Decarbonizing Bridges: A View From Sweden

Seizing opportunities to reduce carbon emissions through material choices and approaches that support environmental sustainability

Decarbonization is a challenge common to all sectors of the built environment. This high-priority issue involves both operational carbon (from the in-use phase of a structure) as well as embodied carbon; the latter includes carbon from the manufacture of materials and the transport and assembly of components used to produce a structure. In the following Q&A, we spoke with bridge engineers Daniel Ekström and Johan Lindersson, WSP in Sweden, to explore opportunities to reduce carbon emissions associated with bridges—focusing on material choices and approaches that support environmental sustainability.

Photo: Trafikverket and Degree of Freedom
The bridge is part of the Olskroken project in Gothenburg, Sweden. The project used alternative additives to decrease the amount of cement in the concrete bridges, supporting carbon-emissions reduction.

What opportunities exist to reduce carbon emissions associated with bridges, both existing and new?

Daniel Ekström: It is important to approach the reduction of carbon emissions with a holistic perspective to support genuine benefits instead of suboptimization within each domain. Creating bridge structures involves a chain of interdependencies among, at a minimum, material suppliers, structural engineers, contractors and the client, where choices made by each party may have a significant effect on possible choices by others, and, in the long run, the performance and durability of the finalized construction.

There can be large reductions with very small changes related to material choices. For a concrete bridge, it is possible to generate a total carbon footprint reduction of between 40 to 50 percent, compared with the commonly used concrete mix in Swedish bridges, through simple and available choices.[1] Using reinforcement made from recycled steel scrap or additives such as slag or fly-ash to reduce the amount of cement in the concrete are examples of individual changes that can add up to have great impact whether repairing, refurbishing or building a new structure. In addition, using materials produced by renewable sources of power can add to the positive impact. Lead engineers can help a lot by making good choices regarding suppliers and use of additives to favour environmentally friendly production. To compare materials and validate that choices support the use of sustainable building materials, engineers should refer to environmental product declarations (EPDs), though EPDs still are not obligatory for manufacturers.

[1] Ekström, D., Al-Ayish, N., Rempling, R. et al (2017), "Climate impact optimization in concrete bridge construction," 39th IABSE Symposium, September 21-23 2017, Vancouver, Canada - Engineering the Future

Johan Lindersson: In addition to considering choices in a broader context, it is also important to challenge traditional approaches and existing standards. For example, the technical specifications of the proposed bridge, or any type of infrastructure, should include solutions that support carbon-emissions reduction. Workshops, early in the project process, could be held to pull together parties to identify the largest possible climate-health contributions. Projects would also benefit from having a dedicated sustainability coordinator whose role would focus on solutions supporting the climate and environment overall. That person could, at the start of the project, conduct a survey to identify potential parameters that would help reduce the climate impact for that particular project.

Capturing early opportunities to decrease emissions might also involve considering if the proposed bridge could be made smaller, and in that way use less material, or if it is needed at all. Close and early communication with road or rail engineers can help identify the most sustainable infrastructure solution in a particular context.

For existing bridges, prudent repair and replacement of parts support sustainable solutions that can extend the life of the bridge. Developing more fine-tuned calculations to more accurately reflect the bridge's physical "behaviour" and structural capacity can support a better understanding of the remaining lifespan of the bridge. When we have a better understanding of the structural capacity, we know if a bridge really needs to be replaced or strengthened, or whether it can be used in the same manner.

When building a new bridge, we could consider if it is appropriate to create a standardized bridge, which could be a prefabricated structure; prefabricated structures, which are commonly manufactured in a controlled environment with less impact from outdoor weather, typically optimize formwork and rebars, resulting in less waste of material.

How can technology facilitate the reduction of carbon emissions in bridge projects?

Johan Lindersson: Technology can help in different ways. Water, wind or solar power can be applied in cement or steel manufacturing instead of burning fossil fuel. In the planning and design of a project, automated design brings opportunity to develop algorithms that can test many different parameters to find the best structural solution and identify the most environmentally friendly measures. With the LCPro digital tool developed by WSP, engineers can automatically create lifecycle analysis and lifecycle cost reports. The LCPro application imports parameters from our 3D design, calculates different climate values from a database and then creates standardized reports. Since LCPro is automated and very fast in presenting the climate impact of various parameters, it could be used to quickly compare different solutions with regard to one or more climate parameters of interest.

Daniel Ekström: Using 3D modelling and visualization tools enables us to create a more informed basis for decision making from the start, providing a common view for the client and the engineering disciplines involved as well as other stakeholders in the project. It is also a way to engage all parties in an ongoing dialogue to achieve the greatest reduction in CO_2 emissions.

The main workload for bridge engineers is normally focused on the latest stage of detailed design where we establish construction documents based on a well-defined single solution. Using digital tools in earlier stages,

such as in the conceptual or preliminary design stages, can help us find more potential solutions. Parametric design makes it possible to keep more potential solutions, parallel options, longer in the process—rather than excluding options, due to lack of information, in order to push the design process forward. Delayed decisions can allow clients to better understand what they need and what they want. Time gained from using automated processes can be invested in more creative design processes and creative engineering. Technology is then giving us an opportunity to optimize design within a well-defined scope of potential solutions.

Further, the possibility to monitor the bridge once it is built—how the bridge actually "behaves" in its real environment—is also very important. The data gained from monitoring through a digital twin may very well affect how we create designs in the future; perhaps we can even shift from probability-based design rules to close monitoring of our structures over time, and by doing that reduce resource use.

Potential to reduce carbon emissions through material selection in the design of bridge projects:

Figure 1 – The chart shows CO_2 emissions based on data from a 2018 survey made by the bridge department, WSP in Sweden.
*The data was collected from WSP engineers to reflect the impact of one engineer over a year: in private life, at the office, and from design. "Office" refers to energy use at the office as well as business travel—the latter comprises the majority of the "office" category; "private life" refers to impact from everything done in/part of private life, including home, travel, food, and consumption (products and services); and "design" refers to materials specified by structural drawings for proposed bridges and associated structures.

Can environmentally friendly solutions strengthen resilience to the impacts of climate change?

Johan Lindersson: Climate-change impacts can be of various types, and we must take these impacts into consideration when developing the design. This need can, in turn, raise additional questions. For example, extreme cold can result in more ice that pushes against bridge supports, and this occurrence might increase the use of de-icing agents, which can shorten the technical lifespan of a bridge. One countermeasure is to include more concrete cover. Then the issue of using more material arises. Utilizing environmentally friendly additives in concrete to reduce the amount of cement therefore becomes even more important; making the bridge more resistant to de-icing agents or to the wear and tear of sea ice grinding on the supports could extend the lifespan of the bridge, and thereby generate benefits over the long term.

The effects from rising sea levels or from flooding after severe rain could be prevented by shifting the location of a bridge to a higher level, but that, in turn, could mean a longer road and longer travel requirements. One way of addressing increased water in rivers is making supports with much more erosion protection.

What are the key takeaways to move forward with decarbonization efforts?

Daniel Ekström: All professionals play their important part differently in the project lifecycle, but real change requires a holistic approach so that each contribution can add up to make significant impact in the carbon-reduction challenge. Again, it is important to understand the chain of interdependencies when creating bridge structures; one choice may have a large

effect on possible choices for others and impact the ability to find the most sustainable solution overall.

As engineers, we have a great responsibility to both inform and influence our clients. The decision may not always be ours, but at least we have made our clients aware that there may be better choices to consider.

Johan Lindersson: Engineers have the potential to reduce far more CO_2 than many other people in society by addressing the type and amount of material used in construction, refurbishment and repair.

The carbon emissions diagram helps us understand not only the impact of our design work but also, and perhaps even more significant, how much positive impact we as engineers can make to reduce carbon emissions.

While the approaches we have discussed are focused on bridges, it is essential that everyone involved in developing the built environment challenge their way of working, to include measures that will reduce each carbon footprint.

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