Load capacity assessment and strengthening of a railway arch bridge with backfill

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Summary

In this paper, a load capacity assessment and strengthening measures of a multi-span railway arch bridge with backfill are presented. The bridge is located in Stockholm, Sweden, and constitutes a vital link for the national railway network. The bridge consists of 20 concrete arches with overlying backfill, each with a span of 20 m. After more than 80 years of service, severe deterioration of the concrete was found during conditional assessments. A load capacity assessment was performed and the theoretical ultimate load was found to be highly dependent on the development of soil pressures along the arch barrel. The demands from the railway authority are to increase the allowable axle load from 22,5 to 25 tonnes and extend the service life by 50 years. Due to the uncertainties in structural behaviour and progressing degradation, extensive strengthening measures for the arch barrels were decided. To allow for full traffic at all times, the strengthening was performed in stages, to minimize any temporary reduction in load capacity due to removal of existing material. The strengthening was designed using non-linear finite element analysis and each stage of strengthening has been verified using in-situ field measurements.

Keywords: concrete arch bridge; backfill; finite element analysis; soil-structure interaction.

1. Case study bridge

An elevation of the case study bridge is shown in *Fig. 1*. The bridge consists of 20 concrete arches, each with a span of 20 m. In addition, the bridge consists of a vertical lift span and a 150 m steel truss arch. The total length is 753 m and was at its completion in the 1920's the longest bridge in Sweden.

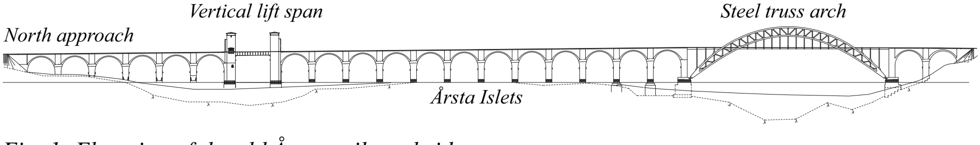

Fig. 1: Elevation of the old Årsta railway bridge.

Conditional assessments revealed severe deterioration of the concrete arch barrels. Material testing of the compressive strength showed great scatter in the results and several cores recorded zero strength. An extensive load capacity assessment was initiated and field measurements were performed to be used for model calibration.

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2. Finite element analysis

The field measurements of induced strain in the arch barrel during train passage showed pronounced 3D-behaviour. This is mainly due to the influence of the large spandrel walls, which are supported by the arch barrels without any intentional composite action. A three-span 3D-model of the bridge was developed, partly illustrated in *Fig. 2*. Good agreement with the field measurements was found when using a Young's modulus of 37 GPa for the concrete and 100 MPa for the backfill, all assumed linear elastic. The backfill and the spandrel walls are connected to the arch extrados by an elastic surface coating, allowing for partial separation. The ultimate limit load capacity was estimated using nonlinear material models for both the concrete and the backfill. A reference model with reduced material strength, loss of reinforcement and a conservative approach for soil-structure interaction showed the need for strengthening to meet the requirements of the bridge owner.

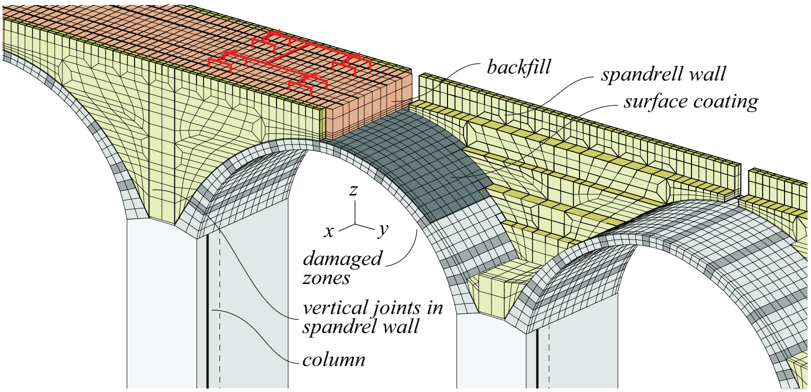

Fig. 2: View of the 3D FE-model.

A procedure for strengthening of the arch barrels was developed, allowing for full traffic load during all stages. The method consisted of removing part of the existing concrete by water blasting and casting of new reinforced concrete, illustrated in *Fig. 3*. To increase the transverse capacity, tendons were post-tensioned across the bridge, anchored by longitudinal concrete arch ribs. Additional reinforced concrete was cast on the arch intrados. FE-analysis were carried out for each stage of strengthening. The final design was found to meet the requirements of the bridge owner and is currently being carried out. The full strengthening is planned to be finalized in early 2013.

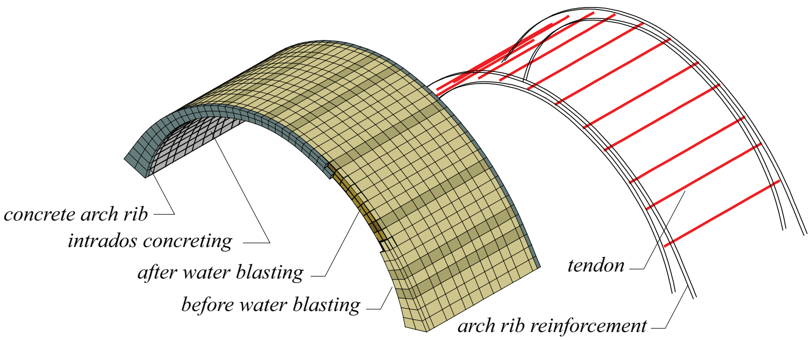

Fig. 3: View of the 3D FE-model for modelling of strengthening stages.