis between nature and technology. While the radical ground-breaking projects, of Foreign Office Architects, Alejandro Zaera-Polo and Farshid Moussavi, with their sensual expression of structural elements, geometrically controlled deformations of section and organic repetition of architectural units to achieve dynamic open-ended structures, are in a direct lineage with the principles of Additive Architecture that Utzon advocated and so effectively established with his own work.

4 CONCLUSIONS

This paper has argued the implicit value of rediscovering the potential held by understanding and re-interpreting natural forms and systems within contemporary and future architectural discourse. It is clear that Colin St. John Wilson's paradigm of 'the Other Tradition' as exemplified by Aalto, was further developed by Utzon, most significantly in the Sydney Opera House and has through the work of other outstanding architects and engineers continued to evolve and inform contemporary architecture. In the apparent cultural vacuum that modernism has left, such an approach appears as a credible, humane and potentially poetic paradigm that is at its core truly sustainable.

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