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Bridges in fifty years

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Abstract

Bridge design has changed significantly in the last 50 years due to advances in tools. In the next 50 years, bridge design will be governed by the effects of climate change and our understanding, that we must build in a more sustainable way. The history of bridge design is a history of calculation methods, production methods, structural types and materials. From these areas, We can predicted the future of bridges in the next 50 years. And because bridges shape our environment, no matter how our bridges will be designed and build in the future, they must look good.

Looking back

Ask an 80-year-old civil engineer who started his career in bridge design in 1970 about what has happened since then. Perhaps he would first talk about tools, as digitalization has changed so much. Writing, drafting and calculating was mostly done by hand fifty years ago and today it basically is all handled with computers. The world has become global and faster, due to the internet and Artificial Intelligence is becoming so strong that soon it will challenge bridge designers at the core of their work. Since 1970 the records record spans of suspension and cable-stayed bridges have gone up from 1998m to 2023m and from 319m to 1104m, respectively. Bridges for high-speed train bridges became common all over the world. New typologies such as Extradosed Bridges or curved girder bridges were developed and steel-concrete composite sections were used much more frequently. The strength of all building materials for bridges has increased very much. On the negative side, today many bridges need replacement, often after less than 50 years of life, because of fatigue caused by tremendously increased heavy vehicle traffic. This is why fatigue resistant Carbon Fiber Reinforced Polymers (CFRP) have been entering the market in recent years.

Japan and Germany, where I come from, are countries with an ageing society where most infrastructure is built already. Therefore, and for reasons of sustainability in bridge design the focus is shifting to “renovate, reuse and recycle”. We must not forget, however, that this is not so everywhere. Africa will become the hotspot for future construction. In the next 30 years 10 times the population of Japan will be born on the African continent and this means that many new bridges will have to be built there, not to speak of the need for housing, buildings for education and health care as well as structures for food and energy production.

Our old engineer would surely confirm that in 1970 he had not foreseen the world of bridges as it is today and neither will anyone be able to predict what the next 50 years will bring. As a matter of fact, more than 20 years ago I wrote an article on “autonomous bridges” [1] and claimed that soon our bridges could be autonomous, might be full of microchips, sensors, processors and actuators to make them adaptive and intelligent (see Fig. 1). I was wrong, hardly anything in this direction has happened so far. So much about predictions.

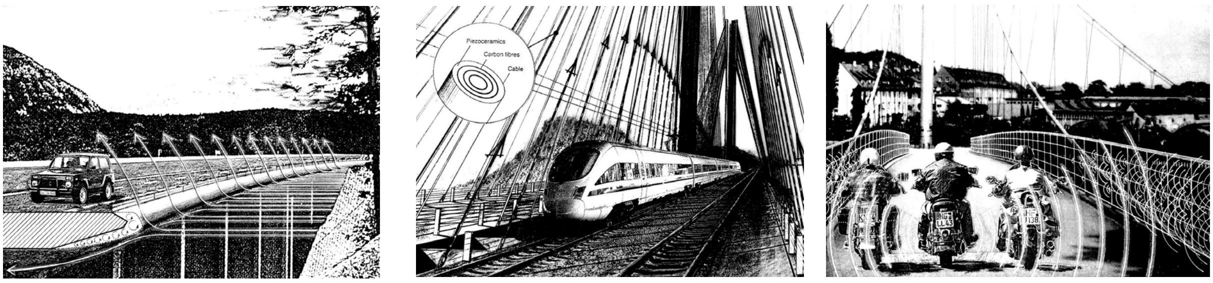

Fig. 1 Bridges with adaptive cross sections covered with micro flaps to control air flow (a), intelligent cables made of carbon and equipped with piezo ceramics to reduce deflections from live loads (b), and micro loudspeakers for cancelling traffic noise (c).

Looking forward

In bridge design we will probably not see the disruptive changes, that other industries are going through these days, but it would be surprising if during the next 50 years there was less change than during the last half century. We can look at present trends and extrapolate them to a certain extent. Like everything else in the world also bridge design will be governed by the effects of climate change and our understanding, that we must build in a more sustainable way.

The European Union has just decided to stop producing car which burn fossil fuel by 2035. Worldwide we are moving away from burning fossil fuels, also in other industries. Sooner or later, we will have abundant renewable, clean, and affordable energy. With electricity from the sun, hydrogen and e-fuels can be produced. Then, energy consumption for making materials will be of less importance and our focus will shift even more to saving our scarce resources. Since the building industry is a major consumer of resources, such as concrete aggregates, cement, steel, timber and water, this will certainly affect all future bridge design.

Future bridges will have to be built with minimized quantities of materials. We will see more lightweight bridges which is not only good for sustainability but also because such bridges do not obstruct the view and are perceived as elegant. Lightweight bridges are flexible and can react well to seismic loads and impact. Climate change is already causing stronger temperature variations and stronger wind loads. Bridges, therefore, must be designed for increased resilience. The challenge will be to build lightweight and resilient bridges.

Demands are also changing. We are seeing new types of traffic, consisting of more electrified and autonomous public transport, more bicycles and pedestrians. High speed bicycles lanes have to be separated from pedestrian which will lead to wider deck sections and adequate bridges types for this type of traffic. Many megacities are so congested already that we will see more elevated cycle ways. Not only for safety reasons, but also for guidance and aesthetics illumination and integration in the urban context of cycle and pedestrian bridges will play a more important role.

The history of structures in general and bridge design is a history of new computing methods, new manufacturing methods and structural types as well as new materials. We can also try to extrapolate in these areas:

- Sensors for bridge monitoring and computing and the data they produce have started to play a role in bridge maintenance and repair, even though more than a few bridge monitoring systems produce tremendous amounts of data no one uses. The more we understand what data is useful for collecting and the more we understand the power of Artificial Intelligence, Big Data and Digital Twins, the more we will be able to apply these tools not only to detect issues before they become a problem but even to avoid them altogether. These tools have the potential to revolutionize bridge design. They shall assist us in improving our designs but since they cannot take responsibility it is us who must use them in an appropriate way. Humans shall draw the right conclusions and final design decisions also those regarding loads, construction and operation of bridges.

- Changes in manufacturing are also appearing if we look at advanced technologies such additive and subtractive manufacturing. These methods will allow for more intricate structural details with better flow of forces. Prefabrication in general will certainly play a greater role in bridge design as prefabrication under controlled conditions leads to higher quality and precision as well as less waste. Further, bridges made of prefabricated elements can be constructed faster and ultimately disassembly and reuse will be easier.
- Life cycle analysis will be become the standard to analyze our bridge structures. Overall value will be more important than initial cost. Therefore, we probably will see more Integral Bridges. They need less material and thus have a smaller CO_2-footprint. Integral Bridges are not only elegant, but they are also safer than simple girder bridges because they are structurally redundant and more durable because there are no joints and bearings (Fig.2).
- When we look at materials, CFRPs are very promising because of their high strength combined with little weight and neither fatigue nor corrosion problems (Fig. 3). These materials are still expensive and recycling is still an issue. However, once sufficient renewable energy is available, perhaps we will be able to produce carbon fibers from the CO_2 in the air. Sustainable bridge design can also succeed with classic materials used in a new way. Recycled steel and concrete will become more relevant and we might use more weathering steel as it requires no coating which has to be replaced regularly. Natural materials such as stone and timber as well as materials from "urban mining" can be used at least for pedestrian bridges, which are less loaded than road and railway bridge.

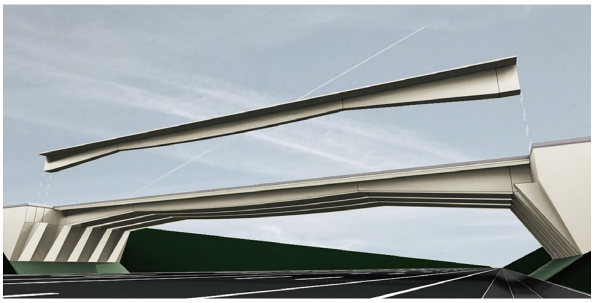

Fig. 2 Integral Bridge and prefabrication are no contradiction. This bridge proposal shows concrete beam elements, post-tensioned with CFRP strands which are cast onto abutments to form an integral frame [2].

Fig. 3 A Network Arch Bridge with carbon hangers [3].

For another issue extrapolation is easy. The future of bridge design, overcoming the challenges to come will depend on well-trained construction workers and well-educated engineers. Engineers who are strong in Conceptual and Structural Design, generalists who know the traditional methods of bridge design and who are versed in the use of state-of-the-art tools and technique. To educate them well professors need to have practical experience in bridge design in addition to their scientific and didactic abilities.

Bridges shape our environment; they are part of what in German is called “Baukultur”. They add to our quality of life and they should do this in a positive way. Therefore, and finally, no matter how our bridges will be designed and build in the future, they must look good.

References

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