Slip in Hanger Cable Anchorages of Dintelhaven Railway Bridge Rotterdam

H.H. (Bert) SNIJDER
Prof. of Steel Structures
Eindhoven Univ. of Tech.
Eindhoven, The Netherlands
h.h.snijder@tue.nl

B.H. (Bert) HESSELINK
Civil Engineer
Movares Nederland BV
Utrecht, The Netherlands
bert.hesselink@movares.nl

K. (Kors) NOORLANDER
(Retired) Civil Engineer
Gemeentewerken Rotterdam
Rotterdam, The Netherlands
korsjosk@xs4all.nl

J. (Jacques) BERENBAK
Prof. of Structural Design
Delft Univ. of Technology
Delft, The Netherlands
J.Berenbak@TUDelft.nl

J.S. (Jaap) SPOELSTRA
(Retired) Director
Grootint
Zwijndrecht, The Netherlands
spoelst9@xs4all.nl

Summary

The Dintelhaven Railway Bridge in Rotterdam, The Netherlands is a stiffened bowstring steel bridge spanning 170 m (Fig.1). Its hangers are formed by cables consisting of parallel strands attached to the arch and the main girder through ‘traditional’ anchorages. Shortly after erection of the bridge, a load test was performed before taking the bridge in operation. It turned out that quite a number of strands of the hanger cables slipped through their anchorages. The main cause turned out to be ‘sticking together’ of the outer wedge surface and the cone shaped hole surface in the anchor plate. This yields a high coefficient of friction between wedges and cone shaped hole surface. Increasing the cable force does not cause the wedges to enter the cone shaped hole any further (as intended), but causes the strands to slip through the wedges. The paper describes these phenomena in detail and gives a practical solution to overcome the problem of slip in cable anchorages.

Keywords: slip; anchorage; strands; wedges; friction, hanger cable; bowstring; steel; bridge.

1. Introduction

The hanger cables of Dintelhaven Railway Bridge in Rotterdam consist of parallel strands attached to the arch and the main girder through anchorages with wedges.

2. Slipping of strands

The time period between assembly of the hanger cables resulting in low cable forces and the substantially stressing of the hanger cables by applying the ballasted track was several months. During train load testing, loud bangs and creaking sounds were heard. When removing the measuring equipment, it turned out that several strands of the hanger cables had been ‘launched’ against the protection caps of the cable anchorages, even perforating some of these caps (Fig.2).

Fig. 1: Dintelhaven Railway Bridge
(Photo: Frank van Dam, Utrecht)

Fig. 2: Damaged anchorage protection cap

https://doi.org/10.2749/222137908796291921

3. Structural design

Each cable consists of parallel strands, individually anchored using three wedges in cone shaped holes in an anchor plate. At the outside, the wedges are cone shaped at an angle of $\alpha = 5^o$. At the inside, the wedges are cylindrical with teeth on their surfaces. When the wedges slide into the cone shaped hole, the teeth bite in the strand thus holding the strands in position.

4. Main cause of slip

The equilibrium of forces around the wedges (Fig. 3) turned out to be the key to find the main cause of slipping of the strands. It can be shown that slip occurs if:

$$\mu_c > \frac{\mu_s - \tan\alpha}{1 + \mu_s \tan\alpha} \qquad (1)$$

Where μ_c is the coefficient of friction on the cone shaped surface of the anchor plate and μ_s is the coefficient of friction on the strand surface. This is illustrated in Fig.4. For the relatively small

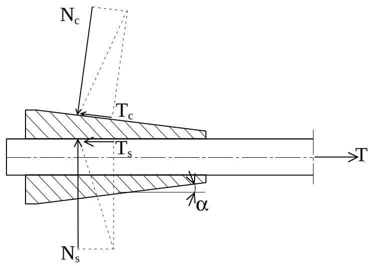

Fig. 3: Force equilibrium at wedges

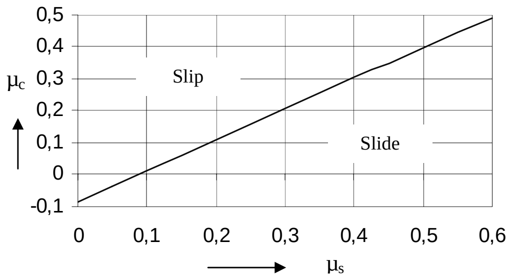

Fig. 4: Slip or slide depends on coefficients of friction

coefficient of friction on the strand surface with $\mu_s = 0.1$ and $\alpha = 5^o$ slip already occurs if (Eqn.(1)) $\mu_c > 0.01$. In case the coefficient of friction on the strand surface is relatively small, almost any friction on the cone shaped surface is enough to make the strands slip. Due to the assembly method of the bridge, the coefficient of friction on the strand surface was relatively small.

5. Solution

Sufficient bite of the wedges on the strands could be achieved by pushing-in the wedges into the cone shaped hole. Pushing-in the wedges was tested in the laboratory of TNO determining the right procedure and showing that there is no detrimental fatigue effect of this procedure.

6. Conclusions

The cable strands slipped through the wedges because insufficient bite on the strands was generated at cable assembly resulting in a small coefficient of friction on the strand surface. Even at low cable forces, the outer wedge surface 'sticks together' with the cone shaped hole surface causing the coefficient of friction to increase to such an extent that the wedges do not slide into the cone shaped hole but in stead the strand slips through the wedges. A small coefficient of friction on the strand surface contributes to this effect. Generating bite of the wedges on the strands should preferably occur at assembly of the cables by either applying a high cable force or by pushing-in the wedges.

Acknowledgement

The authors wish to thank Projectorganisatie Betuweroute of Prorail (www.prorail.nl) for their permission to publish this paper and they want to express their gratitude to all parties involved in solving the problem of slip of cable strands at Dintelhaven Railway Bridge.

References