BOND STRENGTH OF DOVE TAILED TYPE 2 FIBRES IN CONCRETE

Authors:

Richardson A E, Northumbria University, School of the Natural and Built Environment. Newcastle, UK email: alan.richardson@northumbria.ac.uk

Boussoffara R, EI.CESI, Ecole d'ingenieurs, Nanterre, FR

Introduction

This research investigated the bond strength and toughness of a range of widely used commercially available synthetic Type 2 structural fibres and compared these against novel dove tailed (DT) synthetic Type 2 structural fibres. Synthetic fibres tend to be made from low modulus materials when compared to steel crack control products and they suffer a greater diameter reduction and increase in length when compared to steel; for an equal load. Diameter reduction of fibres in concrete causes de-bonding and eventual failure. DT fibres are designed to offer additional bond when a diameter reduction occurs under load.

Fibres were cast into concrete cubes to a depth of half their length and pulled out recording load and extension to ultimate failure.

The findings showed large degrees of toughness were available when using dove tailed fibre technology, The DT fibres transferred less bond stress at the point of the initial pull out prior to the dove tailed feature of the fibre taking effect. The dovetailed fibre under test provided additional grip through the contraction of the internal faces of the dovetail features when under load.

DT fibre details

Polypropylene DT fibres were used at 1.2 mm, 2.0 mm and 2.3 mm overall nominal diameter all of which were 60mm in length. The design makes use of the contraction of the fibre material to enhance the fibre to cement paste mechanical bond when a tensile load is applied. The gripping effect is shown in Figure 1 when the polypropylene fibre is under load, and the black arrows indicate a gripping effect due to the Poisson effect.

(Although beyond the scope of this work the DT fibres 2.0 mm and 2.3 mm were kept the same length as DT fibre 1.2 mm so as to evaluate the interaction of Columb friction on the increased surface area provided by increasing fibre diameter without increasing the fibre length).

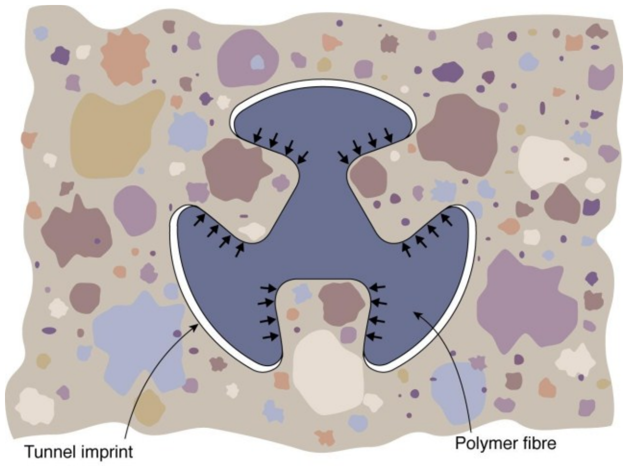

Figure 1 - Cross sectional area of DT fibre under load. (Source Thomas et al)

Comparative fibre details

BS-EN14889 - 2 covers the classification of synthetic fibres and their manufacture, and divides polymer fibres into two main classes according to their physical form, these are Class 1a (<0.3 mm) monofilament and Class 2 (>0.3 mm) fibres, the latter of which are generally used when an increase in residual post crack strength is required.

Three different structural fibre types were used to compare against the DT fibres as well as to compare between themselves. The straight plane rectangular fibres (A) were composed of 90% polypropylene and 10 % polyethylene. They had a modulus of elasticity of 9.5 GPa, a manufacturers tensile strength of 620 MPa, and a rectangular cross section of 1.5mm x 0.1 mm with a length of 40 mm,

The indented/crimped fibres (B) are 50 mm x 0.941 mm nominal diameter polyethylene macro-monofilament Type 2 fibres. The crimped fibre (C) was composed of polypropylene had the following physical properties: specific gravity 0.91, fibre length 50 mm x 1.183 mm nominal diameter, elastic modulus 3500 N/mm^2.

Test methodology

The cubes were manufactured to BS 1881 : Part 108 : 1983 using 150 mm moulds. Consistency of the six batches was monitored using a slump test as BS EN 12350 – 2: 2000 and the slump values ranged between 50 and 80 mm using a water cement ratio of 0.5.

Figure 2 illustrates the mix design and displays the comparative test methodology.

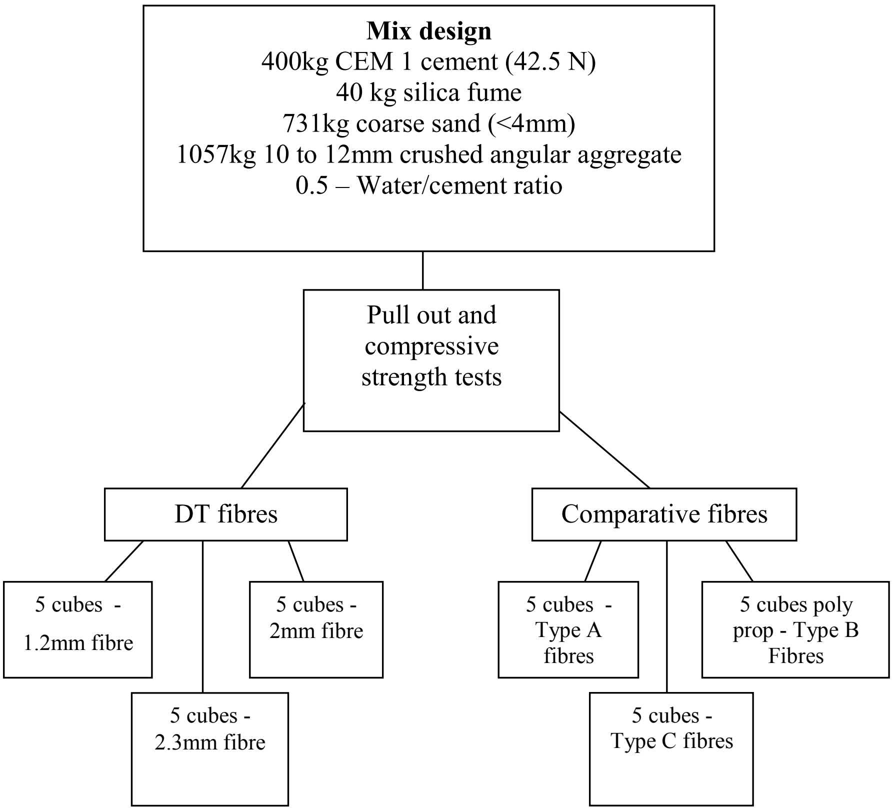

Figure 2 – Manufacturing chart/test program

The pull out test was used to determine the point at which the fibre started to lose its mechanical bond.

The method to test for individual fibre pull out values was achieved using plane jaw clamps with a Lloyds load/strain apparatus as shown in Figure 3, using a strain rate of 1min/mm. The rate of strain was sufficiently slow to allow the first initial movement of the fibre to be observed. The fibres were marked at the fibre/concrete surface intersection to determine the embedded fibre length and the first point of slippage or the first elastic movement of the fibre.

Figure 3. - Pull out testing arrangement of Lloyds testing apparatus

Results

DT fibre stress/strain/elasticity dimensional change test

To evaluate the Poisson effects of a narrowing fibre under load, individual 2.0mm DT fibres were clamped into a Lloyds load/extension apparatus and the fibres were extended (1min/mm) to failure. Load, extension, diameter, gap change in the DT fibre flutes running parallel along the fibre were recorded.

Figure 4 displays the relationship between strain and the flute width reduction. The flute width reduction increases the post load bond strength by contracting around the cement paste.

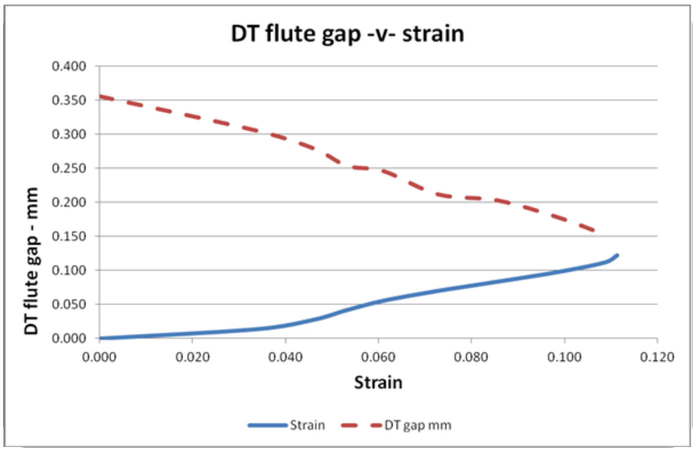

Figure 4 – DT Flute gap versus strain

The failure mode was observed to be longitudinal splitting of the fibres.

The combined fibre pull out, load/extension is displayed in Figure 5. The relative performance of the individual fibres is apparent. The extension shown is a varying combination of slippage and elasticity. Less slippage is apparent in fibres B and C. All of the DT fibres exhibited the highest load transfer following the initial slippage. The DT fibres had an extra 5mm of embedded fibre compared to fibres B and C and 10mm more than fibre A. Comparing the maximum load of the best performing commercial fibre (B) against the maximum load of each of the DT fibres allowing a normalisation of the load values of 17% to account for the embedded differential fibre length and the increased performance of the DT fibres was 15%, 10.4% and 11.5% respectively for 1.2, 2.0 and 2.3 mm fibres. The smaller diameter DT fibre transferred the highest load. Since the C fibres failed the nominal ultimate tensile strength is the average maximum load 133.48N divided by the area of fibre 1.099mm^2 = 121.42N/mm^2.

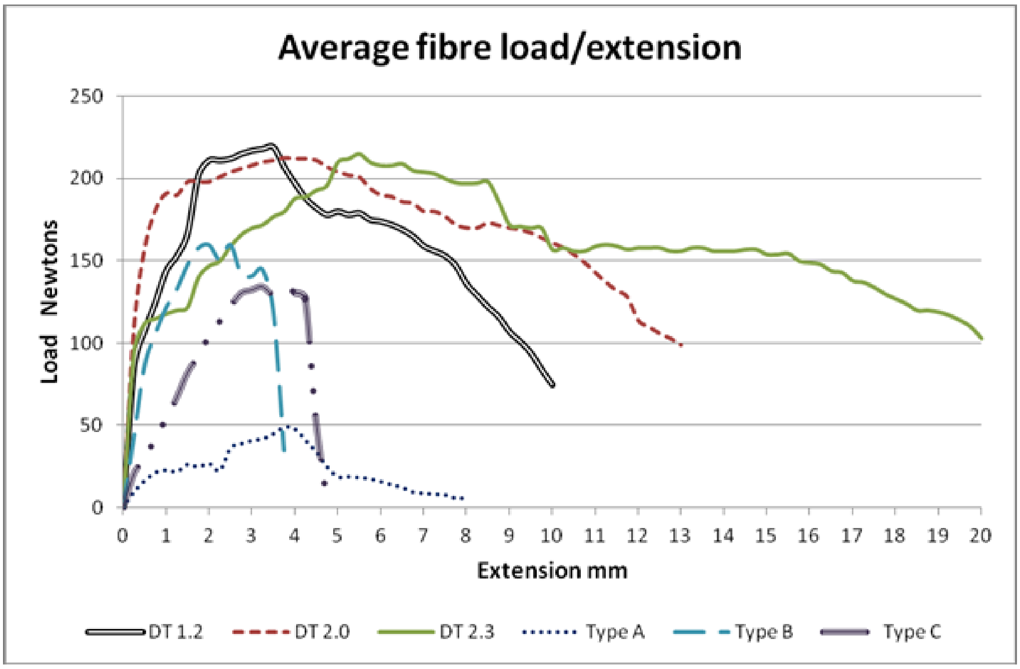

Figure 5 – Combined load extension

Toughness

The toughness values, when compared against the bond stress must be viewed in light of the mode of failure of the A, B, and C fibres. The DT fibres all failed by pull out and none of the fibres snapped, whereas all but two of the A, B, and C fibres failed by snapping at some point in the pull out process. The mean values of ultimate failure are comparatively displayed in Figure 6.

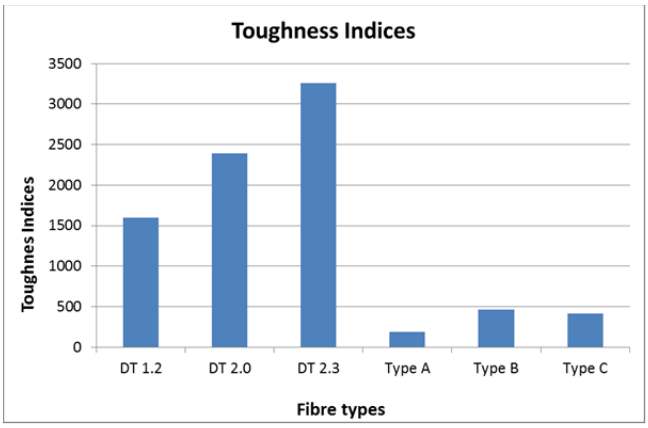

Figure 6 – Toughness Indices of fibre types

Further investigations will be carried out to evaluate equivalent weight of fibres, fibre stiffness, aspect ratio, resistance to tearing, discontinuity under compression and tension, mix-ability relative to fibre numbers and dosage, overall fibre robustness and structural integrity and energy absorption.

Conclusion

The findings showed large degrees of toughness were available when using dove tailed fibre technology, however the DT fibres transferred less bond stress at the point of the initial pull out. All fibres displayed additional load bearing capabilities following the initial movement under load.

Further work is needed to determine the optimum DT fibre diameter and dosage that may provide increased bond stress with large degrees of toughness. A longer fibre (or improved aspect ratio) would provide a greater surface area to transfer the pull out stress. If the fibre length could equate the tensile strength of the fibre to the maximum bond stress, then an optimum structural use of DT fibres could be achieved.

Formatted: Line spacing: 1.5 lines

Acknowledgements: Christopher Walton of Northumbria University for diligent attention to all lab test procedures. Wayne Thomas of Co-Tropic for supply of CoRe dovetail fibres and technical advice.

Reference

Thomas W M, Thomas R L, Paglia C, Ralph B, Fenn R, (2011), “Evaluation of novel fibre reinforcement by punch testing”, *Concrete,* June, Vol 45, Issue 6, UK