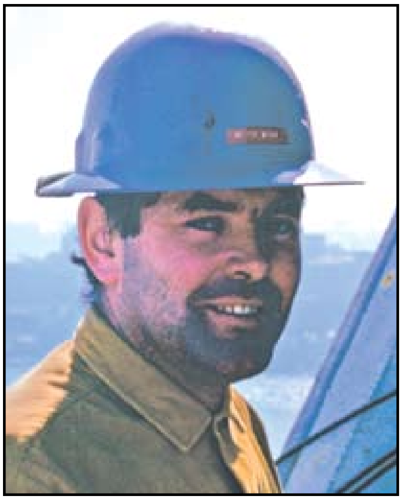
The Imaginative Engineer

Peter Rice (1935-1992)

By Lorraine Lin, Ph.D., P.E. and Bruce Danziger, S.E.

Peter Rice's approach to structural engineering expands our understanding of the engineer's role. Peter contributed to the design of buildings considered icons of structural achievement today. These include the Pompidou Center and the "greenhouses" at La Villette in Paris, the Pavilion of the Future for the 1992 World's Expo in Seville, Lloyd's of London and the Sydney Opera House. Many of his collaborators, such as architects Renzo Piano, Richard Rogers and I.M. Pei, are today renowned in their field partially as the result of their collaboration with Peter.



Peter Rice on site in Sydney (©ARUP)

Peter was a humanist and these beliefs are clearly present in his work. As a young man, he found himself overwhelmed by places like the Louvre Museum in Paris or the National Gallery in London, having grown up in rural Ireland away from the urban centers of culture. He aimed to construct buildings where ordinary people felt good, not alienated or intimidated by their environment. Peter looked to the history of structural engineering, particularly the Victorian engineers, for inspiration, noticing that the engineer's presence was still evident in these earlier structures. Buildings such as the great nineteenth century railway stations or the Grand Palais in Paris showed the engineer's personality in the choice of materials, detailing of the joints, and methods of fabrication and construction.

Gerberette, Pompidou Center, Paris (©ARUP)

> "This is the positive role for the engineer's genius and skill: to use their understanding of materials and structure to make real the presence of the materials in use in the building, so that people warm to them, want to touch them, feel a sense of the material itself and of the people who made and designed it. To do this we have to avoid the worst excesses of the industrial hegemony."
>
> *An Engineer Imagines*, Peter Rice

Three themes run consistently through Peter's work: Innovative use of materials and structural form, strong creative collaborations, and successfully challenging the building industry to construct beyond conventional boundaries. Peter once said that his engineering enabled him to explore the joy of experiencing successful architecture.

Materials

Peter's repertoire of structural materials included not only steel, concrete and timber, but also less obvious choices such as glass, stone, cast steel, cast ductile iron, Teflon fabric, polycarbonate, and ferro-cement. He used these materials to express the ideas within the architecture. Peter and his team combined advanced structural analysis techniques with investigations of materials to develop structural systems appropriate for each material. He believed that materials should be detailed to express their true nature.

Greenhouses at La Villette, Paris. Materials: Tempered Glass and Cables. Architect: Adrien Fainsilber. (©ARUP)

> "I have noticed over the years that the most effective use of materials is often achieved when they are being explored and used for the first time. The designer does not feel inhibited by precedent. . . In any of these structures, there is a simple honesty which goes straight to the heart of the physical characteristics of the material and expresses them in an uninhibited way."
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> *An Engineer Imagines*, Peter Rice

The design team for the Pompidou Center, which included Peter and the architects Richard Rogers and Renzo Piano, adopted the "gerberette" solution to achieve the long spans required to support a heavy library that could be moved anywhere in the building. One of Peter's main contributions was his insistence on the use of cast steel for these pieces. Each gerberette was cast to achieve the articulated profile, reflecting the piece's internal stress distribution under loads. The gerberette acted as a short beam propped on a circular column and tied down at the end with a circular bar. Cast steel was considered an old but unreliable material at the time, so the team used the new science of fracture mechanics to help convince the French building authority of the soundness of the design. This solution enabled the suspended trusses to achieve the required 147 feet (44.8 m) span.

Pompidou Center, Paris. Materials: Cast Steel Gerberette with Hierarchical Steel Structural System. Architect: Rogers & Piano Partnership. (©Bird Wong)

Peter recalled his sense of achievement after the Pompidou Center opened after watching an old woman sitting quietly stroking one of these massive gerberettes on the fourth floor — neither afraid nor intimidated by this very modern design.

For the Menil Collection in Houston, Peter and Renzo Piano made the decision to use

Menil Collection, Houston. Materials: Ferro-cement and Cast Ductile Iron. Architect: Renzo Piano Building Workshop. (©Richard Bryant)

IBM Traveling Pavilion. Materials: Timber and Polycarbonate. Architect: Renzo Piano Building Workshop. (©ARUP)

ferro-cement combined with cast ductile iron trusses to create the louvers for controlling daylight inside the museum. Ferro-cement has a soft grainy texture, which both reflects and evenly diffuses natural daylight. Ductile iron, although not as strong as cast steel, has high resistance to cracking and does not require heat-treatment after casting. The use of cast iron for the trusses allowed for the articulated form possible with casting, without the distortions which typically result from reheating. Construction of the louvers required tracking down a patented method of spraying ferro-cement into moulds with multiple layers of mesh reinforcement. The choice of materials helped make the Menil Collection a great success — subtle and graceful.

For their next collaboration, Peter and Renzo used timber, polycarbonate and cast aluminum to construct the IBM Traveling Pavilion. Although transparent, polycarbonate has high toughness but limited strength, which made it ideal for a single-story demountable structure. The semi-circular "truss" structure used timber struts for the top and bottom chords, and polycarbonate pyramids for the shear elements. Push-fit connections with rubber blocks reduced stress concentrations, due to the different thermal expansion coefficients of polycarbonate and timber. Cast aluminum connections expressed the structural nature of the timber struts — strong in tension and compression but weak in shear. The IBM Traveling Pavilion's special character resulted from the combination of materials and of blurring the distinction between structure and cladding.

Structural Detail for the IBM Traveling Pavilion. Materials: Cast Aluminum, Glued Stainless Steel Blocks & Rubber Blocks. (©ARUP)

When the "greenhouses" at LaVillette were constructed, the design was immediately recognized as a breakthrough in glass technology. Glass is a highly transparent, strong but brittle material. The curtainwall design built upon previous innovations at the Willis Faber Dumas Project in Ipswich, England, where glass panels are suspended in tension for gravity loads. The design at La Villette incorporated additional innovations: The tempered glass panels have drilled countersunk holes for point supports (i.e. spider fittings); spherical bearings keep all loads in the glass plane and eliminate local bending effects; and, the horizontal cable trusses resist out-of-plane wind forces, which required mastery of the nonlinear behavior of the tension structure. Many people contributed to the final design of the glass façade: the design architect Adrien Fainsilber, Peter's team at RFR including his co-directors — Martin Francis (who worked previously with Pilkington Glass) and Ian Ritchie (both had worked on Willis Faber Dumas) — and the French firm Boussois. The creation of the floating glass boxes at La Villette started the explosion of point-supported glass façades we see today.

Greenhouses at LaVillette, Paris. Materials: Tempered Glass and Cables. Architect: Adrien Fainsilber. (©ARUP)

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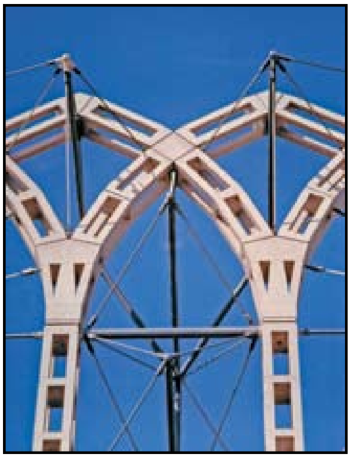
The self-stabilizing stone façade of the Pavilion of the Future in Seville built upon the innovations at LaVillette. The design was a collaboration with the architects Martorell, Bohigas, and Mackay. The standard stone unit was 32 x 32 inches, composed of smaller 8 x 8-inch subunits. Stone is strong in compression, but its use in arch structures is limited by stability rather than strength. Peter and his team at Ove Arup and Partners designed the lightweight stone blocks to perform similarly to classical stone arches, not as precast elements clad in stone. This meant designing the stone arches to allow for adjustments in their geometry due to changing loads, including the formation of hinges. Modeling this type of behavior required the invention of a new method of non-linear structural analysis. However, unlike classical stone arches where blocks are stabilized by the rigid body displacement of neighboring blocks, the stone units at Seville are self-stabilized by cables and struts. The final design is a very light façade of stone arches, but stays true to the character of the material.



Assembled Stone Module of the Pavilion of the Future. Details: Stone Blocks, Steel Struts and Cables. (©Fernando Alda)

Peter worked with many different architects on many different projects, and each project built upon his knowledge gained from previous projects. Lessons from his first project, the Sydney Opera House, are apparent in many later projects: The construction details, whether the tiles on the Opera House or the orientation of fabric seams at the Nuage (i.e. the Cloud) at the Grand Arch in Paris, allow reading of the geometry and bring the structure to a human scale. Repetition of geometry, such as the shells at Sydney and the trusses at the Kansai International Airport, ensures the quality of construction and helps reduce the cost of a novel structural solution.

Collaboration

Peter was able to increase his creativity by finding worthy collaborators. His collaboration with the Italian architect, Pritzker Prize recipient and friend, Renzo Piano, is legendary. However, his list of collaborators was diverse, and included other creative and innovative types. Peter attributed his numerous successful collaborations to his "chameleon factor", which allowed him to work with strong personalities having radically different design philosophies. Peter had a special ability to understand an architect's style and the fundamental ideas about a project. He looked for engineering designs that enhanced the architect's intentions. Innovation became a by-product of his method.

For example, Peter and Humberto Camerlo (a theater director and his friend) conceived, designed and constructed an outdoor theater in the south of France lit only with moonlight. This involved using computer programs to track the relatively fast-traveling moon during a performance with movable reflectors. The reflectors concentrate just enough moonlight to illuminate the stage. In contrast to the high-tech methods used to define the reflectors' geometry, construction of the theater employed primarily artisan techniques — those of carpenters and stonemasons.

Throughout his career, Peter drew upon the experts at Ove Arup and Partners from a range of disciplines – including structural, mechanical, electrical, lighting, and acoustics – to expand the impact of engineering on generating architectural forms. Another lifelong collaborator was Tom Barker, responsible for the innovative mechanical systems used at the Pompidou Center and Lloyd's of London.

Pavilion of the Future, Seville, Spain. Materials: Structural Stone and Pretensioned Cable System. Architect: Martorell Bohigas Mackay. (©Fernando Alda)

Challenging the Industry

Peter blamed the contemporary industrialization of the building process for the loss of expressing the engineer's personal preferences. The accelerated speed of construction and perceived notions of designing cost-effective buildings combined to trap the engineer in a process that does not allow for individual expression. He sought to bring back the joy in building structures that comes from not relying on obvious and first choice solutions.

> "Part of the problem is the sheer power and capacity of the building industry of today and the philosophy which underlies it. . . . People can no longer see the relationship between [the] individual capacity to build, individual inventiveness and the physical environment being constructed. . . The real issue in design must be to break the mould of industry-controlled predictability which dominates so much."
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> *Exploring Materials: The Work of Peter Rice, RIBA Royal Gold Medalist, 1992*

Kansai International Airport, Japan. Architect: Renzo Piano Building Workshop. (By Shinkenchiku-sha, Courtesy of RPBW)

Throughout his career, Peter repeatedly demonstrated the professional and intellectual courage needed to create daring designs and to challenge the industry. Peter did this by using ordinary materials to construct pieces at a human scale, which encouraged people to interact with them. He also introduced novel new materials in an ordinary context. Both were an invitation to the public to experience architecture, not as static photographs but dynamic spaces to be explored with texture and expressed structural systems that could be understood with some reflection.

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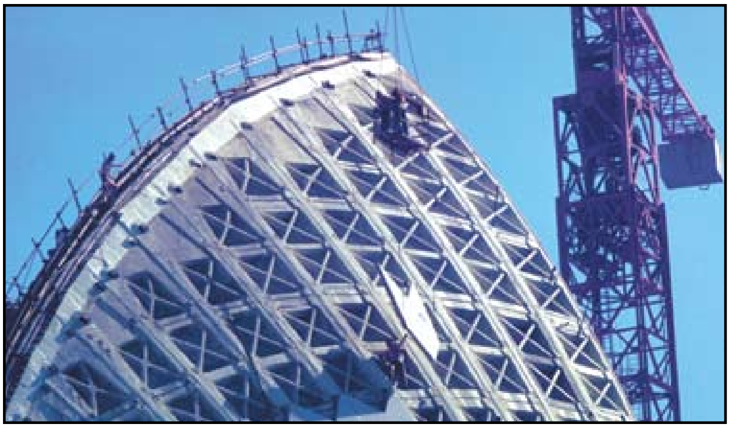
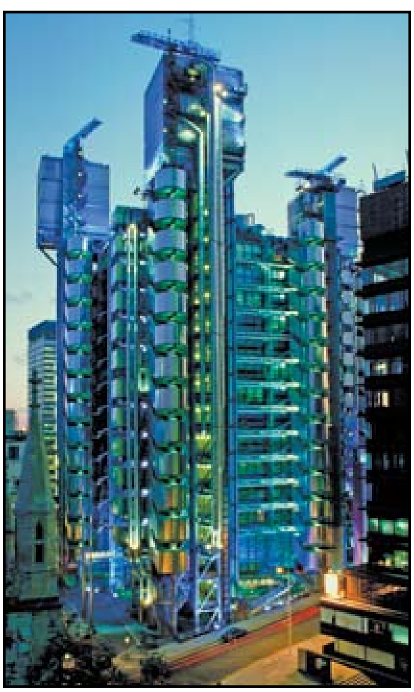


Sydney Opera House Construction. Materials: Concrete Structure. Architect: Jorn Utzon, Todd Hall & Littlemore, Hanson & Todd Pty Ltd, New South Wales Government, CP Wedderburn, Rudder Littlemore & Rudder Pty Ltd. (©ARUP)

The Process of Innovation

The role of the engineer is to innovate to support the creativity of architects. However, engineers are not immune to the industrial hegemony and often contribute to it. They are liable to fall into the trap Peter called the "Iago Mentality," based on the character in Shakespeare's play Othello. Iago undermines all budding inklings of creativity through rational argument, a role that engineers often inadvertently find themselves playing. This is the dilemma of the modern engineer – how to use rationality to support new creative endeavors without killing a nascent idea before it has fully taken shape.

Peter believed that there was nothing mysterious about the process of innovation. Never satisfied with mundane solutions, he would take time to quietly think about the projects and possibilities they offered. Surprisingly, given his range of materials and diverse structural systems, Peter confessed to learning just what he needed to know when he needed it. He found more than once that, after days of searching for a solution to a problem, it would often come to him as a fully worked out concept, sometimes after a good night's sleep. The time spent unsuccessfully searching for an answer seemed to clarify the parameters for him. If great commissions came his way, they were in recognition of the amazing designs that Peter could achieve, not the reverse.

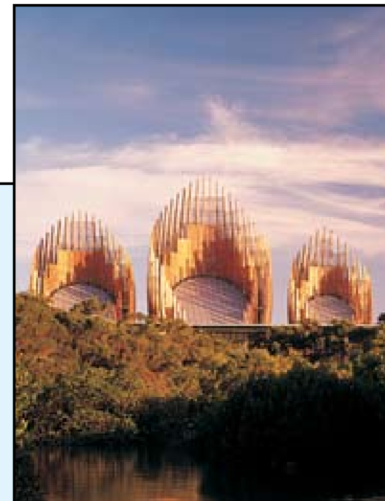


Lloyd's of London. Materials: Concrete Structure with Stainless Steel Cladding. Architect: Richard Rogers Partners. (©ARUP)

He believed that the driving force behind achieving innovative engineering began simply by getting started and having the courage to take risks during the early stages of the design process. For the stone arches of the Pavilion of the Future, Peter discussed the technological advances that made possible the final innovative design. First, enormous improvements in cutting stone allowed for tolerances a little as 1/50th of an inch. Second, the logical framework derived from previous projects, combined with evolving computational methods, allowed for the design of the self-correcting cable and stone system. After making some critical initial decisions about the design, "it's a question of following your nose; the material itself tells you what it wants to do" (RIBA Royal Gold Medal Address 1992). For example, extra cables added to help stabilize the stone arches "fell out" of the analysis and were removed from the final design.

"Peter Rice was one of those engineers who greatly contributed to architecture and strengthened the deep creative connection between humanism and science, between art and technology. . . Architecture is a creative job made up of moments of silence, of sudden intuition, of passionate teamwork — and this quintessence is the nature of Peter Rice."

Extract from Renzo Piano's supporting letter for Peter Rice's RIBA Gold Medal 1992



Jean-Marie Tjibaou Cultural Center, Noumea, New Caledonian. Materials: Timber and Cable Structure. Architect: Renzo Piano Building Workshop. Engineers: Ove Arup & Partners, Agibat. By John Gollings, Courtesy of RPBW

Legacy

Peter's legacy to the built environment is evident in the structures he engineered with his multiple collaborators.

Of course, not every engineer possesses the genius of Peter Rice. Through patient collaboration at the beginning stages of design and the use of state-of-the-art analytical tools, engineers can make substantial contributions to the public's enjoyment of architecture by allowing the not-so-obvious solution to surface. Peter Rice's work shows us that this is possible.▪

Acknowledgements

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