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# Zárate-Brazo Largo Bridges, Rehabilitation Design Basis

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## Summary

One stay cable of the Guazú bridge ruptured in November 1996 after 20 years of service without prior indication of the critical situation. Using information from tests and measurements at the bridge together with a definition of the safety requirements for various emergency and long term conditions a rehabilitation design basis was developed. This rehabilitation design basis provides a basis for the evaluation of the load carrying capacity and service life of the cables.

**Keywords**: Stay cable, Corrosion, Fatigue, Rehabilitation, Reliability, Probabilistic models, Inspections, Tests, Design basis

## 1. Introduction

One stay cable of the Guazú bridge - one out of two quasi identical, combined road and railway cable stayed bridges across the Paraná river between Zárate and Brazo Largo, Argentina - ruptured in November 1996 after 20 years of service without prior indication of the critical situation. Subsequent inspection revealed a substantial corrosion of the wires and that the fractures were fatigue-like. In Figure 1 the Guazú Bridge is shown.

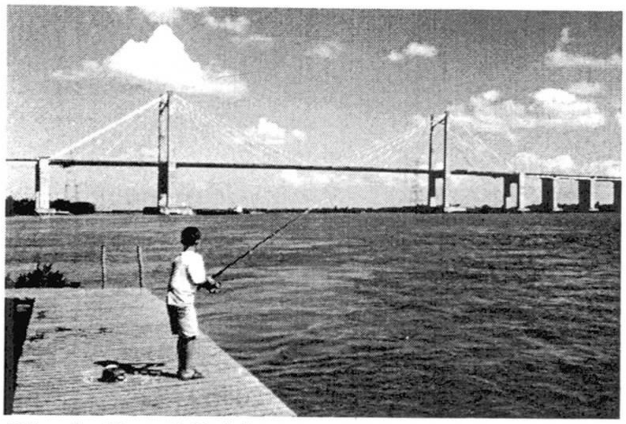

*Fig. 1: Guazú Bridge.*

COWI Consulting Engineers and Planners was entrusted the job of evaluating the residual load carrying capacity of the cable stayed bridges and planning of the emergency replacement of the heavily deteriorated stays.

The evaluation of the residual strength and the planning of the emergency replacement of these stays were performed using a rehabilitation design basis developed specifically for the Zárate-Brazo Largo bridges.

A bridge specific rehabilitation design basis is developed in order to ensure that the reliability of the bridges is acceptable while at the same time ensuring that the bridges are open for the largest possible amount of traffic. In other words, the bridge specific rehabilitation design basis is developed in order to minimise the consequences of the traffic restrictions while ensuring an acceptable level of safety to the user.

## 2. Development of the rehabilitation design basis

The rehabilitation design basis is developed within the framework of the Load and Resistance Factor Design method (the LRFD method). In the rehabilitation design basis characteristic values of loads and resistance factors are given together with partial safety factors which ensure an acceptable level of safety.

The characteristic traffic load is developed for different traffic situations, e.g. the traffic is restricted to a given number of lanes, the bridge is closed for trucks exceeding a certain weight or unrestricted traffic. The traffic load is specified as an Equivalent Uniformly Distributed Load and a set of axle loads. The traffic load is determined on the basis of a state-of-the-art probabilistic model developed by Madsen and Ditlevsen [2] for the Great Belt Bridge in Denmark. The model is based on information on the traffic intensity, the amount of trucks and the mean number of trucks in a platoon. This information can be obtained from observations at the Zárate-Brazo Largo Bridges.

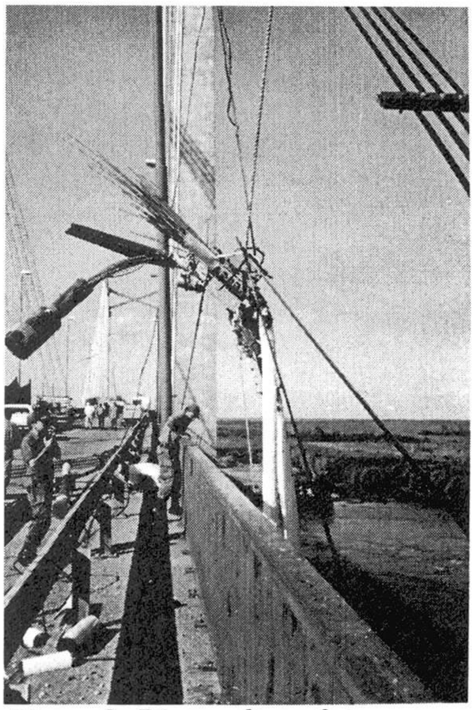

*Figure 2: Dismantling of stay.*

The characteristic values of the load carrying capacity of the stays are determined on the basis of tests of the ultimate strength of wires from the dismantled stays (see Figure 2) of the Zárate-Brazo Largo Bridges.

On the basis of an analysis of the reliability of the bridge in the ultimate limit state, the partial safety factors are calibrated using the methodology given in the EuroCode [1]. In the calibration of the partial safety factors the deterioration of the stays is taken into account such that the partial safety factors depend on the expected service life of the stays.

The deterioration of the stays is predicted using an advanced fatigue model for parallel wire cables suggested by Rackwitz and Faber [3]. The model parameters are determined using results of fatigue tests. These tests were performed on test specimens from the dismantled stays of the Zárate-Brazo Largo bridges. The effect of corrosion is taken into account by calibrating the model using test results valid for corroded wires. Further, the rate of deterioration is updated for the individual cables using information from ultrasonic tests performed on site.

Finally, it is possible to develop a design basis for individual cables as well as the entire bridge. By developing a design basis for individual cables it is possible to use very accurate models and very exact information implying that the partial safety factors generally are lower.

## 3. Conclusions

The development of a rehabilitation design basis using all available information from the Zárate-Brazo Largo bridges concerning the traffic conditions and the actual condition of the stays ensures that accurate predictions of the traffic load and the load carrying capacity of the structure can be made. This implies that cost-effective solutions regarding the traffic restrictions on the bridge and the replacement of the stays can be made for the benefit of both the owner and the users.

## 4. References


[1] EuroCode 1: Basis of design and actions on structures - Part 1: Basis of design.

[2] Madsen, H. O., Ditlevsen, O., Stochastic Traffic Load Modelling for the Eastern Bridge, A/S Storebæltsforbindelsen, Review Board 3, May 1990.

[3] Rackwitz, R., Faber, M. H., Reliability of Parallel Wire Cable under Fatigue, in: Proceedings of the ICASP6 Conference, Mexico, 1991, pp. 166-175.