Origin of the Collaboration between Engineers and Architects in Great Britain in the Thirties

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INTRODUCTION

The creation of the engineering schools in the mid-eighteenth century entails the separation of two disciplines that had been considered as one until then: engineering and architecture. From this moment on the relationship between engineers and architects will evolve from the confrontation of the nineteenth century to the close collaboration of the second half of the twentieth century and today.

During the twentieth century, engineers such as Eugène Freyssinet, Eduardo Torroja or Pier Luigi Nervi developed a new structural and architectural language, in accordance with the properties and the essence of the new material: concrete. Their work would come to be recognised by both engineers and architects as true masterpieces and help to reduce the existing distance between the two disciplines.

However, the true collaboration between engineers and architect is not due to these engineers that somehow act as architects, but to a system based on teamwork. The work of a small group of engineers in Great Britain in the thirties played a key role in the origin of these ideas of working together. Three of these engineers are specially relevant and worth of an in-depth analysis: Owen Williams, Ove Arup and Felix Samuely.

ARCHITECTURE AND ENGINEERING IN GREAT BRITAIN IN THE THIRTIES

Before considering the contribution these three engineers made to the collaboration between engineers and architects it is important to discuss briefly the architectural and engineering situation in Great Britain at the time when they started to work.

The Modern Movement arrived to Great Britain in the twenties, some years after this development on the continent: Erich Mendelsohn was first presented to the British public in 1923 with a monograph of his drawings and projects; in 1924, the Architectural Review published the work of Walter Gropius; and in 1927, a year after its publication in France, the English version of Le Corbusier's book "Vers une Architecture" was published.

In this period before the 1939-45 war Great Britain attracted some of the most influential architects, as it was one of the few European countries where the government was not discouraging the production of Modern architecture in favour of the nationalist styles. For this reason there arrived in Britain many architects including Walter Gropius, Erich Mendelsohn, Berthold Lubetkin, who worked with the group of British young architects Tecton, and Serge Chermayeff; also Wells Coates who, in 1932, founded the MARS (Modern Architectural Research) group, the British wing of the CIAM (Congrès Internationaux d'Architecture Moderne).

This context of Modern architecture and functionalism in Britain presented a great opportunity to engineers, as it was claimed that architects had to abandon their stylistic approach to design in favour of modern structural techniques. However, few engineers took up this challenge, as they were interested only in matters of strength, stability and calculation and gave little or none importance to the design concept.

One of the first engineers who did take up the challenge was Owen Williams who was never directly associated with British modernists or with the MARS group, but was nevertheless a great influence to many members of this group and particularly to Wells Coates. His building for Boots, built in 1932, is considered as a pioneer of the Modern architecture.

Two continental engineers, Ove Arup (Danish) and Felix Samuely (Austrian), were also active in Britain at this time and were interested in collaborating with architects, and they each joined both the Architectural Association and the MARS group. Ove Arup worked closely with Berthold Lubetkin and the Tecton group, while Samuely built the De La Warr pavilion with Mendelsohn and Chermayeff and collaborated with other Modern architects such as Connel Ward Lucas and Wells Coates.

OWEN WILLIAMS

It is not easy to evaluate the contribution Owen Williams made to the architecture of Britain or to the following generation of engineers. To begin with, the technologies he used were not particularly innovative, and we could almost say that he was technically a conservative who refused, for example, the new techniques of prestressed concrete in the post-war years. Besides, despite a fruitful collaboration with architect Maxwell Ayrton, most of his work was undertaken on his own, refusing any possible collaboration.

However, the frank and bold use he made of concrete, the material to which he devoted most of his work, had much influence on the architecture of his time and was decisive in establishing the Modern movement in Great Britain. Moreover, the analysis of his collaboration experience with Ayrton and his following disappointment can help us understand the difficulties that often arise in the design process and emphasise the importance that having common interests interests and trusting in each other skills has in establishing a successful collaboration.

Owen Williams' collaboration with architect Maxwell Ayrton began in 1921, when Williams was appointed as engineering consultant for the British Empire Exhibition in Wembley **(Fig. 1)**. Before this, Williams had worked for two of the main reinforced concrete companies in Britain, acquiring a solid knowledge in the new material, and had established his own firm in 1919.

The working relationship with Ayrton influenced Williams' career greatly, since it triggered his interest in architectural design. Together they worked to develop reinforced concrete as a visually attractive material, developing its aesthetic possibilities in order to change the general impression that concrete was a cheap material for use in industrial structures. This development they both believed could only be achieved through a close collaboration between engineers and architects. In an article published by Williams in 1924, under the title "Concrete as a partnership of engineering and architecture", he wrote:

> The engineer and architect have a long road to travel before their separate roles can be played by one man. [...] The engineer must realise that sound architecture is only sound engineering and the architect must believe that sound engineering is the only sound architecture. Beauty of design must not be considered the sole property of the architect, nor must the engineer assume exclusive possession of the theories of stability.
>
> (Newby 1987, p. 160).

In the buildings for the Empire exhibition Williams provided the technical knowledge to achieve an economy of means, while Ayrton directed his attention to the surface treatment of the concrete. Overall, however, the buildings failed to establish a new language for the use of concrete, as they essentially transformed classical masonry buildings into concrete shapes. However, the collaboration between the two disciplines, received much attention and the project awakened in Williams the interest in further exploring the possibilities of reinforced concrete.

He began to put this search for a concrete structural language into practice in the design of several bridges between 1924 and 1928, which he also did in collaboration with Ayrton. However, Ayrton's progressive lack of interest in exploring new forms in concrete architecture left Williams in a role of technical assistant when they returned to building design, and led Williams to abandon the idea of collaborating with architects. This break up was a big disappointment to Williams, leading him to the conclusion that, since the two professions had very different interests, it was not possible to collaborate. In 1929, in reply to the recommendation for collaboration between engineers and architects made by Ayrton in a lecture at the RIBA, Williams said:

> I do not believe an architect as an architect can collaborate with an engineer as an engineer... You have the opposition of two philosophic ideas.... [...] And if you think of architecture and engineering one trying to be practical and the other trying to say, "We have

a God-given mission to be effective", these two things are actually opposing doctrines, which cannot collaborate.

(Newby 1987, p. 161-162).

At about this time Williams obtained commissions for three major buildings that provided him the opportunity of putting into practice the ideas of structural simplicity he had developed while working on the design of bridges. The most acclaimed of these projects was the pharmaceutical factory for Boots at Beeston in Nottingham **(Fig. 2)**, that is still seen as having key importance to the development of Modern architecture in Britain. The two others commissions were the Dorchester Hotel and the Daily Express building in London, whose designs were also credited to architects, even though Williams assumed the total control of the design.

The Boots building was conceived as a concrete flat slab structure arranged on a rigid rectangular grid with long spans. The flat slab construction was well developed at the time, but the way Williams maximised its architectural potential, as in the "mushroom" heads of the columns, and the almost continuous glazing of the façade, was certainly innovative. The result is an impressive concrete and glass building, whose forms and details are determined by the function of the building and the most efficient use of reinforced concrete. The whole design rejects stylism and adopts functionalism as the main generator of architectural forms.

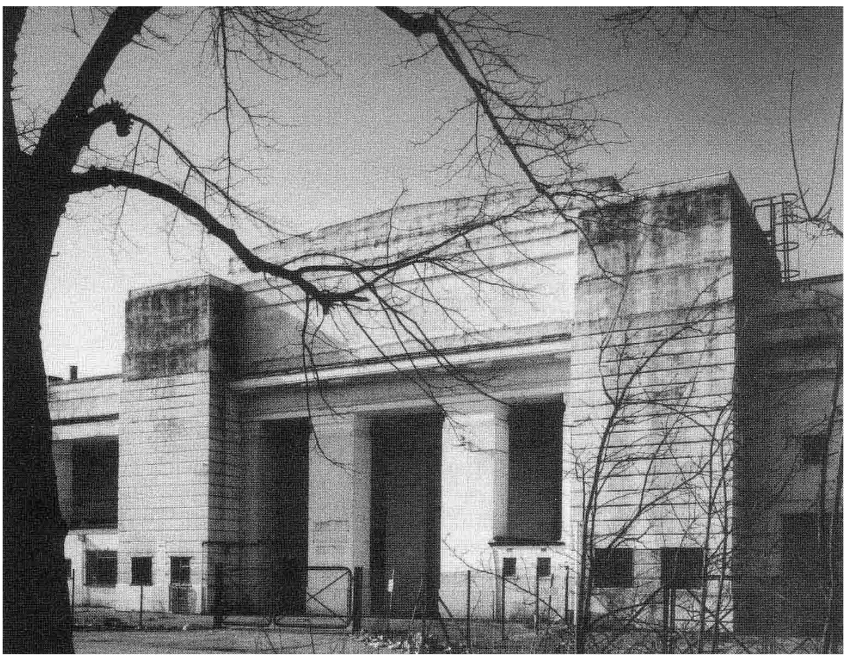

Figure 1. British Empire Exhibition, 1921. Maxwell Ayrton / Owen Williams (Yeomans 2001, p. 21)

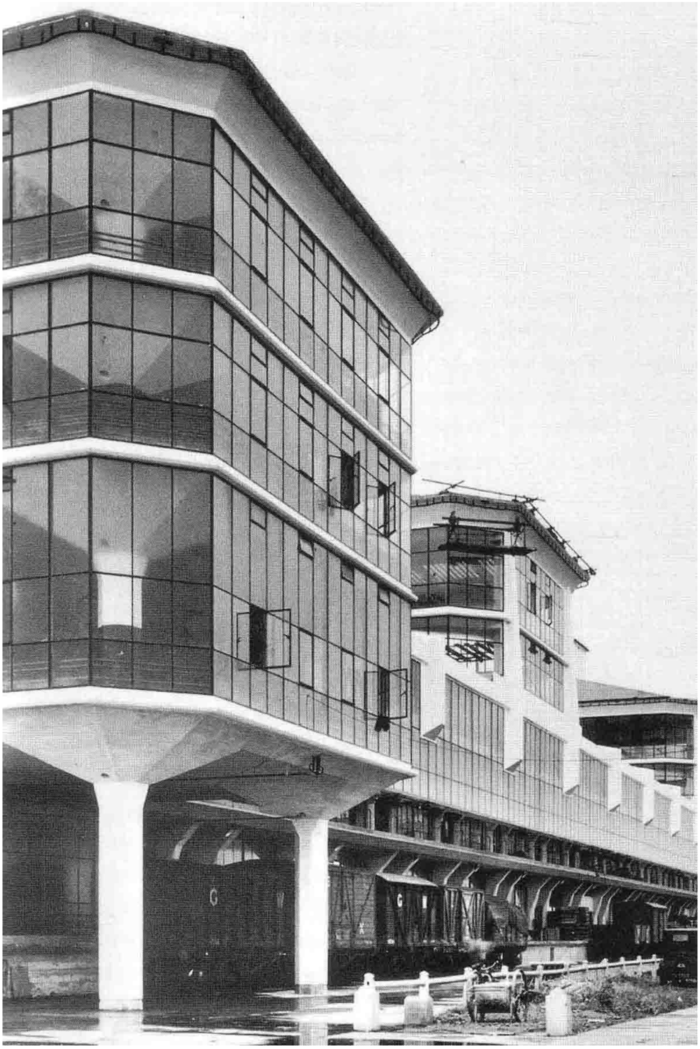

Figure 2. Boots pharmaceutical factory. Beeston, Nottingham, 1932. Owen Williams (Macdonald 2001, p. 13)

Williams functionalist design principles had greater relevance to large-span buildings where the scale of the problem presents more opportunities to maximize the display of the structure than in small buildings. Williams' successes were, therefore, mostly limited to large-scale projects such as the Empire Pool at Wembley in London **(Fig. 3)**. In this building, the structure is formed by a concrete frame structure with a series of three-pinned frames spanning the unprecedented distance of 72 metres. The whole structure is clearly expressed in the exterior, especially the massive counterweights or fins along the sides of the building, leaving the interior free of any evidence of his structural device.

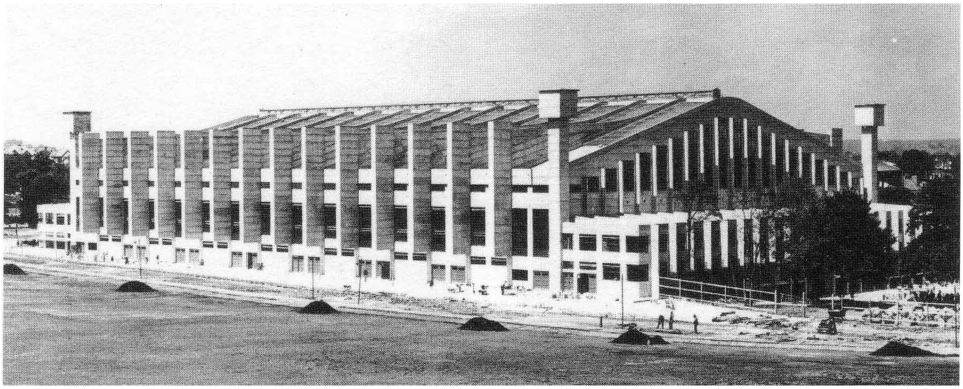

Figure 3. Empire pool. Wembley, London 1934. Owen Williams (Yeomans 2001, p. 109)

Williams' commitment to reinforced concrete undoubtedly had great influence on the engineering and architecture of Great Britain at the time, since it explored the potential of reinforced concrete, showing that it was possible to produce something different from familiar techniques.

OVE ARUP

The work and personality of Ove Arup is respected equally by both engineers and architects and has had an enormous influence on both professions. Arup probably contributed more than anyone to promoting an environment of trust, collaboration and respect between the two disciplines. In this sense it is important to note that Ove Arup was awarded the gold medal by both the RIBA and the Institution of Structural Engineers, a double which has been achieved by only one other man, Pier Luigi Nervi.

In thinking about the contribution Ove Arup made it is important to consider not only his ideas about the collaboration between engineers and architects and the importance he gave to the construction system, but also his humanitarian attitude. This, as well as his philosophy and ethics about the practices of engineering and architecture, have strongly influenced both professions. To understand these aspects better it is worth looking briefly at his life and professional career, since we can find in them the origins of his philosophy and his approach to design.

Ove Arup was born in Newcastle in 1895 and moved with his family to Hamburg the same year. His early interest in the seeking of Truth and Virtue led him to start studying Philosophy in 1913, but he soon became disappointed when he realised that to make any contribution to philosophy it was necessary to specialize; and he was not interested in the detail but in an overall view. He then became interested in Art and for some time considered the idea of becoming an architect. However, he did not feel artist enough to be a good architect, and he decided to start the studies of engineering at the Polytechnic School of Hamburg in 1916, where he graduated six years later.

His studies of philosophy had, nevertheless, greatly influenced his education and contributed to the formation of his ideas and his attitude towards engineering and architecture and the role they have to play in society.

After finishing his studies he joined Christiani & Nielsen, where he stayed for twelve years, two in Hamburg and ten in London. At this time Danish construction engineering was one of the most important of the world, particularly in concrete construction, and Christiani & Nielsen, who were designers and constructors, was a key player. To Ove Arup it was important that he started working in a contractor's office where he could build his own designs. He acquired a solid knowledge of reinforced concrete design and systems of construction, learning that to design you have to know how to build and that "design, cost and organization of the building site are not three separate operations, but need to be considered as one" (Arup 1995, p.15). This lesson deeply influenced his work afterwards.

However, working at a contractors office somehow frustrated Ove Arup, since there were few opportunities to refine the designs in order to create an artistic whole and he frustrated in not being able to continue developing his ideas in this direction. At this time he came into contact with some young architects from the "Modern Movement", in particular with Berthold Lubetkin and the partners of Tecton who were planning a residential block in Highgate, called Highpoint **(Fig. 4)**. Christiani & Nielsen were not interested in the project and Ove Arup moved to J L Kier & Kier Co. on the understanding that, as chief designer, he could work with Tecton and other modern architects. Arup and Lubetkin had already worked together on the gorilla house at London Zoo, and, when Arup was at Kiers, together they built the Highpoint project and the Penguin Pool at London Zoo.

At the time Highpoint One was constructed, tall buildings were usually supported by an orthogonal framework of structural steel. When reinforced concrete was introduced it was usual simply to replace the steel framework by a concrete framework; it was all a matter of columns and beams. Arup proposed to use walls of reinforced concrete as load-bearing elements and to replace the framework of floor beams by concrete slabs, thus removing all the columns and beams. This system needed to be accepted by the Building Authority, which was not easy, but once finished the building was much praised. It represents one of the clearest examples of the marriage of architecture, engineering and construction.

The penguin pool at London Zoo was also influenced by Arup's idea that "the slab was the natural form for reinforced concrete cast in situ" (Arup 1995, p.21) and it was a great success since it showed off the possibilities of reinforced concrete **(fig. 5)**. Felix Samuely also worked in this project; he was responsible for the complex calculations and for proposing the trapezoidal section of the ramps.

Figure 4. Highpoint One. Highgate, London, 1935. Lubetkin & Tecton / Ove Arup (Arup 1995, p. 18)

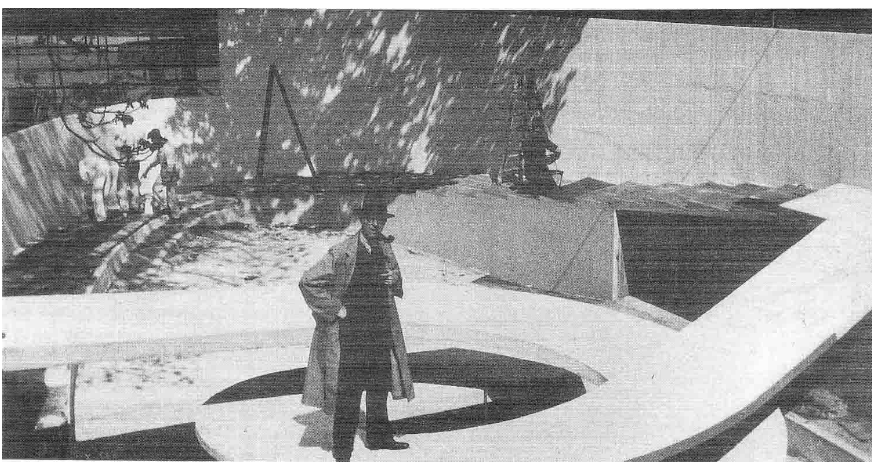

Figure 5. Ove Arup in the Penguin Pool, London Zoo 1934. Lubetkin & Tecton / Ove Arup (Arup 1995, p. 21)

After these works Arup became convinced that all aspects of the design and construction of a project had to develop closely from the start and that the collaboration that this required would contribute to building a better society. He then began his unceasing effort, by means of lectures and articles, to convince people of these ideas.

In 1938, in order to have the freedom he sought, Arup set up the construction firm of Arup & Arup with his cousin Arne and started to work as an independent consultant engineer. By this time he worked on several projects concerned with the war effort, including a shelter for protection against air raids, again in collaboration with Tecton.

In 1946 he left Arup & Arup and set up a new firm, the engineering consultancy Ove H. Arup Consulting Engineer, that would later be renamed Ove Arup & Partners. The success of Ove Arup & Partners was impressive, partly because of the high reputation Arup had achieved since his early collaborations with Tecton, but also because of the great efficiency the firm had in undertaking designs in reinforced concrete at a time when, due to the scarcity of steel, concrete became the main construction material. During this time Ove Arup was responsible for some of the most impressive concrete structures in Britain, such as the concrete shells at the Brynmawr rubber factory in Wales **(Fig. 6)** and the prestressed arches for the Bank of England Printing Works, in Debden near London (1952).

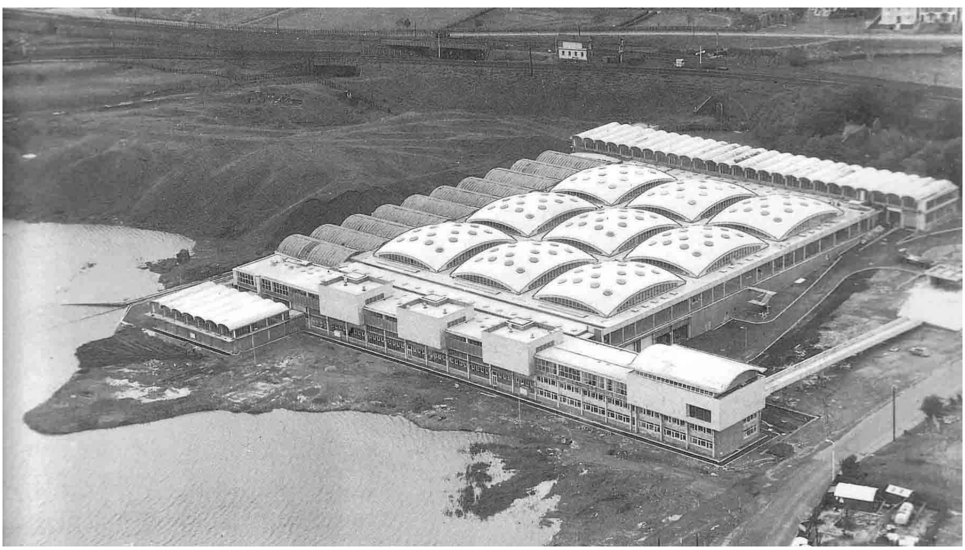

Figure 6. Rubber factory, Brynmawr Wales 1946-1951. Architects Co-Partnership / Ove Arup (Arup 1986, p. 16)

Ove Arup's active presence in the firm was constant until his death in 1988, as shown in projects such as the Sydney Opera House or the Kingsgate footbridge at Durham **(Fig. 7)**, the two projects that most attracted his attention and interest. However, as the volume of work increased, he gradually became less involved in the detail of projects, leaving their direction to chosen assistants. Among these project directors we can find some of the engineers that would later play leading roles in structural engineering during the second half of the twentieth century. Then, "Ove Arup the engineer made way for Ove Arup the thinker, teacher and prophet" (Rice 1989, p.434), dedicating himself to philosophy and thinking. During these times he gave or wrote almost 200 talks and articles, giving his views on a wide range of subjects. The subjects that attracted his greatest attention were the relationships and division of responsibilities between architects and engineers and the roles that engineering and architecture play in society and in shaping the environment.

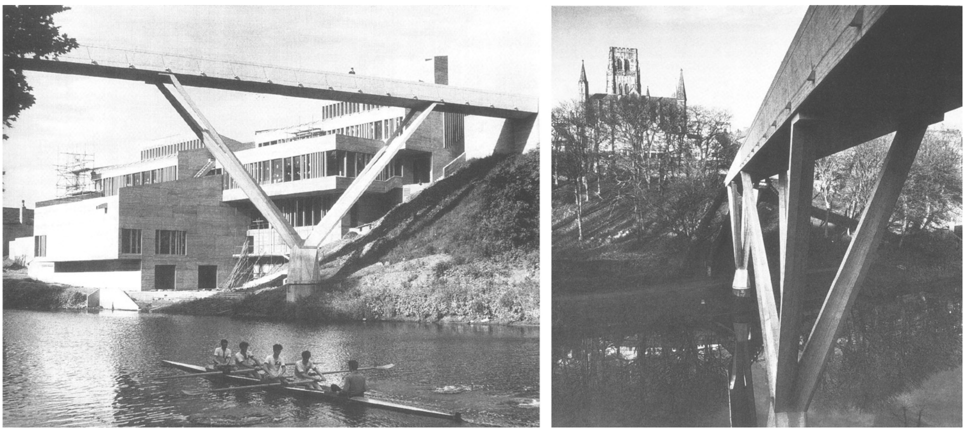

Figure 7. Kingsgate Bridge, Durham, 1961. Ove Arup (Morreau, 1995)

After this brief journey over Ove Arup's life and work we can highlight three main aspects of his contribution to engineering and architecture.

First there was his commitment and the importance he gave to the collaboration with architects, a field where he was a pioneer and even somehow an outsider, since in general engineers of that time tended mainly to be interested in matters of strength and stability and had little interest in contributing to the design concept:

> When he became a consulting engineer in 1946, the idea that an engineer should devote himself to working with architects was at least odd, if not faintly ridiculous. It was considered a marginal activity, one which you did in your spare time. It set Arup apart from the real engineers, a foreigner on two counts. It was an enormous affirmation of his beliefs.
>
> (Rice 1989, p. 430).

For Ove Arup it was necessary for engineers to realise that architecture and design were important, that engineering was useful and necessary but it was not enough, and that engineering could be something more than stability and structural calculus, contributing to give shape to the project. In a lecture in 1968 he says:

> Engineering is not a science. Science studies particular events to find general laws. Engineering design makes use of these laws to solve particular problems. In this it is more closely related to art or craft; as in art, its problems are under-defined, there are many solutions, good, bad or indifferent. The art is, by a synthesis of ends and means, to arrive at a good solution. This is a creative activity, involving imagination, intuition and deliberate choice.
>
> (Arup, Ove & Partners 1986, p. 19).

At the same time he encouraged architects to look at the design as a whole and to understand and respect the contribution engineers can make to design. This way he promoted a better understanding of the two disciplines and of the interdisciplinary design process.

Ove Arup's work can be characterised by the importance he gave to the construction process, as seen in early projects such as Highpoint One and in some construction projects during wartime. At Highpoint One he adapted sliding shutters, developed for the construction of grain silos, for use in constructing load-bearing walls. For the construction of multi-level air-raid shelters he developed, and took a provisional patent on, the "top-down" method of basement construction. (This technique consists in casting each floor slab on blinded earth and then excavating for the next pour, avoiding the cost and labour of building shuttering, and limiting the height of excavation unpropped to one storey).

Perhaps the best example of the importance of the construction process in the development of a design was the Sydney Opera House (1957-1973). Ove Arup's role in the transformation of the architect's competition-winning sketches into a feasible project was of great importance. Jorn Utzon's design of the roof incorporated a complex non-uniform geometry, extremely difficult to construct, which furthermore had too little curvature to work as a load-bearing shell structure. After several years of hard work and close collaboration between Ove Arup and Utzon what emerged was a solution where all the shells were segments of the same geometrical sphere, joined together by structural ribs. This system enabled the use of precasted elements, all with the same shape apart from their length, making the construction of the roof much easier **(Fig. 8)**. As Peter Rice explained: "A complicated and uncertain design had been transformed into a detailed proposal for construction and a solution where every element had a simple, logical and necessary existence" (Rice 1989, p.434).

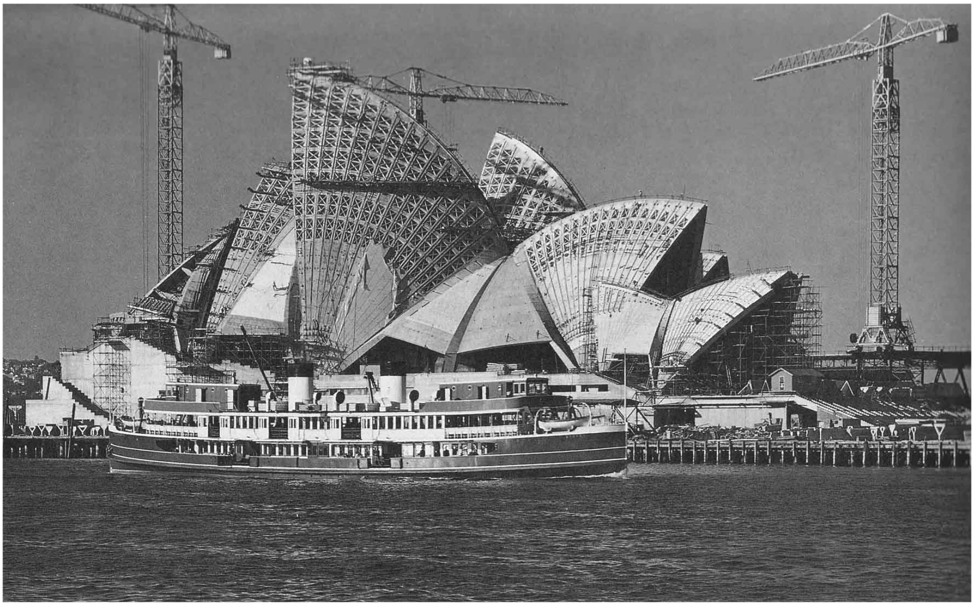

Figure 8. Sydney Opera House under construction, 1957 - 1973. Jorn Utzon / Ove Arup (Arup 1986, p. 100)

Finally, there was Ove Arup's concern about the fate of humanity, the importance of conserving the environment and the role that architects and engineers play in promoting these matters in society and in building a better world:

> My only hope is that this well-educated minority will swell to include the less well-educated majority so that even governments can start to think about how to alter course without creating worldwide chaos. It will be extremely difficult. It must be a slow and controlled process and its success depends on whether we can convince a majority of our leaders and their followers that we need to alter course. [...]. Pulling down is easy, building up is difficult. [...]. In the end all depends on our own integrity.
>
> (Rice 1989, p. 437).

Taken together, these three points – the collaboration between engineers and architects, the importance of the construction process, and the responsibility of engineers and architects in society – are what Ove Arup called "Total Design", the very quintessence of his thoughts and his philosophy, as expressed by two of his closest collaborators, Bob Hobbs and Jack Zunz:

> Ove's commitment to "Total design" is probably his greatest contribution to our profession in particular, and to society in general. Whether the totality refers to the integration of design and construction, the place of structure in architecture, the place of architecture in

> society or to the impact of modern technology on society, Ove brings his intellect to bear on issues with a directness and integrity which has set an example to us all.
>
> (Campbell 1995, p. 36).

FELIX SAMUELY

The other great "architects' engineer" of this period was Felix Samuely who worked briefly with Arup at Kiers. Samuely's approach to structures was quite different to Arup's, as Arup himself explained in a letter in 1982, where he described his relationship with Samuely at Kiers:

> I gradually realised that his [Samuely's] approach to structural design was somewhat different to mine. He was a typical professional engineer; his main endeavour was to produce a structure, which did the job with the least possible material, by applying his considerable knowledge of structural theory in which he had implicit faith. For me the important thing was the cost and soundness of the whole job; the design, materials and construction. I was striving for simplicity, both for its own sake and for ease of construction. My first question was – how can we best build this thing? His was - how can I make an elegant structure which does the job with the least material? The two are not necessarily the same.
>
> (Campbell 1995, p. 34, 35).

To some extent Arup's appraisals are right, since Samuely was highly concerned with the idea of minimal structure, working on structures that pushed the capabilities of the structural materials to their limits, while Arup was more interested in the construction process and the idea of "Total Design". However they both shared the interest in collaborating with architects and devoted their work to this common objective. In this matter, Samuely's interest rested in the suitability and adaptability of the structure to the architectural concept:

> The form of the structure is decided by the architect and engineer as there is no natural law which dictates the position of the structure in space.
>
> (Architect's Journal 1989, p. 7).

This interest of Samuely in the integration of structure and architecture can be seen not only in the projects he designed, but in the importance he gave to the education of engineers and architects, and to the establishment of an ambiance of mutual respect and trust between the two disciplines. To this end he devoted much of his time to teaching structures at the Architectural Association and collaborating as an active member of the MARS group.

In addition to his belief in the establishment of a true collaboration between architects and engineers, Samuely's other major contribution, stemming from his deep knowledge of new technologies and materials, was the exploration of new structural shapes. In this sense he was a pioneer in the development of space structures and folded slab construction in concrete, steel and timber.

After some time working in Berlin for a firm specializing in welded structures, Samuely moved to Russia where he spent two years investigating new techniques for welding structural steel. In 1933 he arrived in London and, after working at Kiers for less than a year, had the opportunity to put into practice the knowledge he had acquired during his stay in Germany and Russia. In collaboration with architects Serge Chermayeff and Erich Mendelsohn, with whom he had worked in Berlin, he designed the first all-welded steel structure in Britain for the De la Warr Pavilion in Bexhill in southern England **(Fig. 9)**. This project particularly caught his imagination not only because of its technical and structural novelty, but because it was done under the influence of the Modern Movement, at a time when these ideas were not yet widely established yet in Britain.

Figure 9. De la Warr pavilion, Bexhill-on-Sea 1935. Felix Samuely with Erich Menselsohn and Serge Chemayeff (www.samuely.co.uk)

Samuely's contribution to reinforced concrete design is less clear, since his first important project with this material was produced while working with Arup at Kiers, as mentioned above. Both Arup and Samuely used structural systems that were new at the time in which the external concrete walls were used as structural elements and floor slabs spanned to a spine beam. Arup employed this system at Highpoint One, while Samuely used it at the Whittingham College **(Fig. 10)** and in his collaboration with Wells Coates for the Palace Gate Flats in London. This last project showed clearly the freedom in planning that concrete made possible when used wisely; unfortunately the onset of the Second World War significantly reduced Samuely's influence in this direction. After the war and due to the shortage of steel and timber, Samuely worked on the development of precast concrete and folded plates in order to develop techniques that economised the use of materials.

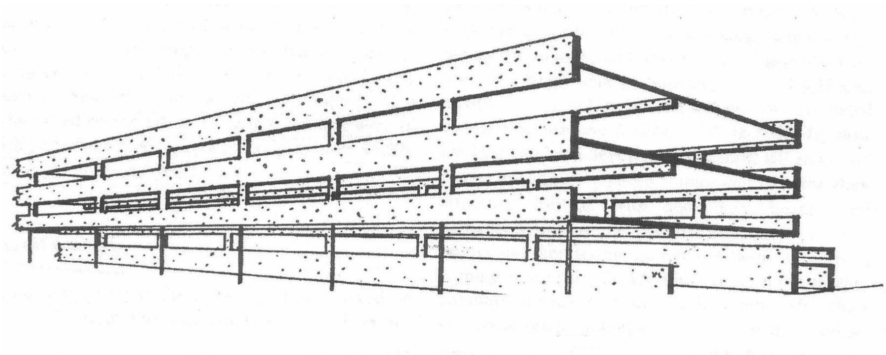

Figure 10. Whittingham College. Brighton, Sussex 1935. A. V. Pilichowski / Felix Samuely (Yeomans 2003, p. 2132)

Perhaps the most well-known structure that Samuely designed was the structure for the Festival of Britain in 1951, "The Skylon", in collaboration with architects Philip Powell and Hidalgo Moya **(Fig. 11)**. The Skylon consisted of a 76-metre cigar-like structure suspended 12 metres above ground by a system of three twin cables. The cables passed over the tops of three inclined pylons 21 metres high, and went down to the foundation anchorage. The major structural problem was to avoid excessive dynamic movement and to control the movement of the structure under wind loads. To achieve this he pre-tensioned the cable-system so that, for any load case, a certain proportion of tension remained in each cable, ensuring that the structure was restrained at any moment by the three cables.

This project was outstanding and represented a significant step in the development of spatial structures, a subject interested Samuely greatly. In a paper delivered to the RIBA he wrote:

> I think that at the moment we are on the eve of a great revolution and that hundreds of years hence people will look back on this time as being the one when construction changed over from 'plane' to 'space'.
>
> (Newby 1984, p. 19).

After his premature death in 1959 Frank Newby, one of his disciples, assumed direction of the firm and built on Samuely's work in the search for new and appropriate structural forms and techniques, collaborating with architects such as Cedric Price, Eero Saarinen and James Stirling **(Fig. 12)**. Newby also dedicated special attention to the analysis of the design process and to the teamwork methodology.

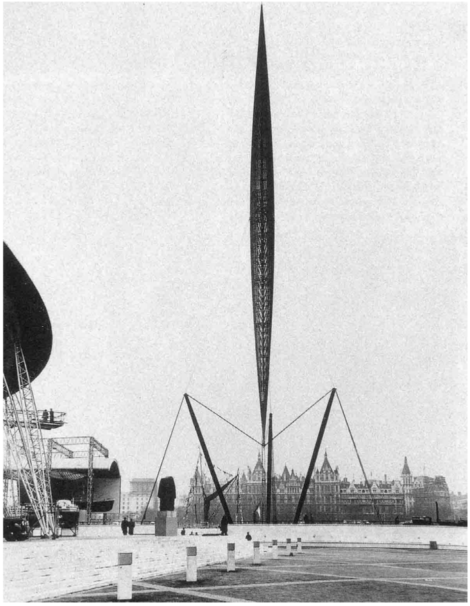

Figure 11. The Skylon. London, 1950-1951. Philip Powell and Hidalgo Moya / Felix Samuely (Picon 197, p. 459)

Figure 12. Aviary, London Zoo 1961-1964. Frank Newby with Cedric Price and Lord Snowdon (www.samuely.co.uk)

CONCLUSIONS

As we have seen, the work, ideas and proposals of the three engineers were quite different. However, they all played key roles in establishing the ways in which engineers can contribute to the design process and in establishing successful collaborations with architects.

From an analysis of their different experiences I would like to highlight the following points, since I consider them the main foundations of the collaboration between engineers and architects:

- Determination of the structural problem. This is the key point to understand the importance of the creative work of engineers and their capability to contribute to design.

- Holistic view of the design process. This means valuing other team members' knowledge and skills and realising the importance of their work in the design process, which is critical to establishing a true collaboration between the different disciplines.

- Self-awareness of the important role that engineers and architects can play in society.

- Education of engineers and architects, so that both can fully understand and appreciate the preceding points.

- Deep knowledge of structural materials and techniques, in order to use them in accordance with their properties, and allowing expression of their intrinsic qualities.

- Importance of taking into account the construction process.

- Complementarity of structural and architectonic project. Architecture and structure should be designed following the same concept so that both complement each other.

The legacy of these three engineers can be seen in the principal British engineers of the following generation: Anthony Hunt, who worked for some time at Felix Samuely & Partners; Frank Newby, who worked with Felix Samuely; Peter Rice, who worked in Ove Arup & Partners and founded the practice RFR in Paris, and Buro Happold, founded by Edmund Happold who also had worked at Ove Arup & Partners **(Fig. 13)**.

These engineers, along with Cecil Balmond (current chairman of the Europe Building division of Arup) represent in my opinion four of the main consulting engineering firms that still exemplify the structural engineers contribution to architecture: Ove Arup, Buro Happold, Anthony Hunt Associates and RFR.

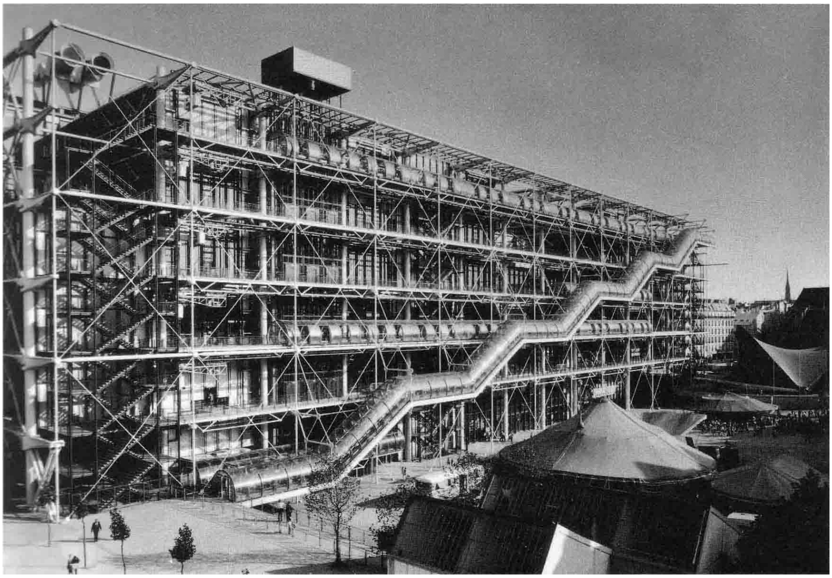

Figure 13. Centre George Pompidou. Paris, 1971 - 1977. Ove Arup & Partners with Renzo Piano and Richard Rogers (Arup 1986, p.104)

All these firms, “disciples” of Williams, Arup and Samuely, have continued to develop their ideas and to apply and improve their lessons, so that the collaboration between engineers and architects is more and more usual and successful. Peter Rice expressed this idea in an article about Ove Arup’s work and influence:

> Architects and engineers have learned to work together, not everywhere, not always, but sometimes, and that has made possible some very fine buildings. It has also changed things, and the message will go on spreading until it will no longer be possible for architects and engineers not to work together as a team.
>
> (Rice 1989, p. 437).

The beginning of the new century has been characterized by extraordinary innovations in auxiliary techniques and the computerisation of design and construction, creating a situation where almost any imaginable shape can be analysed and built. At the same time, our current society is creating a demand for more and more astonishing and spectacular buildings. In this situation the existence of an intense dialogue and collaboration between engineers and architects is more important than ever **(Fig. 14)**.

I think this is the way structural engineers can take up the challenge that new technologies and the architects’ requests in this new century bring: structural coherence and honesty, but open-minded to the new experiences proposed.

Remembering, once again, Ove Arup's words: "Why bringing an architect down to Earth if we can take him up to Heaven?" (Lyall 2002, p.9).

Figure 14. Serpentine Gallery pavilion. London, 2002. Toyo Ito / Cecil Balmond (Ito 2002, p. 52)

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