

Preservation of our Infrastructure Heritage

Jean-Philippe FUZIER : Scientific Director Emeritus, Consultant for Freyssinet

SYNOPSIS

The sustainable development of our world is closely linked to the strength and to the reliability of its infrastructure. Long-lasting rehabilitation of existing structures that meet a multiplicity of demands and construction constraints is the challenge facing us today.

Some of these structures are part of our patrimony, of our heritage. They represent by themselves a cultural signature left by our parents. Sometimes, it is not only preservation which is needed but rescue works should rather be carried out.

Several recent structures all over the world will draw our attention : the Guatemala Cathedral after the 1976 earthquake and the Paris Triumph Arch will serve as an introduction, then suspension bridges (at Agen over Garonne river), the Saint Laurent bridge (stone masonry 900 years old), the Cerna viaduct in Romania (a prestressed cantilever bridge) and the Geelong aqueduct over the Barwon river (Australia).

Each of these structures tells us something about the various techniques and technologies which have been used for their rehabilitation and preservation.

1 OUR INFRASTRUCTURE HERITAGE

1.1 Maintenance Programme and Sustainability

The 20th century has been a period of considerable growth and development in many aspects. Like other disciplines, civil engineering has pushed forward the limits : the challenge was to build higher buildings, longer bridges etc. The 21st century will hopefully see record-breaking achievements of construction but, no doubt, these landmarks will be achieved with more emphasis on environment-friendly and recyclable materials, realistic design, life cycle cost, effective maintenance and pre-emptive repairs.

In fact, in developed countries of Northern Europe, government agencies and large private owners were facing the challenge of maintaining with limited resources large stocks of vital infrastructure : highways, railways, bridges, dams, power stations, harbours, industrial facilities ...

The response to these difficulties has been the development and implementation of Management and Maintenance Systems in order to :

- . handle the necessary information flow and store relevant data ;
- . plan and organise the maintenance activities ;
- . prepare and manage maintenance budgets (cost control).

OECD reported in the 1990's the following : the maintenance needs may be given in terms of percentage of total bridge renewal value. Based on the bridge stock existing at that time, a

simplified approach to this problem would lead to a lifespan of 170 years if the maintenance percentage is 0.6 and 500 years if the percentage is only 0.2 !

The renewal of the transportation infrastructures is estimated to hundreds of billions dollars in the developed countries and only an amount of 1 to 2 % could be usually spent annually for maintenance and repair.

But our world is requesting today much more than a pure economical analysis : other aspects should be taken into account while building an infrastructure. Some of them could be listed hereunder :

- insertion into landscape
- transparency, slenderness, balanced proportions
- regularity and artistic shaping
- historical and cultural relationship
- saving materials and energy.

In fact, we have created a new word “sustainability” which is sometimes defined as follows :
“A sustainable construction is a construction that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

However, this is no more than the very old principles of VITRUVÉ written 2000 years ago :
“Firmitas, Utilitas, Venustas”, the three fundamentals for building a structure. Today the codes request ultimate strength, serviceability and durability.



Figure 1 : The Collège footbridge in Lyon (France)

1.2 Signature and Landmarks Structures

Fortunately, the VITRUVÉ principles have been followed sometimes and sustainable constructions have been achieved, places have been provided where people gather themselves, places where they like to meet each other, places which are attractive, places they are proud of, places where they recognize their history and their culture, in fact places which permit to keep alive the unity of a nation, of a country or of a township.

Then the building or the bridge does not bear simply the signature of its engineers or architects but it is “endorsed” by the city or the country itself. It becomes a signature bridge, a landmark.

It is interesting to look in the past for such places : it is a plaza (the Brandenburg gate in Berlin where people celebrated in 1989 the fall of the wall), it is a building, a church or a temple (the Kaiser-Wilhelm memorial church also in Berlin, the Opera House in Sydney), it is a tower (Eiffel Tower in Paris).



***Figure 2 : The Brandenburg Gate
In Berlin (Germany)***



***Figure 3 : The Kaiser-Wilhelm Church
in Berlin (Germany)***

Sometimes the landmark structures were not built with such a clear intention but the history of the city or of the nation has put them in such a position. A short selection among many references is presented hereafter :

. The Ponte Vecchio in Florence (Italy)

Built in 1345, the actual bridge with its forty-seven shops constructed out of a stone in a single building campaign remains a splendid reference of what we call « living bridges ».

. The Ponte di Rialto in Venice (Italy)

The Ponte di Rialto, built between 1588 and 1591, is possibly the most famous of all inhabited bridges. Its history is closely related to that of its predecessor (a wooden bridge) on the same site and, at the time of its construction, the fervour aroused among architects and public alike was sparked not by the presence of shops along its causeway but by the fact that it had no piers.



Figure 4 : the Ponte di Rialto in Venice (Italy)

. Charles Bridge in Prague (Czech Republic)

The Charles Bridge is 516 m long and 10 m wide. It was completed at the beginning of the 15th century including the two tower gates at each end. This is today the real masterpiece and landmark of Prague.



. Sydney Opera (Australia)



. The Brooklyn Bridge in New York

The Brooklyn Bridge in New York over East River was built in 1870-1883 and connects New York City with Brooklyn. With spans of $283 + 488 + 283$ meters, it is exceptional by its relatively very long side-spans. The construction of the bridge was entrusted to J.A Roebling and after his death in 1869, his son W.A. Roebling was chief engineer on the work which lasted from 1870 to the completion in 1883. The bridge was built with 4 main cables, each consisting of 5300 parallel galvanized steel wires. At the time of completion, the bridge represented a record with regard to span and traffic capacity. It is still in service after various changes in its suspended bridge deck.



With the celebration of its 100th anniversary in 1983, the Brooklyn Bridge was the object of more affection and attention than any bridge in history. But even after all the excitement has subsided, the structure still strikes even the most casual observer as a powerful and moving example of structural art. Since its completion the Brooklyn Bridge has elicited a strong response from artists, poets and the public. But beyond its stature in American popular culture, the bridge stands as a major accomplishment in structural engineering. For many years, it was the longest span bridge in the world and was not significantly surpassed until completion of the George Washington Bridge across the Hudson River in 1931.

. The Golden Gate Bridge in San Francisco

The construction of the bridge was started in 1933 and completed in 1937 under the direction of J.B. Strauss. The bridge is situated in exceptionally beautiful scenery over the entrance to the San Francisco Bay.



The free height above water level is 67 meters. The bridge has 6 lanes, 18 meters wide in total, and 2 side-walks, each 3 meters wide. It was at that time the longest bridge in the world with a 1280 m long main span.

But the history of this bridge is read like a legend : « *The Golden Gate Bridge should never have been built. The waters at the ocean entrance to San Francisco Bay were too menacing, the Gate was too wide to be spanned by a suspension bridge, the costs of so ambitious a project were too high for an economy in the midst of Depression.*

In 1916, the long fight for a Golden Gate Bridge began. Twenty-one years later, in May 1937, the impossible dream was a dazzling reality. The intervening years were filled with drama, disappointment and accomplishment. The Golden Gate required the largest underwater foundation piers ever built, the tallest towers and the longest, thickest cables. What's more, the foundation had to be sunk in the violent, pounding waters of the open sea. » (after Stephen CASSIDY).

In a 1987 celebration commemorating the 50th anniversary of the span, more than a quarter of a million people turned out to walk across the structure. Although officials had anticipated a large turnout, the size of the crowd exceeded all expectations. The Golden Gate bridge remains an icon that occupies a special place in America's cultural consciousness.

2 PRESERVATION AND REHABILITATION

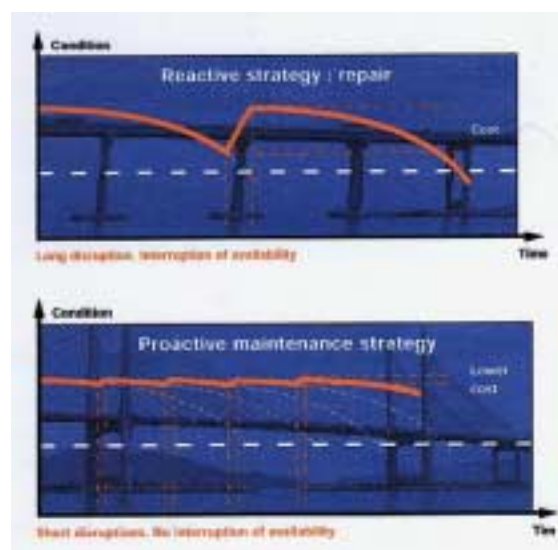
2.1 Principle

All these structures illustrate or interpret the heritage of the country in engineering, technology, transportation, industry, history or culture. This is the responsibility of the nation (or the city) to build such structures but also to preserve and maintain them alive for the future generations. Ensuring the preservation of bridges requires a commitment.

2.2 Reactive and Pro-active Maintenance

To preserve and repair the existing patrimony, there are two options : the “reactive maintenance” strategy and the “pro-active maintenance” strategy.

The “reactive maintenance” strategy is to exploit the capacities of an infrastructure as much as possible without spending any resource in “voluntary” maintenance process : as the structure degrades, it will someday reach a point where the service can no longer be ensured (with respect to security / regulatory / structural reasons). At that point, it is necessary to perform extensive repairs that will alter, interrupt or stop the service for the duration of the repairs.



The “pro-active maintenance” strategy is to say : “even if my infrastructure is in good condition today, I will spend some money to make sure that it will be in satisfying condition tomorrow”.

What is the difference ? In one case (the “reactive maintenance” strategy), the infrastructure manager is blind and runs the risk of a major and generalized damage. While in the other case (the “pro-active maintenance” strategy), the infrastructure manager constantly has a full and updated knowledge of the condition of its structure. He can detect minor defects and correct them before they get larger, he can forecast problems, allocate accurate repair budget and simulate the future evolution based on the past archived data.

In terms of cost, the “reactive maintenance” strategy is more expensive because the process of deterioration of concrete or steel is not linear in time but exponential. In reinforced concrete structure, such minor defects as micro-cracks can grow if water penetrates and ice is formed, leading to larger cracks with a possibility of corrosion of the reinforcement steel that will finally endanger the whole structure. In steel elements, a small defect in the corrosion protection can expose the entire element to generalized corrosion and dissolution. By definition, the “reactive maintenance” strategy will perform extensive and costly repairs at an advanced stage of damage whereas the “pro-active maintenance” strategy would have recommended localized repairs to fill the micro-cracks and to improve the corrosion protection. This cost difference is not only the direct savings in repair costs but also the avoidance of major service interruptions, lower insurance premiums, more efficient long-term planning and greater asset value due to improved confidence in the structural integrity.

2.3 The consequence of a “pro-active maintenance”

As the advantages of the “pro-active maintenance” became obvious to more and more people involved in the infrastructure management, technical methods and tools used to monitor the health of the infrastructure have been inventoried and rules have been set to establish the diagnostic. Each authority has been developing its own maintenance manual, taking into account their specificity, their different priorities, safety requirements, resources and range of competence. One consequence of a “pro-active maintenance” is that it necessitates to record, report, analyze and store tons of data and that it is easy to get lost in the clerical work.

In most cases, it involves inspectors going on site and inspecting the structure, taking hand-written notes of the defects. Back in office, they copy the defect on the structural drawing along with their dimensions and characteristics. According to their manual, they will then affect a mark or a comment for these defects and will establish reports that will be handed to the engineers in charge of the analysis. The engineer may struggle with inhomogeneous notation system, unreadable handwriting and confusing dimensions. One can immediately see that such a system is inconsistent and subjectively dependent on the relative experiences of the individuals taking the notes or making the analysis.

This leads to the development of a new science : information technology and monitoring, to the development and application of new materials and technologies which can extend the service life of our constructed facilities with reduced maintenance (pro-active) and improved durability. Thus applications of advanced composite materials such as glass, aramid or carbon fibres in polymer matrices are becoming increasingly important. In the same manner, development of electrochemical remedial techniques which can be monitored are quite promising. This will be shown in several remarkable examples.

3 RESTORATION OF THE METROPOLITAN CATHEDRAL OF GUATEMALA



The Cathedral of Guatemala is a colonial style building built in about 1780 and seriously damaged by the earthquake of February 4th, 1976.

The church comprises three lengthwise naves with side chapels, a crosswise nave, a dome on the transept and façade towers. The building is 100 m long and 16 m high under the vaults. It is constructed on masonry with stone facings on the façade.

The top part of the towers and the dome had already collapsed during the earlier earthquake in 1917. These parts had then been reconstructed on reinforced concrete and, at the same time, the naves had been reinforced with a gridwork of reinforced concrete.

The parts which suffered the most in 1976 are the main façade with the towers whose masonry has been substantially dislocated, the dome whose supports were sheared, the rear façade which had the tendency to separate from the body of the church and the vaults inside the church which were split but which did not fall.

The restoration plan was prepared in order to provide the greatest possible safety in case of a new earthquake, both in relation to the building and to the worshippers.

The restoration included the following operations :

- . construction of a prestressed concrete connection beam between the towers, located above the vaults and linked by a system of prestressed concrete stringers to the body of the church going as far as the rear façade ;
- . repair of the present tower shaft masonry by a reinforced concrete skeleton, including removal and replacement of the stone facings of these towers ;
- . raising of the dome and re-building of the supports using reinforced concrete ;
- . repair of the walls, vaults and pillars inside the church.

The objective of the repair works was to respect the authenticity of the building : the cathedral should remain a gravity based structure and the vertical loads should always go down through the masonry walls allowing the transfer of horizontal loads by internal friction.

4 STRENGTHENING OF TRIUMPH ARCH IN PARIS

Another unique example, another story, other techniques and technologies involved but the same final concern : the repair works should be invisible.

The construction of the Arc de Triomphe started in 1805. The Emperor Napoleon wanted to erect it to the glory of the Revolutionary armies which gained immortality under his command when he was only General Bonaparte. The monument was finally achieved in 1835 by King Louis-Philippe. It is 45 m long, 25 m wide and 50 m high with a total weight of 50,000 tons.



4.1 Pathology

In 1983 some stones fell from the vault and the facade of the Arc de Triomphe in Paris. An investigation was then conducted followed by a series of measurements and tests to determine the origin of the phenomenon.

The analysis, which was rendered easier by existing building drawings, permitted to establish that the monument was suffering from the settlement of the foundations and a helicoidal movement of the arch.

The foundations, which consist of large stone blocks, had moved as a result of the dilapidation of the joints. The rain water coming from the Esplanade and trickling down the facades as well as the water coming from the terrace and piped through to sewers, which were probably leaking themselves, are the main causes for the underground water flow that had washed out the foundation joints and created a serious deterioration of the lime mortar.

The differential foundation settlement then brought about a “horse-saddle” deformation of the upper part of the building, that is a tendency of the pillar summits to move apart in the direction of the short sides and to converge in the other direction.

The different analyses made it possible to establish a reinforcement plan comprising 5 phases:

- treatment of the masonry joints in the foundations by partial injection of special grouts
- treatment of the cracks in the superstructure by injection of cement grout
- reinforcement of the superstructure through the installation of prestressed ties inside the building
- further grouting in the foundation block
- water-proofing of the building surroundings.

4.2 Grouting

The purpose of the grouting was to stop all movement in the pillar foundations by rendering the masonry work homogeneous whereby two different grouting operations with two kinds of grout, designed by the company Soletanche, were carried out.

The first grout, called Microsol, combines the advantages of cement grouts (stability and strength) with those of chemical grouts (penetrability). The grain diameter is in the range of 0 to 12 μm and can be harmonized with that of the pores of the mortars that need to be treated. The main advantage of this product lies in the formation of stable hydrated calcium silicate crystals presenting a very high resistance to underground waters.

Silacsol is a liquid chemical grout of mineral base made of two components : a high activity silica liquid and a calcium-based reagent. Its honeycomb type structure provides Silacsol with high strength and low permeability.

These two products of different compositions are complementary in their function :

- to fill the voids of the old joints (Microsol)
- to impregnate them to ensure their regeneration and their watertightness (Silacsol).

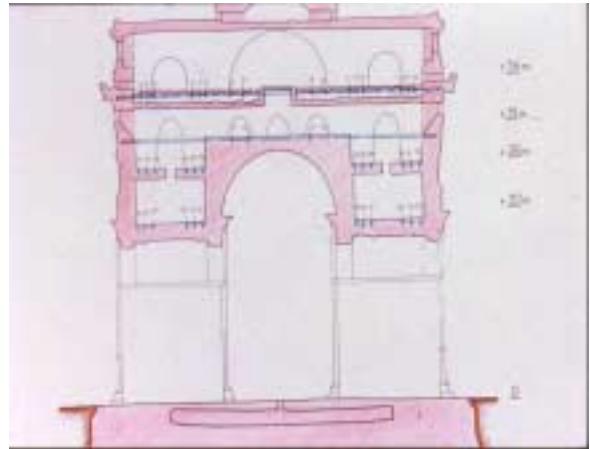
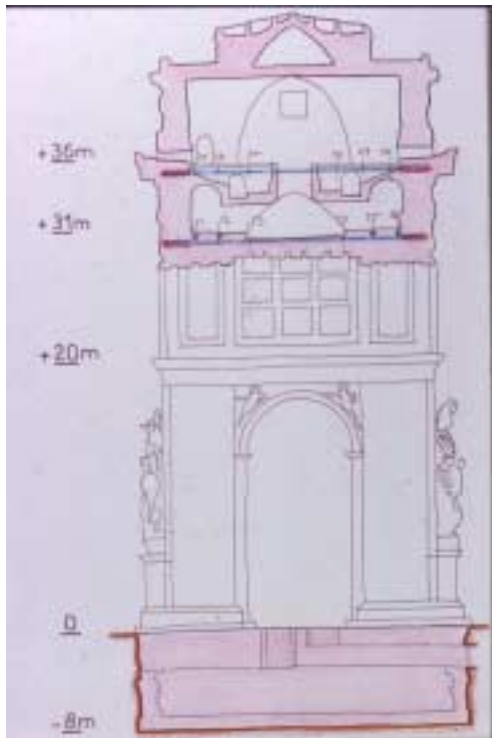
4.3 Reinforcement of the superstructure by additional prestressing

In the case of the Arc de Triomphe, the operation consists of additional prestressing installed inside the structure in order to compress the fractured zones and to centre hereby the oblique forces produced by the thrust of the vaults. This additional prestressing is provided by 112 half-ties anchored in the facings and connected in pairs at their centres by active couplers.

The recess, necessary for anchorage, is formed by direct rotation drilling, core drilling or down-the-hole hammer. The drilling is so done as to place anchorage as near as possible to the outerfacing, allowing hereby a margin of approximately 25 cm in order to avoid breaking through. The parameters characterising the anchorage are as follows :

- the diameter of the drilling
- the drilling method
- the sealing length
- the centering and binding method of the strands within the sealing zone
- the kind of sealing grout.

The definition of the parameters mentioned above required a large number of in-situ tests before actual installation of the ties.



Free lengths of the ties

The external free lengths of the ties are doubly protected. The T15 strand (dia. 15,7 mm, section 150 mm²) is lodged inside a plastic sheath and protected with anticorrosive grease. This operation, carried out in the works, guarantees a self-protection of the strand right from the start.

During the assembly on site, the two strands forming a tie are threaded through a high density polyethylene duct which is itself injected with cement grout after installation of the tie. The free length of the T15 tendon is therefore doubly protected in a grease film which will allow tensioning and possible ulterior adjustments of the tensioning. The active portion, the anchorage coupler 2T15, remains accessible in a closed recess and protected by a casing injected with wax.

5 SUSPENSION BRIDGES

It is always amazing to discover that there are in France more than 200 suspension bridges. In fact, in the last century, this type of bridges was the only one permitting to span a 100 m wide river or more. Some of these magnificent bridges have been built in North Africa (Algeria). Today they need to be rehabilitated and kept as master-pieces of our common heritage.

Some splendid examples : Wadi Kuf in Libya and Sidi M'cid in Algeria, Lorois bridge, Le Mas d'Agenais bridge and Saint-Georges footbridge in France. The various remedial works are presented. In order to extend the life span of these structures, new ideas and new technologies are now available, ready to be implemented.

5.1 Wadi Kuf bridge in Libya

Description

The Wadi Kuf is a cable-stayed bridge designed by Professor MORANDI. It consists of two independent balanced cable-stayed systems having their ends anchored to the abutment by a short hinge strut. The cable stay systems are connected by a simply supported drop-in span. This structure consists of only three spans. The centre span is 280 m long and the two end spans are each 97.5 m, for a total length of 475 m. The simply supported drop-in centre portion of the main span consists of three double-T beams 55 m in length ; each beam weighs approximately 220 tons.

Strengthening and rehabilitation

Due to excessive creep the simply supported drop-in span was critical : the stability was of a great concern and urgent remedial actions were required. The works included the extension of the cantilever tips with an additional steel structure prestressed with bars to the old structure. The drop-in span was lifted up (1220 tons) in order to change the bearings. Because of severe requirements on differential movements between the girders, it was necessary to carry out the lifting operations with a computer assisted method.

5.2 Sidi M'Cid suspension bridge (Constantine / Algeria)

Rehabilitation works

Heavy corrosion of the steel components was found. Already in 1980 four of the six suspension cables were replaced. FREYSSINET was awarded the contract for all the complete rehabilitation project which included :

a) Assessment

It was necessary to carry out several tests on the structure components in order to know the real status of deterioration :

- static and dynamic tests were performed on the deck and on other members of the suspension ;
- liquid penetrating tests on steel members assembly ;
- sonic tests for the pylon masonry ;
- ultrasonic tests for anchorage heads.



b) Recalculation

Using the data collected during the tests campaign, a finite element model was built with TecnoProject in order to recalculate the structure and establish the final assessment. This model allowed the checking of various safety factors during the successive phases of works which were carried out under traffic.

c) Remedial works

These works included :

- watertightness of the anchorage galleries where was found large water leaks ;
- replacement of the existing anchorage bars ;
- replacement of the cables installed in 1912 ;
- replacement of the backstays also installed in 1912.

5.3 Lorois suspension bridge (France)

Introduction

The Lorois bridge crosses the river Etel between Auray and Lorient, in southern Brittany. It is a steel suspension bridge, 237 m in length. The two main suspension cables, formed of seven cables 70 mm in dia., are anchored in massive reinforced concrete blocks on either side of the supports to the access spans. Complete replacement of these suspension cables was carried out in 1996 by FREYSSINET, on behalf of the General Council of Morbihan, without any interruption to traffic over the bridge.



Figure 5 : General view of the Lorois bridge

The last 20 years have produced a number of well-publicised bridge cable failures. Wire failures have normally occurred after electro-chemical corrosion or fretting corrosion. The deviation saddles at the tops of the pylons or at the entrances to anchor blocks are the critical points for two reasons :

- the bending of the cables opens the bundle of wires and permits the water to get in ;
- the bending stresses reduce the fatigue strength.

Due to wire failures in several locations and because of concern about the anchoring capacity of the bars, the owners of the Lorois bridge decided to replace the suspension cables and to build new anchor blocks.



Figure 6 : the Lorois bridge : new suspension cables

Replacement of the suspension cables and hangers

The replacement of suspension includes the following phases :

- minute inspection of the structure and especially the cables anchorages ;
- construction of new anchorage blocks or modification of the existing anchorages in order to carry out the simultaneous fastening of the former and new cables ;
- erection of scaffolding to reach the top of the pylons and construction of new bearing saddles above the existing ones ;
- installation of the new cables using a hauling winch, construction of their anchorages and adjustment of the catenary sequence they form. There are four locked coil cables, 70 mm dia., on each side, formed of parallel round wires and three layers of Z wires. All the individual wires are galvanized. The guaranteed ultimate strength of each cable is 4549 kN ;
- installation and hooking of temporary hangers in order to allow for the removal of the existing hangers detensioned in this way. There are 22 hangers on each side, consisting of locked coil cables 43 mm in diameter, with two layers of Z wires. The guaranteed ultimate strength of a hanger is 1840 kN.
- removal and replacement of the hangers ;
- removal of the former cables ;
- final adjustment ;
- anti-corrosion protection of the cables, hangers, collars, upper and lower fixings on the cables and the deck as well as the saddles and anchor ties.



Figure 7 : the Lorois bridge : new suspension cables in place

All these operations are delicate : they demand a minute presentation and a strict control so as to ensure the stability of the structure at all times, so the traffic can be maintained as much as possible during the works. They require, prior to any repair work on the structure, a detailed survey which extends the bridge's refurbishing schedule even further.

5.4 Saint-Georges footbridge in Lyon (France)

The Saint-Georges footbridge was built in 1852, bombed in 1944 and then restored and new work has recently been done on it. This work was started in summer 1998 and consisted of reinforcing the carrier tendon anchor foundations by prestressed tie rods and dismantling the deck, the former suspension and metal pylons. A new deck then had to be made combining a modern support structure and classical hand rails. It then had to be put into place and attached it to the new suspension elements.



Figure 8 : Saint-Georges footbridge : general view

The choice of dismantling and reconstruction methods had to enable continued river traffic on the Saône river. FREYSSINET worked as the main contractor and suggested innovative construction methods, including the use of two working pylons installed on the banks. These metal pylons were connected together from bank to bank by prestressing strands tensioned and stabilized by temporary stay cables anchored onto stiffeners of the anchor foundations. The deck was disassembled in 1.30 m segments and each of the forty-six elements was held in place and handled using low power pulley blocks suspended from the strands. This method eliminated the need for heavy handling equipment.

The new deck was made in three long elements. They were equipped with their handrails, delivered on a barge and very quickly put into position using a floating crane. After this phase, the two side segments, temporarily guyed to the « working pylons », supported the central segment.

The new suspension was then put into place before the load was transferred from the temporary stay cable to the final hangers. When the geometric adjustment of the deck was finished, the three segments were connected by welding and the structure was put into its final suspension bridge configuration. The footbridge was opened again to pedestrians after the finishing work was completed and after regulatory checks.

5.5 Footbridge over the Garonne in Agen (Southwest of France)

The existing footbridge over the Garonne

Linking the historic town centre of Agen on the East bank of the Garonne river to Le Passage suburbs on the west bank, the footbridge was first built in year 1839. It allows cycle and pedestrian traffic.

It was designed as a suspension bridge supported by chain cables replaced by steel wire cables in year 1883. The cables have been replaced partially in year 1894 and totally in 1936.

Today, the entire footbridge consists of 5 spans. The 3 suspended spans are 29,50 metres, 174,25 metres and 20,60 metres long for left side span, main span and right side span respectively. Two approach spans on the West bank consist of truss beams. The 2,80 metres wide deck consists of a steel structure covered by wooden flooring. Suspension cables rising 18 metres above the deck are supported by masonry towers equipped with saddles on rollers.

Due to ageing of materials and structural problems encountered by the bridge, several components were replaced and pedestrian traffic has been restricted down to 15 people simultaneously on the deck.



Figure 9 : the existing footbridge over the Garonne

Assessment of the structure based on measurements and recalculations carried out in year 1997 led the authorities to temporarily close the bridge before restricting traffic.

Not only were several components subject to heavy deterioration but it also seemed that asymmetrical live loads or wind effects were likely to question safety and structural stability of the footbridge.

In fact, because of the lightness and the slenderness of the deck, the structure hardly withstand dynamic or asymmetrical loads.

Renovation of the footbridge

In order to remedy the problems encountered, in year 1999, authorities launched an invitation to bid for renovation of the footbridge, either by a structural solution conforming with existing structure, or with an alternative solution.

Freyssinet suggested an alternative design for renovation as follows :

- ♦ The deck is renovated with steel I-girders and wooden flooring. Suspended side spans are replaced by simply supported truss beams.
- ♦ Masonry pylons as well as saddles on rollers are dismantled and replaced by single steel pin-connected masts supporting fixed saddles. Because of uncertainties which masonry pylons pedestals are subject to, micro-piles are used for foundations of masts.
- ♦ The suspension is renewed for the main span only and consists of two galvanised steel spiral strands supporting diagonally arranged hangers connected to crossbeams of the deck. Since ultimate tensile strength of existing ones was subject to uncertainties, new anchor blocks with bond sockets and micro-piles are provided for suspension cables.

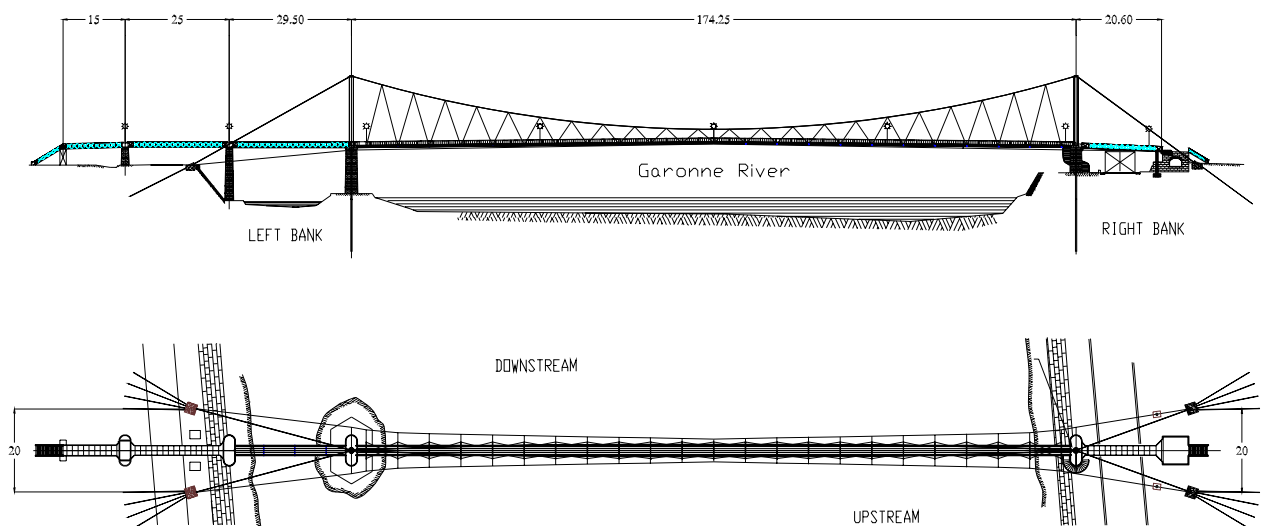


Figure 10 : the new footbridge over the Garonne: elevation and plan

- ♦ Transverse wind-stabilising cables are added on both sides of the footbridge. These parabolic cables are connected to the deck crossbeams by means of transversal tie cables and anchored in the same blocks as the ones used for vertical suspension.

Improvement of dynamic behaviour

Beyond usual remedial works, it was necessary to improve the structural functioning of the suspended span in order to cope with technical problems encountered by the structure. The main issue is transversal instability of the deck. Project specifications specially required to improve structure dynamic behaviour to take care of the wind effects.

The project technical guidelines demanded to keep the deck porosity. This led Freyssinet to design a deck with flooring and handrails very similar to the existing one.

Furthermore, due to budget constraints, the deck made of standard profiles remains very simple. The cross profile has not been specially optimised to avoid turbulence phenomena such as vortex shedding.

Since slenderness and lightness of the deck are close to those of the existing one, improvements of the structure dynamic behaviour mainly result from the addition of lateral stabilising cables.

The layout of these cables is designed to withstand part of wind induced transversal forces and at the same time to pull down the deck to increase its stability regarding bending, swing or torsional effects. The new footbridge is to provide pedestrians with a safe and comfortable crossing.

The integration of the new three-dimensional suspension into the surroundings of the footbridge was also one of the main issue of the project since design had to meet both technical and aesthetic requirements. As for example, to keep a 5 metres clearance for road traffic under right side span, the layout of lateral stabilising cables had to be deflected by means of pin-connected props.

6 CONCLUSION

In the past, only the most remarkable buildings were protected – like cathedrals and castles, emblematic of an historical past. Then the notion of heritage widened via the preservation of buildings and bridges that had become the last surviving representatives of a technique, a science, a lifestyle or, again, of the architecture of the 20th century. Heritage is therefore a fairly flexible notion but, generally speaking, projects involving heritage aim at transmission and permanence.

As a consequence, some have predicted that the role of the engineers will change over the next 20 years. From creators and managers of infrastructure, they will become “stewards of the environment”. This is not totally true : however, the cooperation between the different types of expertise will be needed. Architects and historians working alone only partially succeed. Bridges are engineered structures : their successful rehabilitation and preservation requires the ingenuity of engineers.