FOOTBRIDGES IN PORTUGAL

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1. BRIDGES – road and railway bridges – footbridges

Bridges overcome obstacles, open passageways and provide the way to the other side. Bridges unite territories and people separated by water or topographic barriers. Bridges are man-made objects in the landscape scenery. Bridges are always points of reference.

Road and railway bridges bring about social and economic development. Road and railway bridges grant more efficient travel. Road and railway bridges are made to go along. Often, road and railway bridges are not perceived. Road and railway bridges are for all but belong to no one. Many people hardly notice road and railway bridges.

Footbridges bring about quality of life. Footbridges offer opportunities to meander above ground or water, to take pedestrians away from the busy traffic in urban areas and to offer unexpected views and enjoyment of the landscape, whether built or natural. Footbridges provide meeting points. Footbridges are perceived and touched by the individual pedestrian. Footbridges are for all but belong to each pedestrian. Footbridges may attract pedestrians. Footbridges may frighten people.

Definitely, footbridges are playing a central role in the urban renewal and pedestrian safety demanded by modern society, which is more and more sensitive to the needs of the elderly, of the physically handicapped, of the pregnant women and of the infants.

2. FOOTBRIDGES – design concept

Footbridges may be regarded as large sculptures with practical purpose and severe structural requirements, but they should not be designed as sculptures are. Footbridges are to be used by human beings and their size and applied loads imply that structural demands are dominant. Therefore, beauty and elegance in the architectural concept must spring from efficiency in the structural design. And structural efficiency requires simplicity and purity of structural form and of their structural components.

It should be clear to all involved that the achievement of natural harmony between the beauty of architectural and structural concept, the physical configuration of the local landscape and the social attractiveness and usefulness of footbridges require a fusion of all the various issues, whether social, artistic or technical.

Unfortunately, that is not the view and understanding of many of those holding the initiative and authority to build footbridges. The belief that footbridges overflying streets, roads or motorways, even if in urban areas, need only to be there at a minimum cost has proved to be short-sighted and ignores responsibility towards the built environment and the aesthetic, cultural and emotional dimensions of human beings. Pedestrians disregard those footbridges and seem to prefer to endanger life when crossing busy traffic roads.

Preferably, footbridges should be located and stretched along the natural walkway of pedestrians, who should derive pleasure from their use, never implying the walk of a much longer distance. When possible, pedestrians should be led naturally into the footbridge, well before pedestrians are at the edge of the road to be crossed.

The setting of footbridges in parks or in open land is much easier and, although these footbridges are seen by less people, they tend to be better designed, as if the natural environment is regarded as deserving more esteem than the built environment.

3. FOOTBRIDGES – scope of this presentation

An exhaustive survey of footbridges in Portugal is outside the scope of this presentation, even though their number is not high. Furthermore, only footbridges designed with aesthetics in mind and with structural quality are named. For sure, footbridges designed and built with minimum investment are usually badly conceived, some even structurally unsafe, often bring no advantage to the pedestrian and are generally very expensive to maintain.

The objective of this presentation is then to provide information on some of the most interesting footbridges built in Portugal in the last 20 years. Some footbridges of high quality have been designed lately, but their construction is being postponed or has not been started yet. These bridges are not referred, with the exception of footbridges in the singular context of the river Douro at Porto, because footbridge 2008 is held in Porto and because crossing from Porto to Gaia has been at all times a very special experience and an inspiration for the design of outstanding bridges.

Footbridges are presented here in the following groups:

- Urban footbridges
- Footbridges over roads, motorway or railways
- Park footbridges
- Special footbridges
- Footbridges over the River Douro at Porto

A brief description and at least one photograph or photomontage of each footbridge is provided. Year of construction and name of designer / office are also given.

3.1 Urban footbridges

Urban footbridges are typically made to leap over roads with heavy traffic, rivers or canals. Urban footbridges have always been built but most are unattractive and useless. A major difficulty with urban footbridges is to provide a pleasant and comfortable path to reach the deck crossing over the road at the required height. Electrical lifts are costly to maintain, staircases are tiring and ramps require a long walkway.

FOOTBRIDGE AT BELEM, IN LISBON

This footbridge (Figures 1 to 5) provides passage over the boulevard and railway line along the Tagus riverside, near the heritage and touristic area where the Tower of Belem and the Monastery of Jerónimos are located.


Figs 1 and 2 – Belem footbridge

Its design integrates the bridge into the local restrictions, the curved trapezoidal white painted steel box-girder combines well with the red brick and white limestone covering the concrete abutments and staircases, but railings are unsafe to children and use by wheelchairs is not possible.

The Belem footbridge was designed by Structural Engineers Veiga de Oliveira and José Pedro Venâncio / BETAR Consultores and Architect Manuel Taínha, and it was built in 1996.

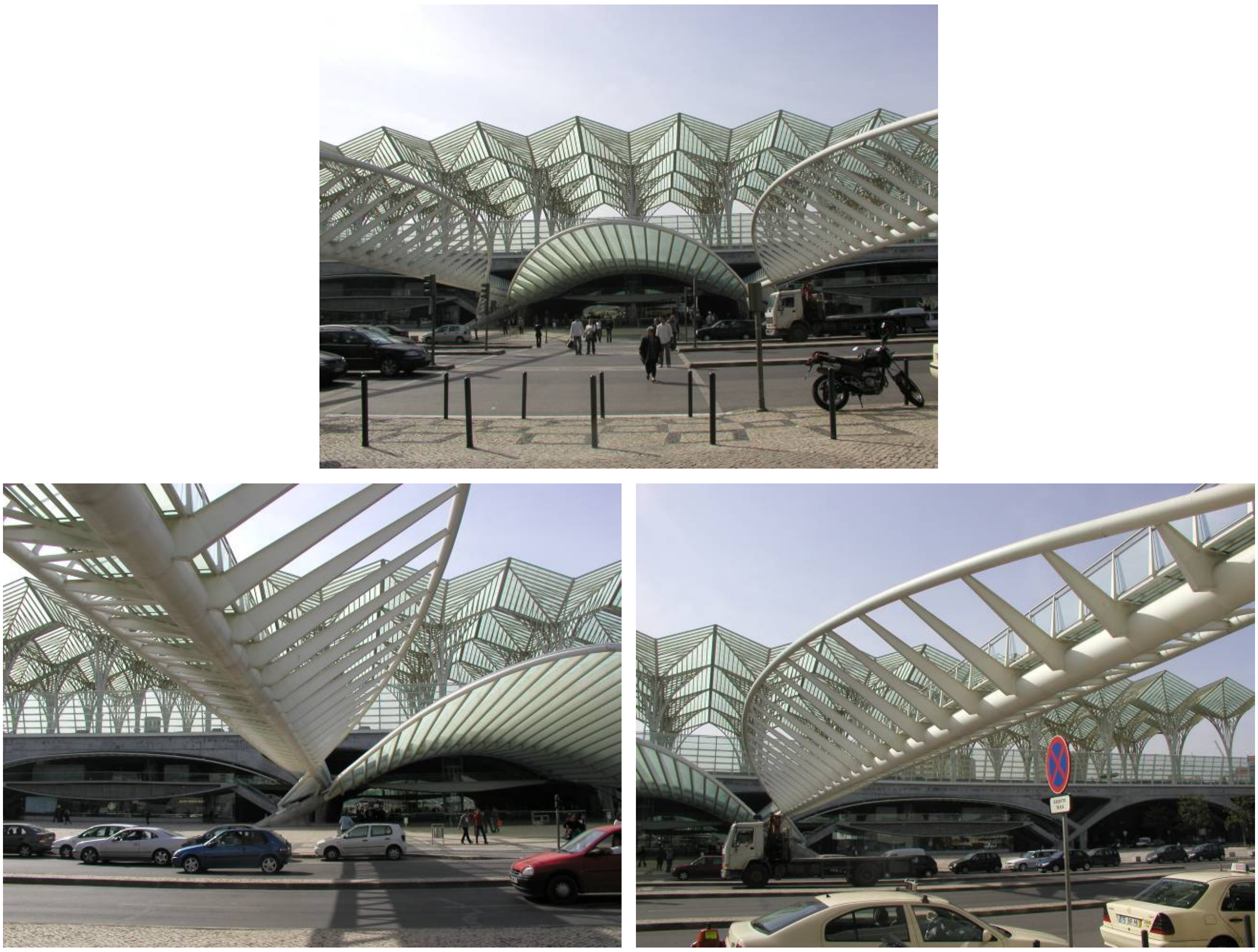
Figs 3, 4 and 5 – Belem footbridge (details)

FOOTBRIDGES AT LISBON EXPO 98

The two footbridges shown in Figures 6 to 9 connect the Orient Railway Station to the Vasco da Gama Shopping Centre at “Park of the Nations”, the site of the 1998 World Exposition.

Fig. 6 – EXPO 98 North footbridge

They were designed by Architect / Structural Engineer Santiago Calatrava as part of the railway station commission. These footbridges are 3-dimensional steel trusses in white painted steel and the pavement is made of glass panels.



Figs 7, 8 and 9 – EXPO 98 footbridges seen from underneath

Vertical vibration of these bridges under walking pedestrians can be uncomfortable but acceleration falls within acceptable limits. On the contrary, acceleration in horizontal vibrations can go over adequate limits with just a few pedestrians. Furthermore, both bridges exhibit a permanent localized deformation that it is aesthetically disturbing and scares pedestrians, although it is structurally irrelevant. For safety reasons, both footbridges are now closed to pedestrians.

FOOTBRIDGE AT FEUP

Access over a public road to the refectory from the Departmental Buildings of the Porto Faculty of Engineering is provided by a stress-ribbon footbridge (Figure 10) designed by Structural Engineer João Fonseca and built in 2001.

Fig. 10 – Stress ribbon footbridge in FEUP Campus

Connections between the precast reinforced concrete pavement slabs were not sealed with epoxy and final adjustment of longitudinal prestressing was not performed, which was specified correctly in the design documents. As a result, the deck catenary displays non desired sag and vertical resonant vibration with walking pedestrians is easily triggered. Notwithstanding, collapse can not be generated and because it is located inside the Faculty of Engineering Campus, it became a prototype for vibration research testing (Figure 11).

Fig. 11 – Vibration testing of the footbridge in FEUP Campus

FOOTBRIDGE AT AVEIRO UNIVERSITY

This footbridge (Figures 12 to 14) was built in 2003 inside the Aveiro University Campus and connects the university departments with the university main refectory and sports facilities.

Architect Carrilho da Graça and Structural Engineer Adão da Fonseca / AFAconsult designed this black painted truss bridge using a “shape optimization” mathematical programming algorithm for minimum steel weight as criteria for the definition of both the truss geometry and the cross-section area of each bar [1].

Fig. 12 - Footbridge at Aveiro University

The straight deck travels horizontally over the salt-marsh of S. Peter and the level difference between the two platforms is resolved at the South end of the bridge by a staircase or by a black painted reinforced concrete ramp that provides the alternative path for wheelchairs and bicycles.


Figs 13 and 14 – Footbridge at Aveiro University – detail of the truss and of ramp at the South abutment

FOOTBRIDGE OVER TWO CANALS IN AVEIRO

This very curious footbridge (Figures 15 and 16) could be said to be made up of three bridges, since it provides three distinct crossings over the canals of Saint Roque and of Botirões, in the town of Aveiro. These bridges form a closed and continuous circle cable stayed from one single inclined "mast".


Figs 15 and 16 – Footbridge over two canals in Aveiro

This circular footbridge in Aveiro was designed by Structural Engineer Domingos Moreira and Architect Luís Viegas, and it entered in service in 2006.

FOOTBRIDGE IN GUARDA

The secondary school at the town of Guarda is in its outer edge and students had to cross a junction with intense traffic at rush hours. It is known that youngsters do not take flyovers if that involves a much extended extra walk. Ramps were needed only on the bridge end opposite to the School (which is already high up). These ramps are inclined at 6% maximum slope with intermediate platforms and climb to 6 meters, which requires ramps more than 100 meters in total length. In order to make them attractive, those ramps were organized into a quite interesting building, but most students just dismiss the footbridge.

This bow-string footbridge (Figures 17 to 19) was designed by Structural Engineer Tiago Mendonça / BETAR Consultores and it was open to public in 2007.

Figs 17, 18 and 19 – Footbridge in Guarda

3.2 Footbridges over roads, motorway or railways

Design of roads or motorways for high speed and heavy traffic or of railways is a very complex and multifaceted job that easily becomes too pragmatic and only concerned with their users, that is, vehicles. Pedestrians seem to be looked at as a minor issue and the large majority of footbridges overflying roads, motorways or railways are built not just at minimum cost but also at minimum concern and effort. Miserably, Portugal displays too many footbridges that are ugly, some even structurally unsafe, badly positioned (specially their ramps or staircases) and thus too often useless. In two words, most footbridges are *extremely expensive* because they destroy the landscape, are not used at all and can be very unpleasant to walk. But exceptions do exist.

FOOTBRIDGES FOR JAE (NATIONAL ROAD AUTHORITY)

The footbridge in Figures 20 and 21 is a prestressed concrete curved beam and it was designed back in 1992 by Structural Engineer Julio Appleton for the Portuguese National Road Authority.

Figs 20 and 21 – Footbridge over the A25 Motorway, near Viseu

The concept was applied to footbridges with discrete ranges of central span but unfortunately only four footbridges have been built since then.

FOOTBRIDGE OVER THE NORTHERN MOTORWAY

The countryside footbridge in Figures 22 and 23 is a cable stayed steel bridge built over the A1 Motorway, near Coimbra. Designed by Structural Engineer Tiago Abecasis and built in 1998, it exhibits a very light structural solution that allowed an extremely rapid construction with minimum disruption of traffic underneath.

Figs 22 and 23 – Footbridge over the A1 Motorway

3.3 Park footbridges

Footbridges in parks are generally designed with aesthetics playing a fundamental role and with pedestrians in mind because parks are supposed to draw people and integration into the landscape is essential in their conception. Most often, footbridges in parks are small, their spans are not very challenging and thus total cost is not a very severe limitation. Bridge designers have then an opportunity to play with their imagination.

FOOTBRIDGE AT PASTELEIRA PARK IN PORTO

The park of Pasteleira resulted from the merger of two smaller parks separated by a one-way street where cars speed up and thus pedestrians are unwelcome. The unification was achieved by the construction of three small timber bridges (Figures 24, 25, 26 and 27) conceived, designed and built by the timber construction firm SOTRIM in 2001.

Fig. 24 – Three footbridges in the Pasteleira Park

It might be said that the timber construction firm seized the opportunity to display its products and versatility.



Figs 25, 26 and 27 – Three footbridges (arch – strutted beam with false arch – strutted beam) in the Pasteleira Park

FOOTBRIDGES AT "SANTO AGOSTINHO" PARK IN LEIRIA

The POLIS Program (2000-2006) was an initiative of the Portuguese Government to improve quality of life in urban areas by the rehabilitation of public spaces in city centres, construction of urban parks and cleaning of river margins or sea shores.

Leiria was granted with the rehabilitation of the margins of the river Lis passing through the middle of the town, and that involved the construction of several public equipments and of five small footbridges. Commissioned to MVRDV Architects and with Pedro Morujão / AFAconsult as Structural Engineer, these beam footbridges may be called Leisure Footbridges, for they provide leisure locations inside themselves.

Figures 28 and 29 show the Bar Bridge, where seats and a bar are provided.


Figs 28 and 29 – Picnic footbridge

Footbridge in Figures 30 to 32 is called Balcony Bridge and provides a balcony space at mid-span where a clock also stands.

Figs 30, 31 and 32 – Balcony footbridge

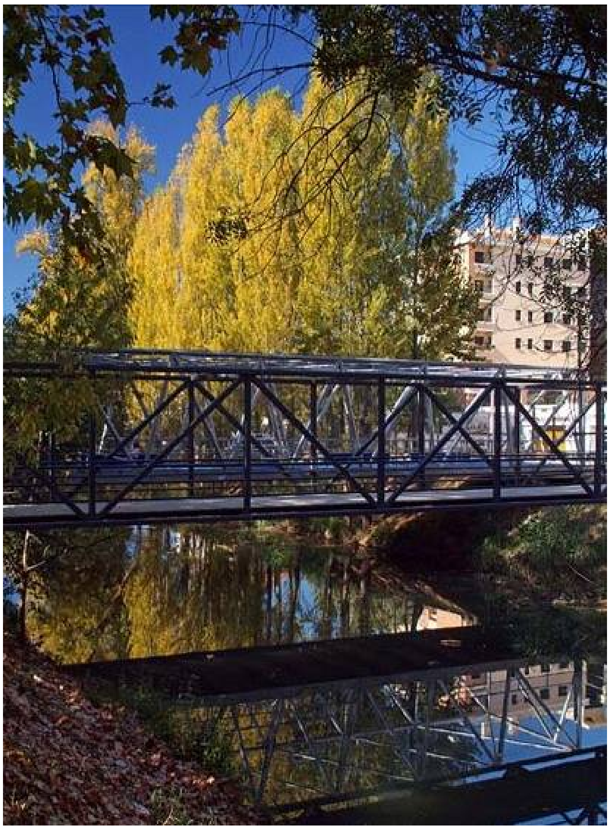
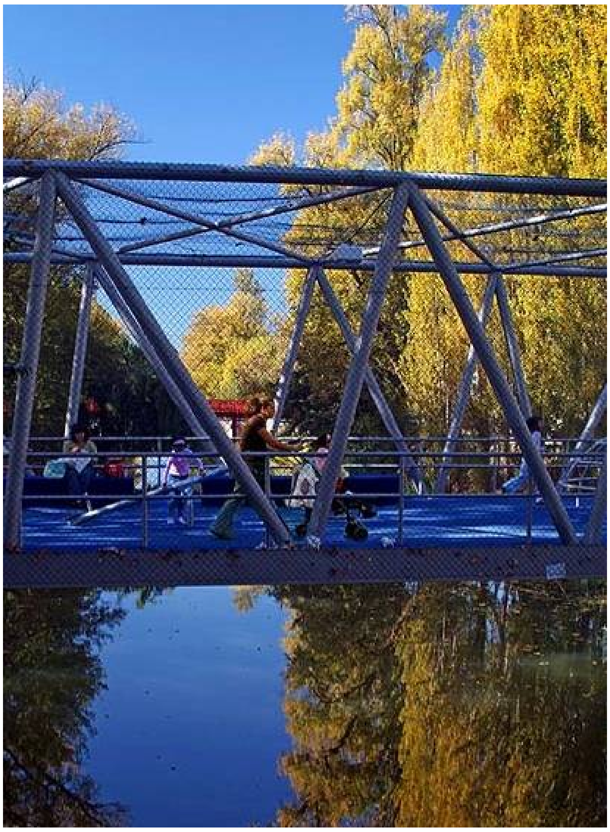
Figures 33 and 34 show the Picnic footbridge, where two tables and benches are fixed in “private” spaces.

Figs 33 and 34 – Picnic footbridge

Footbridge in Figures 35 and 36 is called Sofa footbridge and provides a spacious sofa under a matching lamp and dustbin.

Figs 35 and 36 – Sofa footbridge

Figures 37 and 38 show the Playground footbridge, where children may enjoy several playing equipments and parents may relax inside the truss longitudinal beams.

Figs 37 and 38 – Playground footbridge (photographs by Dias dos Reis)

These five footbridges could be named also as “Pleasure” Bridges and they were built in 2005.

<u>FOOTBRIDGE OVER THE RIVER SORRAIA AT BENAVENTE</u>

This stress-ribbon bridge shown in Figures 39 and 40 was designed by Structural Engineer Luis Câncio Martins and built in 2006 in the Park of Benavente. The ribbon is provided by four longitudinal steel continuous plates over three spans and prefabricated concrete panels of the pavement supply the required stabilising weight.


Figs 39 and 40 – Benavente footbridge

FOOTBRIDGE OVER THE RIVER MONDEGO AT COIMBRA

The city of Coimbra was awarded with one of the most important POLIS sub-programs. Both margins of the river Mondego that are regularly flooded and thus were totally free of construction are now a successful park with splendid public equipments and are connected by a footbridge designed by Structural Engineers Adão da Fonseca / AFAconsult and Cecil Balmond / ARUP-AGU, the latter acting as Architect.

Figure 41 shows the new icon of Coimbra, open to the public at the end of 2006.

Fig. 41 – Coimbra footbridge (elevation view)

The elevation view of this footbridge shows a central arch and two lateral semi-arches supporting, with continuity, the deck. As it is understood from Figures 42 and 43, the bridge is made up of two halves with one shifting with respect to the other. The two halves are parallel to each other and unite longitudinally along 12 metres in the centre of the bridge, thus defining a central “piazza”. Also, the two semi-arches of each half-bridge are positioned laterally with respect to the deck. Together with the deck, they define two triangular frames supporting each other transversally, and the arch behaviour on the longitudinal direction depends upon the horizontal capacity of the foundations.

Fig. 42 – Coimbra footbridge (longitudinal view)

At the very day construction was initiated, this Coimbra footbridge was baptized "Pedro and Ines", matching beautifully the shape and geographical location of the bridge with the tragic medieval tale of love and passion between Prince Pedro and Ines, the Lady-in-Waiting to Princess Constanza.

Fig. 43 – Coimbra footbridge (half-bridge with reflection in the water)

3.4 Special footbridges

Only two footbridges are mentioned in this presentation, and both are rotating bridges built in fluvial harbours located very close to the river mouths in the Atlantic Ocean.

<u>FOOTBRIDGE AT "ROCHA CONDE D'OBIDOS" PORT QUAY, IN LISBON</u>

This footbridge was designed by Structural Engineer Luis Colen with the collaboration of Architects Ana Rita Gama and Sandrine Santos following the concept of cranes typical in harbours. As seen in Figures 44 and 45, the continuous steel beam over the water is stayed by steel stays and the integration of the bridge in the scenery is splendid.

Fig. 44 – "Rocha Conde d'Obidos" footbridge (closed, seen from the north side)

Fig. 45 – "Rocha Conde d'Obidos" footbridge (opening, seen from the south side)

FOOTBRIDGE AT VIANA DO CASTELO MARINE

This cable stayed steel bridge (see Figures 46 and 47) was built in 2007, close to the mouth of river Lima and at the entrance of a marine for recreational boats.

Architect Rui Martins and Structural Engineers Jorge Delgado, Raimundo Delgado, Tiago Gonçalves and Gonçalo Lopes designed a very light structure that resembles a sailing boat leaned by the wind.

Fig. 46 – Viana do Castelo footbridge (closed and seen from inside the marine)

Fig. 47 – Viana do Castelo footbridge (open and seen from outside the marine)

3.5 Footbridges over the River Douro at Porto

3.5.1 Porto or Oporto

"Granitic, baroque, romantic, mirrored in the river ... This is "O PORTO".

Fig. 48 - View of Porto and the river Douro

CALE means place, where a river PORT developed; the PORT of CALE, that is, PORTCALE, which gave the name to PORTUGAL.

3.5.2 World Heritage

The city of Porto, built along the hillside overlooking the mouth of the Douro River, is an outstanding urban landscape with a 1,000-year history.

Fig. 49 - View of medieval and granitic Porto

Its development on the north bank facing the sun left the hill slopes on the south bank free to accommodate the amphitheatre of Port Wine cellars.

3.5.3 Bridges

The river Douro has always been a dividing line between Porto and Gaia, from the 19th Century an inspiration for the design of outstanding bridges, and more recently the scenery of a successful social and leisure life for local inhabitants and visitors alike.

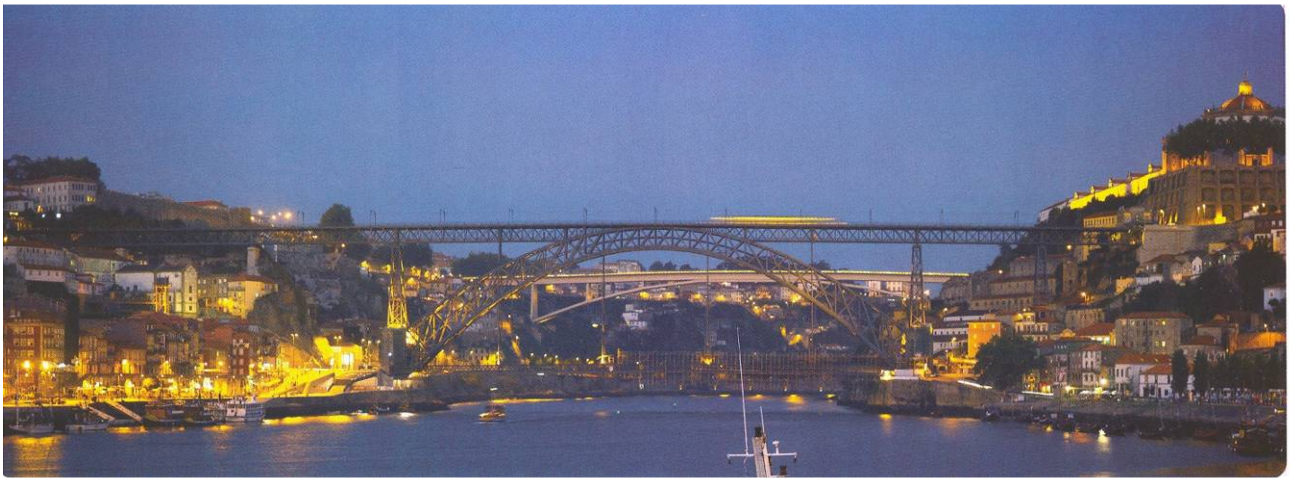


Fig. 50 – Porto – river Douro, world record bridges and night life – Gaia

<u>FOOTBRIDGE OF BOATS</u>

Provisional boat bridges were assembled for very special occasions since the 10th Century, but the first built to last the entire dry season, from April to October, was open to pedestrian and animals in 1806 and it is shown in the engraving in Figure 51.

Fig. 51 – Footbridge of boats (engraving)

<u>SUSPENSION FOOTBRIDGE</u>

The first permanent bridge was a suspension bridge. Its span of 170 m was almost a world record at the time. Designed by Structural Engineer Stanislas Bigot, construction finished in 1843 but the bridge was demolished after 44 years only because the double deck bridge of King Luiz (seen in Figures 50 and 53) had already been built and because it exhibited a too lively behaviour under pedestrians and animals.

Fig. 52 – Suspension footbridge (photograph by Domingos Alvão)

STAINLESS STEEL ARCH FOOTBRIDGE

Porto was European Capital of Culture in 2001 and social and leisure life was increasing rapidly in the city quarters overlooking the river Douro. Need for a bridge dedicated to pedestrians and given the opportunity to include its construction costs in the POLIS sub-program for Porto provided the drive to build a much desired footbridge.

The shortest distance between the two margins is precisely the location of the suspension footbridge of the 19th Century. Construction of another suspension bridge was intended initially by the two Municipalities, but Structural Engineer Adão da Fonseca / AFAconsult developed the alternative design of a stainless steel shallow arch spanning the entire 156 meters distance.

Figures 53 and 54 show the bridge that went into tender, but higher than foreseen construction budget and some opposition to the construction of a bridge so close to the existing King Luiz Bridge lead to the cancellation of the project.

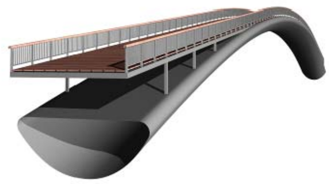


Fig. 53 and 54 – Stainless steel arch footbridge (photomontage) and perspective of model

"RIBEIRA" SUSPENSION FOOTBRIDGE

The European Capital of Culture in Porto is past but social and leisure life boost up in the slopes overlooking the river Douro and looking at each other across the waters. In 2006, the Municipality of Gaia invited Structural Engineer Adão da Fonseca to conceive and design another footbridge 500 meters downstream from the King Luiz Bridge, where the river is around 250 meters wide.

A suspension bridge was found to be the one solution transparent enough to guarantee views are not hindered, as shown in Figures 55 and 56.

Fig. 55 – "Ribeira" suspension footbridge seen eastwards (photomontage)

Pedestrians arriving at the Porto margin are 8 meters above ground and either take an elevator or go through a short ramp leading to the medieval walkway above the arches holding the alignment of houses. Arrival at the Gaia margin is made by the deck curving in order to land parallel to the river. This curvature is fundamental for the horizontal behaviour of the bridge under wind loading or pedestrian dynamic loading and also confers the bridge a perfect inscription into the meander of the left margin, on the way to the Ocean.

Fig. 56 – "Ribeira" suspension footbridge seen westwards (photomontage)

Praise to this footbridge is coming from all sides. At an estimated total cost that may top € 15,000,000, progress in its design and specialized studies is waiting for active support from the Porto Municipality.

4. Acknowledgements

Photographs and information on several footbridges mentioned in this paper were provided by the respective bridge designers, to whom acknowledgements are due.

5. References

[1] AZEVEDO A. F. M., and ADÃO DA FONSECA, A., "Second-Order Shape Optimization of a Steel Bridge", http://civil.fe.up.pt/pub/people/alvaro/pdf/1999_OPTI_Paper_Shap_Opt_Steel_Bridge.pdf in *Computer Aided Optimum Design of Structures VI* (invited paper) S. Hernandez, A. J. Kassab & C. A. Brebbia (editors) ISBN: 1 85312 681 0 - WIT Press, Southampton. pp. 67-76, 1999.