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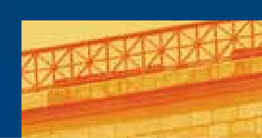
Footbridges - Small is beautiful



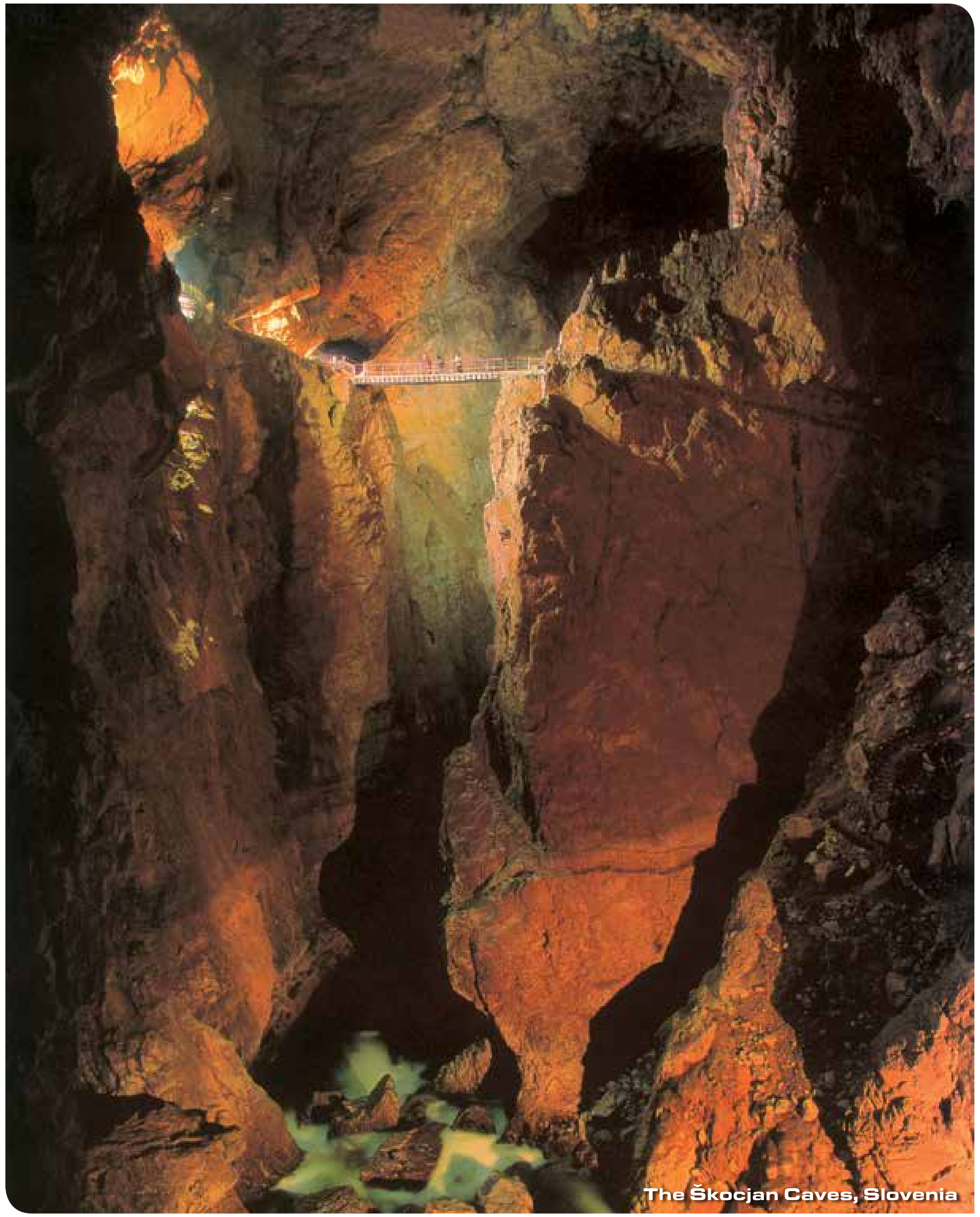
European Council of Civil Engineers

Footbridges

Small is beautiful

Contributions from the following countries

* Country not being ECCE member
** The contribution of JSCE-Japan Society of Civil Engineers as guest



The Škocjan Caves, Slovenia

Claude Monet (1840–1926)

Le Pont Japonais *(The Japanese Bridge)*

FOOTBRIDGES - SMALL IS BEAUTIFUL

Some notes on the history of bridge structures

Written by Gorazd Humar, B.Sc.C.E., ©

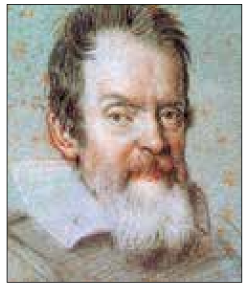
Review: prof. Enzo Siviero, Faculty of Architecture, Venice

Hradeckega Footbridge in Ljubljana, Slovenia, 1867

The article that follows does not aim to describe the entire history of construction, or more particularly of bridge-building, since it does not cover the whole of the historical period in which bridges have been built. The text is a compilation of the author's independent research and a number of his studies relating to the history of bridge-building. It also includes material that the author presents to students in his lectures on the history of construction at the University of Maribor's Faculty of Civil Engineering. The text also contains significant statements and findings from numerous researchers of the history of construction. The author has combined their findings into the overall context of the article according to the logic of their development over time and their importance, and according to his own judgement, so that the text before you can tell the story, supported by historical facts, of the development of bridge-building expertise up to the beginning of the twentieth century.

Some statements and findings are dealt with in more detail because of the interesting points they raise, and serve to make the varied history of construction even more interesting. Why can't the history of construction, and particularly the history of bridge-building, be read like a thrilling novel? The many famous builders and engineers who have built bridges have supplied more than enough reasons to suggest that it can. So let us begin...

The foundations of modern structural mechanics are laid in the 17th and 18th centuries



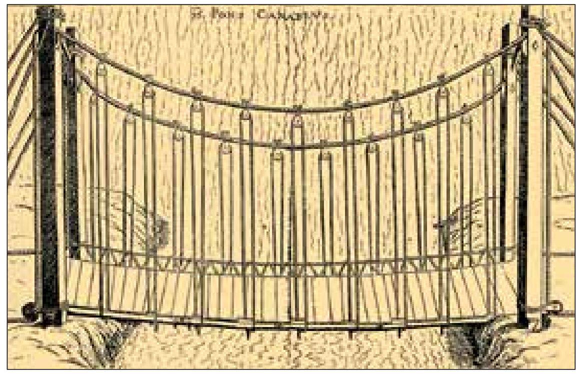
Galileo Galilei (1564–1642)

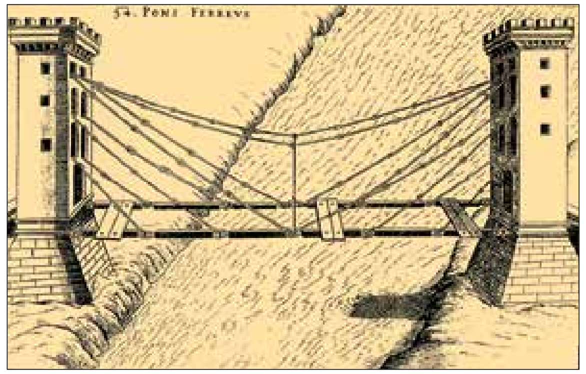
As mentioned earlier, the construction of the Santa Trinita bridge in Florence in 1569 represented a true turning point in the understanding of structural mechanics and, consequently, the line of the arch. The new line of the flattened arch establishes an entirely new understanding of the interplay of gravitational and other forces in the bridge structure. The arch has long since ceased to be the semicircular form used in ancient Rome. It has become increasingly flattened, but the most important thing is that the line of the arch of the Santa Trinita bridge is very close to a catenary, in other words a curve that increases its curvature as it moves from the centre of the arch towards the abutments. In this way the horizontal forces in the centre of the arch are increasingly transformed into vertical forces in the pier or abutment.

The research by Ammannati, the builder of the Santa Trinita bridge, into the interplay of forces in a catenary was successfully continued by one of the fathers of modern mechanics, Galileo Galilei (1564–1642), who was not only famous as an astronomer. As well as establishing the laws of falling bodies, Galileo attempted to determine the path of projectiles. He established that the path of a horizontally thrown object is a perfect parabola. In 1638 he succeeded in proving that a parabolic trajectory corresponds to a catenary. Essentially, the interplay of forces in an arch bridge structure of catenary shape is similar to that in a falling projectile.

Also dating from this period is the first known proposal to build a bridge suspended on chains. This was the work of the Croatian inventor and engineer Faustus Verantius (also known as Faust Vrančić or Fausto Veranzio). His work Machinae Novae, published in 1595, contained his idea for a bridge suspended from chains. This was the first predecessor of a system for the construction of suspension bridges that was widely used in later centuries and is still used today.

Plans for suspension bridges by the Croatian inventor Faustus Verantius (Faust Vrančić), 1595





Of enormous importance for the further understanding of structural mechanics was the research conducted in the seventeenth century by Robert Hooke (1635–1703). He discovered the law of elasticity – known as Hooke's Law – which is still valid today.

The most solid foundations of modern structural mechanics were, however, laid by Sir Isaac Newton (1642–1727). He presented his research in his 1687 work Philosophiæ Naturalis Principia Mathematica, condensing it into the laws that we know today as Newton's laws. Newton's discoveries opened the way to further development of the science of construction.

A crucial turning point in the history of bridge-building came when Jean-Rodolphe Perronet (1708–1794) established the École des Ponts et Chaussées (School of Bridges and Roads) in France in 1747. This school provided the basis for the construction of bridges according to the engineering principles of statics, strength of materials, mechanics and other parallel sciences that contributed, in a scientific manner, to the introduction of new construction principles in bridge-building that were supported by calculations. Perronet's contribution to the further development of bridges is of inestimable importance. With the help of the findings of his school, he entirely changed the shape of the arch as the principal load-bearing element of the bridge. He flattened the arch to a remarkable degree and in doing so did away with all previous conceptions of arch design in bridge structures.

Robert Hooke (1635–1703)

Jean R. Perronet (1708–1794)

Comparison of progress in bridge-building from the Roman era to the 18th century, when J.R. Perronet distinctly modernised the form of the arch and changed the role of bridge piers.

In the picture are the Pont de la Concorde, designed by Perronet, and the Pons Milvius in Rome. Around 1800 years separate the building of these two bridges. While semicircular arches and thick piers were typical of Roman bridges, Perronet's stone bridges had very shallow arches and slender piers, which among other things allowed more water to pass under the bridge

St John Nepomucene - Svatý Jan Nepomucký
Protector against floods and also protector of bridges

Statues, monuments and inscriptions are not a very common phenomenon on bridges in general. Only a few bridges can boast this type of decoration, which can give a bridge a special importance. The ancient Romans used to build stone tablets into their bridges, usually to commemorate the ruler responsible for its construction. By virtue of their function, bridges were structures on which rulers and others liked to place monuments or divine symbols. No-one could cross the bridge without observing the symbol on it.

Erecting statues or commemorative symbols on bridges reached the height of its popularity in The Middle Ages. Perhaps the richest and most beautiful bridge from this point of view is the Charles Bridge in Prague, built over the Vltava in the early 15th century. Today over 30 statues and sculptures stand on the 516-metre-long bridge, transforming it into a true art gallery.

The old Roman bridge (built 133-134 AD by the Emperor Hadrian) leading to the Castel Sant'Angelo in Rome was completely renovated during the Roman baroque period, by

The Charles Bridge in Prague

FOOTBRIDGES - SMALL IS BEAUTIFUL
St John Nepomucene

FOOTBRIDGES - SMALL IS BEAUTIFUL

Photo: Gorazd Humar

The Old Bridge (Stari most), Mostar

Croatia

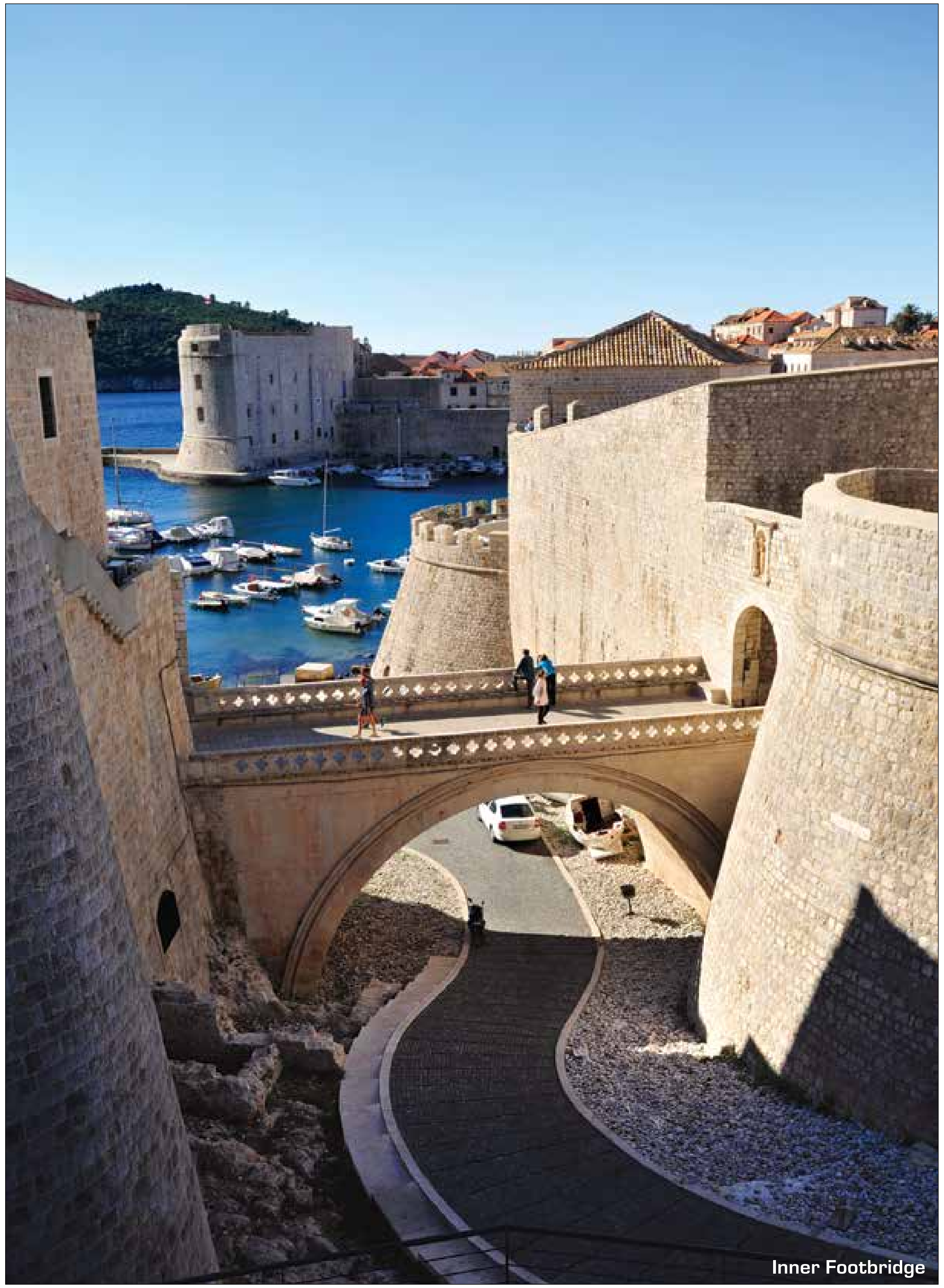
Footbridges of Dubrovnik

- **Dubrovnik**
- 1397–1538
- Access bridges to the walls of Dubrovnik
- Outer bridges extended by a wooden drawbridge

For more than eleven centuries, until the beginning of the nineteenth century, the city of Dubrovnik (Latin: Ragusa) was a republic, defending its survival and freedom primarily through diplomacy but also by building city walls and other fortifications. The Dubrovnik city walls run uninterruptedly for 1,940 metres and represent a unique example of fortification architecture. Today they are an internationally recognised monument. The process of constructing the walls and fortifications continued for centuries. In the fourteenth century the people of Dubrovnik dug a moat in front of the Pile Gate, on the west side of the city. In the fifteenth century they did the same on the east side.

Entrance to the Old Town is through the Pile Gate on the west side, via a two-arch stone bridge and a wooden drawbridge. This stone bridge underwent numerous changes and transformations over the course of the centuries. The original bridge built by military engineer Giovanni da Siena between 1397

Pile Footbridge



Inner Footbridge

Cyprus

Photo: Charis Solomou

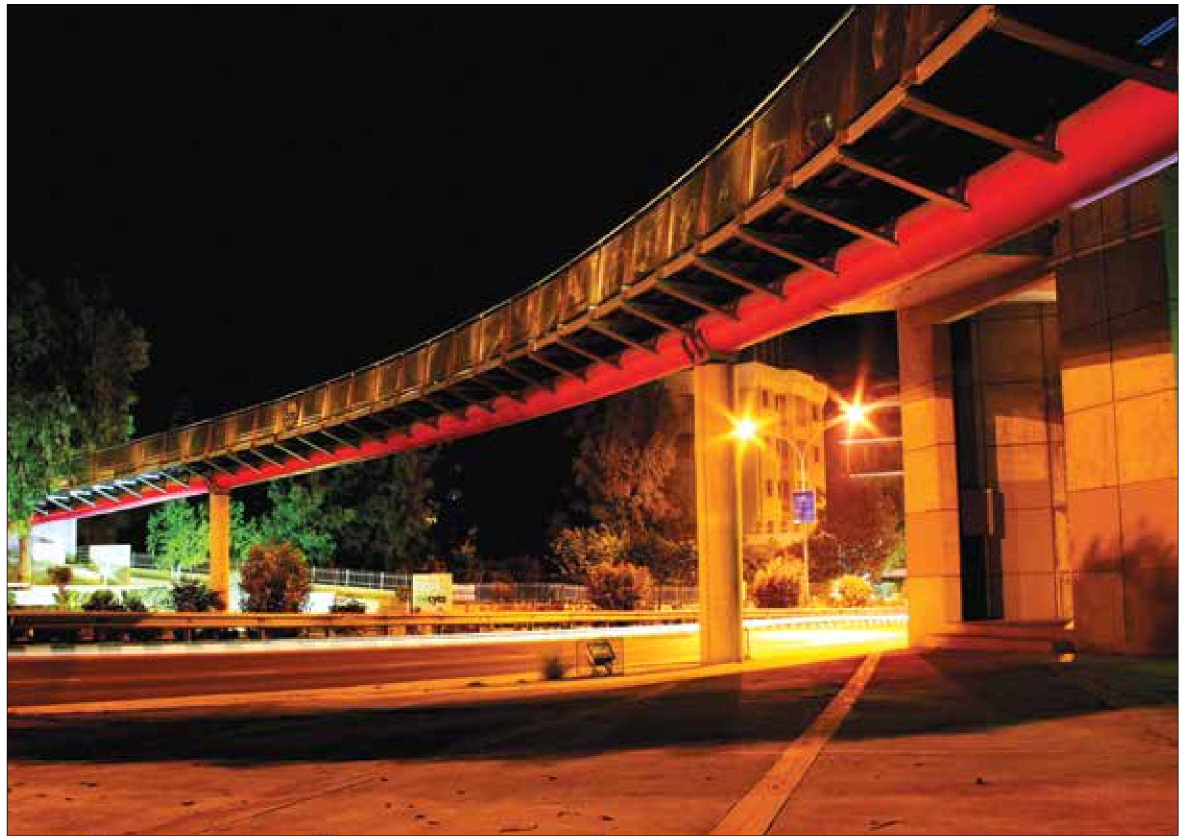
Cyta Footbridge

- **Nicosia**
- 2003
- Metal tube – main supporting element
- Access ramps for disabled users and those with reduced mobility

The bridge structure consists of a curved metal tube supported by concrete columns. The bridge is 1.5 metres wide, spans a distance of 37 metres and has an opening of 70 metres.

Access to people with disabilities or reduced mobility is provided by a 12 metre ramp at the south end of the bridge and a 17 metre ramp at the north end. The Cyta Footbridge is located on Limassol Avenue, in Dasoupolis, Nicosia and connects the Archbishop Makarios III High School with the police road safety park.

Photo: Xristakis Sazeides



FOOTBRIDGES - SMALL IS BEAUTIFUL

Cyta Footbridge

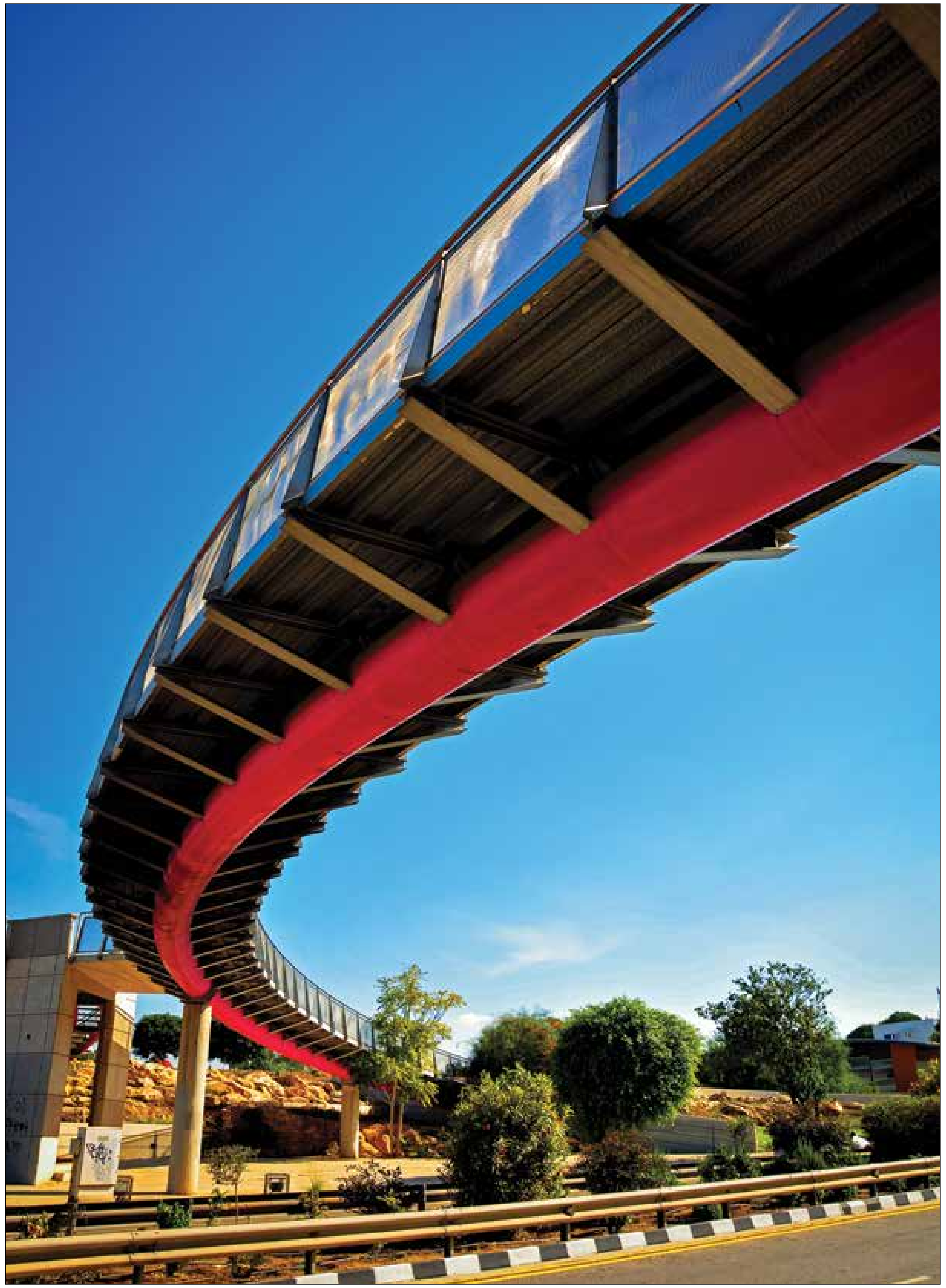


Photo: Charis Solomou

Photo: Gorazd Humar

The Charles Bridge (Karlův most), Prague

Czech Republic

Bridge over the Vltava

- **České Budějovice**
- 2005–2006
- Structure of the year 2006, Czech Republic
- Bridge of the year 2007, Czech Republic

This footbridge in České Budějovice connects the historic town centre with a new residential area. The bridge consists of a tied arch inclined to one side and anchored to a composite deck. The arch has a span length of 53.20 metres and a rise of 8.00 metres and is formed by a steel pipe; the suspenders are formed from I-shaped steel members. The deck is formed by two edge pipes mutually connected by a truss floor beam and a composite deck slab. The steel structure is supported by a short cantilever protruding from the end diaphragm. To resist bending moments, the diaphragms are supported by a pair of piles. The steel structure was assembled on temporary towers. When the towers were removed, the composite deck slab was cast.

The bridge was designed by Stráský, Hustý a partneři s.r.o. of Brno and built by JHP Mosty of Prague.

Main technical characteristics:

Arch bridge – length: 64.5 metres;
span length of the arch: 53.20 metres;
width between the railings: from 3.52 metres

FOOTBRIDGES - SMALL IS BEAUTIFUL

Estonia

Photo: Andrus Kõresaar

Seaplane Harbour Footbridges
(Estonian Maritime Museum)

- **Tallinn**
- 2011
- Total length of footbridges 210 metres
- Width 2.5–4.0 metres
- Winner of major EU award in 2013

The hangars in the Tallinn Seaplane Harbour are the most important engineering landmark in the region (designed and built by the Danish company Christiani & Nilsen Ltd in 1916/17). They are thought to be the first large-scale

reinforced concrete shell structure in the world. The building consists of three main reinforced concrete shells measuring 36.4 x 36.4 metres (average thickness 8–12 cm).

Renovation of the hangars was carried out between 2009 and 2012 (architectural project by KOKO Architects, engineering and technical project by Karl Õiger and Heiki Onton) with the aim of transforming the hangars into a home for the Estonian Maritime Museum.

The architects came up with the idea of a two-level space that would create an impression of the underwater world and the world above the water without actually flooding the hangars. This "two worlds" solution is distinguished by special lighting that creates a visual impression of the split-level space inside the hangars.

Visitors view the exhibits from "sea level" using the 210-metre steel footbridge that passes through the hangar.

A second footbridge marks the radius of the arc of the reinforced concrete shell.

Photo: Andrus Kõresaar

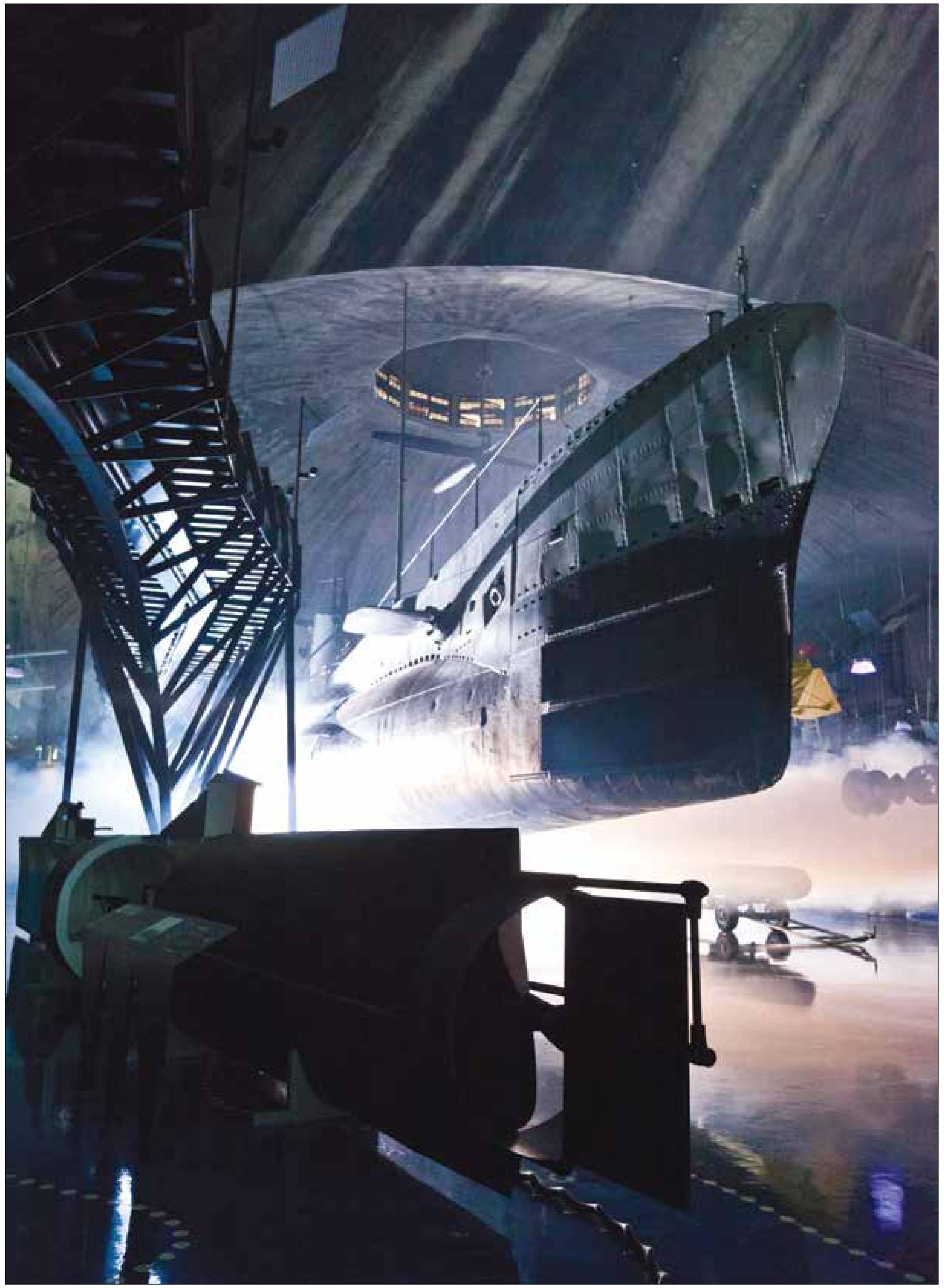


Photo: Andres Teiss

Arts Bridge (Pont des Arts), Paris

Photo: Gorazd Humar

Georgia

The Bridge of Peace

- **Tbilisi**
- 6 May 2010
- Curved steel tubular truss structure covered with glass plates
- Special illumination and light effects
- Opened by the Georgian president Mikheil Saakashvili

Text by: Gorazd Humar
All photos: Gorazd Humar

The Bridge of Peace – the name of this architecturally interesting bridge in the centre of the Georgian capital Tbilisi represents a communication that "celebrates life and peace between people". These are the words of Philippe Marionaud, the French lighting designer responsible for the bridge's special lighting effects. And indeed – the bridge is a wonderful sight not only during the day but also at night, when thousands of LED lights create a colourful and constantly changing spectacle.

These lighting effects also include the deck of the bridge, where LEDs are embedded in protective glass railings. The lights display a message that renders the periodic table of elements in Morse code scrolling along the parapets of the bridge. Along with the nearby Narikala Fortress, which is impressively floodlit, the bridge helps give Tbilisi an attractive appearance by night.

The bridge was designed by the Italian architect Michele de Lucchi, who was also the designer of some important modern public buildings in the vicinity. The elements of the steel bridge structure were produced in Italy and assembled on site. The bridge, which spans 150 metres over the river Mtkvari (Kura), links Tbilisi's old town to a new modern park on the left bank. The bridge has a very particular shape that is somewhat reminiscent of a sea creature. This effect was achieved by a special roof construction covered with glass plates.

Soon after its completion the Bridge of Peace was already established as one of Tbilisi's most important landmarks. Even the name of the bridge sends a strong signal – it is a symbol of peace in modern Georgia.

Client: Old City Rehabilitation and Development Fund
Designer: Michele de Lucchi / **Structural design:** Favero & Milan Ingegneria Srl
Illumination designer: Philippe Marionaud
Illumination made by: Dutch Primo Exposures and RENA Electronica

Photo: Gorazd Humar

The Bridge of Peace, Tbilisi

Germany

Harbour Footbridge

- **Sassnitz, Mecklenburg-Vorpommern**
- May 2006–July 2007
- A balcony over the sea
- Very light and transparent bridge structure

Text: Deutscher Brückenbaupreis 2010

This new footbridge functions as a "balcony over the sea", connecting the harbour of Sassnitz to the town. It has an extremely slender profile with a height difference of 22 metres and combines form and function in a very convincing manner. The bridge is a single-ring beam suspended from eccentric cables and connected to an approach ramp. The bridge is light and transparent, with the result that the view is not obstructed at any point.

The bridge was designed and built by **Schlaich, Bergermann & Partner** of Stuttgart and was the winner of the 2010 Deutscher Brückenbaupreis.

Construction data:

Total length: 243 metres
Span: 119 metres
Ramp: 124 metres
Width: 3 metres
Height difference: 22 metres
Height of mast: 43 metres
Number of cables: 28
Weight of bridge: 320 tonnes

All photos: Wilfried Dechau ©

Great Britain

Postbridge

- **Devon**
- 13th century
- The deck slabs weigh up to 8 tonnes each
- Protected status since 1967

Text by Brian Duguid

The oldest surviving footbridges in the United Kingdom include "clapper bridges", a simple form of bridge constructed from massive stone slabs supported by stone masonry piers. The most famous examples include the Tarr Steps in Somerset, a 55-metre bridge of 17 spans that is believed to date from around 1100; and Postbridge in Devon, a three-span bridge dating from the thirteenth century.

The deck slabs at Postbridge are reported to weigh up to 8 tonnes each. These bridges still rank as significant engineering achievements given the limited means available at the time of construction. The bridges have remained in continuous use since they were built, carrying both foot and packhorse traffic.

Postbridge is recognised for its historic significance and has been listed as a protected historical monument since 1967.

Great Britain

Mathematical Bridge

- **Cambridge**
- 1749, rebuilt in 1866 and 1905
- Historic timber footbridge
- Spans 12 metres over the river Cam
- Very efficient use of timber

Text by Brian Duguid

Few historic timber footbridges have survived. The Mathematical Bridge, which spans 12 metres across the river Cam in the university town of Cambridge, originally dates from 1749. The current bridge is actually a reconstruction to the same design, the bridge having been completely rebuilt in 1866 and 1905.

The design, by William Etheridge, uses straight timbers arranged radially and tangentially to a circular arc, giving rise to the bridge's nickname. It has been suggested that this represents a highly efficient use of the timber, and it has also been used for the timber centring for a number of masonry arch bridges. However, there is little evidence to support this supposition, and many of the timbers in the bridge are likely to carry very little load.

Although the Mathematical Bridge in Cambridge is well known, there is an essentially identical, albeit smaller, bridge of the same type at Iffley Lock in Oxford, built in 1924.

Greece

Palkida or Kalogeriko Bridge

- **Western Epirus, near the villages of Kipoi and Koukouli**
- 1814
- Stone bridge, total length 56 metres
- Three spans of 12, 14 and 16 metres
- Perfectly integrated with the landscape

Text by: Aris Chatzidakis

The Plakida or Kalogeriko Bridge is situated in Western Epirus, close to the villages of Kipoi and Koukouli, in the Central Zagori area. It was built in 1814 in order to link the banks of the river Vikos (a branch of the Voidomatis, which is a tributary of the Aoös, one of the longest rivers in Greece). The stone bridge, which has a total length of 56 metres and is 3.15 metres wide, has three stone arches with spans of 12, 14 and 16 metres respectively. The parapet consists of oblong stones set vertically at regular intervals. The bridge is particularly notable for the way it blends into the landscape. Its shape has led to comparisons with a crawling caterpillar.

The original bridge was wooden but it was later rebuilt in stone following a grant from Serafeim, the abbot of the Profitis Ilias monastery in the village of Vitsa. It was therefore named the Kalogeriko Bridge (καλόγερος, kalogeros = monk in Greek). After the year 1865, according to an inscription, it underwent structural repairs financed by Alexis and Andreas Plakidas of Koukouli, and was therefore was renamed the Plakida Bridge.

Bridges were usually named after the person or institution who financed their construction (rich benefactors, endowments such as the Ottoman vakifs, Turkish officers, ecclesiastics and so on). In some cases, two or more names were attributed to the same stone bridge, since they referred to the people who had covered the cost of repairs, when needed. Bridges were also named after villages, when they were built using funds raised in a given area.

The stone bridges that are found in the mountainous regions of Greece, particularly in Epirus, enabled essential communication between inaccessible rural areas and the principal markets of the eighteenth and nineteenth centuries: the Balkans, Austria (mainly Vienna), Turkey and Egypt. Bridges were essential to the area's economic livelihood.

Most of the bridges in Epirus were built of schist stone, while a mixture of lime, crushed tiles, water, pumice stone and dried grass were added to the binding mortar in order to make it stronger and more resistant. Construction of bridges started from both ends, with the master builders working gradually towards the keystone. The voussoirs had to be set close together in order to direct the thrust of the arch in such a way that the weight of the whole structure would be transferred to the supports. The abutments and central piers had to be bedded on stable ground, so the construction of stone bridges mostly took place in summertime, to take advantage of favourable weather conditions. A well-constructed scaffolding consisting of wooden beams was used to prepare the formed arches and removed after building was complete.

Stone bridges, like most structures of the period (religious buildings, public buildings, domestic architecture), were built by groups of local craftsmen (μπουλούκια or ισνάφια, known also as κουδαραίοι), who moved from village to another and from one region to another. Those responsible for building bridges were known as κιοπρουλήδες, kioproulides (köprü=bridge in Turkish), but they also built other buildings and included craftsmen (μάστορες, mastores) able to work in stone, wood, metal, as well as their young apprentices.

Hungary

"Mayfly" footbridge over the river Tisza

- **Szolnok**
- August 2009 to January 2011
- Main span 120 metres
- Fitted with tuned mass dampers

Text by: Pálossy Miklós / Pont-Terv Zrt, Budapest, Hungary

A new bridge for cyclists and pedestrians over the river Tisza in Hungary was opened to traffic in 2011. The "Tiszavirág" (Mayfly) bridge creates a new link for the city of Szolnok and seems destined to become an emblematic work of art for the city. As well as the design of the bridge itself, the design competition included the reconstruction of the urban square on the right bank and the adjoining green area on the left bank in order to make the bridge fully accessible to pedestrians, cyclists and disabled users. The design competition was won by a team consisting of bridge consultants Pont-Terv and architects ADU. The winning concept was a slender, elegant, splayed arch structure, which was intended to combine a dramatic visual impact with good functionality and economic construction.

The steel arch bridge has a main span of 120 metres composed of two tubular arches splayed outwards at 60° from the horizontal and a spatial truss deck girder suspended by tie-rods. The deck consists of a steel grid covered with composite planks of wood and resin, which is a maintenance-free material. The glass panels spaced regularly along the centre line give variety to the wide homogeneous surface.

The LED lighting consists of a dotted line of lamps on the outer side of the arches, and light beams for illuminating the inner side. The illumination of the deck is provided by LED lights embedded in the handrails.

Since dynamic behaviour is a key issue in the case of slender pedestrian bridges, in-depth aerodynamic studies were carried out and four tuned mass dampers were incorporated into the deck in order to reduce pedestrian-related vibrations.

Erection on site was carried out using two auxiliary supports in the river bed. Since its inauguration the bridge has become very popular in Szolnok, and serves as a venue for various events in the city.

Main technical characteristics:

Main span: 120 m
Length: 186 m (main steel river bridge)
Total length: 320 m (including RC approach bridges)
Width: 5 m
Structural steel: 380 t
Design: Pont-Terv Zrt/ ADU Architects
Construction: KÖZGÉP Zrt

"Mayfly" footbridge over the river Tisza

FOOTBRIDGES - SMALL IS BEAUTIFUL

"Mayfly" footbridge over the Tisza river, Szolnok

FOOTBRIDGES - SMALL IS BEAUTIFUL

Ireland, Republic and Northern

Liffey Bridge - Ha'penny Bridge

- **Dublin**
- 1816
- Cast iron arch spanning 42 metres
- Restored in 2002
- Heritage award in 2002

The earliest known iron bridge in Ireland, the Liffey Bridge, was erected in 1816 for pedestrian traffic to connect Merchants Arch on the south quays of the River Liffey with Liffey Street Lower leading from the north quays.

The bridge is a single span cast-iron arch with an elliptical profile and consists of three parallel arched ribs spanning 42 metres between angled masonry abutments and having a rise of 3.6 metres (The span increases to about 43 metres at deck level). Each arch rib consists of six lengths of cast-iron bars of cruciform section. These are connected together at each rib joint to form two tiers of rectangular openings with chamfered surround, the depth of the opening decreasing towards the crown. The ribs are stiffened by the deck and by diagonal and normal bracing to form a truss in the plane of the intrados. The transverse cross members are of hollow circular section with a bolt passing through, and act as spacers to provide lateral stability. Cast corbels on the outside ribs carry a flat plate that supports the parapet railings.

The Liffey Bridge was cast at the Abraham Darby III foundry at Coalbroookdale in Shropshire, England and was restored in 2002. The Liffey Bridge won the Heritage Award in 2002.

Photo: Robert Cortright, USA

Italy

The Rialto Bridge
(Ponte Rialto)

- **Venice (Venezia)**
- 1591
- Probably the most recognisable footbridge in the world
- Widest footbridge in the world (22.1 metres)
- Public competition held for its construction

Text by: Gorazd Humar
All photos: Gorazd Humar

The Rialto Bridge is undoubtedly the king of Venice's bridges. It is an unmistakable icon of the beautiful lagoon city and at the same time the oldest of the four bridges that cross the Grand Canal, the city's main thoroughfare. It is 22.1 metres wide, making it the widest of Venice's 431 bridges. Another unique feature are the 24 little shops that line the bridge: two rows of them rising up in steps on one side and descending on the other.

The bridge has a rich and varied history, just like Venice itself. It was built in 1591, in the period of the city's greatest prosperity. Preparations for its construction took almost a century, beginning in 1503 when a design for a new bridge was drawn up after the previous wooden bridge was destroyed by fire. It was not until after 1550 that the plan to build a new bridge began to be taken more seriously. The city authorities held a public competition to choose a design. The committee responsible for the competition was presided over by the powerful and influential salt merchants' guild, who wanted new shops on the bridge from which to sell their salt. The public competition was one of the first in history for an important construction project of this kind, and perhaps the first ever held for the construction of a bridge. One of the conditions laid down for the design of the new bridge was that the Doge's ceremonial galley must be able to pass under it.

In 1588, after a long search for a suitable solution and numerous quarrels, construction of the new bridge was entrusted to the architect Antonio da Ponte, who designed a single-arch bridge to span the Grand Canal. The new bridge, built of white Istrian stone, was completed three years later. The biggest technical challenge was represented by the foundations of the main arch, which was squeezed between the houses on either bank of the canal. Using specially designed foundations of considerable width, Da Ponte skilfully transferred the horizontal forces generated by the arch structure into the ground via foundations supported by wooden piles.

In 1591 the Rialto Bridge was opened to traffic. The 24 stone-built shops placed on the bridge soon opened for business and a safe and broad route across Venice's main traffic artery, the Grand Canal, was thus created. Most importantly, with its single arch, the new bridge allowed boats to pass along the Grand Canal unimpeded. The Rialto Bridge is probably the most famous and most photographed bridge in the world.

FOOTBRIDGES - SMALL IS BEAUTIFUL

The Rialto Bridge, Venice

Photo: Gorazd Humar

Italy

All photos: Oskar Da Riz, courtesy Textus Edizioni.

Sea Bridge
(Ponte del Mare)

- **Pescara**
- 2008 - 2009
- Cable-stayed footbridge
- Total length 466 metres, main span 172 metres
- Two separate lanes for byciclists and pedestrians

Jutting out towards the Adriatic sea, Pescara is a city rich in contrasts: on the one side, the sea and a mainly urban territory that face each other, on the other, the river with the same name, Pescara, that splits the urban fabric in two quarters which are distinct and diverse both from an architectural and from a social point of view. In this difference lies, the origin of the "Ponte del Mare" (Sea Bridge), conceived as an element which can facilitate the physical and cultural reconnection of two seemingly opposite realities, with a past which is rich in history and a future in constant growth. Designed by Walter Pichler, an architect from Bolzano, the work is the tangible expression of the desire to give unity back to the urban fabric of Pescara, recreating the continuity of its seafront. The bridge's morphology comes from this desire, two pathways that lift up from their respective banks as one to meet, ideally, in a place of physical and social reconciliation, suspended above the river. In fact, two rows of cables branch off from a central pier to support and balance the bridge's two separate lanes, the bicycle lane which is 4 metres wide and the pedestrian lane which is 3 metres wide, that near the two ends merge into a single 5 metres wide lane. In this way, the bridge recreates a sort of empty space in the air, rich in meaning, that enclosed between the two curvilinear lanes gives the work the symbolic value of a monument to peace and gateway to new cultural exchanges, like those recently developed by the countries that border the Adriatic Sea.

Client: Comune di Pescara / **Designers:** Walter Pichler – Mario De Miranda

FOOTBRIDGES - SMALL IS BEAUTIFUL

Sea Bridge

Latvia

Mitava footbridge over the river Driksa

- **Jelgava**
- 2012
- Winner of 2012 Best Engineering Structure award

Contractor: SIA Tilts
Project manager: Artjoms Gridnevs
Designer: Project 3, Girts Skupelis
Architect: Ivars Slivke

In July 2011 Jelgava city council contracted SIA Tilts to build a footbridge over the River Driksa River and create a whole new area of the city, including two pedestrian promenades, renovation of nearby streets, alterations to the landscape, etc.

A cable-stayed footbridge with a length of 150 metres and a main span of 75 metres was built over the river Driksa. The bridge has two 28-metre pylons and 28 cables and was constructed from pre-fabricated steel sections finished with a timber deck and stainless steel railings forming aesthetically pleasing parapets and seats along the bridge.

The project also included an arched road bridge over the canal connecting the river Lielupe to the Driksa, a two-storey boat station with concrete pontoons for boats, and a steel pontoon bridge located further along the Driksa.

The project included many architectural features such as specially designed lamp posts, bicycle racks, illuminated fountains and steel benches that together complement the overall design concept of this new city district.

The streets were paved with concrete blocks in various colours – yellow, blue, red, white, grey, etc. All the nearby streets underwent renovation and communications were revised and updated.

Alterations to the landscape included moving the canal connecting the Driksa and the Lielupe to allow the expansion of Post Island (Pasta sala). The ground level of the island was raised by approximately two metres and the riverbed was lowered so as to allow boats to navigate freely around the site.

Site engineering and temporary works were designed and managed by SIA Tilts. The project was completed in November 2012 and a beautiful opening ceremony was held on the eve of Latvian Independence Day.

The bridge, which has already become a Jegava landmark in its own right, stands next to a historic palace designed by Francesco Bartolomeo Rastrelli and built in 1738. The present-day development of the city may be seen as a continuation of a process that began with Rastrelli.

Urban regenaration is now in full swing and is expected to bring new life to the area in the form of public events, cafés, restaurants and so on. All this will increase the number of tourists and benefit the local population.

The unique and complex design of this project afforded the contractor, SIA Tilts, plentiful opportunities to demonstrate its engineering and project management expertise. The bridge won the 2010 Best Engineering Structure award.

Technical characteristics:

Length – 200 metres (152-metre steel superstructure, 50-metre concrete superstructure)
Width – 3.5 metres
Pylon height – 24 metres
Number of stays – 28

Mitava footbridge over the river Driksa

FOOTBRIDGES - SMALL IS BEAUTIFUL


Trakai Castle Footbridge

Malta

St Elmo Footbridge

- **Valletta**
- 2012
- 70-metre span classic arched truss
- The new bridge respects the historical context
- Designed to withstand sea storms

Text: Ruben Paul Borg & George Cassar

Malta provided a secure base for the British fleet in the Mediterranean during the nineteenth and twentieth centuries. Grand Harbour, a natural port, incorporates a number of inlets which provide adequate shelter to naval vessels. However, it had one particular drawback: it was not an all-weather port due to its exposure to north and north-easterly winds. With the increasing strategic importance of Malta as a British naval base during the 1800s – as a port of call for ships en route to India – the need was recognised to transform Grand Harbour into a year-round port. Studies were undertaken in as early as 1872 with a view to constructing a breakwater at its entrance. In February 1990, the British Admiralty then commissioned civil engineers Messrs Coode, Son and Matthews to draw up plans to protect Grand Harbour.

Since Grand Harbour was exposed to the north-easterly Gregale wind, the engineer's brief was to render the entire harbour usable when the strong and stormy Gregale wind blew at its most furious, without impeding the circulation of water. The distance between the breakwater arms had to allow the largest warships to enter safely but at the same time protect the harbour against the north-easterly wind – and torpedo attacks. The proposal included a 378-metre arm at Fort St Elmo, following a slightly curved line along Monarch's Shoal, a 122-metre arm at Fort Ricasoli, a spur pier at the base of Il-Ponta ta' l-Imgerbeb (not constructed) and the levelling down of the rocky shore along the bastions to form a wave trap. The Grand Harbour breakwater was constructed between 1902 and 1909, not only as a means of protection against bad weather but also to provide a defensive barrier against a potential naval attack on Grand Harbour. The completed breakwater thus incorporated a wall offering protection against north-easterly storms, a dog-leg steaming course and a boom defence against naval attack, with an enlarged anchorage for vessels within the harbour.

The breakwater arms consist of precast concrete blocks bonded together to form an almost vertical gravity barrier wall 11.4 metres thick and up to 14 metres deep, designed to resist the powerful wave action caused by the Gregale. The layout of the arms was also intended to allow for a system of floating steel boom defences with anchorage chambers hidden in the St Elmo breakwater arm and the tip of the Ricasoli arm.

A precast concrete block production yard was set up at Mistra, supplemented by coralline limestone aggregate from quarries in Gozo. The coralline limestone was also used for the cladding of the breakwater above the level of the sea, the creation of an access stairway at St Elmo and the construction of the lighthouses. The blocks cast at Mistra were transported by barges to Grand Harbour and lowered into place using cranes. Vertical precast concrete dowels were used to join the blocks, with horizontal dowels used to resist horizontal movements, resulting in a homogeneous barrier.

The longer arm of the breakwater is detached from the shore at St Elmo, with a 70-metre gap. The gap allows for the circulation of seawater. In 1906, a two-span iron footbridge was constructed to provide access from the shore to the breakwater and the lighthouse. The footbridge consisted of two spans each measuring 34.4 metres, supported on central supporting structures consisting of cylindrical iron columns with concrete infill. The bridge structures had a width of 6.4 metres and a height of 4.8 metres, with the main elements of the bridges consisting of two trusses with arched top chords and timber decking. In 1941, during the Second World War, the footbridge was partially destroyed in an Italian naval attack and eventually the bridge structures were removed. The central cylindrical supports were retained but one of them was carried away during a storm in December 1991. The breakwater and its lighthouse remained isolated until a new steel footbridge was constructed in 2012.

The construction of a new footbridge was put out to tender by Transport Malta in 2009 and awarded to a joint venture composed of Vassallo Builders, Spanish bridge designers Arenas Asociados and Bezzina & Cole. The new bridge consists of a new design that takes the historical context into consideration. The main structural element of the bridge consists of a single arched truss with a span of 70 metres, designed with similar proportions to the original bridge structure in terms of height-to-span ratio. The bridge deck with an internal width of 5.4 metres and an external width of 6.45 metres, cantilevers out from the bottom chord of the single truss.

The single Pratt truss, which controls the main structural longitudinal behaviour of the bridge, is made up of an L-shaped box girder with high stiffness acting as a bottom chord; a top chord with an asymmetrical triangular hollow section whose top flange extends seawards to give formal continuity to the walls of the abutments; and diagonal and vertical members with a triangular symmetrical section based on the seaward side of the truss. The transverse behaviour of the bridge is governed by cantilever ribs of variable height and an inverted triangular cross-section, joined to the truss. A secondary box girder with a trapezium cross-section is located on the harbour side. Timber decking is fixed to glue-laminated timber beams and the ribs. The new vertical truss rests on the existing masonry abutments and is aligned along the external face of the breakwater. The resulting L-shape transverse cross-section of the footbridge forms an unobstructed viewing platform towards Grand Harbour, while the arch provides a sense of protection from the sea. The bridge is accessed via the original coralline limestone stairway. The single-span structure stands above the remains of the historical central supports. The bridge was designed to withstand the harsh environmental conditions of the site, with protective coatings and suitable access for inspection and maintenance. The new structure is a contemporary design that acknowledges the historical context, the original bridge structure and the ruins. The contem-

Malta

St Elmo Footbridge

porary expression of the St Elmo Footbridge provides a landmark at the entrance to Grand Harbour.

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Montenegro

Ribnica Bridge
(Most na Ribnici)

- **Podgorica**
- First built in Roman times
- One of the oldest bridges in Montenegro
- Also known as the Nemanja Bridge

The origins of the bridge date back to Roman times. It was rebuilt in the Middle Ages when the city was under Ottoman rule. The stone parapet was added after the Second World War.

The bridge is also a popular meeting place for young people, thanks to its romantic setting.

It is perfectly integrated into its surroundings and gives the impression that it has always stood here.

Montenegro

Rijeka Crnojevića Bridge
(also known as Danilo's Bridge)

- **Rijeka Crnojevića**
- 1853
- Very picturesque bridge
- Built by Prince Danilo
- Total length 43 metres

All photos: Robert Cortright

This two-arch limestone bridge over the river Crnojević stands on the site of a former wooden bridge built by Prince-Bishop Peter II (Petar Petrović Njegoš). The new stone bridge was built in 1853 by Prince Danilo, who dedicated the bridge to the memory of his father Stanko Petrović. The bridge was later destroyed by the Turks and rebuilt by Prince Nikola.

Today the bridge is a popular tourist attraction, particularly because of the unique landscape and surrounding mountains. A further attraction is its proximity to beautiful Lake Skadar.

Many famous Montenegrin painters have painted the bridge, giving it additional glamour.

Poland

Malt Island Footbridge over the river Odra

- **Wrocław**
- 2002
- Footbridge to Malt Island

The Malt Island Footbridge crosses one of the arms of the river Odra in the centre of the city of Wrocław. The footbridge connects the riverside promenade to Malt Island (Wyspa Słodowa). The structure consists of two reinforced concrete spans and a main span in the form of a braced steel arch.

Design: Mosty-Wrocław s.c., chief designer Jan Biliszczuk

FOOTBRIDGES - SMALL IS BEAUTIFUL

Poland

Footbridge over the river Dunajec

- **Sromowce Niżne**
- 2006
- Span 90 metres
- Was the longest glued laminated timber bridge in the world when completed

Spanning the river Dunajec, this cable-stayed footbridge links the village of Sromowce Niżne in Poland to the village of Červený Kláštor in Slovakia. The deck of the footbridge is suspended from a pylon consisting of steel tubes. The deck itself is a glued laminated timber structure. On completion in 2006, the bridge became the longest glued laminated timber bridge in the world, with a span of 90 metres.

Design: Mosty-Wrocław s.c., chief designer Jan Biliszczuk

FOOTBRIDGES - SMALL IS BEAUTIFUL


Footbridge over the river Dunajec, Sromowce Niżne

FOOTBRIDGES - SMALL IS BEAUTIFUL

Arch footbridge over the Vistula, Kraków

Portugal

Pedro and Inês Footbridge

- **Coimbra, over the river Mondego**
- 26 November 2006
- Main span 110 metres, deck width 4 metres
- Total length 274.5 metres (30.5+64+110+64+6) metres
- Steel arches with mixed steel-concrete decks and timber pavement

This bridge connects the green parks located along both banks of the river Mondego, very close to the centre of Coimbra. The central span allows rowing competitions and small sailing boats to pass underneath. A central "piazza" is created by the two straight but longitudinally non-aligned half-bridges extending from each riverbank. Half-arches in those half-bridges are shifted upstream on the left bank side and downstream on the right bank side, which ensures improved lateral stability. Structurally, the bridge combines the central arch with two cantilevers extending from the strong triangular cells defined by the half-arches and the deck.

The rowing channel on the left bank required an extra span to provide continuity over a pier located on the peninsula. The small "false" span over the abutment on the right bank reproduces the structural continuity by clamping and ensures lower positive bending moment and lower deflections in the adjacent span.

Designers: CECIL BALMOND (Architecture) and
ANTÓNIO ADÃO DA FONSECA (Structural Engineering)
Structural Engineers at AFAconsult: António Adão da Fonseca, Renato Bastos, António Pimentel Adão da Fonseca and Nuno Neves

Pedro and Inês Footbridge, Coimbra

Slovenia

The concrete for the deck of the bridge – five cubic metres of it – was mixed over a period of eight hours in a small cement mixer set up next to the bridge. The concrete had to be transported using wheelbarrows. The old bridge served as a supporting structure for the new bridge. After completion of the new bridge it was removed and taken out of the cave by the same route.

Client: Škocjan Caves Park
Design: Gregor Gruden, IMK Ljubljana, Slovenia
Contractor: IMKO Ljubljana d.d., Slovenia

The Marinič Bridge

- **Škocjan**
- 1891 - first construction, 2010 - reconstruction
- Footbridge Award 2011, Wroclaw (High commendation)
- Steel tube girder with two bends gives original shape
- Highly complex assembly using high-mountain construction techniques

Text by: Rok Mlakar, Viktor Markelj

The Marinič Bridge is the second bridge in the Škocjan Caves complex to have been reconstructed in recent years. Actually, it is not really accurate to talk about the reconstruction of the old bridge, since the bridge erected in 2010 (2008-preveri) is a brand-new and highly original structure. The first bridge in this location was built in 1891 and was known as the Concordia Bridge. Following renovation between the wars, it was renamed the Bertarelli Bridge.

The Marinič Bridge, which also crosses the river Reka, is located at the entrance to the eastern section of the Škocjan Caves. Above it rises a vertical cliff more than 100 metres high – down which the bridge structure had to be lowered during construction. The new Marinič Bridge replaced an older bridge of simple design that had reached the end of its useful life. The new bridge can hardly be compared to its predecessor, either in terms of size or position, since although it stands in practically the same location it follows an entirely different route.

The essence of the new Marinič Bridge is a supporting structure consisting of a single steel tube with a diameter of 457.20 millimetres and a thickness of 20 millimetres. This 28-metre tube is divided along its length into 12 sections, with crosspieces welded directly to the main tube. These represent the system that supports the steps and landings that comprise the bridge deck. The entire bridge structure was made in three separate sections and bolted together, using prestressed bolts, via flanges on the tubular elements. At two points the bridge is suspended from steel cables fixed to an anchorage in the rock wall. The anchorage is held in place by two geotechnical anchors. Assembly of the bridge's main structure was a particularly attractive operation, since owing to the inaccessibility of the bridge location, it was lowered into position down a 100-metre cliff. A mobile crane was used to lower the bridge substructure to a precisely determined spot.

The new Marinič Bridge undoubtedly represents an additional attraction in the wonderful Škocjan Caves park that serves to make the route through the caves even more interesting. The new bridge rep-

Photo documentation Ponting d.o.o.

Slovenia

The Marinič Bridge

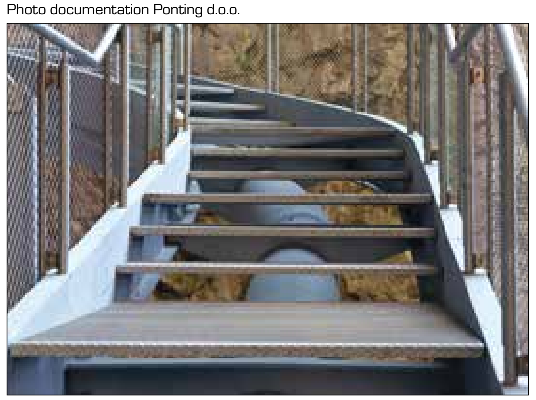
resents an exciting new experience for visitors by offering them new and unique views of the caves. The original, imaginative and attractive design of the bridge is breathtaking, just like the structural concept itself. The impression is completed by the vertical cliff that rises for more than 100 metres above the bridge and, together with the noise of the river far below, sets the adrenaline pumping. Thanks to its well-thought-out design and details, the bridge provides all visitors to the caves with a reassuringly safe way to cross the Reka.

For its planners and builders, the new Marinič Bridge represented a unique challenge. The design and structure of the bridge had to ensure that it would fit unobtrusively into the sensitive and distinctive natural environment of the cave. This called for a considerable degree of expertise, particularly on the part of the planners, when it came to considering structural and architectonic details. The inaccessibility of the bridge's location represented an additional problem for the builders, since assembly of the bridge structure required techniques normally used for construction in mountain areas.

The result of the effective and highly professional cooperation of all parties involved in the construction of the new Marinič Bridge in the Škocjan Caves is a new part-suspended steel bridge that, in terms of its location, is unique in Europe and perhaps even the world.

Client: Škocjan Caves Park, Škocjan, Slovenia
Design: Rok Mlakar and Viktor Markelj, Inženirski Biro Ponting d.o.o. Maribor
Contractor: Joint Venture Primorje d.d. and Kraški Zidar d.d.

Photo documentation Ponting d.o.o.



FOOTBRIDGES - SMALL IS BEAUTIFUL


The "Beruna Bridge" over the Soča near Bovec, Slovenia

Spain

Cable-stayed footbridge over the river Manzanares

- **Madrid**
- 2009
- Footbridge crossing two carriageways
- Two curved and connected U-shaped footbridges
- Single pylon
- Main span 120 metres

The purpose of the footbridge is to connect the two banks of the Manzanares river. Although the river is not very wide, the footbridge has to cross the two carriageways of the M30 peripheral motorway, which run parallel to the river, one on each side (Fig. 1) and the landing space is reduced since two streets run parallel to the river on both sides. The conceptual design consists of two curved U-shaped bridges connected in the centre and supported by a single pylon located on one of the river banks by means of cable stays. The shape of the bridge is the result of all the mentioned constraints as well as of the need to respect the maximum grade permissible for disabled users. The design was produced with the help of a scale model. The main span measures 120 metres and the height of the pylon is 42 metres.

The deck is a 2.44-metre-wide steel trapezoidal closed box which is complemented by transverse beams and a tube to increase the structural width and, consequently, the horizontal moment of inertia. The cables are of the locked coil type with a maximum diameter of 40 mm which were prefabricated to their exact length before installation. The steel pylon has a circular cross-section with a diameter ranging from 1.5 metres at the base to 0.3 metres at the top.

The deck was built in segments in a steel workshop. It was erected on site and welded to provisional supports limiting the spans to approximately 25 metres. These operations had to be performed during the night to allow interruption of traffic along the M30 motorway.

Owner: Municipality of Madrid / **Design:** Carlos Fernández Casado S.L. (Spain)
Contractor: FCC (Spain) / **Steelwork:** Megusa (Spain) / **Cables:** Tensoteci (Italy)

FOOTBRIDGES - SMALL IS BEAUTIFUL

Cable-stayed footbridge over the river Manzanares

Pedro Arrupe Footbridge, Abandoibarra (Bilbao)

Switzerland

The Chapel Bridge
(Kapellbrücke)

- **Lucerne**
- 1333
- World's oldest covered wooden truss bridge
- Features painted triangular panels dating from the seventeenth century
- Current total length 170 metres

Text by: Gorazd Humar

The covered wooden Chapel Bridge over the river Reuss is one of the most recognisable symbols of the city of Lucerne and stands at the point where the waters of Lake Lucerne flow into the Reuss. Lucerne boasted three covered wooden bridges in the Middle Ages, of which only two survive today.

Built in 1333, the bridge (at that time 202.90 metres long) connected the old part of the city in a diagonal line with the new district on the opposite bank of the Reuss.

The bridge stands on wooden piles driven into the riverbed. Its deck is covered by a wooden roof running the entire length of the bridge. The roof thus protected the supporting truss structure of the bridge and the (relatively small) individual spans.

The Chapel Bridge is the oldest surviving wooden truss bridge in the world.

The bridge is best known for the numerous religious paintings situated on triangular wooden panels in its interior. A devastating fire in 1993 destroyed almost two-thirds of the bridge, and with it the majority of the famous seventeenth-century paintings that adorned it. Of the 147 paintings on the bridge at the time of the fire, only around a third survived. Most of these have since been restored. In 1994, shortly after the fire, the bridge was renovated and new concrete piles were driven into the riverbed to support the renovated section.

The bridge crosses the Reuss next to the 33-metre-high octagonal Water Tower (Wasserturm), which stands in the river and is believed to have been built in around 1300, just a few years before the bridge was built. At the time of their construction, both the Water Tower and the bridge formed part of the defences of the city of Lucerne.

FOOTBRIDGES - SMALL IS BEAUTIFUL

Photo: Gorazd Humar

The Chapel Bridge (Kapellbrücke), **Lucerne**

Turkey


Photo supplied by Freyssinet

Three footbridges in Izmit (UG 1, UG 2, UG 3)

- **Izmit**
- 2009
- Cable-stayed footbridges
- Constantly changing light effects during the night
- Total length: UG 1 = 99 metres, UG 2= 107 metres, UG 3= 110 metres

Text: Freyssinet

Three very similar yet different footbridges were built as pedestrian overpasses over the D-100 national road in the city of Izmit. All of them are cable-stayed footbridges and each has a single pylon. The decks are made of steel girders covered by concrete slabs. The stays were supplied by the French company Freyssinet (Freyssinet Ht1000, with outer HDPE pipe). The heights of the 3 pylons range from 38 metres (UG 3) to 43 metres (UG 2). The width of the deck of all three footbridges is 3.9 metres.

During the night the footbridges are illuminated, with lights producing special and constantly changing effects in different colours. One of the three footbridges (UG 2) is also known as the Mimar Sinan Footbridge after the famous Turkish architect and bridge builder Mimar Sinan (1490–1588), who built several famous mosques and bridges during the Ottoman period.

Photo supplied by Freyssinet

UG 2 - Mimar Sinan Footbridge

Photo: Robert Cortright

Owner: Kocaeli Metropolitan Municipality / **Design:** Yüksel Proje / **Contractor:** Ilke Construction Company / **Cable stays supplied and assembled by:** Freyssinet, Freysaş Turkey

Japan

All photos: M. Matsui and Hirano

Kintai Bridge
(Kintai-kyo)

- **Iwakuni, Yamaguchi Prefecture Spans the river Nishiki**
- 1673
- Length 193.3 metres, main spans 35.1 metres, width 5 metres
- 15th reconstruction completed in 2004

Text by M. Matsui

The Kintai Bridge is a unique bridge consisting of five wooden arches spanning the river Nishiki.
The bridge was built in 1673 to link the town where Kikkawa Hiroie, the feudal lord, and upper-level samurai lived, and the town where mid-level and low-level samurai and merchants lived. The river Nishiki served as an outer moat for the lord's castle. Later, in the Edo period (from the early seventeenth century to the mid-nineteenth century), the common people came to enjoy peaceful everyday lives, and a bridge was built to be sturdy enough to withstand floods and provide a crossing between the two towns.
To date the existing bridge has been repaired and reconstructed 15 times. Rebuilding the bridge has always been done locally. For this reason, the necessary skills and techniques have been passed down from generation to generation.

Original designer: Kikkawa Hiroie, first lord of the Iwakuni Domain (17th century)

FOOTBRIDGES - SMALL IS BEAUTIFUL

Photo: M. Matsui and Hirano

Kintai Bridge, Iwakuni

Japan

All photos: M. Iso

Kokonoe "Dream" Suspension Bridge
(Kokonoe "Yume" Otsurihashi)

- **Tano, Kokonoe, Kusu District, Oita Prefecture**
- October 2006
- Single span unstiffened suspension bridge
- Main span 390 metres, width 1.5 metres
- The longest pedestrian suspension bridge in Japan

Text by M. Iso
Photos: © Kawada Industries Inc.

With a main span of 390 metres, the Kokonoe "Dream" Suspension Bridge is the longest pedestrian suspension bridge in Japan, spanning the Naruko Gorge at a height of 173 metres.

Owner: Town of Kokonoe
Structural Designer: Kyodo Engineering Co. Ltd.
Constructor: Kawada Industries Inc.

Japan

Hama Mirai Walk Footbridge

- **Nishi, Yokohama, Kanagawa Prefecture**
- 2008
- two-span, continuous steel deck, box girder (rigid frame) bridge
- two spans of 47.9 and 40.7 metres, deck width 10.4 metres
- 2011 JSCE Civil Engineering Design Prize

Text by N. Kuroshima

All photos: N. Kuroshima

The Hama Mirai Walk Footbridge spans the river Katabira and links the Yokohama East Exit and Minato-Mirai 21 areas. The footbridge is a tube-shaped deck which allows breezes to flow through it while providing shelter from wind, rain, snow, etc. The bridge is the integration of functional and aesthetic values achieved through modern technology.

Owner: City of Yokohama / **Designers:** Nippon Engineering Consultants Co. Ltd., M+M Design Office, and Nakajima Tatsuoki Lighting Design Laboratory Inc. / **Structural designers:** Nippon Engineering Consultants Co. Ltd. and Kanebako Structural Engineers / **Constructors:** ***Substructure:*** Kajima Corp. and Iwaki Kogyo Co. Ltd. JV, ***Superstructure:*** Yokogawa Bridge Corp., ***Shelter:*** Tsuboi Corp., ***Lighting:*** Kouyo Electric Equipment Co. Ltd., ***Deck:*** Techno-Japan Co. Ltd.

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Civil Engineers

Footbridges

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