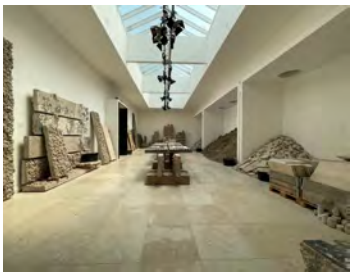
Shifting values – repair and reuse

Just to be clear from the start: I have never designed or built a new bridge – and yet you, dear Jürg, invited me to give a keynote: Thank you for that. Whether you will regret it in 30 minutes' time – remains to be seen.

To be on the safe side, I've brought you a present, a painting by Carl Blechen, a quite important German artist of the Romantic period who was born in Cottbus in 1798 – and there we have a nice connection between the city of my university and your Switzerland, specifically the Schöllenen Gorge north of the Gotthard: Blechen painted the construction of the second 'Devil's Bridge' in 1828 – and as far as I know, it's used as footbridge today. Let me begin.

1 The legacy of high modernism: a break with tradition

The dominant theme of this year's Biennial in Venice is sustainable architecture and, with it, repair and reuse. I was particularly impressed by the Danish pavilion, which stages reuse in a radical way: the curators have neatly sawn parts of the beautiful building into pieces and stacked the resulting building elements in various piles – ready to reuse.






However, I was surprised by a certain attitude in the treatment of the topic of repair and reuse, namely that this is now a completely new, revolutionary turn in architecture. Even a cursory glance at the history of building and construction shows something completely different: it is permeated by repairing, strengthening and transforming, like a common thread.



St. Mary's Church_Berlin [Sonnleitner_2014]; Constantin's arch_Rome [www]

Mehmed Pasa Sokolovic bridge_Visegrad_ Bosnia and Herzegovina [Lorenz]



Building phases and spolia

Since ancient times, new construction has been the exception – repair, renovation and extension, on the other hand, have been the rule, from medieval town houses to baroque palaces. What we call 'reuse' has been known in architectural history since ancient times as 'spolia' – the Arch of Constantine in the top is full of it. There is hardly an older building that does not reveal a long history of renovation in its construction phase plan. At the bottom right is the Mehmed Pasa Sokolovic bridge in Visegrad in the Serbian part of Bosnia-Herzegovina, which I had the honour to evaluate for authenticity on behalf of UNESCO some time ago: Of course, only part of it dates back to the original construction period towards the end of the 16th century!

Why are repair and reuse still considered something special, even new, today?

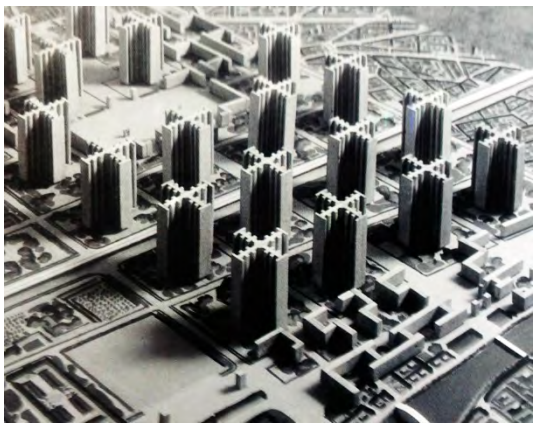
The answer lies in a break with tradition. Our current patterns of thinking are the result of the last 200 years of building history. They were characterised by industrialisation and mass production, new, artificial building materials, an enormous acceleration of construction processes, an increasingly global construction industry – and all this embedded in a seemingly unchangeable capitalist economic system that cannot help but produce more and more.

Right in the middle of it all are we, engineers and architects. A hundred years ago, the latter devoted themselves to architectural "modernism," whose promise of a future "international style" was defined precisely by a departure from history, tradition and regional cultures. Its counterpart was the equally ahistorical promise of progress made by engineers. It became the narrative of an entire era, now referred to as "high modernism."

With this term, historian Ulrich Herbert proposed a new perspective on recent history. It no longer divides the century between 1880 and 1980 into categories such as pre-war, interwar and post-war periods, but rather understands it as a historical unit. It began with high industrialisation and ended with the sobering insight that it was precisely because of it that the ecological balance was being thrown off kilter globally The great unifying feature of this era was an unshakeable belief in a technologically based progress: whatever happens, the course of history is certain, humanity is progressing steadily towards the better, and the key to this lies in the ever-new achievements of a science based technology. We, the engineers, the disciples of Prometheus, who brought fire to mankind, are nowadays the guardians of this narrative. We not only shape this world – with our perspective and our view of the world, we also shape society's view and understanding of it.

The power of this narrative dates back to René Descartes. It was he who established the scientifically defined concept of rationality that was to become so successful in the emerging natural and engineering sciences. It is primarily structured around dualisms: spiritual and material world, humanities and natural sciences, science and art, technology and nature, humans and nature .. and so on. It was against the background of this dual-organised think room that Thomas Tredgold formulated the founding charter of the Institution of Civil Engineers in 1818: *"Civil engineering is the art of directing the great sources of nature for the use and convenience of man."*

Mastering nature through technology – the founding charter of the ICE set out the guiding principle whose implementation would shape civil engineers' understanding of progress until today: wider and wider, higher and higher, lighter and lighter, and faster and faster!

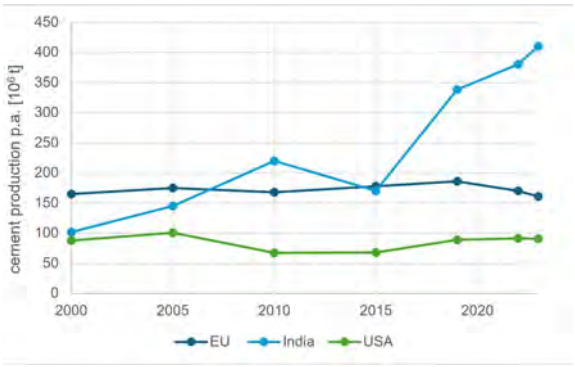


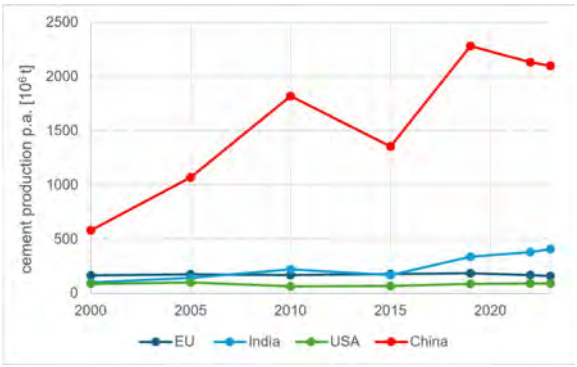
And of course: always new. Progress does not look back; the old must give way to the new: according to Le Corbusier's *Plan Voisin* of 1925, half of Paris was to be demolished to make way for a new ideal city with 60-storey high-rise buildings. Who was still interested in preserving, maintaining and repairing the old? The bitter legacy of high modernism is not only a planet that has been ruthlessly exploited and is now completely overwhelmed, but also a profound break with the actually old tradition of repair and reuse.

For historians, high modernism and its promises of progress came to an end half a century ago. But the construction industry apparently has its own rules. Neither further unlimited growth nor the focus on new construction as the most important task have been seriously questioned to date.

For about two decades, however, the search for new, more sustainable ways of building has become a central topic in research and development. New materials and construction methods are being explored. Conventional reinforced concrete or even traditional steel production is under fire; numerous presentations at this symposium bear witness to this.

However, this has hardly had any impact on everyday construction. The figures for cement production in Europe and worldwide tell a completely different story. Nowhere in the world has there been a noticeable decline in the amount of concrete used in construction. And the figures from Europe and the US seem almost positive compared to those from China.

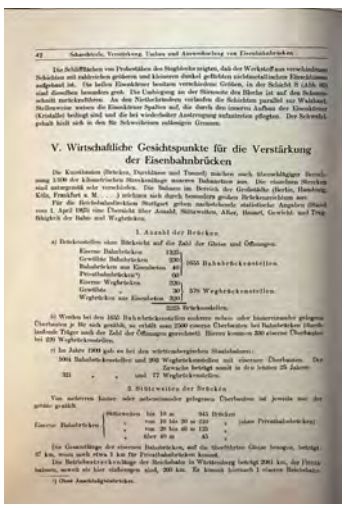




In Germany, they could even rise again soon: financed by a recently approved infrastructure investment programme worth €500 billion (!), thousands of existing bridges will be inspected over the next 10 to 15 years in the Deutsche Bahn network alone. It is to be feared that they will primarily be replaced by massive reinforced concrete structures with generous concrete coverings "on the safe side". The construction sector is as clumsy as an oil tanker.

2 Repair and reuse reloaded

This also includes the unwavering commitment to new construction as the always best option, especially when dealing with Europe's ageing transport infrastructure. However, demolition and replacement are particularly questionable from an ecological perspective in bridge construction precisely because their embodied carbon almost entirely determine the sustainability footprint. Interestingly, the idea that a new construction is fundamentally superior to any old bridge only became the prevailing mindset in the *late* modern era. As late as 1926, for example, a comprehensive work by the renowned German engineer Karl Wilhelm Schaechterle was published, which was decidedly devoted primarily to the reinforcement of existing bridges.


V. Wirtschaftliche Gesichtspunkte für die Verstärkung der Eisenbahnbrücken

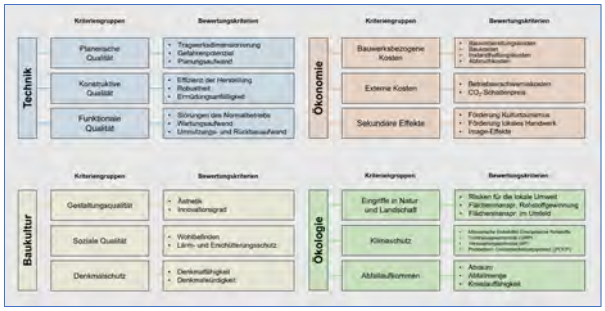

III. Verstärkung von Blechträgern und Brücken mit gegliederten Hauptträgern durch Vergrößerung der Querschnitte und Auswechseln einzelner Teile

1. Verstärkung ohne Entlastung vom Eigengewicht

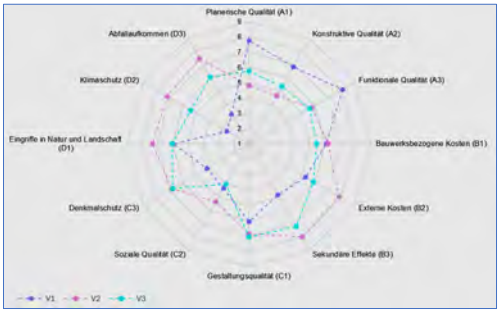
It was probably only in the second half of the 20th century that repair and reinforcement came to be regarded as a stopgap solution: "*Only a dead Indian is a good Indian*" was a brutal saying among US settlers in the past – "*Only a new bridge is a good bridge*" has been the deeply ingrained paradigm of most bridge builders ever since, and remains so today.

Until the beginning of the 21st century, wealthy Germany could afford this. Today, this is no longer the case, even if many people do not want to admit it. But let's leave the costs aside: from an ecological point of view, maintaining an existing bridge through repair or even upgrading is far superior to any new construction.

Just recently, we could finish a research project, titled "*Steel railway bridges as a legacy of high modernism – Principles for holistic decision-making between repair and renewal*". The aim was to provide, for the first time, a robust and transparent methodology for the everyday decision-making process between maintaining and replacing an existing (railway-)bridge. In addition to technology and economics, ecology and building culture were consistently included as central evaluation categories. On the right, you can see a possible visualisation of the results of such a comparison between, for example here, replacement, partial replacement and reinforcement.



Criteria groups and criteria in the hierarchical structure of the four central assessment categories [Schulte 2025]



Langenargen railway bridge__synoptic comparison of three options:
V1 (option 1) = replacement construction
V2 (option 2) = reinforcement
V3 (option 3) = partial replacement
[Schulte 2025]

Research project ‚Steel railway bridges as a legacy of high modernism – Principles for holistic decision-making between repair and renewal' (BTU CS_2021–24)

The first case studies carried out with this methodology show beyond doubt that even in cases of extensive repair requirements and a high degree of intervention, indicators such as carbon footprint and resource consumption only reach a fraction of the values of the new variants (taking into account the entire life cycle, of course). Repairing, strengthening and transforming are highly effective options on the path to a low carbon and resource-efficient construction in the future.

However, the key to success is doing it right: building in existing structures means rethinking construction! An "existing structure engineer" must learn to think very differently from a "new construction engineer". First and foremost, it is crucial to develop a fundamentally different attitude

towards the building, which I like to call "philosophy of acceptance", a benevolent approach to the object ‘at eye level’, in which the focus is not primarily on finding weaknesses, but rather on discovering its strengths. As simple as it sounds, it is not a matter of course. Time and again, we see so-called "renovation projects" planned by renowned firms ultimately implanting a new building into the shell of the old one. They don't trust the old, their attitude is wrong.

On a technical level, the existing building engineer needs in-depth knowledge in very specific areas – historical materials and construction methods as well as today's highly developed options for appropriate condition assessment, realistic structural safety evaluation and effective and precise interventions in the structure of the old building. When approaching an ageing building, one should follow the approach of a good doctor. There are different suggestions to define the investigation phases in such a "medical approach"; I myself favour the division into "diagnosis", "safety evaluation" and "design of intervention" (therapy). This is already an important step in avoiding falling back into "building new mode" in the concrete project planning. But it is not enough. In more than 20 years of working with historic structures, I have learned that a few guiding principles are crucial for each of the three phases:

For example, regarding phase 1, the **diagnosis**:

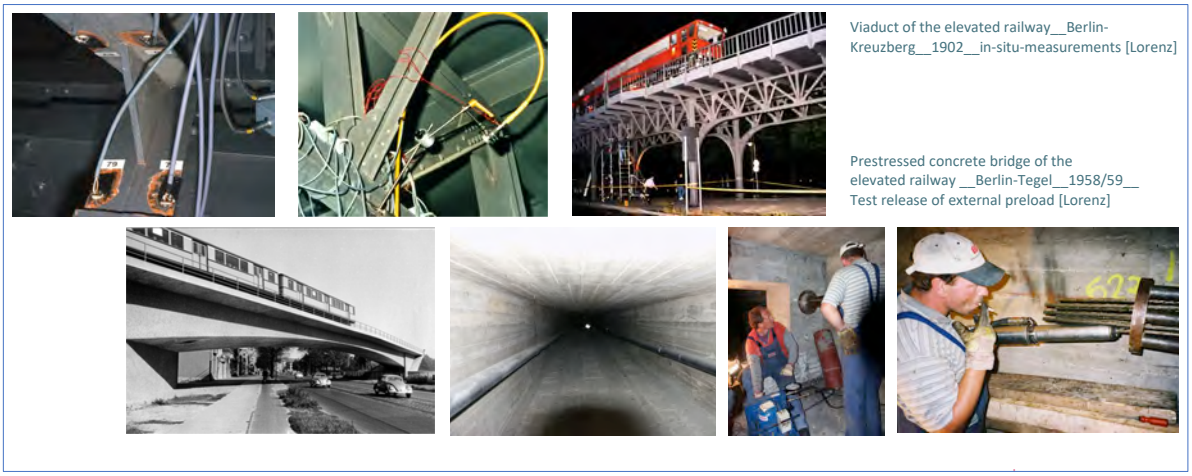
- The better the preliminary survey, the more precise the later intervention will be – convince the client of this!
- Research and use all available archive material!
- Always start with a precise anamnesis!
- Use the wide range of non-destructive testing methods!
- And don't forget to take a close look yourself!

At least at this occasion, I would like to use a few projects from our Berlin office to illustrate the phases; for example here the investigation of one of the last still existing sections of the first elevated railway viaduct in Berlin-Kreuzberg, which was completed in 1902, and which could actually be achieved in the end.

Viaduct of the elevated railway__Berlin-Kreuzberg__1902__structural survey [Lorenz]

Regarding phase 2, **safety evaluation**, it is crucial from the structural point of view to develop a model that is as close to reality as possible. Recommendations derived from this …

- The structural model results from the building, not the other way around!
- Use measurements and monitoring! Measure beats calculate!
- (… and according to Schwedler ☺:) The structural model must be optimised until it corresponds to the measured reality!



Viaduct of the elevated railway__Berlin-Kreuzberg__1902__in-situ-measurements [Lorenz]

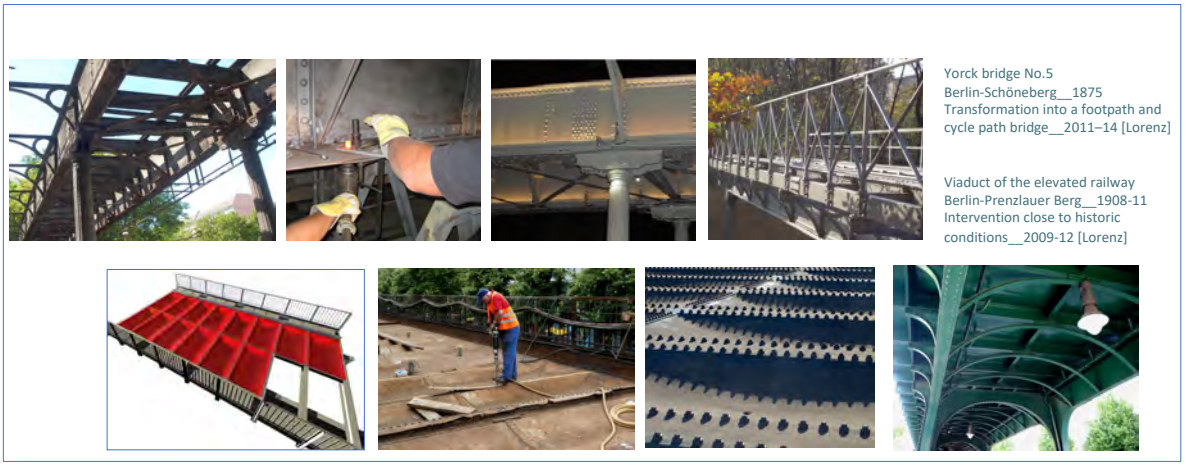
Prestressed concrete bridge of the elevated railway __Berlin-Tegel__1958/59__ Test release of external preload [Lorenz]

The examples above show different load tests and associated measurements on the same viaduct, and below, the investigation of a prestressed concrete bridge that had been given additional external prestressing in the box girder with the aim of retrofitting it (... not by us!). New cracks in the bridge indicated that this was in fact ineffective – and this was indeed confirmed when the tendons were loosened experimentally.

Finally phase 3, the **design of intervention**:

- As much as necessary, as little as possible – the principle of sufficiency!
- Stay as close as possible to the existing structure with necessary reinforcements!
- Analyse precisely which structural elements the interventions can be limited to – modular thinking!
- The best therapy is nothing without a care concept – sustainability requires maintenance!

I would just like to highlight the second recommendation here, because I have noticed time and again how important it is: Stay as close as possible to the existing structure with necessary reinforcements!



Yorck bridge No.5 Berlin-Schöneberg__1875 Transformation into a footpath and cycle path bridge__2011–14 [Lorenz]

Viaduct of the elevated railway Berlin-Prenzlauer Berg__1908-11 Intervention close to historic conditions__2009-12 [Lorenz]

The pictures in the bottom section show another viaduct where, despite considerable resistance, we were ultimately able to ensure that the damaged old barrel -shaped metal sheets from 1910 were

not replaced with a solid track with concrete slabs or similar, as had been requested, but that the historical structure was essentially used again (with minimal but decisive improvements to the details). In the end, this proved to be the best solution, both technically and in terms of conservation.

Contemporary repairs are anything but old-fashioned fixes. The spectrum of possible interventions ranges from the latest materials and technologies (adhesive bonds, CFRP lamellas, UHFB, but also monitoring, etc.) to conservative but proven methods. This is precisely why the reload of repair and reuse is so fascinating – the contrasts between new and old, heritage and high-tech are fading away.

Just how difficult it is to break through firmly entrenched patterns of thinking is demonstrated time and again in the discussion about the remaining "service life" of older steel bridges. A definitely open-minded colleague recently told me: "No engineer would sign off on a steel bridge that is more than 100 years old being used by the railway for another 50 years". But – if I can veryfy that the stress ranges are always below the fatigue strength limit in reality – then why not? Despite the term "service life", a bridge is not a human being! But suddenly engineers no longer trust their own figures: the idea that a steel bridge can still be reliably used by the railways in 500 years' time, provided the load level remains constant and it is properly maintained, seems to be a concept that we still have to get used to.

3 Shifting values – How do we want to build the future?

However, repair and reuse is just one of many options in the context of the upcoming paradigm shift", the sustainability turn". In conclusion, let me outline a few points from my personal perspective that could promote this transition. I will say right away my proposals are neither mature nor complete, but rather fragments of an approach.

1. More respect for the value of the old! For me, this is not only a primary requirement because the option of "preservation instead of renewal" offers the chance to break the fatal spiral of "always new" and "always more": in this sense, repair and reuse can be understood as a contribution by the construction sector to the development of realistic degrowth strategies! But in general, more respect for the old is good for us engineers: engaging with the old and with the ways of thinking of our predecessors can help us to become a little more sceptical about our own seemingly self-evident practices of design, construction and calculation, and perhaps to consider the possibility that they may ***not*** be the best. Last but not least, engaging with the old brings with it an exciting change of perspective on the material: no longer asking what we can do with the material, but rather: what does the material do to us?

2. **Vitruvius needs an upgrade.** At the time of Augustus, Vitruvius, a retired architect receiving an imperial pension, formulated three categories against which all architecture should be measured: *firmitas, utilitas, venustas* – structural integrity and durability, functionality and good design, beauty. Even if it's more than 2000 years old, Vitruvius' triad is as valid as ever.

And yet today it is no longer sufficient to locate the quality of "architecture" solely between these three poles. An upgrade has become indispensable; a fourth category is needed for the

evaluation of "architecture", and the Latin *convenientia* perhaps best describes it: sustainability, in the full breadth of the term as we understand it today. Currently, it is not only a sufficient condition, but a necessary one – *a conditio sine qua non.* Johann Wilhelm Schwedler, the astute Prussian civil engineer from the second half of the 19th century, coined the guiding principle: "Every design must be revised until the simplest solution is found." A timelessly good guiding principle. However, a second guiding principle has become just as important today: "... to optimise every design until the most sustainable solution is found."

3. What is required is the exploration of undiscovered spheres of possibility between nature and technology. Let us recall once again the ICE charter: *"... the art of directing the great sources of nature for the use and convenience of man"*. 200 years later, this model of controlling nature through technology is passé. Even ICE has modified it on the occasion of its 200th anniversary. It did not work; nature is more powerful, and it is striking back. We civil engineers in particular have contributed significantly (and continue to do so) to destroying natural balances and turning the world upside down on an ever-larger scale. No matter how well-intentioned we may be in individual cases, we are part of a destructive chain of actions. But what can we do? As vague as it may still be: Perhaps we should try to shift the coordinate system in which we operate. Is our "Cartesian" thinking, primarily structured by dualisms of "either/or", still relevant today? It is actually astonishing how stubbornly we cling to it, as if quantum physics, neural networks and artificial intelligence had never existed! Take, for example, the treatment of bridges that are listed: The ever-recurring debate about preservation versus demolition often falls short! That is precisely why I introduced the term "*Weiterbauen*" ("*continued building*") almost twenty years ago: it breaks down the dualistic space by understanding old and new, heritage and high tech, not as opposites, but as complementary.

4. Endure imperfections! One of the favourite topics of conversation among people in Berlin is complaining about the unreliable public transport. It's a problem, for sure – and yet this favourite complaint is based on a tacit assumption, namely the expectation that public transport should actually function smoothly at all times. Stop: Isn't that the classic, high modern belief in progress again?! How can we expect all the elements of such a complex system to constantly mesh together without disruption and function flawlessly – regardless of all incompatibilities, limited financial resources and, above all, the inevitable disruptions at the interfaces with the users, people with their own rebellious logic? What does this tell us? I know it goes against the very foundations of every engineer's understanding, but I think we should at least learn to tolerate imperfection a little more. Taken further, this has significant consequences. They affect the fundamentals of our understanding of safety and the underlying considerations between failure probabilities and the appropriate effort to limit them. This is not the place to go into detail, but it draws attention to a final guideline for shifting values, which is really nothing new, but which I would nevertheless like to mention here:

5. Less regulation – more openness, more courage, more risk! The originally highly valuable standardisation and regulation of construction has developed into a barely comprehensible apparatus of for example European building standards. Not only does this make it difficult to implement innovations. It also has a destructive, soporific effect when engineers are allowed to shirk their professional responsibility all too easily by referring to the standard! It is not enough to

incorporate sustainability into the standardisation – the current standardisation itself is the problem!

But is it really up to us, engineers and architects, to take responsibility for these fundamental challenges? Aren't the decisions made elsewhere anyway? And didn't previous generations fare well by seeing themselves primarily as silent and rule-observing servants of technology – regardless of who that technology was currently serving? Everyone can decide that for themselves. In any case, I would argue that we building planners should also contribute our own unique expertise to the discourse on what are arguably the most important issues of our time. The concept of "sustainability" is based on a complex system of values that must be constantly renegotiated by society – and engineers and architects have a lot to contribute to this negotiation process. This is all the more true in view of the current threatening rollback in environmental policy, which calls into question the relevance of science itself. The future is perhaps more uncertain than ever before. It is often difficult to even imagine a future that is somehow compatible with and sustainable for humanity. But: The time for action is now – even if we cannot really imagine the "post-concrete era" yet.

John Wilkinson (1728-1808)
[Lemuel Francis Abbott]

Great Eastern in the Millwall Dock (Isle of Dogs)__ca. 1857
[William Parrot__Building the great Leviathan]

Isambard Kingdom Brunel
In front of the ship's chains
of the Great Eastern__1857
[Robert Howlett]]

Wilkinson's prediction at about 1800 and Brunels reality at 1859 – Visions become realities

Perhaps we can draw courage from the visionary power of the pioneers of early steel construction at the beginning of the 19th century. John Wilkinson, one of the pioneers of building with iron, was so infatuated with iron that long before his death he had a cast-iron coffin made for himself, in which he insisted on being buried. It was this same Wilkinson who, towards the end of the 18th century, formulated the idea of iron ships sailing the world's oceans. His compatriots thought he was mad – they couldn't imagine such a thing. Just over half a century later, Isambard Kingdom Brunel – who was actually quite a madman himself – built the 211-metre-long Great Eastern. He did not live to see its successful launch, but his leviathan was to remain the largest ship in the world for several decades. And today, to my knowledge, quite a few iron ships sail the world's oceans.