# Sensitivity Study for Computational Assessment of Prestressed Concrete Bridges

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## Summary

A current challenge for civil engineers is the conservation of existing infrastructures which includes maintenance, assessment and, if necessary, strengthening according to new code requirements. For the evaluation of the actual load carrying capacity and the remaining service life, detailed knowledge of the material properties and a realistic structural model is required. If necessary, the latter has to be adjusted for existing structures by in-situ measurements and inspections. In this paper, the structural behaviour of a concrete hollow box girder bridge is investigated by nonlinear analysis with a 3D finite element model. Based on these results a sensitivity study is performed by variation of material properties.

In a first step the redistribution of section forces in the transverse and longitudinal direction of the structural system due to nonlinear material behaviour is discussed. It will be shown in which way the force flow is influenced by nonlinear material behaviour in comparison to a linear elastic analysis. Second, the ultimate limit state (ULS) is discussed by means of a sensitivity analysis. Finally, the influence of the used material assumption and the statical system in nonlinear calculations to the load bearing capacity is discussed. This might help in the judgement whether the service life of a bridge can be reached or a strengthening is necessary.

**Keywords:** concrete structures; nonlinear analysis; finite element; hollow box girder bridge

## 1. Introduction

The construction of prestressed concrete bridges started in the 1940s and reached its peak in the 1960s. By that time, the need for new bridges was very large and it was extensively taken advantage of the prestressing technology. Today, higher traffic loads and serious durability problems require regular inspections of the bridges. Since the planned service life of most of these bridges is not reached, it is often more economic to maintain and strengthen them, rather than replacing.

## 2. Computational Examination of Existing Bridges

### 2.1 Introduction

In 2009 a study was published in which it is shown that almost 90% of sequentially built bridges of the years 1958 to 1976 had cracks or damaged coupling joins and strengthening was necessary. 78 out of 118 bridges built until 1979 have a hollow box cross section, so that this study concentrates on that type of bridges . The question arises whether global or local strengthening of such bridges is really necessary or a corrosion protection might be sufficient. Exemplary Analysis on a Hollow Box Girder Bridge

### 2.2 Exemplary Analysis on a Hollow Box Girder Bridge

In this paper a two span bridge with a two-cell cross section is studied with a span of 60 m. The focus is on the distribution of shear forces at a distance of 1,0*H* from the support.

To perform an analysis of an existing structure the geometry and the used materials have to be known. The geometry of the bridge can be taken from construction plans or by an in-situ



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measurement. In this study the variation of the geometry is neglected. Defining the service life of the structure the knowledge of the used material and their actual properties is deciding. For the here performed analysis standard values for the concrete and reinforcement steel is used. Due to different in house testing the mean values (σ) and the coefficient of variations (μ) of these materials could be determined. In accordance to JCSS a normal distribution for concrete and a lognormal distribution for reinforcing steel are adopted.

# 3. 3D nonlinear FEM-Model

## 3.1 Finite Element Model

For the nonlinear calculations the FE-model is discretized by shell elements. In this paper only shear forces due to movable loads (axle, main and adjacent track loads) are considered. Therefore, only the live loads will be increased to determine the ultimate load.

## 3.2 Nonlinear Calculations of Load Bearing Capacity

This traffic load is increased incrementally until the maximum load bearing capacity with the factor $f_P$ is reached. For this calculation mean values of the material properties are used. The load bearing capacity is limited by the biaxial concrete compression strength due to bending near to the intermediate support.

The shear forces near to the intermediate support are smaller taken into account nonlinear material behaviour than for the linear elastic approach and larger at the end supports. The differences between the linear and nonlinear simulation cannot be only explained by the redistribution of the forces in longitudinal direction because the reaction forces for both simulations are nearly equal. Therefore the redistribution of the shear forces is caused by nonlinearities within the cross section and the slabs close to the web. Due to cracking, parts of the slabs close to the web contribute to the shear transfer in longitudinal direction.

# 4. Sensitivity Study

In a computational assessment of existing bridges the knowledge of the used materials is necessary. On the basis of a statistical evaluation it is possible to define a mean value and a standard deviation for concrete and reinforcing steel. These values are used to perform a sample of simulations on the presented bridge to assess the load bearing capacities. The main outcome is that the variation of material properties has a minor influence to the shear forces in the ultimate limit state.

The evaluation of the maximum load factor $f_P$ show a mean value of the load bearing capacity of $f_{P,m}$ = 2,32 and a coefficient of variation of 6%.The latter indicates that the variation of material properties has a minor influence. The load bearing capacity depends mainly on the statical system of the considered bridge, respectively the statically indeterminate of the structure.

# 5. Discussion and Conclusions

In this paper was shown how shear forces were redistributed in the bridge when concrete cracking and local steel yielding occurred. In a second step a sensitivity analysis was done by means of varying the material parameters of concrete and reinforcing steel. The latter has a minor effect and shear forces are mainly influenced by the statical system of the bridge. Based on these first results from a sensitivity analysis a more detailed probabilistic approach will be done as next step, so that a remaining service life can be determined more exactly.

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