TALAT Lectures 2701

Bridge Deck

8 pages, 5 figures

Basic Level

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Objectives:

- to illustrate the structural use of aluminium extrusions for the replacement of damaged concrete bridge decks as realized in a case in Sweden
- to describe the technical and economic advantages of the chosen light-weight aluminium design

Prerequisites:

- basic knowledge of structural engineering and extrusion design
- TALAT lectures no. 1302, 1501, 2200, 2300 and 2400

Date of Issue: 1994

2701 Bridge Deck

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2701.01 Background

Road bridges are long-term investments with an expected lifetime of at least 50 years. In many cases bridges are in such a poor condition after a much shorter time that they need to be repaired or replaced. A severe climate, the use of road salt and increasing traffic loads are three major factors causing deterioration of bridge structures. Deterioration of concrete decks is mainly due to the first two factors. In areas with poor soil conditions increasing traffic loads have caused damage to foundations and supporting structures.

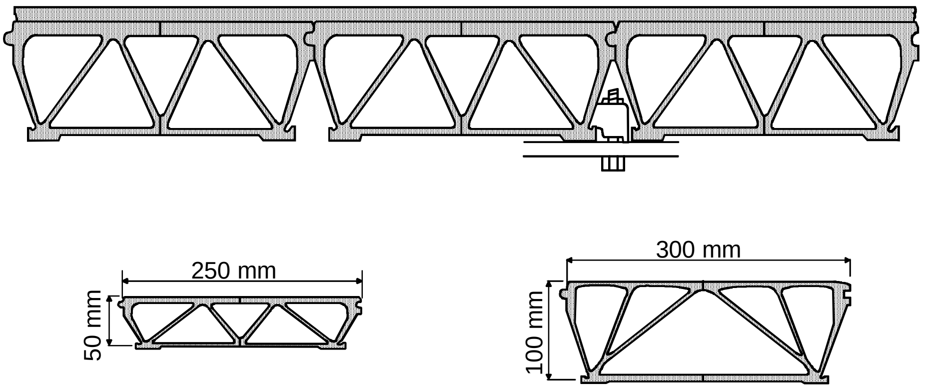
In cases of severe damage to concrete decks the usual course of action is to replace the deck with a new one. There are several methods for undertaking this. If the foundations are damaged, or if the bridge is to carry increased loads, then reinforcement of selected areas is usually necessary, often at great cost.

Bridges are structures in which a considerable part of the load-bearing capacity is allocated to carrying its own weight. For a steel girder composite bridge most of the dead load lies in the concrete deck. By replacing the concrete deck with a lighter one it is possible to increase the allowable live load without reinforcing the main structure or the foundations.

A lightweight system for replacing damaged concrete bridge decks has been developed and used in Sweden. The basic concept is an orthotropic plate of aluminium. Weight reduction has made it possible to use the existing foundations, supports and structural systems for increased allowable live loads on bridges that otherwise would have to be replaced.
This orthotropic plate is built up of hollow aluminium extrusions. The extrusions are fitted together by means of a tongue and a groove in the upper flange, as shown in **Figure 2701.01.01**. This type of connection transfers shear force from one extrusion to the other. At the same time it allows each extrusion to rotate independently of the

neighbouring ones. The hollow section is used to create a high degree of torsional stiffness in the extrusion.

Section through an
Aluminium Bridge Deck Extrusion



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When subjected to concentrated loads, which is most often the case for bridge decks, the resistance of the deck is due to a combination of the bending and torsional stiffness of the extrusions. In this way the load distribution will be considerable and concentrated loads will be carried by at least seven extrusions at the same time.

The cross-section of the extrusion has the form of a truss or an arch. This is to ensure resistance against local deformation due to point loads such as tyre loads caused by vehicles.

The deck is mounted to a secondary structure of steel girders or, as in certain cases, directly to the main structure. The distance between the supporting girders varies between 1.2 and 3.0 m depending on the size and the type of extrusions.

Fasteners of extruded aluminium are used to fix the deck to the supporting structure. The fasteners hook on to grooves in the lower flanges of the extrusions and are bolted to the supporting structure (see **Figure 2701.01.01**).

The surface of the deck is covered either with an acrylic-based material called Acrydur or with an asphalt covering. Acrydur has been applied to bridges for many years and has shown a very high resistance.

The weight of the described deck system lies between 50 and 70 kg/m^2. The weight of standard concrete decks is normally between 600 and 700 kg/m^2. The aluminium deck is corrosion resistant in a marine environment. Construction time is short, which is favourable when repairing bridges in areas with heavy traffic.

This system has been applied to drawbridges, pontoon bridges and stationary bridges with primary structures of steel. It can also be applied in constructing new bridges, often with the additional advantage of a reduction of weight of the primary structures and also of the size of required foundations.

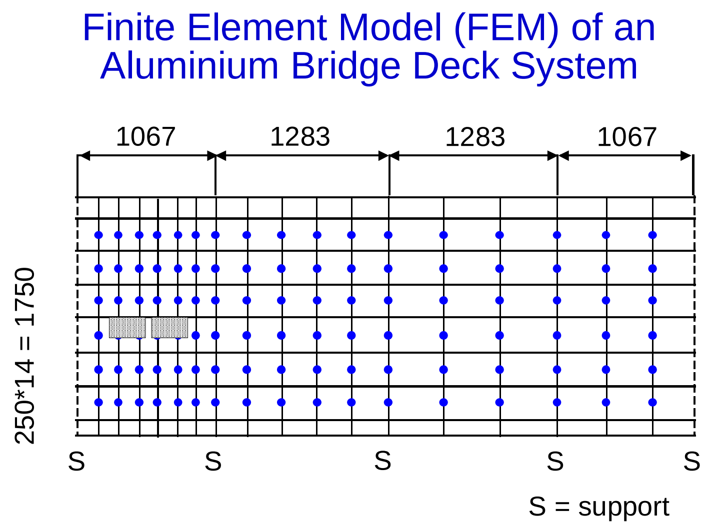
In areas with poor ground conditions the weight reduction caused by incorporating the deck system has allowed the use of the existing foundations to support increased loads without the need for additional reinforcement. In piled foundations this often means fewer piles.

The reduction of weight resulting from the use of the aluminium deck system increases with the size of the bridge. This is largely due to the fact that the relative magnitude of the dead loads increases with increased span.

2701.02 Theoretical and Experimental Investigations

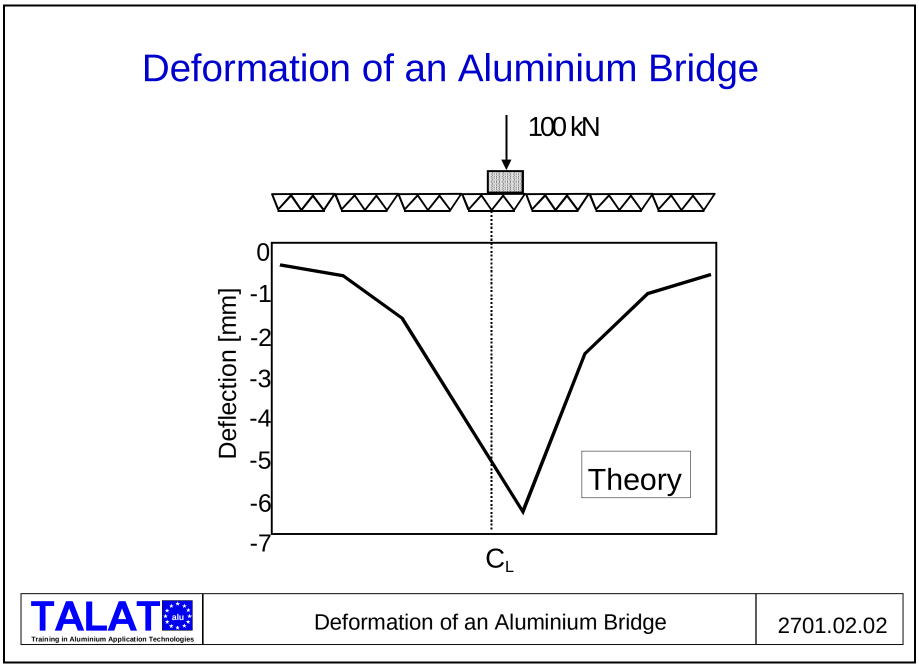
The system is designed to fulfil the requirements given by the Swedish National Road Authority. These include resistance to static and dynamic loads according to the Swedish bridge and building codes.

At first an analysis of the deck was undertaken by modelling the structure by the use of finite elements. A model of the deck was formulated using beam finite elements. The extrusions were simulated by beam elements having the flexural and torsional stiffness of the proposed section. The effect of interaction between extrusions was simulated by using connecting beam elements with almost infinite flexural stiffness. The model is shown in **Figure 2701.02.01**.



Finite Element Model (FEM) of an Aluminium Bridge Deck System 2701.02.01

Here, the applied load is represented by a pair of truck tyres. The load was placed in the most unfavourable position to cause the largest possible deformation in the structure, as shown in **Figure 2701.02.02**. The deformation reached a maximum of 6.5 mm at the right end of the extrusion subjected to the applied load. In this case the load was 100 kN.



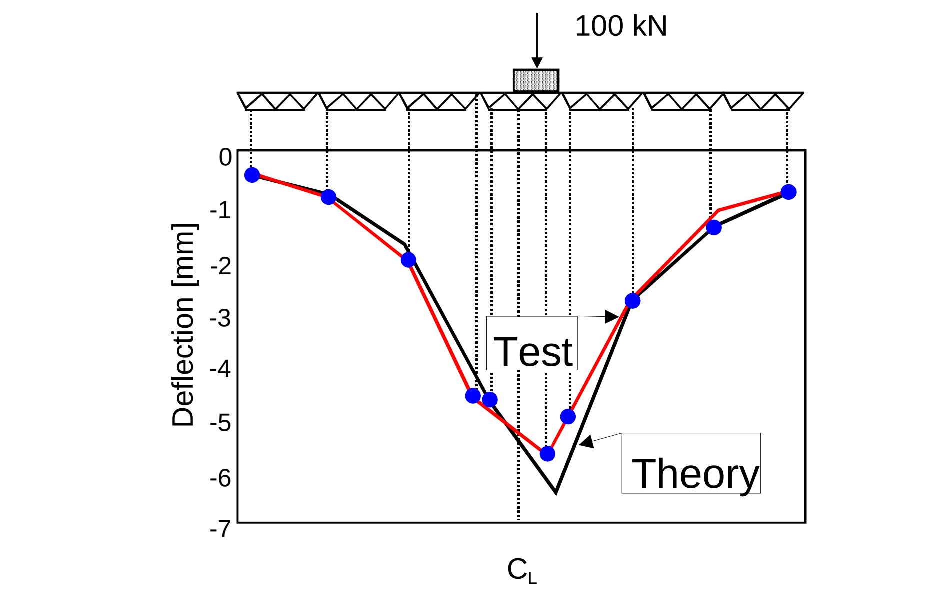
A full-scale model was tested to confirm the results of the theoretical investigations. These tests included static loading as described above and dynamic loading in accordance with the requirements set by the Swedish National Road Authority.

The results of the static loads showed very good agreement with the results from the FEM analysis. A comparison between these results is given in **Figure 2701.02.03**. The static load was increased to an ultimate value of 320 kN, which is well beyond the dimensioning load of 100 kN. The maximum deflection of a deck element under a load of 320 kN was 27 mm.

Dynamic loading was applied to investigate resistance to fatigue. The load had an amplitude of 96 kN and a maximum value of 100 kN. The frequency was 1-2 Hz and a total of two million cycles was applied. No cracks or signs of fatigue were visible after the test and the maximum residual deflection was 0.4 mm.

Extruded deck elements were tested in bending and torsion to investigate the influence of the surface material. These showed that the Acrydur surface has a negligible influence on the structural behaviour of the deck.

In conclusion, the experimental investigation confirmed the applicability of the FEM analysis. The results were in good agreement with the calculated values and the structural resistance of the deck was well within the requirements (**Figure 2701.02.03**).



Comparison of Deflections Obtained from the FEM-Analysis and Full-Scale Tests (Load Position According to 2701.02.02) 2701.02.03

2701.03 Economic Aspects

In many cases the aluminium bridge deck can be a very competitive technical and economic alternative to the conventional concrete bridge deck. Even though the cost for the aluminium deck is approximately the same as for a corresponding concrete deck, the aluminium deck has a number of advantages:

- Time for detail design is kept to a minimum.
- Very short time for construction works, which greatly reduces the total investment costs in many cases. For example, the replacement of a concrete bridge deck by an aluminium deck was achieved in just three days in order to disturb the traffic as little as possible. Beyond, costs for a temporary bypass road could be avoided.
- In many cases the reduction of the dead load can make it possible to use the existing bridge foundations and main girders. This is maybe the greatest advantage and should be studied carefully for each particular case.
- After completion, the costs for maintenance are also kept at a minimum because the Acrydur paving is almost impossible to wear down and, in addition, by a careful choice of a suitable aluminium alloy, the corrosion resistance will also be very good.

2701.04 Case Study

The new aluminium bridge deck system has been used in about 20 bridges in Sweden, with a recent case being the Tottnaes Bridge south of Stockholm.

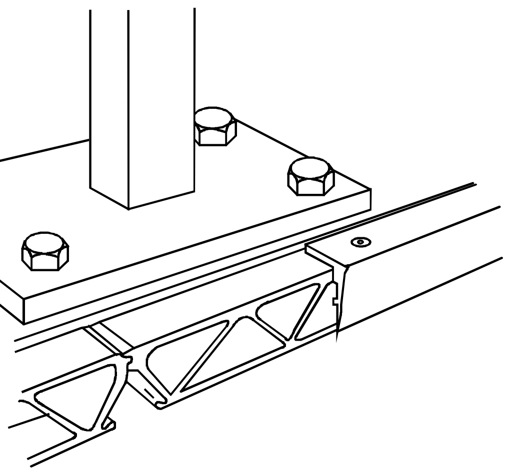
The Tottnaes Bridge, a four-span steel girder bridge with one span designed as a swingspan, was in immediate need of repair, primarily resulting from the deterioration of the concrete bridge deck. A study of the foundations (wood piles) showed that it would not be possible to increase the allowable live load without reinforcement, which was required if the bridge was to carry modern heavy vehicles.

The only possibility available to keep the old bridge foundations and, at the same time, increase the allowable live load was to reduce the dead load of the bridge. This was accomplished by the use of the new aluminium bridge deck system. Compared with the old concrete deck a reduction in the dead load of about 550 kg/m^2 was obtained, which was enough to maintain the existing bridge foundations without reinforcement.

Because the Tottnaes Bridge is the only connecting link between the mainland and the island of Toroe, a short time for the restoration of the bridge was of great importance. Using the aluminium bridge deck elements with the Acrydur surface applied to the aluminium extrusions, and by preparing the support details and connections in advance, it was possible to reduce the repair time to a minimum.

All other details such as railing and connections between the railing and the bridge deck as well as edge beams (**Figure 2701.04.01**) are readily available products well tested and approved by the Swedish National Road Authority.

Detail of Railing and Edge Beam of an Aluminium Bridge Deck System



TALAT Training in Aluminium Application Technologies	Detail of Railing and Edge Beam of an Aluminium Bridge Deck System	2701.04.01

2701.05 References

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2701.06 List of Figures