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Behavior of wires in parallel wire stayed cable under general corrosion effects

Jun Xu *, Weizhen Chen

Department of Bridge Engineering, Tongji University, Shanghai 200092, PR China

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ABSTRACT

Many cable-stayed bridges around the world have their stayed cables replaced due to corrosion problem. The problem has in fact led to a worldwide concern about corrosion damage evolution in stayed cables. To have a deep understanding of the corrosion effects, an investigation regarding mechanical properties of wires at different corrosion extents and corrosion distributions at cable cross sections was conducted on the stayed cables replaced from Shimen Bridge in Chongqing, China. The result of the investigation was a contribution to the establishment of a model for mechanical behaviors of corroded wires and a support to the presumption of the corrosion distribution at cable cross sections. A numerical cable based on a parallel–series system was modeled to observe the mechanical behaviors of corroded cable in terms of given service load, cable length, and corrosion rate. It is noted in the paper that strain hardening begins from the worst corroded wire, and the residual deformation of the wire is leveled off after a period of rapid growth, which indicates a significant decrease of distributed loads of the wire.

1. Introduction

Cables, as one of the ideal high-strength components, are widely used for suspension bridges, cable-stayed bridges and tied arch bridges. These bridges, however, cannot overcome the major limitation that their cables are prone to corrosion and their service life is much shorter while the maintenance cost is much higher than other members of the bridges. To overcome the limitation, bridge engineers employ various anti-rust treatments such as cement grout, galvanizing, grease, high-density polyethylene (HDPE) pipe, polyvinyl fluoride tape, or their combination. But none of them provide lasting protection and many in-service stayed cables are quickly corroded. The first stayed cable damage was reported in Maracaibo Bridge in Venezuela around 1974 [1]. The Köhlbrand Bridge in Germany was built from 1969 to 1974 [1]. During an inspection conducted in 1976, however, 25 wires were observed to be severely corroded and broken. In 1995, one stayed cable in Haiying Bridge in China ruptured from the upper part [2]. A year later, one stayed cable in Guazú Bridge in Argentina ruptured [3]. It is documented that during the past 20 years at least 10 cable-stayed bridges in the mainland China have had their cables replaced [4]. The abovementioned facts highlight the importance of an in-depth research on corrosion damage evolution of stayed cables.

2. Mechanical properties of corroded wires

The earliest research on corroded wires was first reported by Hopwood and Havens, who developed a grading method to differentiate galvanized wires into 4 corrosion stages according to visual inspection [5]. But investigation shows that resistance reduction does not occur until wires come into Stage 3 or 4, which means this method is not effective for accurate assessment of wire strength. Apart from the grading method, tensile test is another assessment choice. During a 1988 inspection, Matteo et al. carried out tensile tests on corroded wires pulled from suspension cables of the Williamsburg Bridge [6]. Barton et al. [7] and Nakamura and Suzumura [8] also performed tensile tests on corroded wires produced via accelerated corrosion approach. But all these researches do not provide mathematical expressions or curves to describe the effect of corrosion extent on the mechanical properties of wires.

In order to find out an effective assessment approach of corroded stayed cables, tensile tests were conducted on wire specimens pulled from the replaced cables in Shimen Bridge. Shimen Bridge is located in the southwest of China. It is a cable-stayed bridge with concrete girder. Its cables suffered from general corrosion and wires were found to be broken in the worst corroded cables. The testing procedures are given as follows:

1. The corrosion product on wire specimens was removed by a cloth containing 10% H_2SO_4 solution. The appearances of the wires before and after removal of the corrosion product are shown in Fig. 1.
2. As non-destructive methods for measurement of irregular cross sections were not available, d_{min} which is defined as the minimum diameter of wire was measured using digital caliper with the precision of 0.01 mm. Given the irregular cross sections, the least value of the five measurements of the minimum diameter on each specimen was recorded as d_{min}.

* Corresponding author. Tel.: +86 13816856463.
E-mail addresses: jxuun@tongji.edu.cn (J. Xu), tongji_bridge611@126.com (W. Chen).

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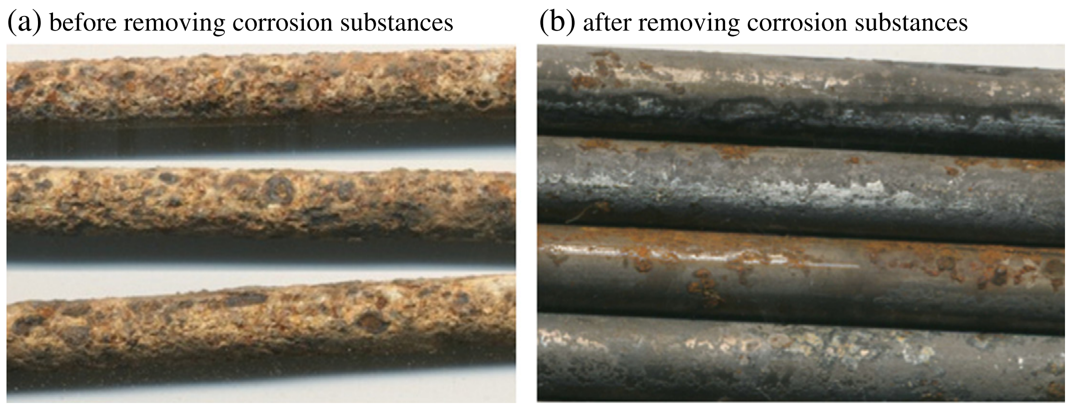

Fig. 1. Specimen of corroded wires before and after removing corrosion substances.

3. The wires were cut into specimens each at a length of 250 mm and with the worst corroded section in the middle of the specimen.
4. After conducting tensile test on the wires, elongation of the 50 mm portion of a specimen with the worst corroded section in it was measured with an extensometer.

In the tensile test, F_y, u_y, F_u, and u_u — yield force, yield strain, ultimate force, and ultimate strain — were recorded respectively. As plotted in Fig. 2, these mechanical parameters change with d_{min}. According to the fitting curves in Fig. 2, the bearing capacity and elongation of the wires decreased with corrosion extent. But the change in yield strain is not as obvious as that of the other three parameters. It should be noted that as the d_{min} of the corroded wires tested are all larger than 3.27 mm, the validity of the fitting curves in the zone where d_{min} is less than 3.27 mm needs to be further verified.

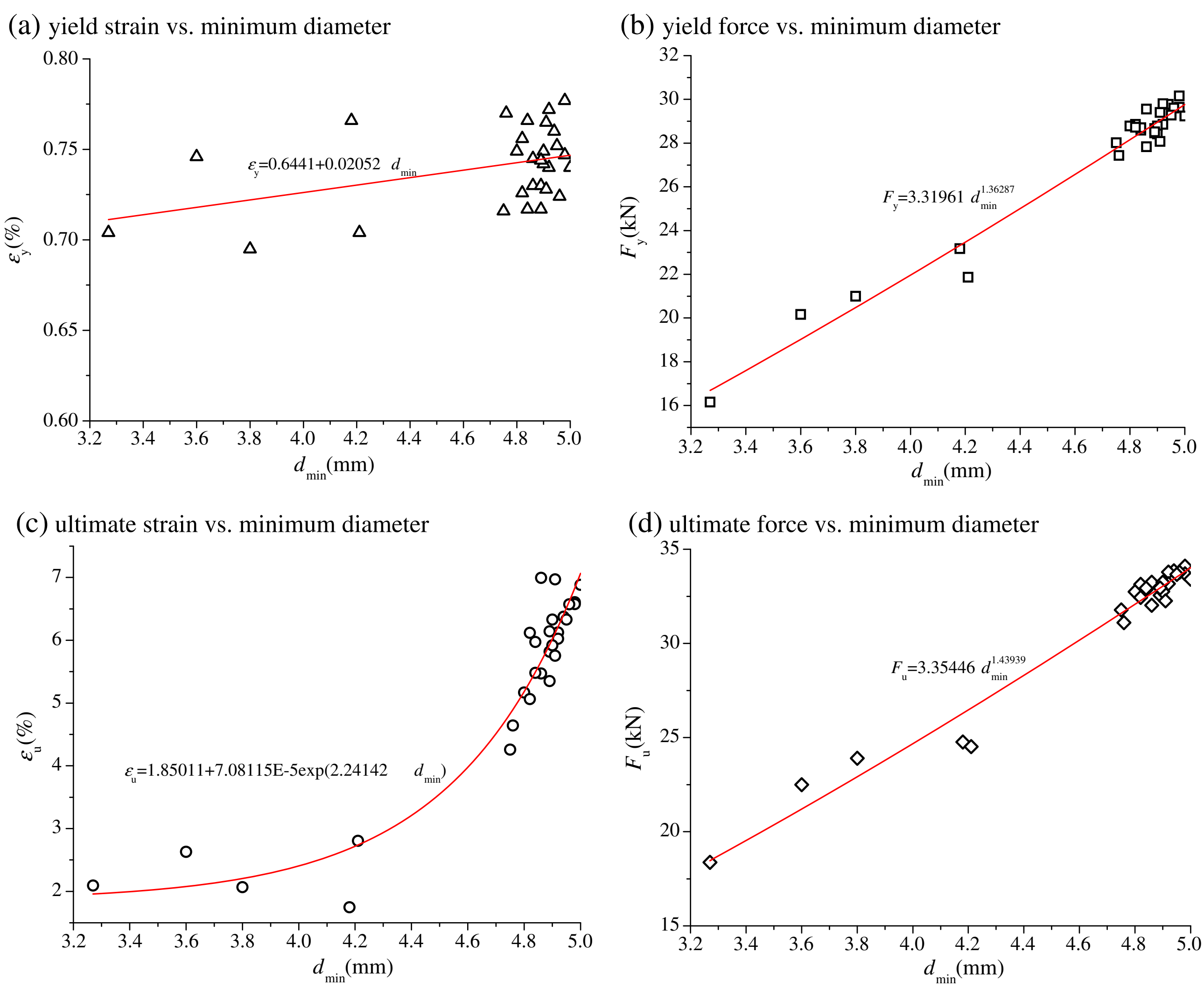

Fig. 2. Mechanical parameters of corroded wires.