# PULL-OUT TEST TO DETERMINE BOND BEHAVIOR OF TEXTILE REINFORCED CONCRETE

Gifu University, PhD student, Bui Si Muoi
Gifu University, JSCE Member, Minoru Kunieda

## 1. Introduction

Textile Reinforced Concrete (TRC) has emerged in recent years as a new, valuable and alternative construction material. TRC encompassing a fine-grained concrete matrix reinforced by multi-axial noncorrosive textile fabrics is explored as a sustainable solution. The sustainability attributes offered by TRC spans over a wide range, including favorable mechanical performance, high corrosion resistance, long life service as well as thinner and light-weight structures.

In fiber composite materials, such as TRC, bond behavior between the textile yarns and the cementitious matrix is a principal factor influencing the global structural behavior. For that reason, the determination of bond behavior is functional for properly understanding on working behavior of TRC and providing crucial input data for numerical models. Pull-out testing is a typical method utilized to gain bond phenomenon related to reinforced concrete. The aim of this research is to introduce a simple method of pull-out test for defining bond behavior of TRC.

## 2 Material description

The pull-out test specimens are fabricated of mortar according the mix composition described in Table 1.

The textile reinforcement mesh in this study is a stitch-bonded biaxial fabric in connection with a symmetric construction [0°/90°] (Fig 1). The textile consisted of two carbon filament yarns, the longitudinal yarn (warp yarn) and the transverse yarn (weft yarn). The mesh size is 10 mm and 8.5 mm in warp and weft directions, respectively. At the joint point, knitting threads used to hold the fabric together in a stable manner.

**Table 1** Composition of the mortar

| Composition | Mass rates (-) | Quantity (kg/m$^3$) |
|---|---|---|
| High early strength cement | 0.375 | 518 |
| Fly ash | 0.125 | 173 |
| Sand | 1.000 | 1380 |
| Water | 0.125 | 173 |
| Super plasticizer | 0.005 | 7 |

## 3 Specimens

The TRC specimens are produced in hand lamination process in steel formworks as large-format textile reinforced concrete slabs with dimension of 1000x1000x15 mm. The textile layer and mortar layers are placed in the formwork alternately with a mortar layer on bottom and top. The reinforcement layers are arranged symmetrical to the thickness, level and parallel to slab surface. After curing period, the slab is cut into small specimens measured 310x60x15 mm.

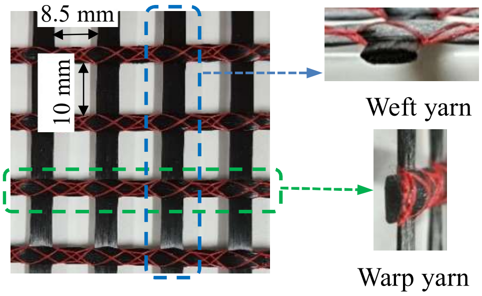


**Fig 1** Textile fabric used

The textile reinforcement inside these specimens is arranged symmetrical and parallel to the edges. During the pull-out test, only one individual yarn (warp yarn) of the structure is tested. The specimen is divided into 3 parts: the upper part and the lowest part used for clamping, the mid part is the tested area where the pull-out failure of yarn carries out (see fig 2). The parts of specimen are separated by two holes with diameter of 10 mm. At the position of the holes, the tested yarn also is cut to ensure the pressure from clamp devices not affect the result of test. In the tested area, there are two different types of embedment length of

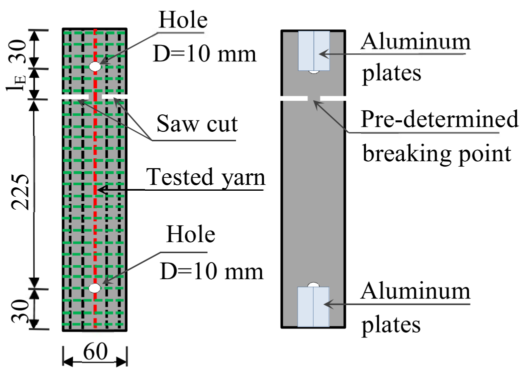


**Fig 2** Specimen used for pull-out test

warp yarn: the short and long anchorage length that are split up by the saw cuts on the both sides of specimen. The saw cuts not only play the role of isolating tested yarn but also creating the predetermined breaking point of specimen. The short anchorage length, $l_E$, limited by the upper hole and the saw cuts. The length $l_E$ should not be smaller than 14 mm in order to ensure safe handling of specimen. If the distance of the transverse yarn is smaller than that, $l_E$ should be chosen as a multiple of this distance [1]. In this research, $l_E$ equals two times of the distance (25 mm). In contrast, the long anchorage length is defined by saw cuts and the second hole. This length must be sufficiently long to prevent the slip at the free unloaded endpoint.

**4. Test setup**

As shown in figure 3, the tensile load is applied via clamping device on the upper and lower ends of the specimen. The type of clamping device used are flat chuck tensile grip that have flexible connection to testing machine. On top of the upper grip, a 2 kN load cell is placed in order to measure the load. The total deformation of the test specimen is measured using two LVDT deformation transducers positioned on either side of the center of the specimen. At the saw cuts position, two Clip-on Displacement (COD) transducers arranged to determine crack-opening.

**5. Result and discussion**

The force-crack opening curves in figure 4 consists of three distinct sections that are characteristic for textile reinforcement in a fine-grained concrete matrix: an ascending, a descending and a slightly ascending branch. The first ascending branch represents for the activation of adhesion between yarn and matrix. After reaching the bond strength, the destruction of the adhesive bond occurring due to debonding of the yarn from matrix. As a result, the force transmission falls dramatically while simultaneously leading significantly increase of the relative displacement. Lastly, the remaining pull-out force is based on friction which tend to gradually rise. However, when the deformation grew, the friction reduces regularly due to the decrease of embedded length (fig 4, 5). Figure 6 shows the difference between result measured by LVDT and COD. Before the adhesion completely eliminated, with the same tensile force level, the total deformation of specimen is always greater than value of crack opening. This deviation is due to the elongation of specimen under the impact of tensile force.

**6. References**

[1] Lorenz, E. and R. Ortlepp, *Bond Behavior of Textile Reinforcements-Development of a Pull-out Test and Modeling of the Respective Bond versus Slip Relation,* in *High Performance Fiber Reinforced Cement Composites 6.* 2012, Springer. p. 479-486

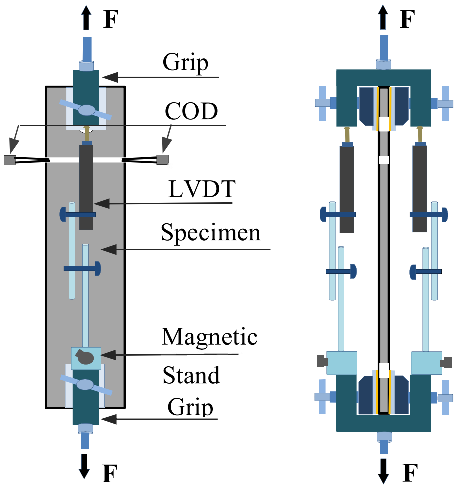


**Fig 3** Test setup of pull-out test

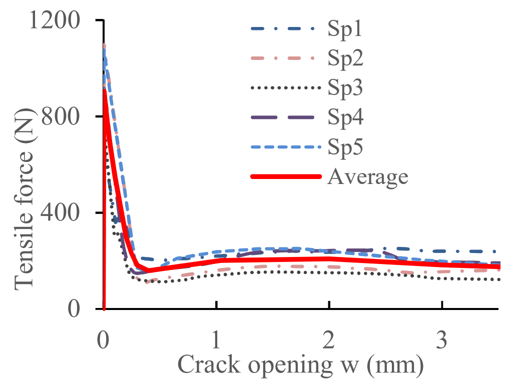


**Fig 4** Tensile force – Crack opening relationship

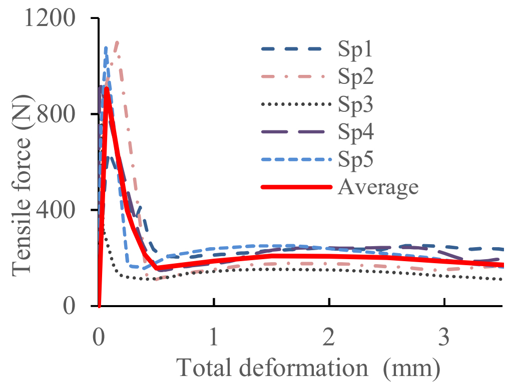


**Fig 5** Tensile force – Total deformation relationship

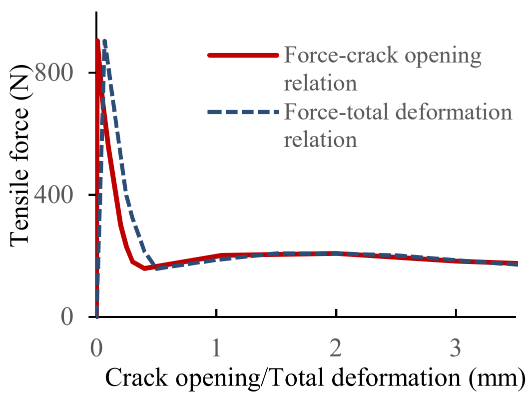


**Fig 6** Comparison between Force-Crack opening relationship and Force-Total deformation relationship