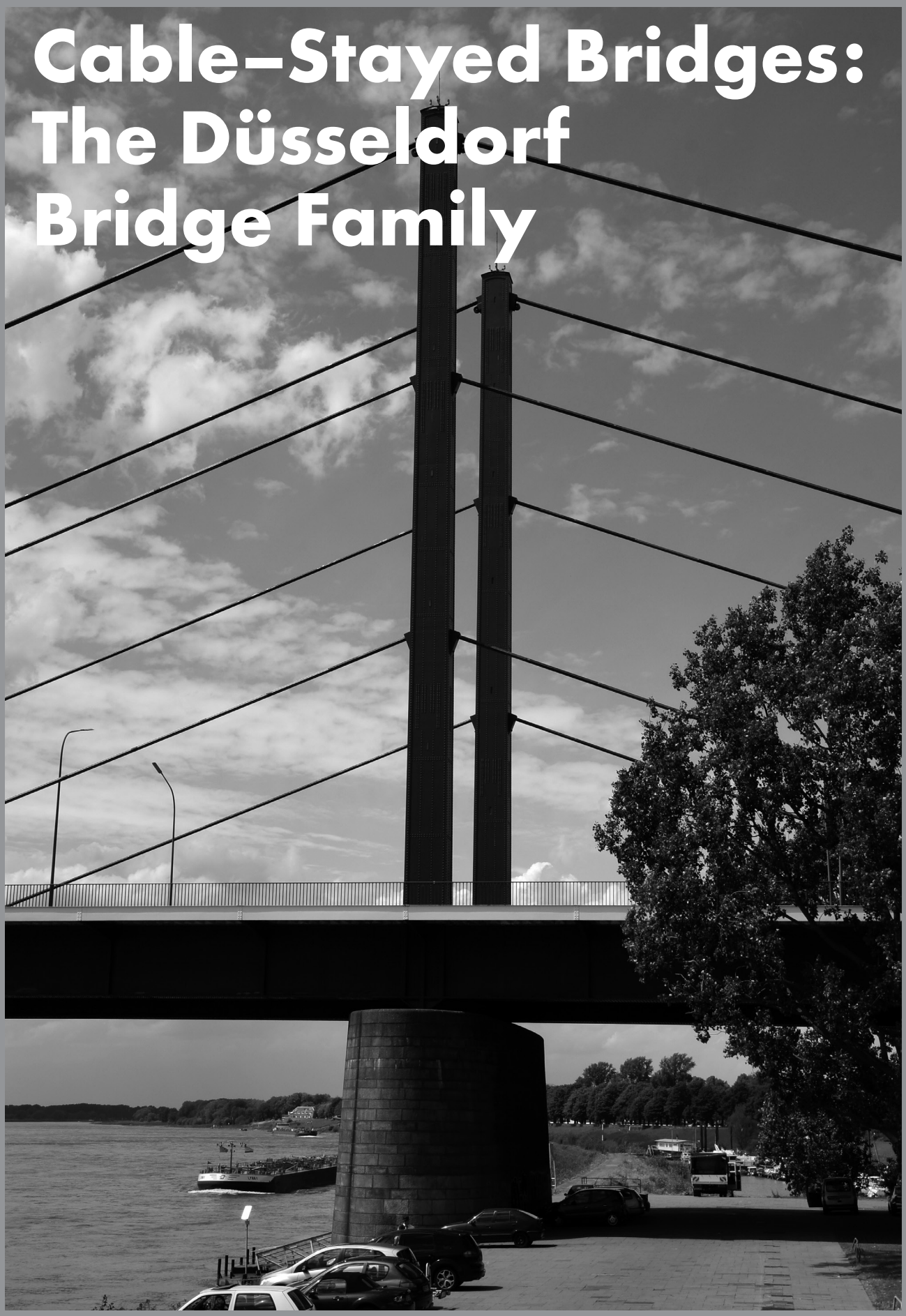
Cable–Stayed Bridges: The Düsseldorf Bridge Family



THE heart of the famous Düsseldorf Bridge Family are the three cable–stayed bridges built between the late 50s and early 70s of the last century. They mark the beginning of the development of Modern cable–stayed bridges, but not only from a technological point of view. Instead they develop the aesthetical potential once the new structural type has become favorable all over the world.

By Annette Bögle

SPANNING light and elegance over the Rhine riverbend in Düsseldorf, these three cable–stayed bridges became famous as the Düsseldorf Bridge Family and marked the beginning of the development of Modern cable–stayed bridges. But the principle of using cables to hang up the walkway and the use of tension elements instead of compression and bending elements with the aim of reaching wider spans is quite old. Indigenous bridges still use natural growing materials like lianas for suspensions. The stay–cable as structural principle is also well known from sailing boats with their spatial guyed masts. Likewise the striking element of a cable–stayed bridge is the mast with diagonal cables, anchored directly on the mast and a suspended bridge deck in both directions.

Early realized bridges with stay cables are quite often a combination of suspension and stay cables of which the Brooklyn Bridge by John August Roebling is one of the most famous examples. Here additional stay cables stiffen the bridge deck against wind impact and heavy traffic load and give the bridge a singular appearance with a high recognition value. But it was not before mid 20th century that the structural potential of this principle was fully detected and developed as a Modern rational structural principle, particularly consequence of the increasing industrialization of the building trade.

The first stay–cable bridges have only few (1 to 3 or 4) stay cables. In this case the deck is only supported on few points which results in a correspondingly larger depth of the beam. Instead more cables with smaller distance simplify the structure of the deck as well as the construction method. Consequently quite large spans can be built with an exceptional slender deck. To arrange the cables there are numerous possibilities, but two extremes can be described. Technically, the most efficient one is the fan shape with all cables meeting at the top of the tower. The other extreme is the harp shape where all cables are parallel and equally distributed over the height of the tower.

< Theodor Heuss Bridge, Düsseldorf, 1957. Photo by Nicolas Janberg.

The Strömsund Bridge, built in 1956 in Sweden, gets the credit to be the first Modern cable–stayed bridge. The bridge hangs from two cables on each side, building a fan. From different angels this leads to an irritating appearance of the cable. It seems that the design of this bridge focuses on the development of a new structural type, for example with pre–tensioned stay cables, but from the aesthetic point of view the bridge just shows the known language of suspension bridges and is not further developed. On the way to a distinct structural aesthetic expression, the design of the Düsseldorf Bridge Family seems to be more important.

As in many cities, the Second World War left tremendous marks in Düsseldorf and the existing bridges over the River Rhine did not last beyond its end. This in particular had an immense impact on infrastructure and economy as Düsseldorf connects important economical centers from east to west and along the Rhine River from north to south. Consequently not only the simple connection of the river banks was very important for the city, but also a reasonable link to the whole road network. Furthermore all bridges had to be reconstructed in a time where high quality material, especially high grade steel, was very scarce, making the design of material–efficient bridges mandatory. The responsible architect of the urban concept of the first three bridges, Friedrich Tamms, required a slender and elegant design avoiding any mighty or powerful gestures, also focusing on the design of cable–stayed bridges.

The boundary conditions were dominated by the river traffic: navigation required a big clearance and the quite lively river traffic was not to be disturbed during construction. With these conditions, the most favorable typology at that time was the newly developed structural type of the cable–stayed bridge which allowed the light appearance, efficient use of materials, large spans and cantilevered erection. With the design and construction of these bridges, the leading engineer Fritz Leonhardt gained fundamental knowledge on the structural behavior of cable–stayed bridges. In this way the Düsseldorf Bridge Family can be seen as the starting point of the development and establishment of this worldwide fascinating bridge type.

1

Figure 1. The impressive net generated by the vertical hangers and the diagonal stay cables of the Brooklyn Bridge, New York, by **John August Roebling**, 1883.

Figure 2. *Kniebrücke* (Knee Bridge), Düsseldorf, 1969.

Figure 3. Theodor Heuss Bridge known as the North Bridge, the first member of the Bridge Family. Düsseldorf, 1957.

Figure 4. Oberkassler Bridge, the third bridge which forms the core of the Bridge Family. Düsseldorf, 1973.

2

Not by accident Leonhardt became involved in the design of these bridges. He had been working with Tamms before the war at the office for construction management of the *Reichsautobahn*. Leonhard was not only enthusiastic about bridge building, furthermore in the early 30s he had the opportunity to travel through the United States and to study the most Modern suspension bridges like the just finished George Washington Bridge in New York and to meet the responsible designer Othmar Amman; both certainly an impulse for his fascination for any cable suspended bridge in particular and his sustainable interest in a holistic design of bridges which goes beyond the solely calculation of bridge design.

Today 7 bridges belong to the Bridge Family, but the heart consists of the three cable-stayed bridges built between the late 50s and the mid-70s. Even if during this long time period there has been much progress in design and construction, the original urban and aesthetic concepts of Tamms were realized for all bridges with all of their recognizable values. Although each of them is in a slightly different situation and function they speak a similar structural language as they all use harp-shaped stay cables. The harp-arrangement was chosen to avoid any entanglement of the cables which would appear e.g. if the cables met at the top of the mast in a radiating way.

The Theodor Heuss Bridge—among many local peo-

3

4

ple still known as North Bridge—was built in 1957 as the first member of the Bridge Family. Instead of the common pylons of suspension bridges in form of a gateway, here two pairs of slender masts characterize the symmetric bridge with a main span of 260 m. The aerodynamically shaped deck is held by only three parallel cables on each side of the masts, thus the deck has to be comparably thick. But the harp arrangement of the cables avoids any irritating view through a maze of cables. Furthermore the few cables disappear from a distance and the bridge seems to be slender and strong at the same time.

The slender freestanding steel masts taper till the top and do not need any cross beams, thus the lateral stiffness is quite small. But as the deck is stiff and the masts are only 40 m high, it is sufficient. The detailed analysis of the load bearing behavior of this bridge and its construction allowed the clarification of the principle of stay–cable bridge structural behavior.

The next bridge being built in the riverbend was the *Kniebrücke* (Knee Bridge). The design was finished in the 50s but was not realized before 1969 and then with only minor changes. To achieve an accent opposite to the high–rise buildings on the right river bank the bridge is unsymmetrical with only one pair of masts towards the left side. The 114–meter–high masts and the 4 parallel cables are arranged outside the deck. To avoid cross beams, the masts have a T–shaped cross section. Here each stay cable is anchored directly to the columns of the adjunct floodland bridge which lead to a stiff suspension in the main 320 m span and allows this unbelievable slender deck.

Located between these two described bridges the Oberkassler Bridge was built in 1973. The design of this bridge was strongly influenced by the construction process. The bridge had to be built next to an existing auxiliary bridge and then, as the first cable–stayed bridge, shifted laterally into the final position. Therefore only one mast was chosen and placed in the middle to create a symmetrical bridge. The four parallel cables are symmetrical to the mast which has the advantage of a total balanced bridge under dead load. In this case, as well as during the shifting process, the anchorage of the back stay cables in the columns in the floodlands is not needed.

With these three bridges, the core of the Düsseldorf Bridge Family was erected. The city is proud of its harmonious appearance and identifies itself with its bridges. This once more proves the importance of structural design in general and of the contribution of Fritz Leonhardt and his team to structural design in particular. Furthermore Leonhardt influenced the engineering community not only through his design, but also as a teacher, lecturer and through his publications. Not only to focus on simple feasibility but also develop aesthetic quality along with technical innovations is the important message for today's engineering coming from Fritz Leonhardt and his Düsseldorf Bridge Family.

References

Bühler, Dirk, *Brückenbau im 20. Jahrhundert, Gestaltung und Konstruktion*, Munich, DVA, 2004

Janberg, Nicolas and Billington, David P., "Die Ästhetik moderner Schrägseilbrücken", Baukultur 3, 1998, 12–16.

Kleinmanns, Joachim and Weber, Christiane (Hrsg.), *Fritz Leonhardt 1909–1999. Die Kunst des Konstruierens/The art of engineering*, Fellbach, Edition Axel Menges, 2009.

Leonhardt, Fritz, *Brücken/Bridges*, Stuttgart, DVA, 1982.

Svensson, Holger, *Schrägkabelbrücken: 40 Jahre Erfahrung weltweit*, Berlin, Ernst und Sohn, 2011.

Walther, René, *Schrägseilbrücken, Bau und Technik*, Düsseldorf, 1994.

Annette Bögle

Engineer of structural design, author and curator. Since 2011 she is professor at the HafenCity University in Hamburg, teaching structural and architectural engineering.