Long span bridges and Fritz Leaonhardt's heritage

by Michel Virlogeux

FIP and *fib* Honorary President

1. Introduction.

It is not possible to take part in a series of lectures in memory of Fritz Leonhardt, ten years after the 1999 event and almost ten years after he passed away, without referring to him. Of course many engineers, who worked with him or whom he educated when he was Professor at the Stuttgart University, are in a better situation to evoke him, his career and his achievements. But I can show what he has been for a young engineer – since I have been a young engineer some years ago – who lived and worked in another country and was not associated with his University, his company nor the wide circle of his close relations.

I saw him for the first time – from very far – at an IABSE Congress in Tokyo, in 1976. I was thirty years old at the time and I have been deeply impressed by the great engineers to whom I could listen to there, including of course Fritz Leonhardt who certainly was the most famous. And it is clear that it had a strong influence on my career.

It is only very much later that I could really speak with him for the first time, in another IABSE event, devoted to the maintenance of historical monuments, in Rome, may be in 1993 ; he was almost alone in the Castello San Angello and I could discuss some time with him. I must confess that I don't remember of what; but this is probably at this occasion that he told me that I was wrong to speak about "bridge architecture" since this could give the impression that bridges are to be designed by architects.

But my closest relation with the Fritz Leonhardt school came through two of his most famous past collaborators, who became very good friends and whom I really admire, René Walther and our Chairman, Jörg Schlaich.

When you look backwards to the last 50 years – and even more – and to the structures designed or imagined by Fritz Leonhardt, René Walther and Jörg Schlaich you can have a clear idea of Leonhardt's influence on modern civil engineering.

But I have been two long and have to concentrate on my theme, and more precisely on two aspects of Leonhardt's work:

– his influence on bridge architecture; I keep this wording despite his recommendation,

– ands his pioneer works in cable supported bridges.

2. Structural art.

I remember that, in 1999 I think, Paul Andrä evoked Leonhardt's red books. I cannot keep smiling when thinking of the famous small red book by Mao Tsé Toung – to which Paul in fact referred –, and of the big red books of Fritz Leonhardt which are certainly more influencial today than the other one.

I must confess that have I never read these big red books; but as soon as they have been published, I have considered Leonhardt's book on bridges as one of the most important on bridge history and architecture.

Besides the historical presentation of bridge construction, this book – published in four languages – develops Fritz Leonhardt's philosophy of bridge elegance. I took some examples from this book to evidence which are the keys to bridge perfection according to Leonhardt, and to me:

– unity,

– good proportions,

– a clear flow of forces,

– a perfect integration in the site,

– slenderness – without being excessive – to maintain the transparency of the landscape,

– "Ordnung"; I cannot find a good word in English or French to express the idea that the bridge lines must be organized and coherent,

– harmony,

– and adapted colours when needed.

These ideas govern what David Billington calls the structural art, in complete opposition with some modern trends which tend to design structures for "originality", often for provocation, frequently in a complete opposition to a logical flow of forces.

The bridges which I have designed follow Fritz Leanhardt's philosophy of bridge elegance – even if initially I ignored it – and are rather classical. I have never designed a bridge with the goal of making from it a "signature bridge", or a "landmark"; I have always tried, as a designer or only as a consultant, to erect a honest structure, adapted to the functional goals and to the site, as shown by some examples such as:

– the Truyère viaduct, close to the famous Garabit viaduct by Lucien Boyer and Gustave Eiffel,

– the Piou and Rioulong viaducts,

– the La Planchette viaduct,

– the Antrenas and Truc de la Fare overpasses,

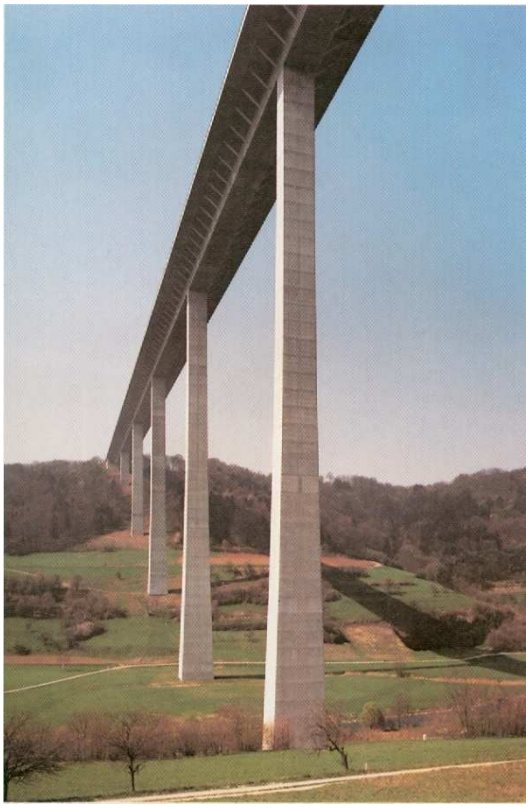
– the Verrières viaduct, all on the A75 Motorway;

– the Bridge over the Loch at Auray,

– the Seyssel cable-stayed bridge, my first cable-stayed bridge,

The second Cologne–Deutz Bridge (1978)

The Moselle Viaduct at Winningen (1972)

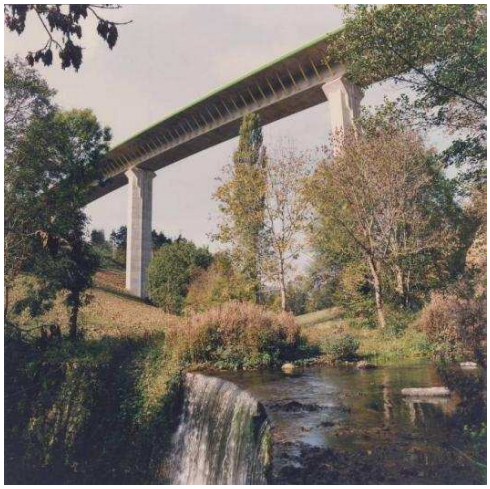


The Koshertal Viaduct (1979)

The Neckar Viaduct at Weitingen (1977)

The Truyère Viaduct on the A75 Motorway

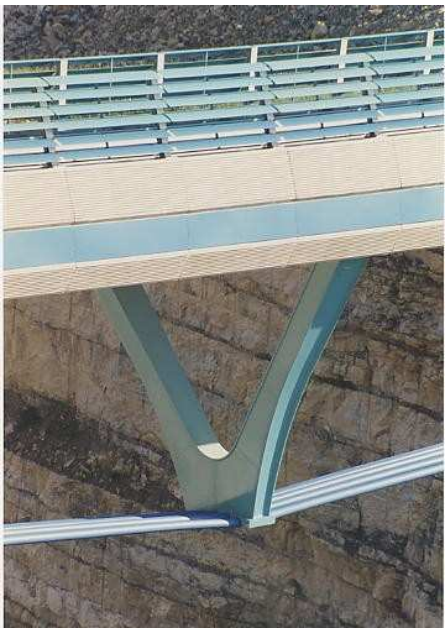
The Piou Viaduct on the A75 Motorway



The Rioulong Viaduct on the A75 Motorway

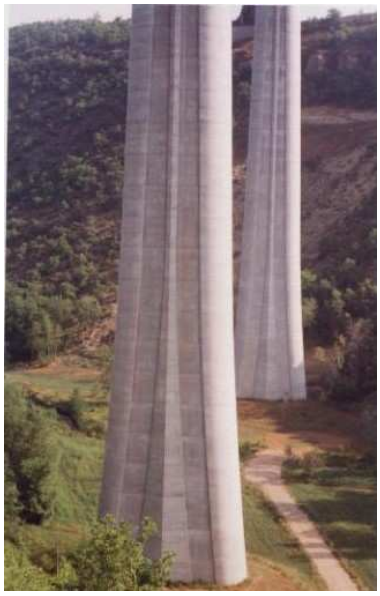
The La Planchette Viaduct on the A75 Motorway

The Antrenas overpass on the A75 Motorway



The Truc de la Fare overpass
on the A75 Motorway

The Verrières Viaduct on the A75 Motorway



The bridge over the Loch at Auray

The Seyssel Bridge over the River Rhone

– the Sarreguemines pedestrian bridge, widely inspired from Jörg Schlaich's splendid pedestrian bridges, even if by far less audacious,

– the Chateaubriand and Morbihan arch bridges,

– the Burgundy cable-stayed bridge,

– the Limoges urban arch bridge,

– the Gignac arch bridge, close to a famous stone arch of the 18th century,

– and finally the Gustave Flaubert mobile bridge.

Even in such more or less classical structures, it happens that a problem appears during the development of the design, calling for an amendment, or an addition. But amending or adding is not the correct solution; the design has to be reconsidered from start, and the solution developed in such a way that this problem is incorporated in the set of data and constraints, and solved by the global design concept itself; this is the key for the unity and coherence of the structure.

Our chairman, Jörg Schlaich, rightly recommends variety; I hope that these examples, as well as those given by Leonhardt in his book, show that variety can be produced without opposing structural logics. I am convinced that rather classical structures, if properly designed, produce a nice and quiet space; my personal opinion is that "signature" structures, "landmarks", frequently designed with some provocative shapes, are more aggressive to the public and must remain the exception.

3. Pioneer cable supported structures.

Fritz Leonhardt has been a pioneer in many domains of civil engineering, but I am of course mainly interested in cable supported bridges.

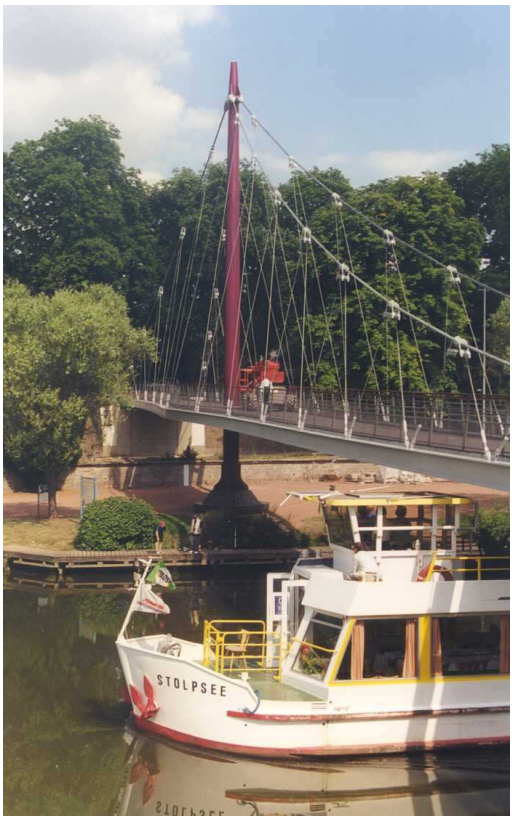
3.1. As far as I know, his first achievement has been the erection of the Kölhn-Rodenkirchen Bridge in 1938, a rather classical suspension bridge with a deck which has some common points with the – unfortunately – famous Tacoma Bridge; but which had not to suffer the same end.

After the war Leonhardt proposed an original concept for the Tagus Bridge in 1960, and for the Emmerich Bridge in 1961. I could not find his project for the Tancarville Bridge in 1955.

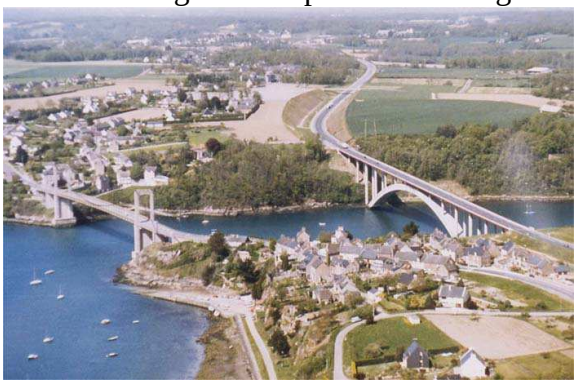
For the Tagus and Emmerich bridges he proposed a suspension with a unique, axial main cable, with a system of inclined suspenders producing a cable net, and with a stream-lined deck made of two small box-girders at the deck edges, connected by floor-beams. This system has never been used, and the fatigue failures of the suspenders in the Severn Bridge, designed by Freeman-Fox and Partners, prevented the development of inclined suspenders.

It is clear that an axial cable makes erection more difficult, but I am not at all convinced that inclined suspenders – producing a global truss effect – cannot be efficient on condition to be correctly sized and designed; as evidenced by Jörg Schlaich's pedestrian bridges, including my small bridge at Sarreguemines.

And it would be interesting to clarify the story I once heard about the wind tunnel tests performed by Scruton at the British Marine Laboratory which inspired the design of the streamlined box-girder of the Severn Bridge, a really pioneer achievement.



The Sarreguemines pedestrian bridge



The Chateaubriand Bridge
over the river Rance

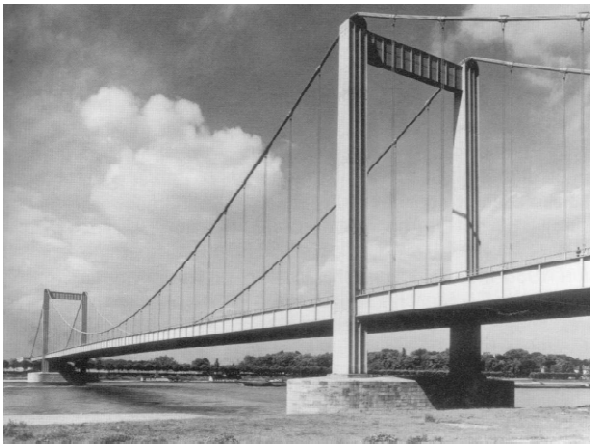
The Morbihan Bridge over the River Vilaine
at la Roche-Bernard

The Burgundy Bridge at Chalon-sur-Saône

The new bridge over the River Viènne at Limoges

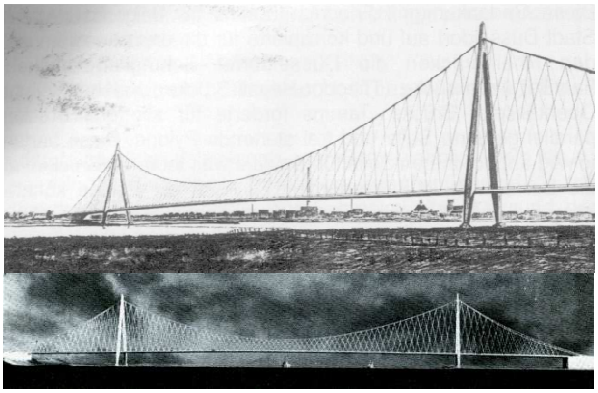
The Gignac bridge over the river Herault

The Gustave Flaubert Bridge over the River Seine at Rouen

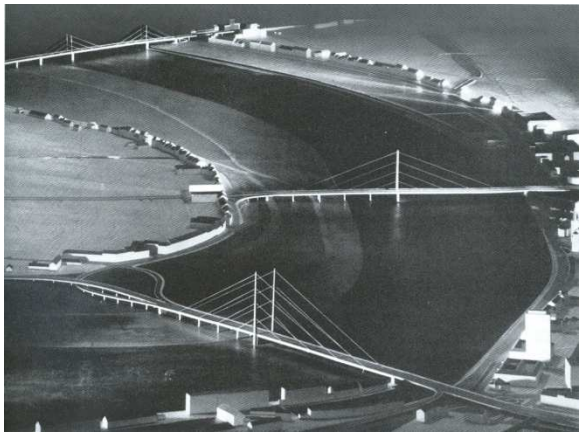


The Cologne – Rodenkirchen Bridge (1938)

The Leonhardt's project for
the Tagus Bridge (1960)



The Leonhardt's project for Emmerich Bridge
on the river Rhine (1961)

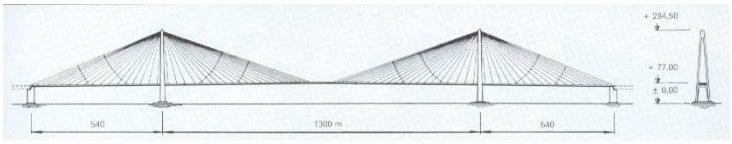


The Düsseldorf Bridges on the river Rhine

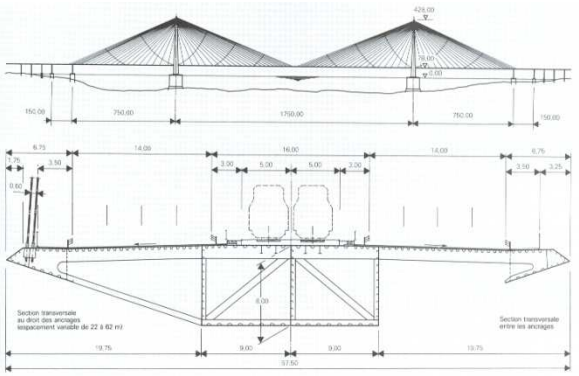
The North Bridge

The Kniebrücke

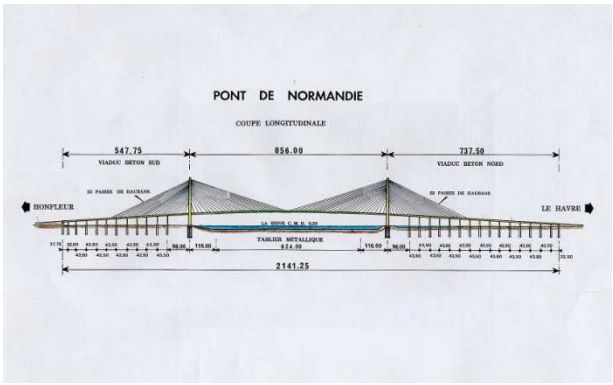
The Oberkassel Bridge



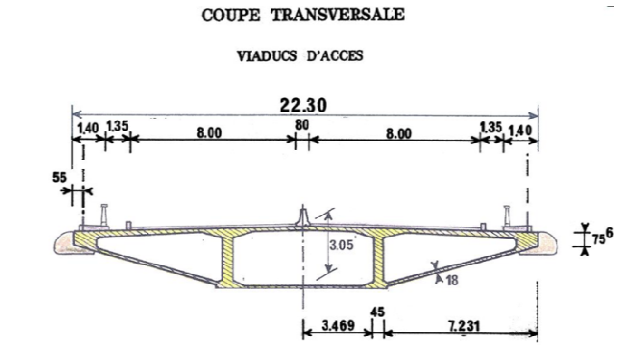
The Lambertini-Leonhardt project for the bridge crossing the Messina Straights (1970)

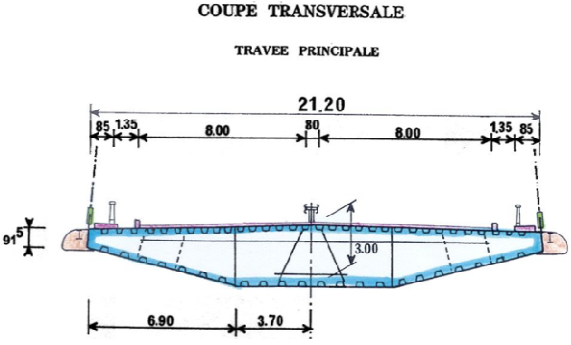


The second Leonhardt's project for the bridge crossing the Messina Straights



The Normandie Bridge





3.2. If Franz Dischinger – and in France Albert Caquot as soon as 1952 – have built the first ones, Leonhardt has certainly leaded the domain of cable-stayed bridges during many years.

The famous Düsseldorf bridges, the North Bridge, the Kniebrücke and the Oberkassel Bridge constitute a famous series of three different – variety again – cable-stayed bridges adapted to the city site. One – three in fact – of the many examples of cable-stayed bridges designed by Leonhardt and his team.

Leonhardt has been the first, by far, to see the fantastic possibilities of cable-stayed bridges when, with the Lambertini group, he proposed a cable-stayed solution to cross the Messina Straights with a span of 1 300, and later 1 750 metres. At the time the longest cable-stayed span was less than 400 metres long! And today, 40 years later, we have not yet reached such long spans since the longest ones, in Hong Kong and China, are only about 1 100 metres.

I am not sure that we shall build cable-stayed bridges with spans of 1 500 metres or more in the coming years since other solutions – suspension bridges, or solutions associating suspension and cable-staying – may reveal more efficient. But his project was a very clear sign that with typical spans between 300 and 400 metres we were, at the time, very far from the limit.

3.3. I don't remember if I knew this project when I became fully in charge of the design of the Normandie Bridge, in 1986; and even if I had seen it, it was so far beyond the knowledge at the time that it could not be a reference for me, the longest span being then 465 metres long only for the Alex Frazer Bridge to Anacis Island, in Vancouver area.

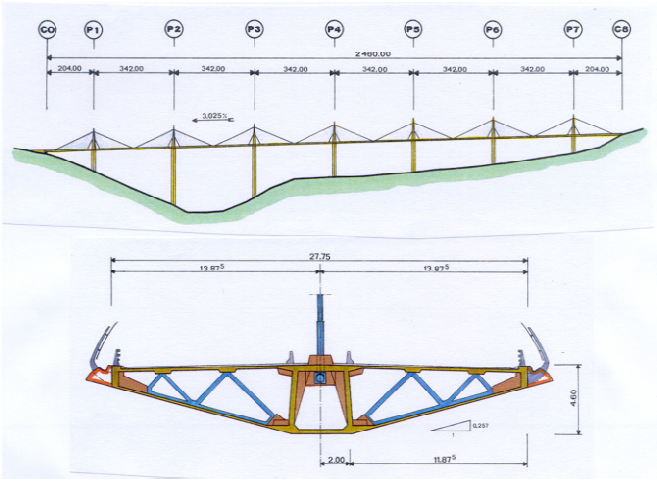
But I was comforted in my opinion that we could jump to almost 900 metres (856 finally) by the three major German cable-stayed bridges with a unique tower: the Severin Bridge, 302 metres in 1959; the Kniebrücke, 320 metres in 1969; and the Düsseldorf Flehe Bridge, 368 metres in 1979. These bridges evidenced that, except for wind effects, we could easily reach 700 or 800 metres.

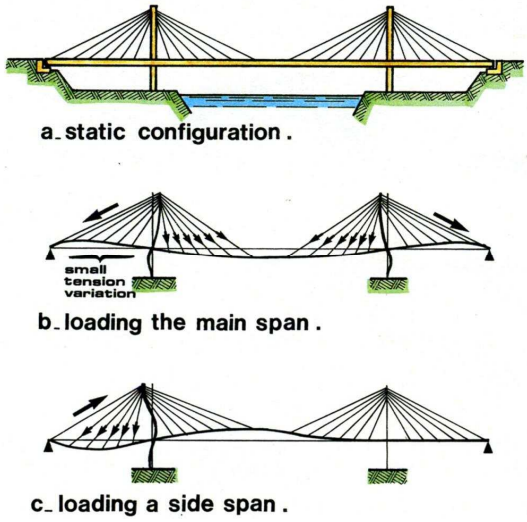
I designed a streamlined box-girder taking inspiration from the English suspension bridges designed by Freeman-Fox and Partners, the Severn, Humber and first Bosphorus bridges, just adapting the box-girder shape to the erection conditions of the approach spans in prestressed concrete.

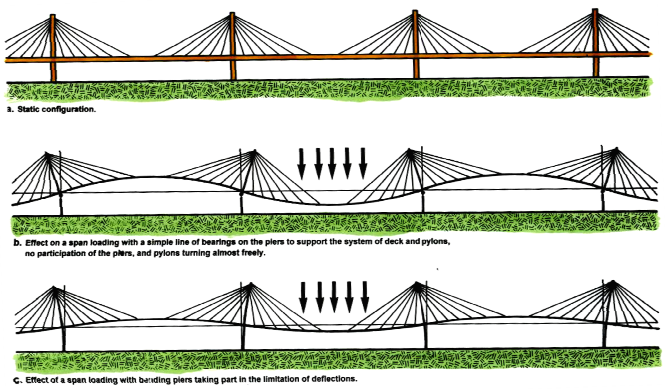
And later, in January 1990, when I became conscious that the main vertical vibration modes of the bridge were in the same frequency range than the first natural vibration modes of the longer stay-cables, I decided to install cross-cables – which we call "aiguilles" in French – to change the frequencies of cable vibrations, taking inspiration from the cross-cables installed in the Faro Bridge, Denmark, and in the two large suspension bridges of the Kojima Sakaide route of the Honshu Shikoku project in Japan, which had been installed for another purpose, to prevent rain and wind induced vibrations; and which broke due to a too small size and a too low tension. But then I was also aware of Leonhardt's Messina project and of the cross-cables which he designed to increase the rigidity of the stay cables, limited by the large sag of extremely long cables.

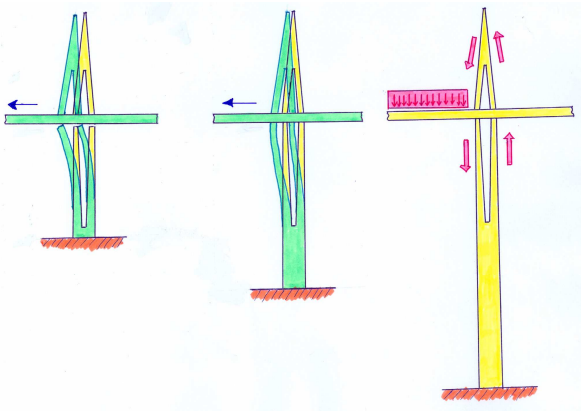
In my first drawing I gave a curved line to these aiguilles, to attach each stay cable perpendicularly as in Leonhardt's project, but there had been some fear that some attaches could move along the stay cables and detension the cross-cables, and finally they are straight.

I confess that I have been very proud when Fritz Leonhardt told me that he appreciated the design of the Normandie Bridge, just adding that he considered that the tower shafts could have been thinner.


C0
P1
P2
P3
P4
P5
P6
P7
C8
204.00
342.00
342.00
342.00
342.00
342.00
342.00
204.00
27.75
4.60
2.00


a_static configuration.
small tension variation
b_loading the main span.
c_loading a side span.


a. Static configuration.
b. Effect on a span loading with a simple line of bearings on the piers to support the system of deck and pylons, no participation of the piers, and pylons turning almost freely.
c. Effect of a span loading with bending piers taking part in the limitation of deflections.



3.4. Today the Millau Viaduct is much more famous than the Normandie Bridge. But it would not have been possible to design the MiIllau Viaduct as I did without the experience of the Normandie Bridge, and without the confidence in my understanding of these large bridges given by the erection of the Normandie Bridge. Most probably my project would have been considered too risky without the success of the Normandie Bridge.

And it may not have been selected without the reputation and the talent of the architect, Norman Foster. This is for me an occasion to say that working with him has been a fantastic and an extremely agreeable experience.

4. And more as a conclusion.

4.1. These two bridges, the Normandie Bridge and the Millau Viaduct, have in fact very classical shapes. Their elegance come from their adaptation to the site, to their slenderness, their proportions … We are fully in the line of Leonhardt's philosophy of bridge architecture.

Despite the modern tendency to provocative architecture, these – I may say simple – structures are highly appreciated by the public. During the last year of the Normandie Bridge erection there have been about 300 000 visitors. And in Summer, every day there have been, these last years, about 7 000 visitors of the Millau Viaduct, about 4 000 at the visiting center on the A75 mortorway, and about 3 000 at the visiting center below the bridge. The Millau Viaduct is now officially one of the twelve main sites of the Midi-Pyrénées Région.

4.2. But, except for these very large and attractive structures, politicians and media call for more sophisticated bridges; the "signature" bridges and other "landmarks".

Forgetting that, at the end, this is the public who will decide what is a real landmark.

In this situation engineers have to be more imaginative, more creative to design structures which have more originality, to produce more variety as requested by Jörg Schlaich. But this variety, this originality must remain structurally logical; it must come from real needs, functional or commended by the site.

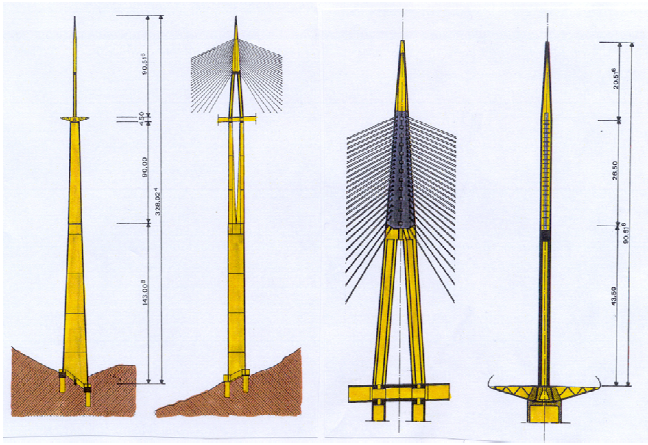
I can take some good examples, a stress ribbon bridge over the Colorado river designed by Jiri Strasky, one of the best designers worldwide today, and three splendid pedestrian bridges by Jörg Schlaich.

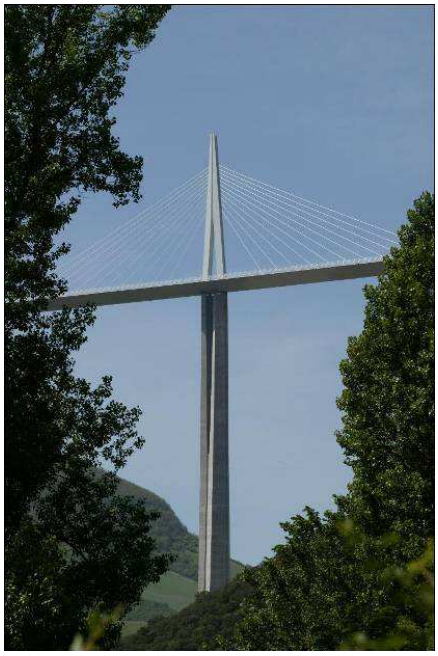
4.3. I could not have designed the Kelheim pedestrian bridge, I have not enough imagination for that. But I had the opportunity to design a large curved cable-stayed bridge in French Brittany which is now under construction.

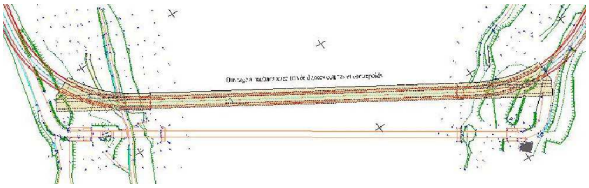
Works are not going smoothly because the contractor has probably underestimated the erection conditions. But works are progressing and visiting the site in the coming months would certainly be interesting. And, for sure, crossing this bridge will be extremely striking.

o
o o

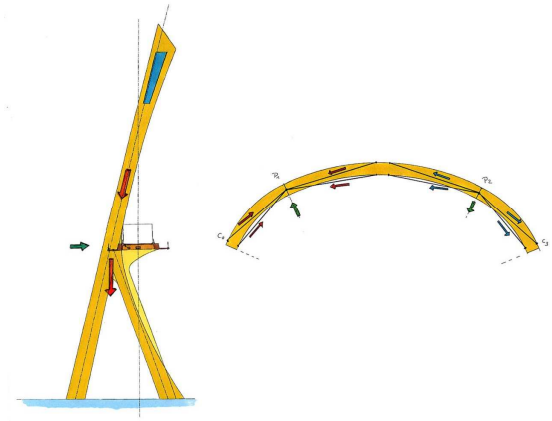
I have to conclude, and I just want to state that Fritz Leonhardt had, directly or indirectly, a strong influence on bridge design worldwide. When Jacques Mathivat, who was the President of the French Association of Bridge and Structural Engineering at the time, and I, as the Secretary, created the Albert Caquot Medal in 1989, the French Association, under a very strong pressure of Jacques Mathivat, attributed the first Medal to Fritz Leonhardt because he







The Térénez Bridge



considered that none deserved it more. And two of his former collaborators, and now followers, René Walther and Jörg Schlaich, received one also some years later.

Literature

[1] Fritz Leonhardt. Brücken-Bridges, Deutsche Verlags-Anstald, 1982.

[2] Fritz Leonhardt. Ponts-Puentes, Presses Polytechniques Romandes, 1982.

[3] Hans Wittfoht. Triumph der Spannweite, Beton Verlag, 1972.

[4] Hans Wittfoht. Building Bridges, Beton Verlag, 1984.

[5] René Walther, Bernard Houriet, Walmar Isler and Pierre Moïa. Ponts haubanés, Presses Polytechniques Romandes, 1985.