Footbridges
Construction Design History

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With photographs by Wilfried Dechau

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About this Book

In his introduction to the 1984 reprint of Georg Mehrtens' classic, *Der Deutsche Brückenbau im XIX. Jahrhundert*, which was first published in 1900, Ernst Werner commented succinctly: "It is the fate of bridges that serve only the pedestrian simply to be overlooked in the chronology of bridgebuilding." It was not until the new millennium that this began to change somewhat – not least because a remarkably large number of cities saw the beginning of a new era as an occasion to polish up their image with a "millennium bridge". A bibliographic search on the subject of bridges carried out in the German National Library at the beginning of 2007 returned a total of around 2,500 publications. When the search term was restricted to footbridges, the catalogue produced 31 titles, of which a considerable number were bibliographic lists of essays and articles. The huge discrepancy in the results is partly explained by the fact that bridges have a great metaphorical and symbolic value, and thus appear in countless titles relating to politics and society. The literature on footbridges is sparse at an international level too. Apart from the published proceedings of two conferences and the *fib guidelines* of 2005, no attempt has yet been made to focus exclusively on this small and impressively varied type of structure. With this book, we hope to have made a modest start.

The idea of writing a book about bridges that are for the sole use of people on foot – or at most on bicycles – excited us greatly. We hope that engineers, architects, landscape architects and town planners will find it stimulating, and that the lay reader will find it just as appealing.

We wanted to give as broad a view as possible of footbridge construction in Europe without being tied to any current ideology or doctrine. Bridges that strive for perfection as structures alone have as much of a place in our selection as those designed to delight the eye with ornament. But more about this later.

Approach

This book presents around 90 footbridges in a latent chronology. By "latent", we mean that we have not blindly followed their exact dates, preferring to explain their variety in terms of more complex relationships that can best be grasped thematically. After all, some types of structure are the result of technological or scientific developments linked to particular periods, while other approaches to design belong to ages with a particular way of expressing form. At one time the engineers are spurred on to achieve ever lighter structures; at another the architects realise the bridge's effectiveness as a quasi-homoeopathic means of repairing the damaged townscape, and at yet another the bridge as a technical artefact is sublimated to the aesthetic of an Arcadian landscape. The history of footbridge construction is therefore a prime example of how the histories of technology, art and the world in general overlap, and we wanted to take into account the complex interplay between them.

The specialist knowledge of the structural engineer comes to the fore in essays that explain the technical aspects in straightforward and understandable language, so that anybody can understand the aesthetic potential that is inherent in a particular structural design. Finally there is a compendium, listed by location, of a further 120 footbridges that we had no space to discuss in detail. We hope it will provide a starting point for readers who want to discover more for themselves after this first glimpse of a fascinating area of bridgebuilding.

Selection

Which bridges should we discuss in greater detail – and for what reasons? One thorny question followed another. We had no intention of hiding the fact that one of this book's authors works for Schlaich Bergermann and Partners, a practice which to date has built more than 50 footbridges, but as a quick glance at the book will confirm, there was no question of using it as a showcase for their work. So it was back to the difficult decisions. We selected bridges of relevance to one or another aspect of the relatively short history of the footbridge; bridges that appealed to us both (or to one of us, at least); bridges that are unequalled in some way; bridges that could certainly be improved; bridges that demonstrate courage in construction, astuteness in design, or an infallible sense of form. We made a point of seeing all of the bridges ourselves (with a few exceptions), as did our photographer, who enjoyed our complete confidence.

Our selection is necessarily incomplete, subjective and open to argument – completeness was never our aim. We admit that our view, naturally, is one from the German-speaking countries. We were kept busy enough just by having to work together as an engineer and an architectural critic: a rare combination, in which agreement is certainly not reached without argument first, but ultimately we succeeded because we both had the will to make it work.

Acknowledgements

To venture upon the first ever study, however limited, of the construction, design and history of any type of structure is a daring, not to say crazy, undertaking, and we would never have begun it if we had not been able to count on assistance from many quarters. For their advice and information we would like to thank Jan Biliszczuk, Berthold Burkhardt, Keith Brownlie, Dirk Bühler, Jürg Conzett, Cornel Doswald, Sergej Fedorov, Andreas Kahlow, Andreas Keil, Martin Knight, Jörg Reymendt, Jörg Schlaich, Klaus Stiglat, René Walther and Wilhelm Zellner. Without the energetic and support and encouragement of Auyon Roy, Simone Hübener and Andrea Wiegelmann, this book would never have appeared in 2007 – and might not even have made it in 2008. We would also like to thank our knowledgeable translators, Chris Rieser and Richard Toovey.

In addition, our special thanks go to Wilfried Dechau, who discovered many bridges, especially older ones, during his constant travels as our photographer; he would set off on account of one bridge and come back with seven. During the last few years he has taken new photographs of almost all of the bridges in this book – a labour whose documentary value to the study of the history of footbridges cannot be overestimated.

Ursula Baus, Mike Schlaich, July 2007

Kronsforde, bridge over the Elbe-Trave Canal, 1959

Bridges and Pictures

At the age of 15, with the first single-lens reflex camera of my very own, I naturally took shots of the area around my parent's house. That included the bridge across the Elbe-Trave Canal. I crossed this bridge every day on the way to school and I could see it from my room. Of course, it would be going too far to say that this was the origin of my affinity for bridges. My enthusiasm for looking at bridges through the medium of photography was (re-)awakened 30 years later on, when I photographed the Max Eyth Lake footbridge by Jörg Schlaich. In 1989, this was a welcome and relaxing diversion for me from the routine of conventional architecture photography. I recently revisited the bridge to photograph it again for this book (see p. 92).

In spite of that refreshing intermezzo, bridges remained an exception in my work. This changed with the building of the Storebaelt (Great Belt) bridge in Denmark: I visited the site many times between 1996 and 1998 to record the exciting process of building what was, for a brief period, the suspension bridge with the longest free span in the world. I managed to get a lot of interesting shots, some of which were shown in the *brückenschlag* exhibition in 2000, and in a photo calendar. They were followed, in 2004, by a project on the Traversiner footbridge. This gave me a unique opportunity to photograph work on site in the Grisons Alps every day for a period of several months. Its immediate results were a book and exhibition about the Traversiner footbridge. At the same time, plans for this book by its two authors were gaining substance, and I gradually came to the decision that my camera and I should take an active part here too.

This meant taking up-to-date photographs of as many of the bridges featured in it as possible. The illustrations that the authors had managed to collect up to that point were very disparate, so it was going to be difficult to produce a book that would be pleasant to look at. The idea of starting again from scratch and giving the book a consistent photographic identity therefore eliminated a lot of problems at one stroke.

It was clear that this could only be done to a certain degree. Trips to Coimbra and London, for example, turned out to be unnecessary, since outstanding photos of these bridges had already been taken by Christian Richters, Nick Wood and James Morris. It also seemed out of proportion to make a long trip through Norway for a few bridges far apart, when plenty of photos of them already existed. Not to mention the problem of time travel: some bridges no longer existed, because they had been built for special events, and in these cases we were fortunate in being able to use photos taken previously by Leo van der Kleij and Florian Holzherr. That still left plenty to do, however. All the same, we were not really aware that we had let ourselves in for an almost endless task. I came back from every journey with at least twice as many bridges as I had been expecting to find on the basis of the source material. On my travels, almost everyone I talked to about the objects of my interest had a suggestion to make. And so the itinerary became ever longer and, at the same time, more fruitful. My thanks are due above all to Martin Knight and Cornel Doswald, from whose expertise I benefited in England and Switzerland. The most adventurous discovery for me personally was, by the way, thanks to Bill and Alison Landale, my bed-and-breakfast hosts in Ellemford, Berwickshire, without whom I would never, ever, have found the uncommonly delicate and apparently fragile – yet astonishingly practical – suspension bridges across the River Esk (see p. 198).

It can, on the other hand, be quite frustrating to have to ask for information in order to find a certain bridge. It then becomes clear how much people's perceptions of one and the same bridge can differ. In Maidstone, for example, neither the name "Millennium Bridge", nor words like "suspension cable", "concrete" or "new" were of much help in finding out which way to go. Not to mention the name of the bridge's engineer, Jiri Strasky. Everyone who we asked directed us to a cable-stayed bridge, which, although it was also called the Millennium Bridge, had nothing in common with the one that I was looking for, except that it, too, crossed the River Medway – at the other end of the town.

Internet route planners are also of limited use, since their purpose is to give directions to drivers – who have, of course, no need of footbridges. The most reliable sources of information are topographic maps, but they are not always to hand – or, at least, not all of those that are

Vagli di Sotto, bridge by Riccardo Morandi. 5 June 2007, 12.20 and 13.27

needed. And even then, they are only of use if they are up-to-date. One example of this was the footbridge over the Bregenzer Ach river near Langen and Buch. These two villages lie five kilometres apart, as the crow flies. The footpath winds along the valley for stretches, petering out in meadows among herds of cows. The older people in the village still remember a bridge that was there when they were children. A spring flood washed it away one night. But a little bit further upstream, they tell me, there is another one like it, near Fischbach and Doren – and that one is still standing. Off I go again. My navigation system knows many Fischbachs, but none of them near Bregenz. The faint hope that I might find signposts to this, the only bridge in the vicinity, proves, as it so often has, to be naive. Signposts tell you about places to get to, not ways of getting there. In other words: the next village, and not a bridge on one of the ways to it. The exception does prove the rule, of course, and once, looking for a suspension bridge across the Subersach near Egg, I did find a signpost that said *Wire bridge – Lingenau*.

This at least confirmed that the bridge still existed and was passable, so the walk there carrying a heavy camera was not going to be completely in vain – although you never know whether it is going to be worth the effort until you actually get to the bridge. Only then do you see, if it is an old bridge, how much of it has survived and in what condition – and how much it still has in common with the original design. Warning signs advising pedestrians to cross one at a time can be an indication that the bridge is in its original state, but this is not necessarily so. All that is certain, in that case, is that it has not been spoiled by insensitive reinforcement or renovation. The Kettensteg in Nuremberg, for example, may appear to hang from its chains, but it is now supported in a different way. The faint-of-heart would nevertheless be well advised not to tread heavily when they cross this particular bridge. That could set it swaying and oscillating badly – not dangerously so any more, but not every stomach can cope with it. After a taking a first look around, I check out the bridge. Go on it; look down. Walk across. Get down off it at the other side, if possible. See what is supporting it and how – then where and how the loads are distributed and ultimately transferred to the abutments. First I look, then I take the photos. The weather and the light are important factors, without a doubt. Only once, in Maidstone, did I have to stifle the pangs of conscience and settle for photographs taken in bad weather. There was no sign of an improvement and I had a plane to catch at Heathrow airport. Even in rain, the bridge itself makes a good impression, as can be seen on page 76.

Whatever one photographs, it can only be "shown in the best light" if the weather cooperates. This is clear to see in two exposures, taken only one hour apart, of Riccardo Morandi's bridge in Vagli di Sotto, which is set exquisitely in the landscape. The first, which I took shortly before a storm, shows shimmering green water that is as smooth as a mirror, whereas in the second, taken as it began, the surface has become matte, criss-crossed by fine ripples.

One of the last journeys that I made for this book took me to Bilbao in June 2007. Upon entering my hotel room, I hardly believe my eyes. Above the bed hung a drawing of an old, asymmetrical footbridge: one that I had never seen before, although I had travelled to over 200 bridges in the previous three years. Did it perhaps cross the Nervión river? In Bilbao? When? Where? I could see, as it were, the writing on the wall: obviously, even if several photographers were to spend a further three years on this quest, they would still encounter unknown structures. The next surprise came hard on its heels, when I tracked down the place in Bilbao where, according to the hotel staff, the bridge had once stood. What I found was an arched concrete bridge (which up to then had been completely unknown to us) that connected to two different levels on the higher bank of the river in an exceptionally clever way (see p. 55). Of course, we had met a bridge of this type before: it seems likely that the Bilbao bridge was known to Marc Mimram, to whom we owe the Pont de Solferino in Paris.

Wilfried Dechau, 2007

Você quis saltar? Did you want to jump? *Pascal Mercier, Night Train to Lisbon*

Looking at the history of bridgebuilding as part of architectural history, we see that today's comparatively distinct and unquestioned differentiation between footbridges and other types of bridge came about slowly at first, and by no means constantly. The history of footbridges is linked to that of bridgebuilding in general – sometimes more so, sometimes less – and this is one of the aspects that make it so interesting to study the footbridge on its own, as a type of bridge in its own right. In order to define the characteristics of the footbridge, which of course has a longer history than the road bridge, we need to look at when its typology began to differ from that of large-scale bridges. This occurred towards the end of the 18th century, when Enlightenment thought, science, early industrialization and the increasing importance of the economy stimulated rapid technological and social change, together with a growth in mobility and traffic. In the 19th century, advances in transport technology began to exert a fundamental influence on bridgebuilding, with ever-higher standards required for road and rail. These new, high-performance modes of transport made fresh demands on bridge construction, in response to which a specially qualified expert in bridgebuilding appeared on the scene – the structural engineer – whose profession quickly acquired a coherent profile.

Footbridges were only indirectly affected by these technological changes and from this point onwards their development took a course of its own. After all, trains today may reach speeds of 400 km/h or more and the volume of road traffic may require six, eight, or even ten lanes (with all of the consequences that this involves for large-scale bridge construction), but a human being, whether standing, walking or jumping, remains a constant factor in the equation. To this extent, the interplay of technical progress, imagination and functional variety in the case of footbridges is open to other influences, which bring forth an inexhaustible variety of distinctive designs. It is a brief that again and again allows more to be done than providing a mere footbridge – the degree to which credit for this is due to architects, or structural engineers, or both, becomes clear only upon examination of individual cases.

What happens on a footbridge, anyway? Not feeling firm ground underfoot usually indicates a precarious situation. At the same time, a swaying surface, or a narrow pathway, can also produce a shiver of excitement when we have to let ourselves in for more or less perceptible oscillations, or glimpses into a yawning abyss. Bridgebuilders have to live with the awkward fact that people react to oscillations and heights in very different ways: some may become dizzy with euphoria, while others may find their knees turning to jelly.

Footbridges are generally built to satisfy a tendency to laziness, a love of convenience, or a joy in contemplation; whether they cross rivers, streets or valleys, their main purpose is still to shorten the route from one place to another. Only in very rare cases is it the thrill of danger, or the temptation to be free of the ground, that motivates people to build them.

Tarr Steps, Exmoor, earlier than 1000 BC

Making these shortcuts not only safe enough even for sleepwalkers, but also pleasant to walk across, is an important part of the brief when designing a footbridge. Of course, the basic principle applies: a bridge should be structurally sound, easy to maintain and cheap. All the same, a lot more can be achieved by paying attention to criteria such as an appropriate route, attractive views, a comfortable environment and a memorable appearance. A footbridge's balustrades, parapets, hand rails, surfacing, niches and balconies should take into account that people will not only walk across it, but would also like to stop for a moment, lean against it, rest on it, sit down and look around, or just be alone – and that whatever they do, they will touch it. Thus, a footbridge does not remain just a bridge, but matures into a jogging track, a boulevard, a promenade, a place for a rendezvous and, finally, a landmark. Last but not least, lighting design has a prominent part to play, as pedestrians experience night-time illumination in a completely different way from a car driver concentrating on the road. With such a variety of tasks, standard solutions seldom prove satisfactory. The basic types of structure as such are in no way adequate to meet all of the different requirements. In order to achieve a design that is more than just the shortest way of connecting two points, it is best to vary them, combine them and develop them experimentally. This naturally stimulates the design ambitions of the structural engineer, but the architect and the landscape designer also feel called upon to take over engineering's choicest task. In matters relating to atmosphere, significant forms and the sensory effects of material properties, most structural engineers find themselves out of their depth, inasmuch as they have received far too little exposure to design-related topics of this sort during their studies. Merely calling upon the repeatedly quoted Vitruvian terms utilitas, firmitas and venustas is not of the slightest help in enriching the world of contemporary building. Anyone who seriously demands that a structure be useful and stable and beautiful makes themselves as laughable as a politician who, quoting Goethe, says that Man is noble, helpful and good. Even when they do not appear banal, Vitruvius' terms no longer have a definite substance to offer. The architects' situation mirrors that of the engineers: they are given a basic understanding of structural theory as students, but rarely develop it into an ability to design structures. Of all things, then, it is the modest footbridge, a class of structure comparable in status to the semi-detached house, which on account of its complex characteristics puts the much-vaunted cooperation between architects and engineers to the test. One of the professions is defending a source of income; the other is hungry for new ones.

For us (an architecture critic and a structural engineer) the most important thing is the result; we examine each case to see where credit is due and we can recommend, both from our own experience and in general, aiming for amity and lively debate. The fact that the footbridge, such an unpretentious structure, is still capable of experimental and imaginative development, in spite of all of the standards and regulations, makes up much of its charm. This applies throughout Europe, where a jungle of rules and red tape makes building a complicated and expensive business.

A simple suspension bridge (c. 1890) near Ardez in Switzerland. It can be crossed by only one person at a time.

Parameters and Structural Design

Users experience footbridges much more directly than road or railway bridges. As we cross a footbridge, we can touch the structure and study the details, thereby allowing us to grasp the structure fully in every sense of the word. These are bridges to be touched. The design freedom for the structural engineer is much more pronounced than for road or rail bridges in spite of some parameters particular to footbridge structures. This design freedom is a welcome and exhilarating challenge. In this section, the issues unique to footbridge design will be summarized briefly. Additional information can be found in the *technical overviews* and the references, which provide an introduction to the technical literature.

The Third Dimension

Pedestrian bridges allow the design to break free of the linearity of high-speed traffic, whose bridge decks generally attempt to join two points separated by an obstacle as directly as possible. The geometry of the bridge deck in the horizontal plane can be chosen freely and may be quite curved. A spatial experience may be achieved by the suspension of the bridge deck, by a moveable bridge, or by the intersection of multiple pathways.

The geometry of the gradient of the bridge deck may also be relatively freely chosen, which also opens up new possibilities for emphasizing the spatial geometry of the structure. Walkable arches and stress ribbon bridges are therefore possible design alternatives for footbridges, although it should be noted that deck gradients greater than 6 percent present problems for wheelchair users. It is not simply the maximum slope that presents a problem, but the potential energy required to overcome the slope. This may be expressed as the inverse of the product of the length and slope. Alternative pathways must be offered for wheelchair users where there are steep deck gradients or stairways.

Dimensions

Most pedestrian bridges are narrow, with decks between of 3 and 4 m. As a rule of thumb, 30 pedestrians per minute for every metre of deck width can cross the bridge without impeding one another. Even with the largest crowds, this figure rarely reaches 100 pedestrians per minute. Most European codes call for a minimum deck width of 2 m for bridges open to pedestrian and cycle traffic.

Given these pedestrian densities, it is surprising that the pedestrian live load of 5 kN/m^2 called for in most European codes is roughly equal to the loading of the main lane of a roadway bridge. In many countries, this load may be reduced for longer bridges. Statistics show that such crowding (5 kN/m^2 is equivalent to 6 people per square metre) is very improbable on a long bridge deck. As pedestrians are much less sensitive to deflections than road or railway traffic, footbridges may be much more slender and lightweight than road or railway bridges. Because of this, footbridges are often lively, and dynamic analysis of the structure should be carried out in the early phases of the design.

Load testing – where numerical calculations cannot replace the intuition and experience of the engineer, here on site for the construction of the footbridge in Sassnitz

Materials and structure

In addition to asphalt and concrete, many other materials can be used as deck surfacing. For timber surfacing, the danger of slipping should be considered, especially if the wood planks follow the longitudinal direction of the structure. The moisture expansion of the wood must also be taken into account. Grating surfaces are cheap, allow light to pass through the deck and do not require drainage. They are, however, difficult surfaces to cross for pedestrians who are barefoot or wearing high heels. Laminated glass surfaces must have a high level of opacity to prevent people below from viewing through the deck. Glass surfacing is primarily found in interior spaces or for covered footbridges.

Railings require particular attention and must be at least 1.2 m for bridges open to cyclists. The railing should be designed to withstand a transverse load of 1 kN/m applied at the height of the handrail. Because of the height of the guard-rails, they are often incorporated into the global structural system of the bridge. The design of the handrail has an important impact on the visual impression of the bridge. The railing may appear either opaque or transparent from afar and must give the user a sense of safety. It often seems appropriate to integrate the lighting system into the handrails or railing posts, just as the shadows cast from the railing effect the visual impression of the deck during the day. New materials and innovative structural systems are often more readily approved by the owners and local administrations than large bridges where the total risk and costs are much higher.

Freedom of design

Bridge design has long been regarded as the most rigorous in the challenging field of civil engineering. With the smaller scale of footbridges, bridge designers can finally let their hair down and truly indulge their creative side. Self-critical engineers often seek advice from architects, industrial designers, and landscape architects for design issues such as the integration of the structure into the surrounding environment, the light, colour, and feel of the structure. In cases where the engineers and architects in the design have a good history of cooperation between one another, the traditional roles of architect and engineer become blurred to the benefit of the overall project.

It is often said of large bridges that "a bridge

St Gallen-Haggen, Bridge over the Sitter, Rudolf Dick, 1937[1]

is no destination". This is however not at all true for the design of footbridges. The pedestrian should remember his or her experience crossing the structure as being particularly pleasant. The footbridge designs of the last few years have shown just how much is possible in bridge design. The increasingly large number of design competitions has shown how seriously the design of these structures is taken. The challenge of structural innovation, the audacity of competition, and the owner's desire to create a landmark structure often overshoot the goal. Bridges that are designed to impress often break with rational technical design tenets. We have to admit that these technically unreasonable structures may become quite impressive given the right lighting and spatial perspectives but must not be taken as design ideal.

The design team should not overlook the role of the structural system as a catalyst for the diversity of footbridge design. Moreover, the development of the appropriate structure, given the surrounding environment, functional requirements, or the additional requirements of the owner, must be seen as the central challenge of the project.

1 Dick, Rudolf, Von der Sitterbrücke Haggen-Stein bei St. Gallen, in: Schweizerische Bauzeitung, 118, 1941, pp 122-123

Truly, opposing what is customary is a thankless task. *Heinrich Heine*

Any general history of bridge construction inevitably begins with footbridges. The search for the origins of bridgebuilding has so far taken us back to early civilizations in China, Mesopotamia and South America. There is archaeological evidence of simple suspension bridges for those with a steady head for heights, small timber beam bridges and stone slab walkways for people and animals, like those at Tarr, Exmoor, or in Post-bridge on Dartmoor, and Lavertezzo in Switzerland (see p. 20). It may well be that globally accessible Internet data banks, such as Structurae, Bridgemeister and Brückenweb, are creating a new basis for writing a more reliable history of early bridgebuilding. That is neither within the capacity of this book, nor is it our intention.

Our interest begins explicitly with the time in which traffic-related requirements resulted in quantum leaps in bridgebuilding and also in the birth of structural engineering as a definable profession -- one that has dominated the construction of footbridges, too, to this day. It soon becomes clear that the qualifications and professional ethos of the structural engineer were determined to a great degree by each new means of transport: first the railway train, with bridges and vast station sheds, then the car, with gigantic motorway bridges. Cost-effectiveness, too, played an increasingly important part, which limited the structural engineer's freedom to play with forms in order to achieve a particular, contemporary design. Looking back over the development of the foot-bridge in comparison, we see that the relationship between construction, material, form and cost-effectiveness allowed much greater room for manoeuvre. Because people experience the built environment much more slowly and with greater immediacy on foot than they do in cars or trains, this freedom was used, then as now, in a cultural, time-dependent sense: intuition and experience, experimentation and science; displays of magnificence; gracefulness and bareness these are the themes that, in retrospect, are of specific relevance to the history of footbridges. They do not replace each other in sequence, but rather add to a growing wealth of design and structural concepts, which the present age can draw upon and continue to work with.

The mediaeval stone bridge at Lavertezzo in the Verzasca valley, Switzerland

Bigger, faster, further – traffic, architect and engineer

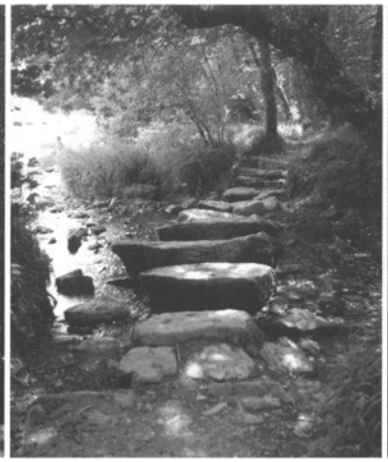
Ever since traffic and its technical requirements began to drive innovation in large-scale bridge construction, the footbridge has developed along a recognizably separate path. The small-scale structure for human beings and animals gradually became something special. Building it remained nonetheless the responsibility of structural engineers. Their professional identity changed repeatedly from the mid-18th century onwards, as experience was arranged in a systematic framework, theoretical knowledge grew exponentially and economics put pressure on the construction industry. This becomes evident if we outline how things stood towards the end of the 18th century.

Economy in bridgebuilding

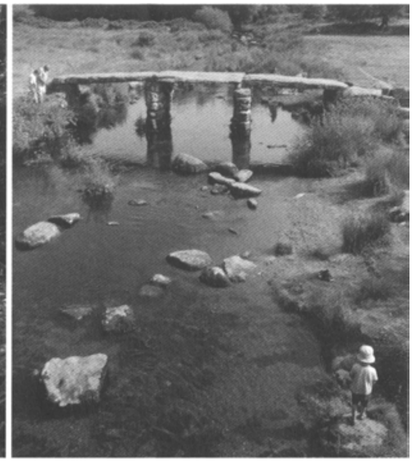
On 14 February 1747, Jean-Rodolphe Perronet was appointed head of the newly founded École Nationale des Ponts et Chaussées (National School of Bridges and Roads) in Paris. He was not merely an engineer, but also an extraordinarily talented organizer and an important contributor to an ambitiously planned compendium of knowledge: the encyclopaedia edited by d'Alembert und Diderot. Perronet took the art of building (which even now we keep wanting to see as an inviolate whole) and split it with an axe that has continued in use to this day: economics. Admittedly, he did so on orders from above: Jean-Baptiste Colbert, the finance minister of the Sun King, Louis XIV, had decided to wrest control of road, canal and bridgebuilding from the hands of the aristocracy, tradesmen's associations and religious orders. His aim was to make it better and, above all, efficient, as part of a policy of centralization under the absolute monarchy. Once again, politics was driving developments in the construction industry. The process had begun in 1716 with the establishment of an engineering corps, from which the École Nationale des Ponts et Chaussées was later created. Many parts of the country became more accessible: at the beginning of the 18th century, the stone bridges in France had numbered around 600, but by 1790, 400 more had been built, while the number of wooden bridges doubled during the same period.[1] The military had already started crucial initiatives to advance knowledge of roadbuilding and fortress construction in the 17th century; these resulted in the founding of a military engineering school in Mézières in 1736.[2] Colbert then drew a fateful conclusion: he postulated that economy is essential for an infrastructure to be built up efficiently – and Perronet, of all people, raised economy of material to the status of an aesthetic principle. Towards the end of his working life, he prided himself on having been the first to give works of art a form "qui tire de l'économie de matière un moyen de décoration".[3] The efficient use of material itself became an aesthetic criterion, the first step on a path that was to have immeasurable consequences for (engineering) bridge construction and later for architecture as a whole.

1 Barrey, Bernard: Les Ponts Modernes, 18e 19e siècles, Paris, 1990, p. 25f.; Grélon, Stück, 1994, p. 84
2 Kurrer, 2003, p. 39; Straub, 1992, p. 163f.
3 Picon, Antoine: Perronet, in: L'art de l'ingénieur, Paris 1997, p. 364; Marrey, 1990, pp. 39 and 60f.

Tarr Steps, Exmoor, 1000 BC



Clapper Bridge, Postbridge, Dartmoor



Thus the *Querelle des Anciens et des Modernes*, a peculiar disagreement over reverence for Antiquity and the modern spirit of innovation that had broken out in literary circles half a century earlier, was joined by another issue. No sooner had engineers liberated themselves from the dogma of classicism, than design became pervaded by the concept of economy. This did not change with the degradation of the ENPC to a practice-oriented school and the re-establishment of the École Polytechnique for more academic studies. On the contrary: the theoretical and practical branches of the new profession, the engineer, drifted ever further apart.[4]

Truth of Construction

Thriftiness was a concern not just of the French, but of the English too.[5] It is also worth remembering that a Jesuit significantly influenced the formation of opinion in the architectural debates that began in the mid-18th century. In 1753, Marc Antoine Laugier, who was living in Paris as court chaplain, published his *Essai sur l'architecture*, one of the most important texts on architectural theory of its time. In it, Laugier fulminates against pomp and display and, taking as an example a touchingly primitive hut consisting of four tree trunks, a pitched roof and a bit of wattle-and-daub, expounds on *truth of construction*. This marks the first appearance of a term that has remained hotly disputed in the assessment of architecture in general (and of bridges in particular) up to this day. There is, after all, no agreement about what a *true construction* might be and whether, if it were taken to mean something like a *right construction*, it would always also be *beautiful*.

The aesthetics of economy and the truth of construction were ultimately joined at around the same time by a further aspect, that of esteem for the functional. This was the work of an Italian Franciscan monk, Carlo Lodoli (1690-1761), who promoted the opinion that architecture (which when referred to then always included what we now think of separately as engineering construction) should be functional. In his writings, Lodoli relates function less to the arrangement of spaces than to the material display of purposes.[6] These topics belonging to architectural theory penetrated far into areas in which the image of the nascent structural engineering profession (in a narrow sense) was becoming more sharply focused: intuition and experience; science and economy.

It should not be forgotten that, for bridgebuilding especially, crucial impulses came from the military sphere. Matters relating in any way to visual appearance had no part to play there, functionality and efficiency being the sole criteria for a way of building that eventually developed a long and inventive tradition.[7]

4 Grélon, Stück, 1994, p. 17f.
5 ibid., p. 85
6 Laugier, Marc Antoine, Essai sur l'architecture, 1753/86; Memmo, Andrea (ed.); Andrea Lodoli
7 Schütte, Ulrich, Baumeister in Krieg und Frieden, Wolfenbüttel, 1984

Cambridge, reconstruction of the bridge of 1749

Old Walton Bridge, oil painting by Canaletto, 1754

Intuition and Experience

In England and, above all, France, the technical and scientific aspects of construction played an ever greater part in defining the profile of the engineer, who in principle was also thinking economically. In England, where there was no institution comparable to the École Nationale des Ponts et Chaussées, an attempt to educate students specifically in construction was made by John Soane (1753-1837), the best-known architect in the country, who became a professor at the Royal Academy in London in 1806. He was already greatly interested in bridgebuilding when he set off on the Grand Tour for the first time in 1778. On the way to Rome, he stopped off in Paris to visit Perronet and see his brand new stone bridge, the Pont de Neuilly, built in 1768-74.[1] It was wooden bridges, however, that Soane encountered on his return through Switzerland. The history of wooden bridge construction has many celebrated structures: Julius Caesar's rather vaguely described bridge across the Rhine, built during his successful advance northwards through Europe;[2] the Danube bridges that are carved on Trajan's column in Rome and the bridges described by Alberti[3] and Palladio[4] respectively – the latter inspiring countless footbridges throughout Europe.

Wooden bridge construction in England might best be represented by a small footbridge designed by William Etheridge (1707-1776) and built by James Essex in Cambridge in 1749. Known as the "mathematical bridge", it also served as a model for Garret Hostel Bridge in Trinity College (1769) and the bridge at Iffley Lock in Oxford (1924).

1 Maggi, Navone, 2003, p. 11
2 Gaius Julius Caesar, De bello gallico
3 Alberti, Leon Battista, Zehn Bücher über die Baukunst, ed. Max Theuer, Darmstadt 1975, p. 202ff.
4 Palladio, Andrea, Die vier Bücher zur Architektur, eds. Andreas Beyer and Ulrich Schütte, Zurich/Munich 1984(2), p. 219ff.

Hittisau, Kummabridge, 1720

Wettingen, 1795

Schaffhausen, 1795

Etheridge followed it soon afterwards with a larger wooden bridge: Old Walton Bridge, which survives only in the well-known painting of it by Canaletto from 1754. It was a larger version of the "mathematical bridge" in Cambridge, which was reconstructed in 1866 and 1905. The design did not give the wooden elements sufficient protection for a bridge of this sort to survive.

The Grubenmanns' Wooden Bridges

What Soane saw in Switzerland amazed him: up in the Alps, wooden bridge construction had matured to a surprising degree in the hands of the Grubenmann brothers, without the benefit of any academic infrastructure of the sort existing in London and Paris. Their lack of theoretical knowledge was more than compensated for by their love of experimentation and their store of experience. This caused a sensation. William Coxe, another Englishman, in his *sketches of the Natural, Political and Civil State of Switzerland (sic)*, writes of the bridge in Schaffhausen: "If one considers the size of the plan and the boldness of the structure, one is astounded that the builder was a common carpenter without any science, without the slightest knowledge of mechanics and wholly unversed in the theory of mechanics. This extraordinary man is named Ulrich Grubenmann, a common countryman from Tüffen, a small village in the canton of Appenzell, who is very fond of his drink. He has uncommonly great natural skilfulness and an astonishing aptitude for the practical part of mechanics; he has progressed so exceptionally far in his art by himself that he is justly counted among the innovative master builders of the century."[5]

Soane and his assistants painstakingly drew the covered wooden bridges in Schaffhausen (1757), Wettingen (1760) and many others that, in spite of spans of over 50 m, fitted into the landscape well. Because most of the Grubenmanns' wooden bridges were destroyed by 1800, these drawings would have been of great value, but in Basel, John Soane lost almost all of them along with his drawing equipment.[6] As well as their refined construction, Soane praised the picturesque quality of the Swiss wooden bridges and logically, in his lectures, examined the interplay between the structure and appearance of a bridge and the landscape.[7] He considered Perronet, who was of Swiss origin, to be a good engineer, but a bad architect, saying that the Pont de Neuilly bridge, in particular, lacked the "beauty of elegance".[8]

Indeed, the Alpine region was home to an outstanding, continually growing tradition of wooden bridge construction, which reached a peak of experimental daring and accumulated experience in the work of Hans Ulrich Grubenmann (1709-1783) and Johannes Grubenmann (1707-1771).[9] Even before the Grubenmann brothers, the art of building wooden bridges was certainly advanced. The first hanging truss bridge had been built in 1468 over the Goldach near St Gallen, with a span of 30 m. This type of bridge spread rapidly in the 16th century, with spans ranging mostly from 20 to 30 m; the longest, at 38 m, was the bridge over the Limmat at the Landvogteischloss in Baden, Switzerland, built in 1572.[10]

5 quoted by Killer, Josef: Die Werke der Baumeister Grubenmann, 1985, p. 35

6 For the varied transfer of drawings of bridges from Switzerland to England, see Navone, Nicola: The eighteenth-century European reputation of the Grubenmann brothers, in: John Soane, 2003, p. 31f.

7 Burns, Howard: From Julius Caesar to the Grubenmann brothers: Soane and the history of wooden bridges, in: John Soane, 2003, p. 19

8 Burns, p. 20

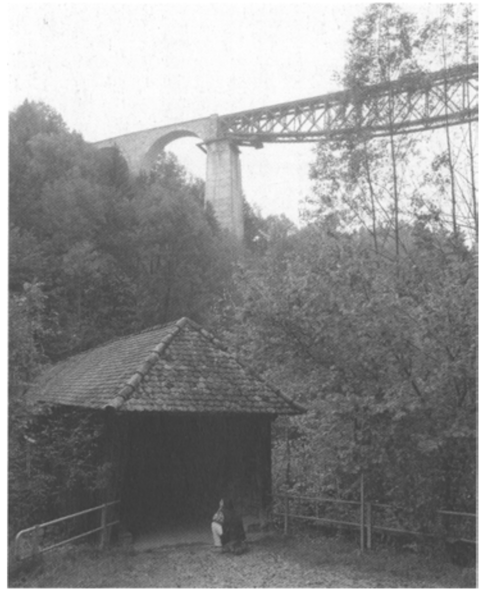
9 Stadelmann, Werner: Holzbrücken der Schweiz – ein Inventar, Chur 1990; Killer, Josef: Die Werke der Baumeister Grubenmann, 1985; Steinmann, Eugen: Hans Ulrich Grubenmann, 1984;

10 Killer, 1984, p.23

Urnäsch, Kubel, 1780

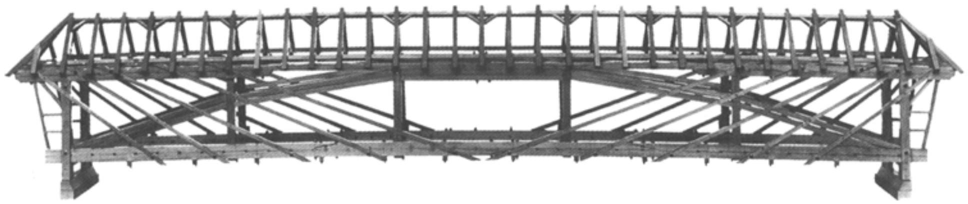
Also worthy of note are the Kumma bridge of 1720 in Hittisau and the Rosanna bridge of 1765 in Strengen. Hans Ulrich Grubenmann, in particular, became astonishingly ambitious in spanning great distances with timber structures, because bridges with foundations in the water were repeatedly washed away by floods. Only two of his bridges have survived in the Appenzell canton: the Urnäsch bridge of 1778, between Hundwil and Herisau, and the Urnäsch bridge of 1780, between Herisau and Stein im Kubel. Both of them are narrow, covered bridges with a span of around 30 m and are designed to carry horse-drawn traffic as well.[1] The structure of both consists of a hanging truss with struts arranged in a five-sided polygon and four pairs of suspension posts. Above all, though, it was the aforementioned bridges in Wettingen and Schaffhausen that aroused fame and admiration. Two points should be considered here. The first is that although these were vehicular bridges, they might well not be perceived as such today, in view of the remarks made by William Coxe when he visited Switzerland again after ten years: "The bridge stretches and gives, as though it were hanging on enormously thick elastic ropes; it trembles and quakes under the tread of any pedestrian, and under the laden carts that drive over it, the swaying becomes so great that the inexperienced fear the collapse of the same."[2] Grubenmann first wanted the Schaffhausen bridge to span the full 119 m from bank to bank, but his clients insisted that the middle pier of the previous bridge be used as a support. Grubenmann's impressive models (among them one of the Schaffhausen bridge) can be found today in the Grubenmann Collection in Teufen.[3] The line between footbridge and road bridge is drawn differently nowadays, of course, and swaying is not tolerated. Although timber construction in Switzerland was also refined by Josef Ritter (1745-1809) and Blasius Baldischwiler (1752-1832), the baton for large-scale wooden bridges passed to the American bridgebuilders.[4]

The second point concerns the aesthetic effect of the bridges. A look at them reveals nothing about their construction: they are mostly clad, making them appear like long timber houses, and, as the contemporary view of the Wettingen bridge shows, they were even painted with architectural forms. The visual integration of this bridge as a long building into its village context and the way in which the pitched roofs over the long arches of the bridge in Schaffhausen fit into the surrounding roofscape both confirm that the contemporary understanding of beauty is to be measured in terms of the picturesque treatment of the bridges and not of their structure, which could only be seen from within – and then only with difficulty in the dim light. To this day, it is precisely as footbridges that covered wooden bridges continue to be built in the unique styles of their respective periods (page 148 onwards).

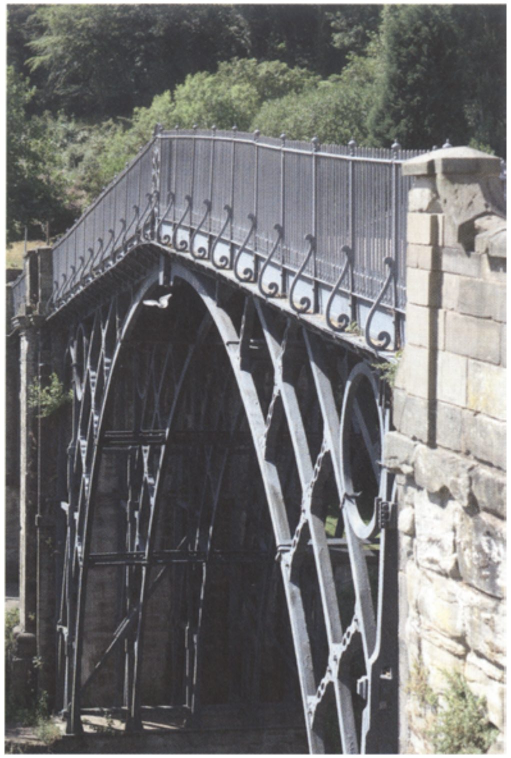


1 Stadelmann, 1990, IV 8 and 9
2 Coxe 1786, quoted in Killer, 1984, p. 36
3 The original model of the Schaffhausen Bridge is in the Allerheiligenmuseum, in Schaffhausen, and there is a reproduction in the Grubenmann Collection, in Teufen.
4 After c. 1800, large-span timber bridges are developed above all in the USA by Theodore Burr, as truss structures, Kurrer, 2003, p. 47

View inside the Urnäsch bridge in Kubel; structural model (below)



Coalbrookdale Bridge, 1779



Science, Economy, Experimentation

The effect on the 18th century of improvements in ironworking, early calculating methods and the approaching Industrial Revolution cannot be underestimated. Until the end of the 17th century, the blast furnaces in which pig iron was smelted were fired with wood. They reached a maximum temperature of 1200 °C, producing iron of a quality and malleability that did not permit large components to be formed. Then, in 1709, Abraham Darby (1678-1717) had the idea of firing the furnaces with low-sulphur coke, which allowed temperatures of up to 1500 °C to be obtained. This produced runny, malleable iron for casting – a milestone for bridgebuilding, too, although the iron thus manufactured early on was brittle and could only be subjected to loads in compression.

In 1779, a design by architect Thomas Farnol Pritchard (1723-1777) for a wooden bridge spanning 30 m was built using cast-iron components as an experiment. This became the celebrated iron bridge of Coalbrookdale, erected by John Wilkinson (1728-1808) and an iron foundry owner, Abraham Darby III (1750-1789). It was the first of a line of cast-iron arched bridges, which ended, however, as early as 1819 with the construction of Southwark Bridge in London, by John Rennie the elder. At 73.20 m, it still has the longest spans of any cast-iron bridge in the world.[1]

The types of steel manufactured nowadays form strong joints when welded and are available as tubes, rolled sections, sheet and cast parts. Such components can be welded together to create bridges with huge spans, which thanks to the high strength of steel can be made significantly more slender than concrete bridges.

Cast Iron and Wrought Iron

The first cast-iron bridge to be built in France, however, was a footbridge. It crossed the River Seine with an overall length of 166.5 m. Louis Alexandre de Cessart, Inspector General of the École des Ponts et Chaussées, and Jacques Dillon built the Pont des Arts in 1802-04 with nine arches, each spanning 18.5 m. In 1984, it was replaced with a reconstruction in steel, which had seven arches instead of nine.[2] The Pont des Arts is nevertheless still much loved by Parisians on account of its function as a footbridge; it is also a place to meet, or spend an evening (or even the whole day), rather like a public square. Sited between two stone bridges, Pont Neuf and Pont du Carrousel, the delicate structure appears to skip gracefully and easily over the Seine. Along with the Passerelle Debilly and the new footbridges near Solférino (see p. 142) and Bercy (see p. 144) the Pont des Arts displays the historical dimension of the Seine's relationship to the city.

It was another project for a pedestrian bridge that gave Antoine Rémy Polonceau an opportunity to explore the limits of feasibility in 1829: his bridge across the Seine near rue de Bellechasse uses cast iron and wrought iron in a combination of arches and suspension bridge, with a free span of 100 m.[3]

The development of iron production was definitely motivated by a desire for technological progress, coupled with the economic prospects dependent upon it. Perhaps surprisingly, these interests played along with the architectural expectations of absolutist rulers up to the end of the 18th century and, in some cases, into the age of European Restoration. This placed the main emphasis on the picturesque quality of buildings and other structures, as their settings in English and German landscape gardens demonstrate perfectly. Before the efficiency of iron (and later on, steel) was consistently and methodically improved, every known type of bridge had been incorporated into the range of available designs for footbridges and tastefully installed in the parks and gardens of Europe.

1 Pelke, Eberhard, 2005, p. 24
2 Lemoine, Bertrand, Pont des Arts, in: Les Ponts de Paris, Paris 2000, p. 211
3 Paris, Archives nationales, Cartes et plans; illustration in: Deswarte, Lemoine, 1997, p. 93; the Polonceau truss system was invented by his son, Barthélemy Camille Polonceau.