Investigation of cracking due to restraint forces in Swedish concrete slab frame bridges

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It is common knowledge that when a thing, for example a concrete block, heats up it expands, and when it cools down it retracts. But what happens if the block is restrained, and unable to deform freely? A block that wants to retract, but is restrained, will have tensile forces arising inside of it. These forces will in most cases cause the concrete to crack. In this paper 11 Swedish concrete bridges have been examined where cracking caused by restraint forces have been investigated.

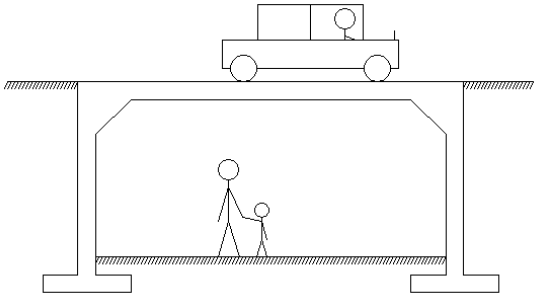

Figure 1 - Concrete slab frame bridge

The slab frame bridge is one of the most common of all Swedish bridge types. It consists of two concrete walls and a concrete roof. The cars drive on the roof and the crossing pedestrian walks in the tunnel, as shown above in Figure 1.

In the bygone days before modern computers these types of bridges were designed in 2D. The most important loads where the traffic load and self-weight loads. These loads affect the bridge in the longitudinal and vertical direction. Not much regard was taken for loads in transversal direction. Here the reinforcement amount was decided by praxis rather than calculation. Today these bridges are designed in 3D with the aid of advanced computer design programs. As this type of bridge is a frame structure it will suffer from restraint forces in the transversal direction due to temperature change and concrete shrinking. The problem with restraint forces is that the magnitude of the forces decreases as the concrete cracks. This is a problem for the design programs as they can't reliably account for the cracking in the concrete. This has led to that the amount of transversal reinforcement prescribed by the design programs being much higher than what have been standard earlier. Therefore different new methods for deciding the reinforcement have been developed, but none of these have been verified in the field.

This paper has therefore investigated 11 existing bridges. The bridges have been redesigned with a design program and had their reinforcement amount recalculated with two different methods for deciding the reinforcement. One is the standard reinforcement method and the other is a method where special regard is taken for the restraint forces. The bridges have also been investigated in the field and examined for cracks.

The results showed that only one of the examined bridges had cracks that exceeded the crack allowance. This means that the present reinforcement was mostly adequate. The computer calculated reinforcement gave reinforcement need that was higher than the present reinforcement. The standard reinforcement method gave a reinforcement need that was at maximum 20 times higher than the present reinforcement amount. Another method, where special regard is taken for the restraint forces, gave a reinforcement need that was two times higher than the present reinforcement amount. This indicates that restraint forces are no problem for Swedish concrete frame bridges, but rather a problem for the design programs.