



Numerical and experimental study on the interaction cable structure during the failure of a stay in a cable stayed bridge

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ABSTRACT

Corrosion, abrasion and fretting fatigue may cause deterioration and, eventually, the failure of a post-tensioning tendon or a stay cable on a cable supported structure. In the present study, the stress acting during the rupture on the remaining portion of the stay which fails is derived, and the role of the rupture time on the response of the structure is discussed from a theoretical and a numerical point of view. In addition, the load–time curve during the rupture and the total time of the rupture of undamaged and damaged wires of seven-wire steel strands are investigated in an experimental program defined on the basis of the previous theoretical results. In the locally damaged specimens, a notch is machined into their outer wires. The specimens are tested under tension at three different strain rates in order to determine the influence of this parameter on the rupture time and on the load–time curve. The damaged specimens also allow us to determine the influence of a local reduction of the cross section on the stiffness and ultimate load of the specimen.

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1. Introduction

Multi-wire steel strands are used as tensioning components of prestressed concrete structures as well as in cable supported bridges and roofs. Such strands are grouped in tendons and protected against processes of corrosion, abrasion, fatigue or a combination of them as it is the fretting fatigue phenomenon. On structures with an exterior post-tensioning system and on cable supported bridges, see [1–5], tendons are specially exposed to these processes. The damage on a tendon of such structures may become severe causing its partial rupture [6–8], or the total failure of the stay as it happened in 1996 on Zárate-Brazo Largo Bridges due to a combination of corrosion and fatigue [9]. The failure of a stay may also be caused by a road accident or fire. Thus, some codes and recommendations [10,11], suggest studying the accidental limit state of the failure of a stay.

The rupture of a tendon or a stay causes a dynamic load whose magnitude varies during the rupture time from the load acting on the anchorages of the stay before its rupture to zero. The present recommendations on cable stayed bridges [10,11], propose a simplified procedure for obtaining the maximum dynamic response to the aforementioned dynamic load which consists on

using a dynamic amplification factor in a static analysis. Recent studies, such as [12–18] focused on conventional cable stayed bridges, and [19] for the case of the unconventional ones, have demonstrated that using a dynamic amplification factor equal to 2.0 for evaluating the response of a cable stayed bridge to the sudden loss of a stay, as suggested in [10,11], becomes unsafe in some cases and, consequently, a dynamic analysis is recommended instead the simplified static analysis. In addition, the accidental limit state of failure of a stay became the controlling requirement in the design of some of the recently erected cable stayed bridges which resulted in a higher construction cost of the bridge [16].

Since the response of a single degree of freedom system to a step load with finite rise depends on the shape of the load–time curve and on the rise time [20,21], the rupture time is one of the parameters which must be adequately considered in the dynamic analysis in order to obtain an accurate response of the structure. On the other hand, the comprehensive literature, recommendations and codes focus on how to test and determine the strength and final fatigue resistance of the tendon or stay [10,11,22–24], but they do not establish the rupture time or the procedure for obtaining it.

This paper deals with the interaction stay bridge during the rupture of the stay and with the rupture time of the wires of a steel strand. The first objective is to study the force and stress acting on the stay during its rupture in order to define an experimental program which reproduces the stress conditions acting on the stay during its rupture in a cable stayed bridge. The second objective

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