Engineering challenges from assessment of Schalkwijksebrug

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Summary

Structural assessments of eight steel arch bridges, originally built between 1934 and 1976, are performed in a large Design & Construct project which involves the refurbishment of eight bridges for road traffic over the Amsterdam-Rijnkanaal. The aim of the project is to obtain a technical life time extension of at least 30 years for the bridges with minimal obstruction of road and naval traffic during execution of the works.
Usually existing old bridges will not meet all requirements for new design when the design codes for new structures are applied without any adjustments.
This paper describes engineering principles and advanced calculation methods successfully applied for the assessments of the Schalkwijksebrug. These principles and methods differ from those usually applied in designing new bridge structures and may be applied for assessment of other existing bridges in order to prevent unnecessary rejection and obtain life time extension of the structure.

Keywords: steel bridges, arch bridges, existing bridges, assessment, engineering, renovation, refurbishment, life time.

1. Introduction

The Design & Construct project KARGO involves the refurbishment of eight steel arch bridges for road traffic built between 1934 and 1976 over or near the Amsterdam-Rijnkanaal in the Netherlands. The main requirement of the project is to obtain the most economical solution for a remaining technical life time of at least 30 years for the bridges while obstruction of road and naval traffic should be minimized during execution of the works. The Engineering Department of the Municipality of Rotterdam is currently working as the contractor's engineer and is responsible for the assessments of the existing bridge structures.
This paper describes engineering principles and some of the advanced calculation methods successfully applied for the Schalkwijksebrug, a steel arch bridge with concrete deck slabs.

2. Engineering principles from assessment of the Schalkwijksebrug

For the design of new (bridge) structures many codes and design rules are available in order to prove the required safety level of the technical design. For existing (bridge) structures however, no design rules are available yet. Usually existing old bridges will not meet all requirements for new design when the design codes for new structures are applied without any adjustments.

For the structural assessment of the Schalkwijksebrug, a stiffened steel arch bridge for road traffic originally built in 1972, the following specific engineering principles and advanced calculation methods are used in order to prevent unnecessary rejection and obtain a 30 years life time extension.

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Basically loads derived from Eurocode EN1991 were to be used for the re-calculations of the existing bridge but the following load reductions are taken into account:

1. Determined weight of light-weight concrete deck slabs;
2. Reduced reference period of 30 years;
3. Reduction factor α based on the actual measured number of heavy vehicles N_{obs};
4. Trend reduction factor for traffic loads;
5. Traffic loads on actual traffic lanes only for global analysis;
6. Reduced partial load factors and load combinations based on a reduced acceptable reliability level for existing bridges;
7. Distribution of self weight due to favourable mounting and erection methods.

The fatigue life assessments performed are based on requirements for fatigue for the design of new structures and load model FLM4 from Eurocode 1. However, the number of relevant heavy vehicles (N_{obs} = 75.000 vehicles per year) taken into account is based on traffic counts and the more favourable traffic type "Medium distance" is applied because the road on the Schalkwijksebrug is classified as a regional road.

A detailed ANSYS shell model is used to account for an accurate modelling of the local bending stiffness around the governing connections between cross girders and main girders. An elastic-plastic analysis was performed to prove that these sections have sufficient strength without modifications of the structure.

The existing concrete deck slabs are connected to the cross girders' top flanges by means of dowels in order to create a composite steel-concrete girder in transverse direction. Longitudinal tensile forces in the concrete deck slabs occur due to shear-lag. In order to reduce these unintentional effects a system of external post-tensioning is installed which results in a reduction of the resulting longitudinal tensile force in the steel main girder and concrete deck slabs so that transverse shear capacity is sufficient and rejection of the concrete deck slabs is no longer necessary.

The following advanced approach is used to prove that arch instability is not a problem and that the arches of the Schalkwijksebrug meet the requirements for buckling stability:

1. Based on the governing first order linear load combinations, the governing sideward buckling shapes of the arches are determined;
2. Based on the in situ measured transverse misalignments of the arches a design value of 58 mm is determined as the maximal initial deformation to account with;
3. A second order calculation is performed based on the governing load combinations, governing buckling shapes and the design value of the initial deformation;
4. A cross-section analysis based on the calculated second order forces is performed on the members of the arches.

To facilitate the extra weight of a fully wrapped scaffolding structure on the bridge two temporary support frames with cable stays were being installed during execution of the renovation works. In order to meet the requirements for buckling stability of the arch , temporary diagonal end bracings were applied supporting the arch ends.

3. Discussion and Conclusions

In order to prevent replacement of complete bridge structures due to assessment failure, advanced engineering principles and calculation methods may be applied. These principles and methods differ from those usually applied in designing new bridge structures.
From the assessment performed for the Schalkwijksebrug it can be concluded that when more effort is taken in analysing and assessing the structure more theoretical capacity can be mobilised so that unnecessary strengthening is prevented.
The engineering principles and the advanced calculation methods described in this paper are successfully applied for the Schalkwijksebrug and may be applied for assessment of other existing bridge structures in order to prevent rejection and obtain a life time extension of the structure.