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Effect of the boundary conditions on the Australian uniaxial tension test for softening steel fibre reinforced concrete

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HIGHLIGHTS

- Results are presented on uniaxial tensile tests on twelve identical SFRC "dogbone" specimens tested with end conditions: fixed-fixed (FF); fixed-rotating (FR) & rotating-rotating (RR).
- The FF condition results in cracking stresses lower than the ones obtained with FR and RR conditions.
- Specimens with RR end conditions displayed significant out of plane rotation during testing.
- It is concluded that the FR end conditions serves as a compromise to the issues associated with the other test setups.

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ABSTRACT

In order to promote the regular use of steel fibre reinforced concrete (SFRC), a rational framework of material models identifying the key material parameters must be established. When considering the design of a structural member manufactured with SFRC, the defining property is its post cracking, or residual, tensile strength. In principle, a direct tension test is the ideal test that should be used in gathering the softening, or residual, parameters of SFRC experimentally. However, there are many parameters which may influence the results of the uniaxial tension test, and the choice of boundary conditions for the test is one of the most relevant ones. Three boundary or end conditions are possible: fixed-fixed, fixed-rotating, and rotating-rotating. In this paper, results of uniaxial tensile tests on twelve identical SFRC "dogbone" specimens tested with the end conditions listed above are presented. Each condition exhibits behaviour not present in the theoretically ideal tensile softening curve. Investigating this is the focus of the present study. It is concluded that the fixed-rotating end conditions serves as a compromise to the issues associated with the other test setups and seems to be more suited for uniaxial tension testing of softening SFRC.

1. Introduction

The primary objective of adding fibres (steel, polypropylene or otherwise) to concrete is to bridge cracks once they form. This fibre-bridging action provides some post cracking resistance to the concrete when stressed in tension. Quantifying this post-cracking behaviour defines the material for design. In principle, a direct tension test is the ideal test that should be used to determine the softening, or residual, parameters of steel fibre reinforced concrete (SFRC) [1–10]. Unlike results from tests of prism in bending or round panel tests, the results from the uniaxial tension test do not require an inverse analysis, or other methods to post-process. That is, the results from the uniaxial tension test can be directly inputted into design models (i.e. for shear, flexure etc.). Another advantage of uniaxial tensile loading conditions is that Mode I failure takes place; this is considered the most relevant failure mode of quasi-brittle materials such as concrete.

Despite their apparent simplicity, several difficulties emerge when conducting direct uniaxial tension tests on SFRC. The first is the nature of the test set up. Along with specimen size, specimens shape, heterogeneity of the material, and presence of notches, the boundary conditions at the specimen ends are one of the parameters that most heavily influence the results of

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Nomenclature

A_c	cross-sectional area of cracked concrete	f_{ct}	tensile strength of concrete matrix
A_f	cross-sectional area of individual fibre	k_t	fibre orientation factor
b	width of member	l_f	length of fibre
E_t	tensile elastic modulus of concrete	ε_{ct}	concrete cracking tensile strain
$f_{0.5}$	tensile stress provided by fibres at a COD = 0.50 mm	θ	rotation
$f_{1.5}$	tensile stress provided by fibres at a COD = 1.50 mm	ρ_f	fibre dosage

uniaxial tension test. The type of boundary conditions that should be applied to a uniaxial tension test continues to be an ongoing matter of discussion in the scientific community [11–14], and is the motivation for this paper.

The categories of boundary conditions are essentially limited to rotating ($\theta \neq 0$) and/or fixed (non-rotating) ($\theta = 0$) boundary conditions. Rotating boundaries allow the specimen ends to freely rotate (around all three axes) during the test; fixed boundaries prevent rotation of the specimen ends by the bending stiffness of the test setup. An ideal boundary condition would apply uniform uniaxial tension to the specimen, and produce a stable tensile softening curve. Hence, fixed ends providing homogeneous load introduction (uniform displacements) at the specimen ends would basically be

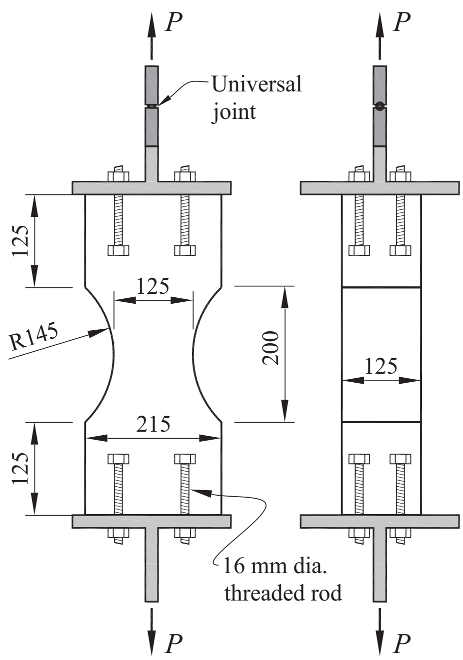

Fig. 1. Details of AS5100.5 [16] and DR AS3600 [17] uniaxial tension test specimen for SFRC.

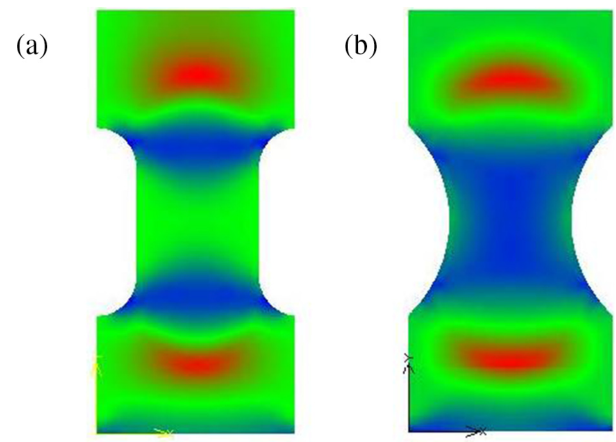

Fig. 3. Linear elastic principal tensile stress distribution of two different dogbone specimens.

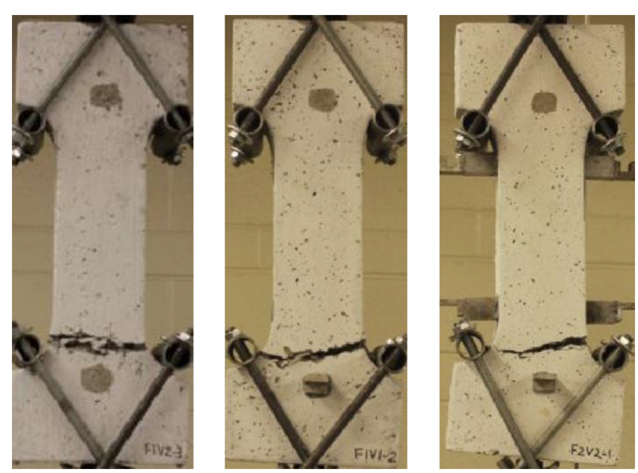

Fig. 4. Photographs of Luo [22] failed dogbone specimens.

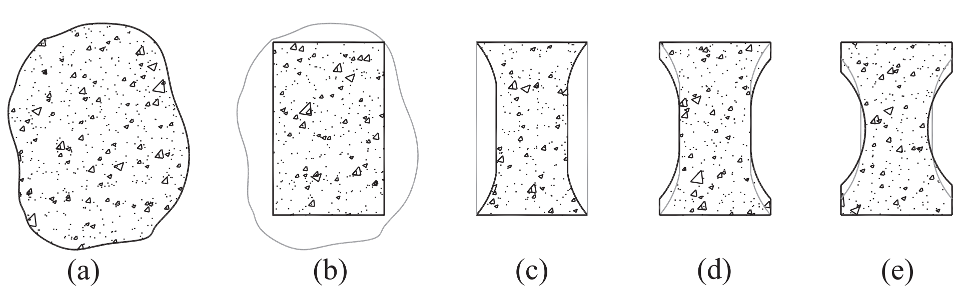

Fig. 2. Dogbone specimen design evolution van Vliet [18].