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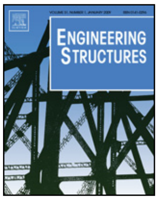

Numerical procedure for the analysis of damaged polyester ropes

Juan Felipe Beltrán[a], Eric B. Williamson[b,*]

[a] *Department of Civil Engineering, University of Chile, Blanco Encalada 2002, Santiago, Chile*

[b] *Department of Civil Engineering, The University of Texas at Austin, Austin, TX 78712, USA*

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ABSTRACT

In this paper, a numerical model capable of representing the impact of damage on the overall response of jacketed polyester (PET) ropes is presented. This model considers rope behavior under axisymmetric loading conditions and can account for the degradation of rope properties, including the effect of broken rope components, on overall rope response. To consider the confinement effect of rope jacketing on interior rope components, the rope jacket is assumed to behave like a thin-walled tube. If a rope has broken rope components, the rope analysis is linearized by discretizing the rope into a series of two-noded axial-torsional elements. The formulation of these elements accounts for material and geometric nonlinearities. Results of numerical simulations are provided to show how changes in the L/d ratio (rope length/rope diameter) and the initial state of rope damage influence the capacity, failure strain and stiffness of a damaged PET rope. Experimental data are used to validate the proposed model.

1. Introduction

Ropes are characterized by having a high axial strength and stiffness in relation to their weight, combined with a low flexural stiffness. This combination is achieved by using a large number of components, each of which is continuous throughout a rope's length. When loaded axially, each component provides tensile strength and stiffness, but when deformed in bending, the components have a low combined bending stiffness (provided their bending deformation is uncoupled from the axial response). To facilitate handling, it is necessary to ensure that a rope has some integrity as a structure, rather than being merely a set of parallel components. This characteristic is achieved by twisting the components together [1].

A rope can be a critical load carrying member in many engineering applications, including cranes, lifts, mine hoisting, bridges, cableways, electrical conductors, offshore mooring systems, and so on [1–3]. Different classes of ropes, suited for different purposes, have a different number and arrangement of rope components within a rope cross-section, and rope components can be made from a variety of different materials. Although a rope is intended primarily to carry a tensile load, the construction of a rope is such that individual rope components are subjected to bending and torsional moments, frictional and bearing loads, as well as tension. The magnitude and distribution of the stresses resulting from these loading effects determine the overall rope response, which can be expressed in terms of the rope extension and rotation [2].

For many years, steel wire ropes have been used extensively for load bearing members mainly due to the strength offered by steel, coupled with the flexibility of rope construction, rope geometry, and wire size that can be suited to a particular application. Over the last few decades, however, the rope industry has been capable of producing fiber ropes with very high tenacity. Considering the many advancements made in fiber rope construction, synthetic-fiber ropes can potentially replace steel wire ropes for certain applications. The major difference between synthetic-fiber rope and steel wire rope components is their strength-to-weight ratio. Synthetic-fiber ropes can be up to 10 times lighter than a steel wire rope for a given member strength, reducing the weight (load) of the system and installation costs [3]. Cases where synthetic-fiber ropes have replaced steel wire ropes are numerous and include the use of ropes for lifting equipment and materials at construction sites, deep water mooring systems, anti-collision and protective nets, heavy-lift helicopters used in military and commercial operations, and ship assist lines [3].

Each field of rope application has developed a specific body of knowledge, based on extensive testing and field experience, leading to empirical rules for each particular application. Unifying these empirical rules under some general mathematical and mechanics-based theory would allow a better understanding, and in the long term, a better prediction of the mechanical behavior of ropes than current methods allow. In addition, a unified modeling approach can help reduce the need for expensive tests under a variety of operating conditions. Thus, due to their extensive use

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* Corresponding author.
E-mail address: ewilliamson@mail.utexas.edu (E.B. Williamson).

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