Construction and Building Materials 183 (2018) 243–252

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Comparison of test methodologies to evaluate steel-concrete bond strength of thin reinforcing bar

Eliene Pires Carvalho *, Marcela Palhares Miranda, Danielle S.G. Fernandes, Guilherme Victor Alves

Academic Civil Engineering Department, Centro Federal de Educação Tecnológica de Minas Gerais (CEFET), Brazil

HIGHLIGHTS

- Test methodologies could influence the bond properties results for thin rebars.
- Test specimens in the pull-out tests could influence the steel-concrete bond strength for thin rebars.
- Thin rebars present good performance in bond-strength tests.

ARTICLE INFO

Article history:
Received 10 November 2017
Received in revised form 8 June 2018
Accepted 13 June 2018

Keywords:
Steel-concrete bond
Thin rebars
Bond tests

ABSTRACT

The evolution of concrete is enabling the production of slender reinforced concrete components with the application of thin rebars. Although there are many studies related to the steel-concrete bond, a specific standard for bond tests of thin rebars is still missing. This paper presents some questions about methodologies for bond tests and the geometry of pull-out test specimens. This paper also presents bond coefficient (η_b) values for thin rebars. An experimental programme was performed for this purpose. The results showed that cylindrical specimens in pull-out tests presented bond-strength values closer to bond-strength values from beam tests. A test methodology adopting cylindrical specimens is suggested.

1. Introduction

Steel-concrete bonds are very important for the structural behaviour of reinforced concrete elements, and the characteristics of the steel-concrete interface are influenced by an extensive range of parameters [1]. Many authors have conducted experimental investigations into the most important influencing parameters upon the bond: the surface geometry characteristics of the steel rebar, the quality of the concrete (i.e., high-strength concrete, self-compacting concrete, fly ash concrete, recycled aggregate concrete, lightweight aggregate concrete and geopolymer concrete), and the position of the bar during concreting [2–13]. It was verified that most of the tests used to evaluate steel-concrete bond included beam tests [14] and pull-out tests [15], both specified in EN 10080 [16]. A beam test setup is a 4-point bending test for determination of the bond-strength for bent concrete girders. Fig. 1 shows a beam test setup for rebars with diameters ≤16 mm (C = cover concrete).

The pull-out test consists of pulling a steel bar (Fig. 2).

Both the beam test and the pull-out test are intended to determine the bond of reinforcing steel and are used to serve as a basis for the comparison of reinforcing bars and wires of approximately the same bar or wire diameter with different surface configurations.

The importance of the test setup in determining the bond-slip law have been cited in previous studies, some of which highlighted the need for the establishment of a uniformly accepted test method [17–22].

With regard to the pull-out test, it was verified that some researchers have made modifications in the test specimens [2–6,8], compared to the EN 10080 recommendations. These modifications include modified shape and size of the test specimens (cubic or cylindrical), different anchorage lengths, varying position along the length of the cube or the cylinder, or concentric or eccentric pullout. Modifications in tests specimens may influence the bond results from pull-out tests. It is already known that the bond strength depends on a stress state in rebar and the surrounding concrete, and the stress transfer between the steel and concrete can be affected by the different parameters. The cover to bar diameter ratio C/d is one of the most important parameters because rebar embedded in concrete and submitted to the pull-out test tends to displace in the direction of the applied force. The rebar

* Corresponding author at: Rua Piauí 1571 ap. 1104, Belo Horizonte, Minas Gerais CEP 30150321, Brazil.

E-mail address: eliene@civil.cefetmg.br (E.P. Carvalho).

https://doi.org/10.1016/j.conbuildmat.2018.06.109
0950-0618/

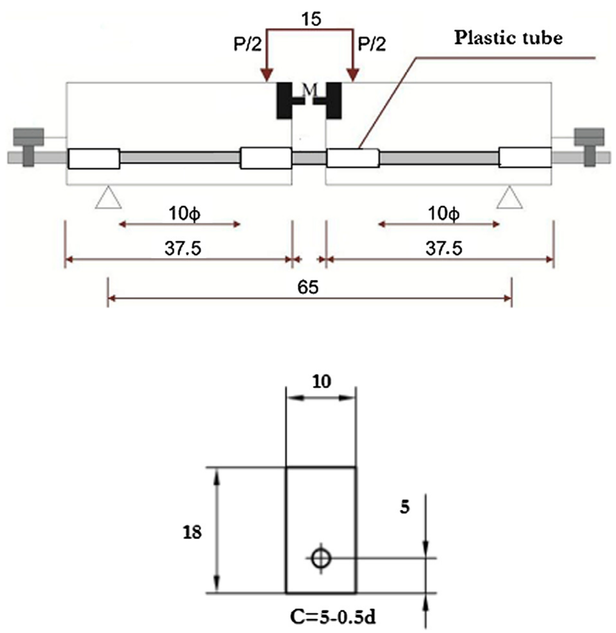

Fig. 1. Beam test set-up (Dimensions in cm) – EN 10080.

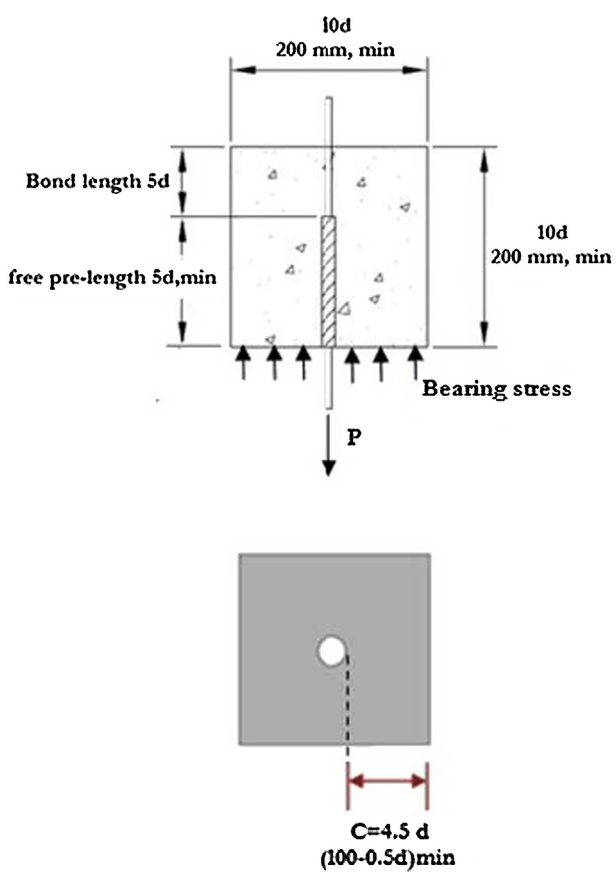

Fig. 2. Cubic pull-out test specimen – EN 10080.

forces the concrete cover to dilate radially. If the cover is rather thick, splitting through the cover may be delayed or even prevented, affecting the bond strength [23,24]. Ratios C/d≈5 can produce pullout failure. Another important parameter in the bond behaviour of steel bars under pull-out tests is the anchorage length (*l*) (Fig. 3). As shown in Fig. 3, the state of stress along the anchorage is not uniform, but the average bond stress (τ_{av}) is usually adopted for any stage during loading. This stress can be calculated by Eq. (1) [25,26].

$$\tau_{av} = P/\pi.\phi.l \tag{1}$$

where:

τ_{av}: average bond stress;
P: applied load;
ϕ: rebar diameter, and *l*: bond length.

It is important to state that an increase in embedment length decreases the maximum average developed bond stress value. The average bond stress (τ_{av}) can be conservative, but it may be sufficient as basic calculation values and for comparison, as specified in EN10080 [16].

Another aspect related to the importance of the test setup in steel-concrete bond tests is the stress state that occurs in conventional pull-out tests where the concrete surrounding the bar is placed under longitudinal compression (Fig. 4). The bearing stresses of the concrete against the plate causes a fictional component that resists the transverse expansion, which would reflect Poisson's ratio [25].

One known way to decrease this effect is to adopt a free pre-length where bonding is prevented (Fig. 3) [25]. Tastani et al. [23] emphasized the sensitivity of the measured bond properties to the pull-out test setup. They highlight that the test can produce spurious influences on specimen behaviour and can lead to non-conservative estimates of bond strength. The authors presented results of an experimental investigation of the performance of an alternative bond test known as DTP-BT (direct tension pullout bond test) shown in Fig. 5. As per [23], the modification was about

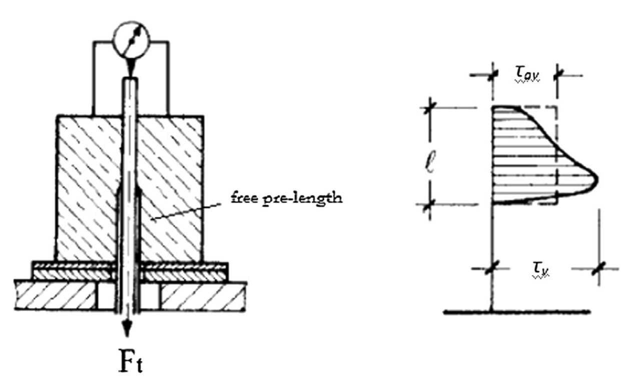

Fig. 3. State of stress along the anchorage length [25].

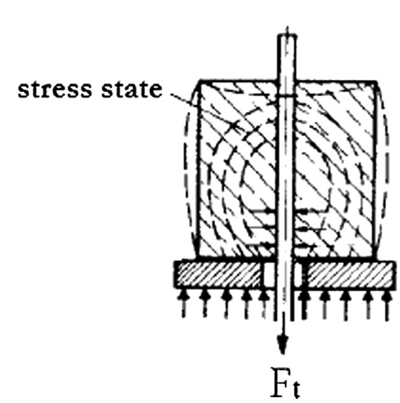

Fig. 4. Stress state in pull-out test [25].