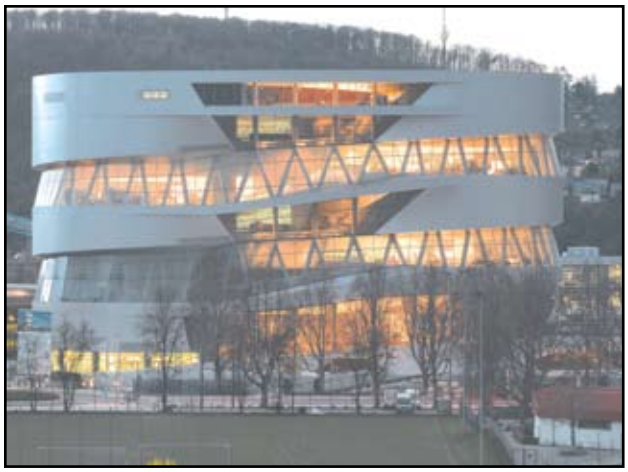
The Stuttgart School of Building Design

By Martin Trautz, Univ.-Prof. Dr.-Ing & Lorraine Lin, Ph.D., P.E.

Tanzbrunnen Fabric Roof in Cologne, Germany. Architect: Frei Otto. Courtesy of ILEK.

In Germany, the southern city of Stuttgart is a hot spot for engineering innovation. With a population of less than 600,000 inhabitants, Stuttgart is the home to internationally renowned companies, such as Daimler Benz, Bosch, and Porsche. However, not only premium cars and automotive products come from Stuttgart. The region is famous throughout Germany for the inventiveness of its people. It also gave birth to one of the most interesting modern movements in structural engineering and architecture, the "Stuttgarter Bauschule," also known as the Stuttgart School of Building Design.

To a casual observer, a key feature of the Stuttgart School appears to be aesthetic and structural expression. However, hidden features which have made this possible include the high technical competence of engineers and architects, a high degree of integration of both disciplines starting at the university level, precision construction methods, and a desire to construct lightweight structures. The faculty at the local university has maintained close links with regional engineering offices; in fact, many of the key members of the Stuttgart School have been simultaneously university professors and partners in thriving engineering practices, which has allowed them both the resources to innovate new ideas and the actual projects to put them into practice. An important condition that facilitated the flourishing of structural innovation in Stuttgart has been the constellation of personalities associated with Stuttgart University.



Museum of Daimler-Benz, Stuttgart Germany. Engineer: Werner Sobek. Courtesy of Christian Richters, Münster, Germany.

Curt Siegel (1911-2004), professor of statics and structural design at the faculty of architecture between 1950 and 1970, widened the spectrum of that discipline by introducing a systematic classification of load-bearing structures as an additional topic of his lectures and as a new field of building sciences. Siegel called this new field, which joins together static analysis of structures and structural forms, "Tragwerklehre." This can be translated as "teaching on structures" or the translation of statics and materials science into physical objects. In 1957, together with Fritz Leonhardt (see more below), who was then the chair of concrete structures at the faculty of civil engineering, Siegel organized design projects for students of architecture and structural engineering. Leonhardt recognized that Siegel's approach to "teaching on structures" was instructive not only to architecture students but also structural engineering students, so he was instrumental in ensuring that it became part of the engineering curriculum, as well.

Around this time, Leonhardt and Siegel fostered the appointment of Frei Otto (see more below) as the chair of lightweight structures and the foundation of a connected institute that conducted research on related subjects, which later became famous as the "Institute for Lightweight Structures" (IL). Frei Otto is an architect with a deep understanding of all things related to structures, structural forms, and development of structures in nature as well as in engineering. He specialized in design of tents and cable-net structures, and had already established a research laboratory for lightweight structures in Berlin.

These individuals formed the "critical mass" needed to extend the type of research conducted on the basics of structures, lightweight structures, structural detailing, and natural structures for which the Stuttgart School became famous. In 1969, Frei Otto and Fritz Leonhardt were initiators and founders of the first special research group, SFB 64, which conducted research on longspan structures at the faculties of architecture and civil engineering and was funded by the DFG (the German Research Foundation). This research group attracted many ambitious young engineers and architects. It also developed the scientific groundwork for one of the most challenging projects planned for the 1972 Olympic Games in Munich – the stadium buildings designed as a "landscape of tents" and built of cable-net structures by Günther Behnisch (b.1922) and Frei Otto. It was also one of Jörg Schlaich's (see more below) early outstanding projects. Schlaich later became well-known in his own right as a representative of the Stuttgart School, first while working at Leonhardt's office and then with his own practice.

This, then, is how the School began and developed as a collective project. To understand it better, we need to turn to the individual work of these founding members.

Founding Members

The Bridge and Tower Builder

A pioneering figure of the Stuttgart School was Fritz Leonhardt (1909–1999), a very gifted and intelligent engineer who made major contributions to bridge design and difficult civil engineering projects. The son of an architect, Leonhardt was born in Stuttgart and studied at the University of Stuttgart and Purdue University. During his stay in the United States, he hitchhiked across the country to study American long-span bridges and high-rise buildings. After returning from the United States, Leonhardt accepted a job in 1935 working for the German Highway Building Authority. There he was given the opportunity to build the first German suspension bridge near Cologne (Autobahnbrücke Köln-Rodenkirchen), which became the longest span in Europe at that time.

continued on next page

In 1953, he founded his own engineering practice together with Wolfhardt Andrä (1914-1996). The Leonhardt-Andrä Partnership (LAP) later became the most renowned engineering firm in Germany. One of their first projects was the development of standardized telecommunication towers for the German Postal Authority. In contrast to the steel structures traditionally used for this structure type, Leonhardt designed a tower in prestressed concrete, which he first constructed in his hometown. The "Stuttgart Television Tower" became a standard for many television towers in the world, and also an icon of Stuttgart. Leonhardt also developed the concept for cable-stayed bridge design that was first put into practice in Düsseldorf over the Rhine River in 1957. Positive acceptance of his design led to two more bridge projects, which became two additional cable-stayed structures in Leonhardt's veritable collection of bridges – later known as the "Düsseldorf Bridge Family." The planning and building of the Munich Olympic Stadium roofs as cable-net structures is further evidence of Leonhardt's versatility and engineering competence.

During his career, Leonhardt developed new systems for long-span suspension and cable-stayed bridges with improved aerodynamic stability that were more economical than traditional bridge designs. He also pioneered new systems and construction methods for prestressed concrete, including long-span prestressed concrete bridges. He is the author of *Bridges: Aesthetics and Design* (1982), a classic book on bridge design. His greatest ambition was to build a long-span mono-cable bridge, a suspension bridge with just one suspension cable. Unfortunately, Leonhardt was not able to fulfill this wish, which was left for others to pursue.

Stuttgart Television Tower, Germany. Engineer: Fritz Leonhardt. Courtesy of M. Ladner.

The Düsseldorf Bridge Family, Germany. Engineer: Fritz Leonhardt. Courtesy of SAA.

From Natural Structures to Lightweight Structures

Frei Otto (b.1925) was born the son of a sculptor in Saxony. His early interest in gliders and flight led him to develop an interest in lightweight design. Otto started his studies in architecture in Berlin and won a scholarship for a stay in the United States. There he met and was influenced by several architects who had left Germany to escape Hitler's regime, including Richard Neutra, Erich Mendelsohn, and Ludwig Mies van der Rohe. He went on to complete an innovative dissertation entitled *The Hanging Roof* (1954), which later became a standard work for tents and tension structures. In 1952, Otto founded his architectural office in Berlin, which evolved into a research center for the study of lightweight structures. In 1961, he founded a research group for biology and architecture at Berlin University, which investigated and compared natural structures with architectural structures.

With the founding of the Institute for Lightweight Structures (IL) in Stuttgart, Otto finally gained the solid research platform needed to pursue his broad, multi-disciplinary vision of natural structures, bionics, lightweight structures, forming processes, structural forms and textures, and reconstruction of historical design methods. A series of forty-one delightful and innovative books numbered "IL 1" to "IL 41" chronicle the work of Frei Otto and his Stuttgart-based institute.

In contrast to his outstanding reputation as a researcher, Otto's constructed work as an architect/engineer is not as comprehensive. However, the projects where Otto has been involved are almost all extraordinary, and therefore very popular. Together with Peter Strohmeier, the owner of a tent construction company, Otto developed the first tents with anticlastic form (i.e. double curvature similar to a saddle), which were built for garden

Power Plant Manzanares, Spain. Engineer: Jörg Schlaich. Courtesy of SBP, Stuttgart.

exhibitions and outdoor festivals. The most famous ones were constructed in Kassel in 1955 and Cologne in 1957 (Tanzbrunnen).

Appropriately, the Institute of Lightweight Structures is housed in an experimental building, an early cable-net structure similar to the German Pavilion for Expo '67 in Montreal or the roofs of the Munich stadium. In 1975, Otto was a consultant for an innovative timber grid structure with a pneumatic-like form designed as the roof of a multi-purpose hall for Mannheim's Garden Exhibition. The great aviary at the Munich Animal Park (Großvolière München-Hellabrunn) is characteristic of the architectural designs of Frei Otto. It is a large, light, cable-net structure covering more than 54,000 square-feet (5,000 square-meters). Recent consulting activities include the Japanese Pavilion for the World Expo 2000 in Hanover, Germany – a bamboo structure designed by the Japanese architect Shigeru Ban.

Shells and Structural Machines

Jörg Schlaich (b.1934) was born the son of a Lutheran minister and studied engineering at the University of Stuttgart, Technical University of Berlin, and Case Western Reserve University in Cleveland, Ohio. Schlaich became a protégé of Leonhardt with his research work on concrete structures. In 1963, he joined the office of Leonhardt-Andrä Partnership (LAP) and eventually became a partner, where he worked as a designer on many innovative projects. He was responsible for the design of a widespan concrete shell covering a swimming hall in Hamburg, several bridges, and also footbridges constructed of special structures.

In 1980, Schlaich established his own engineering practice with Rudolf Bergermann (b.1941). They started with an extraordinary project in Spain – the planning of a thermodynamic powerplant powered by air traveling through a 660-foot (200 meter) high chimney driven by the temperature differential between the ground and atmosphere. Schlaich-Bergermann Partnership's second project was the Hoogly Bridge near Calcutta, which they took over from LAP and then completed. This cable-stayed bridge was specially designed for ease of construction by requiring riveting rather than welding, which made it ideal for a developing country like India. Additionally, Schlaich extended a series of extraordinary footbridges in and around Stuttgart, which were variations on suspension bridges, cable-stayed designs, and bridge designs corresponding to the flow of forces.

Professor Schlaich's strength is invention and the realization of ideas, as his constructed projects clearly demonstrate. In 1974, Schlaich was appointed the chair of concrete structures and the successor to Fritz Leonhardt at Stuttgart University. Schlaich has been able to make many of Otto's ideas real, such as gridshells enclosing a swimming hall (Schwimmhalle Neckarsulm), the Hamburg History Museum (Museum für Hamburgische Geschichte), and an ice rink roof with an arch stabilized by a cable-net in Munich. More recent projects include adaptive bridges, such as a foldable bridge near Kiel in Northern Germany and a suspension bridge with a variable opening near Duisburg. Today, Schlaich collaborates with many famous architects, including Frank Gehry, Rafael Vinoly, Thomas Herzog, and Volkwin Marg. One of his most famous projects, the Twin Towers Memorial, is in New York City.

Next Generation

No school would be a school without disciples. Many of today's influential engineers and architects from the Stuttgart School have stood on the shoulders of giants. Schlaich considers himself a disciple of Leonhardt. He has mentored many other engineers, who worked as researchers at his institute at Stuttgart University, then later became practitioners and lecturers in structural engineering and related disciplines at various universities in Germany. Many of Otto's disciples became scientists, professors, and teachers, such as Ewald Bubner (b. 1932) at the University of Essen, Berthold Burkhardt (b.1941) at the University of Braunschweig, and Bernd Baier (b.1943) at the University of Essen. Another example is Mahmud Bodo Rasch (b.1943), who converted to Islam and now is the most important planner of lightweight structures and tents in the Arabic world, including for the Great Mosque at Mecca.

Cable-net clad with timber at the Institute for Lightweight Structures and Conceptual Design (ILEK), University of Stuttgart. Architect: Frei Otto. Courtesy of ILEK.

Among the next generation of engineers who have studied and worked with Schlaich, Werner Sobek (b.1953) is probably the best known. He studied civil engineering and architecture in Stuttgart and benefited from the multi-disciplinary approach taught

Folding bridge near Kiel, Germany. Engineer: Jörg Schlaich. Courtesy of M. Winzenburg.

there – the direct result of the educational infrastructure put in place by Leonhardt and the other professors. As both a structural engineer and architect, Sobek has developed strong collaborative relationships with architects, which has made him one of the few internationally recognized structural engineers. Sobek started as an engineer in Schlaich's office, where he designed a pneumatic roof for the Roman arena in Nimes, France. He opened his own engineering practice in Stuttgart in 1992 and was appointed in 1995 the successor to Frei Otto as the director of the Institute for Lightweight Structures (IL), which was merged with a large institute headed by Schlaich to form the new "Institute for Lightweight Structures and Conceptual Design" (ILEK). Together with the German-American architect Helmut Jahn, Sobek planned and designed the new airport in Bangkok. Daimler-Benz's new museum in Stuttgart is likely his most exciting recent project, which he developed with the Dutch architect Ben van Berkel. The building has a complicated free-form architectural design that required even more complex engineering.

Jan Knippers (b.1962) is another of Schlaich's disciples. He studied in Berlin and was later backed by Schlaich at Stuttgart University and worked in Schlaich's office. Knippers is a specialist in the design and analysis of gridshells. He is responsible for the design of the Kiel Folding Bridge, a movable bridge in the German state of Schleswig-Holstein. In 2001, he took over the chair formerly occupied by Curt Siegel and founded his own practice. His most famous project is a beautiful curved glass enclosure for the company Peek & Cloppenburg in Cologne, which he designed with Pritzker Prize-winning architect Renzo Piano.

Conclusion

The Stuttgart School of Building Design has increasingly extended its influence and expanded its reputation, first nationally within Germany, then throughout and beyond Europe to North America, Asia, and the Middle East. This includes the United States – where many of its founding members, such as Leonhardt, Otto, and Schlaich, studied as young men and found some of their early inspiration.▪

Univ.-Prof. Dr.-Ing. Martin Trautz is Head of the Chair for Structures and Structural Design at the Faculty of Architecture at Aachen University (RWTH Aachen) in Germany. He also heads his own engineering consulting practice in Frankfurt/Main and Aachen. Professor Trautz earned his Ph.D. from Stuttgart University and has worked with many of the individuals mentioned in this article. He may be reached at ***trautz@trako.arch.rwth-aachen.de****.*

Lorraine Lin, Ph.D., P.E. was a guest researcher at the Institute of Lightweight Structures (IL), University of Stuttgart in 1995, where she conducted research on natural tension structures. She holds graduate degrees from UC Berkeley in structural engineering and the Graduate School of Design at Harvard University.