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Probabilistic FE Analysis of a Cable-Stayed Composite Bridge

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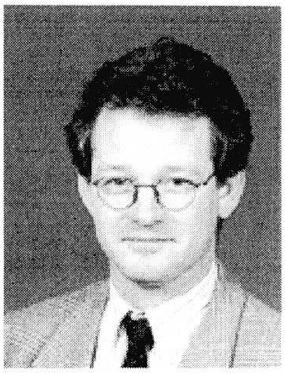

Abstract

1. Introduction

In 1998 a new cable stayed bridge was designed near the city of Kampen in the Netherlands. Figure 1 shows an artist impression of the cable stayed bridge to be built. The bridge has been designed by the civil engineering division of the Dutch Ministry of Transport, Public Works and Water Management. The cross-section of the main span has a composite character. The main span is built up out of a beam grid of steel. The concrete slab on top of the beam grid is initially used as compression zone in the total cross section of the bridge deck.

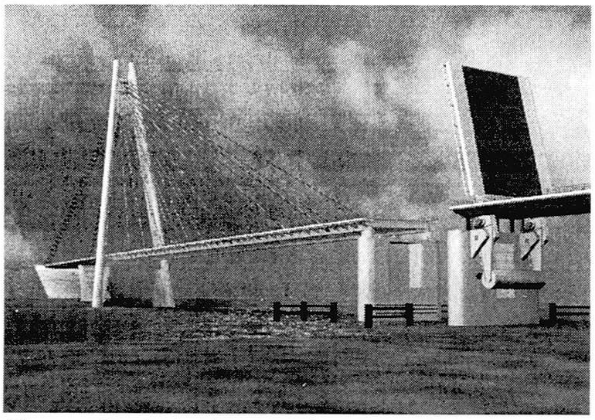

Figure 1: Artist impression

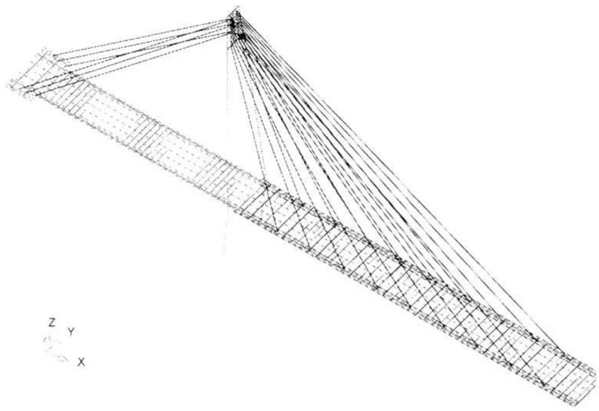

Figure 2: FE mesh of the 3-D model

In the design process, the safety of bridges is insured by means of partial safety factors for both strength and load parameters. As a result it is generally accepted that the structure as a whole matches the desired probability of failure. In the paper another method is followed. A full probabilistic analysis on the complete composite structure is performed using FE analysis.

2. Bridge Structure

Figure 2 shows the FE mesh of the bridge with a main span of 148.4 m, a side span of 92.5 m, while the height of the pylon reaches 70 m above the bridge deck. The net width of the bridge deck is 17 m, four traffic lanes of 3.25 m each and two maintenance lanes with a width of 2 m each. The bridge is supported at the both ends, the pylon and in the middle of the left side span. All supports are assumed to be springs, representing the soil's stiffness.

The cross-section of the main span has a composite character. The main span is build up with a beam grid of steel and is subdivided in sections with a length of 14.5 m. Each bridge deck section contains two main girders and four cross beam girders. On top of the beam grid lies a concrete slab with a thickness of 0.25 m. The cross beam girders on both sides of the connection between the stay cable and the bridge deck are heavier then the other two cross beam girders of the section. The connection between the concrete bridge deck and the beam grid is designed with a so-called stud connection (see Figure 3 for FE mesh) which is typical for steel concrete composite structures.

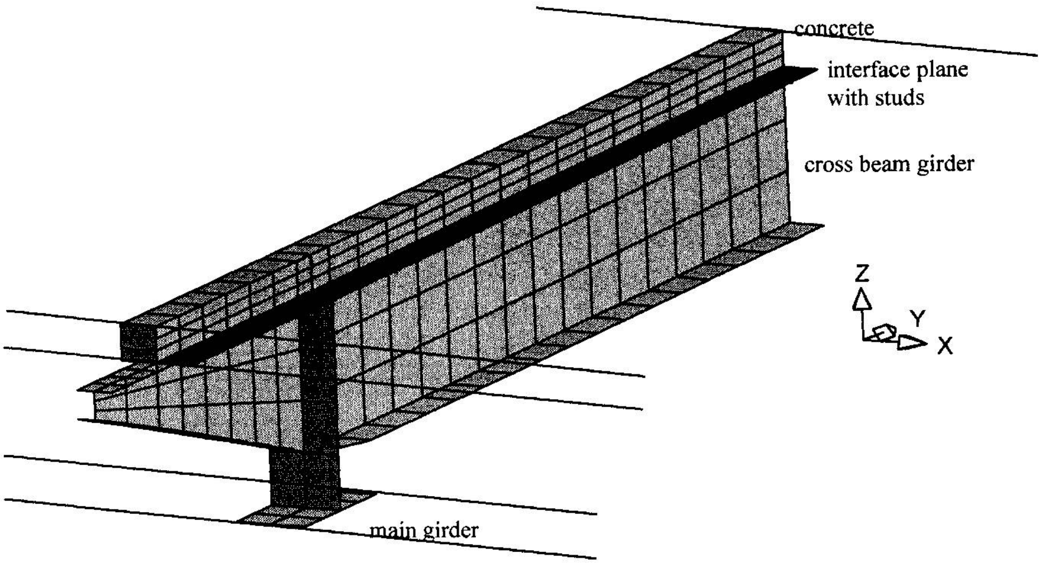

Figure 3 : FE mesh of half steel section main span

3. Results of the Stochastic Model

The thickness of the concrete deck, material properties of steel and concrete and the prestress force are random variables. The ultimate limit state is overstressing of either the cables or concrete-steel deck. The model has in total 58 independent stochastic variables. The probability of failure of the bridge structure is computed by means of the ACDS procedure. The 3-D model results in a reliability index $\beta = 5.05$ (intervals $4.8 < \beta < 5.4$), corresponding with a probability of failure $P_f = 4\ 10^{-7}$.

The paper shows the possibility to perform a probabilistic analysis in the design environment. The probabilistic FE analysis shows that there is an additional safety compared to the safety required by the building codes. It may be concluded that this bridge, designed by using partial safety factors, is much safer then required, at least for the limit states considered.