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An Innovative Tensile Test for Short GFRP Bar Samples

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Abstract

A significant bar length is specified in Standard test methods for the evaluation of the uniaxial tensile strength of glass fiber reinforced polymer (GFRP) rebar; 1000 to 3000 mm for the range of 6 to 32 mm diameter (ASTM D7205). Yet, such sample lengths are not always available. For example, in the case of assessment of existing structures, where cored/sawn samples are usually of limited diameter/length.

This paper presents an innovative test method for the measurement of the uniaxial tensile strength of short GFRP bar samples, which has been initially developed for 16 mm diameter bars of 254 mm length. Coupons of approx. 11 x 254 x 2.5 mm (width x length x thickness) are extracted from the bar samples via precision sawing, and tested under direct tension after attaching tabs of 57 mm length to the ends. Tests on full-size bars from the same kind as the coupons permitted the calculation of a correlation factor between both tensile strength measurements.

Keywords: GFRP test methods, GFRP bar tensile strength, GFRP bar sampling, GFRP reinforcement assessment

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Introduction

There are many situations in which material properties need to be measured from samples which cannot or have not been procured or extracted for the specific purpose. One typical case is the length of glass fiber reinforced polymer (GFRP) bars obtained from coring or sawing existing structures. Usually, analysis of such samples is limited to non-mechanical tests, since mechanical testing involves samples of significant size. Such is the case for assessing the tensile properties of GFRP bar, where the sample length is a function of the bar diameter and varies from approx. 1000 to 3000 mm for bar diameters of 6 to 32 mm. Such lengths are clearly impractical when it comes assessing existing structures.

Experimental program

The experimental program aimed at obtaining a correlation between the uniaxial tensile strength of a rebar (acc. to ASTM D 7205), and that of coupons extracted via precision sawing from the same rebar. As the cross section of the coupon is significantly smaller than that of the rebar, the length required for the tensile test, decreases significantly; the thin and rectangular cross sections of the coupons allow shorter and more efficient anchoring and gripping of the specimens to the testing machine.
Firstly, the program included the design and development of the coupons itself, from its extraction to the fixation on the testing system. On the other hand, uniaxial tensile tests were carried out on new full-size bars, and on coupons from the same lot of rebars. This allowed the calculation of a bar-to-coupon correlation factor. Later, as part of a specific structural assessment program [1], tests were performed on coupons from bar samples extracted from an in-service bridge deck, and results compared to uniaxial tensile tests at the time of install of vintage full-scale bars used in the bridge 17 years before.

The test

Utilizing a CNC diamond blade wet-saw, thin cross-sections were cut from rebars of standard 16mm diameter. Each length of rebar section yielded three rectangular coupons of cross-section of about 11mm x 2.5mm and 254 mm in length. A schematic of coupon extracted from rebar and end of rebar from which coupons were extracted is shown in Figure 1.a and b, respectively. All coupons were cut close to the same size as possible, both ends of the coupons were tabbed with 57mm composite tabs using epoxy adhesive. Tabbing allows even load transfer from the testing machine to the coupons while also protecting the rebars from being crushed due to the grip pressure applied during testing. Typical tabbed coupon and set-up of coupon tensile testing shown in Figure 1.c and d, respectively. A 6-mm strain gage (type FLA-6-11-5LJC) was attached to the center of the gage section of the coupon to measure longitudinal strain and the coupon placed in the testing machine with pre-load of 1.5 kip. An extensometer (EXT 2.01- 0200-025-ST) was also attached to the coupon to get secondary strain measurement. Force, longitudinal strain, and longitudinal displacement were recorded during the test (load rate 1.27mm/min, data acquisition rate 9/s).

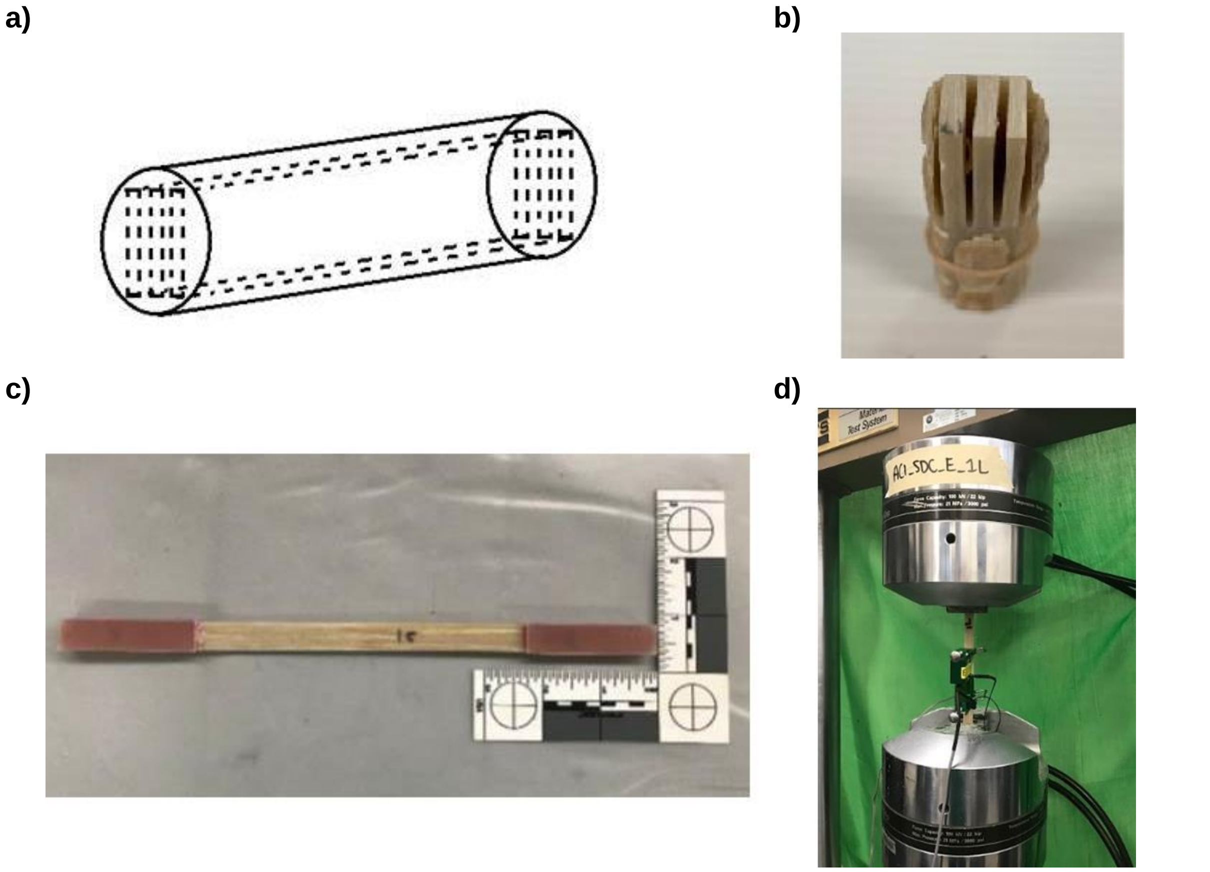

Figure 1: Coupons extracted from rebar – (a) Schematic of tensile coupon extraction from rebar (b) Remnant of rebar after coupon extraction, (c) Tabbed tensile coupon (d) Tensile testing set-up with extensometer on the coupon for strain measurement

Results and analysis

Figure 2 shows the stress strain curve for four coupons extracted from rebars, one from pristine rebar and three from the 17-year-old existing bridge deck. It can be observed that all curves behave linearly, as for typical GFRP full-size bar.

The overall average strength of the coupons extracted from the bridge samples, was 621 MPa. The new generation pristine coupons yielded an average strength of 669 MPa. The tensile strength of new generation pristine full-size bars of 16-mm diameter tested according to ASTM D7205, was 823 MPa, and that of the vintage bars of the same diameter used in the construction of the bridge, 785 MPa.

To determine the condition of the extracted bars that have been in service, a correlation factor was calculated using data from tensile tests at the time of installation of the GFRP bars and the results obtained from the tensile tests of new generation pristine full-size bars, new generation pristine coupons and extracted coupons.

The modified tensile test indicated that the extracted GFRP bars had a reduction in strength of 2.1% over a period of 17 years [1].

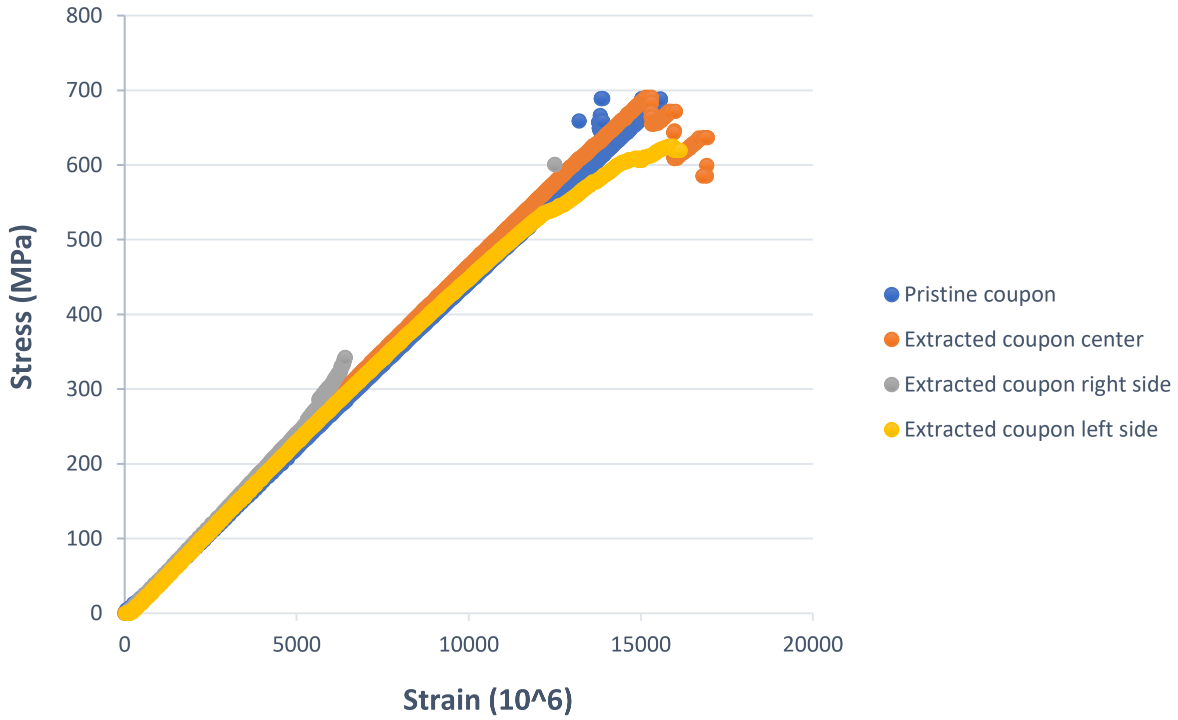

Figure 2: Stress strain curve of coupons

Conclusions

This study presents an innovative uniaxial tensile test method for relatively short GFRP bar samples; i.e. with length significantly below Standard requirements.

A correlation factor between the tensile strength of 16-mm full-size bars tested according to ASTM D7205, and that of 11 x 2.5 x 254 mm coupons extracted from the same, was calculated. Coupons showed approximately 81% of the strength of full-size pristine rebars.

Applying such correlation to coupons from bars extracted from an existing bridge, a reduction in tensile stress of 2.1% over a period of 17 years in service, was observed.

The experimental program and analysis presented in this work, is limited and should be validated by extending it to other rebar diameters, lengths, strength levels, etc.

References

[1] American Concrete Institute, Strategic Development Council (2019), Proposal for Technical Report, "Durability Study of GFRP Bars Extracted from Bridges with 15 to 20 Years of Service Life".