Engineering Structures 175 (2018) 661–668

Contents lists available at ScienceDirect

Engineering Structures

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

# Evaluation of bond strength between steel rebars and concrete for heat-damaged and repaired beam-end specimens

Nesma Ghazaly, Ahmed Rashad, Mohamed Kohail*, Omar Nawawy

*Structural Engineering Department, Ain Shams University, Cairo, Egypt*

ARTICLE INFO

*Keywords:*
Bond strength
Elevated temperature
Steel fiber
Deep repair
Shallow repair
Bonded length
Heat damaged
Restoration

ABSTRACT

Many researchers investigated the factors affecting the bond between steel and concrete. Studying the residual bond behavior after subjected to fire and how to restore the bond strength is an interesting subject. This study focus on studying the effect of concrete cover (3Ø, 5Ø), bonded length (30 mm, 50 mm), different elevated temperature regime (600 °C, 800 °C) and different repairing techniques (shallow, deep) and materials (concrete, steel fiber reinforced concrete) on both the residual and restored bond strength. The experimental program consisted of testing twenty-five beam-end specimens. The test results indicated that the heat-damaged specimens can lose up to 74% of ultimate bond strength. The deep repaired specimens restored almost 87% and 91% respectively of original bond strength for concrete cover 30 mm and 50 mm. However, the shallow repaired specimens restored almost 74% and 77% respectively of original bond strength for concrete cover 30 and 50 mm. The most effective repairing material, used in this study was the steel fiber reinforced concrete (SF). It restored almost 96% of original bond strength. Furthermore, simple relationships are proposed based on the available test results to predict the bond strength and characterize the bond stress – slip behavior. The proposed relationships yield good agreement with the experimental results. Also, a modified analytical model is proposed to predict the bond stress- slip relationship. The proposed modified analytical model yields good agreement with the experimental results.

## 1. Introduction

During last decades the bond behavior of steel rebars to concrete has been studied as well as the parameters that affect the bond strength such as the thickness of the clear concrete cover, bonded length, nominal bar diameter and concrete compressive strength [1–5]. When subjected to elevated temperature, the bond strength between concrete and steel reinforcing rebars may deteriorate. The bond strength after subjected to fire had a great interest from researchers aiming to investigate the factors affecting it [6–24]. The Previous investigation showed that the concrete cover increases the residual bond strength. Also, the higher temperature significantly decreases the bond strength.

Degradation of bond strength at elevated temperature may significantly influence the load capacity of the RC elements. To recover the structural integrity of heat- damaged RC elements rehabilitation works are required. A few researchers investigated the different repairing techniques and materials for heat- damaged RC elements [13,25–29]. These methods were conducted by breaking off the deteriorated concrete layers, preparing the surface for the application of the repairing material then replacing the damaged concrete layers with different repairing materials. Limited data exists in the literature on restoring the bond between concrete and steel rebars for heat-damaged RC elements using either shallow repair and deep repair [13].

An extensive research program has been initiated at the Ain Shams University to investigate the residual bond strength for heat-damaged RC elements using different repairing techniques and materials. Shamseldein et al. [13] studied the effectiveness of using different repairing techniques (deep and shallow) and different repairing materials (concrete, polypropylene fiber reinforced concrete, polymer modified cement mortar and commercially available fiber reinforced polymer modified cement mortar) to restore the bond strength between concrete and steel rebars for heat-damaged RC elements. This paper presents an experimental investigation on the evaluation of the residual bond strength between concrete and steel rebars for heat-damaged beam end specimens. It also discusses the effectiveness of repairing materials and techniques on restoring the bond strength between concrete and steel rebars. The parameters considered in this study include: concrete cover, bonded length, different elevated temperature regime, repairing materials and repairing techniques. Based on the available experimental data, a simple analytical model was proposed to describe the bond

* Corresponding author.
*E-mail address:* m.kohail@eng.asu.edu.eg (M. Kohail).

https://doi.org/10.1016/j.engstruct.2018.08.056
Received 24 April 2018; Received in revised form 17 August 2018; Accepted 19 August 2018
0141-0296/ © 2018 Elsevier Ltd. All rights reserved.

**Nomenclature**

*Notations*

| | |
|---|---|
| $C$ | concrete cover |
| $f'_c$ | cylinder concrete compressive strength |
| $f'_{cT}$ | cylinder concrete compressive strength after heating to T °C and cooling |
| $f'_t$ | average splitting tensile strength of repair materials |
| $k_l$ | ratio between bonded length and rebar diameter |
| s | slip page |
| $s_u$ | slip page corresponding to the ultimate bond stress |
| $\alpha$ | parameter characterizes the ascending branch of BPE model |
| $\tau_u$ | average ultimate bond strength |
| $\tau_{u,T}$ | residual bond strength after heating to o T °C and cooling |
| $\varnothing$ | rebar diameter |

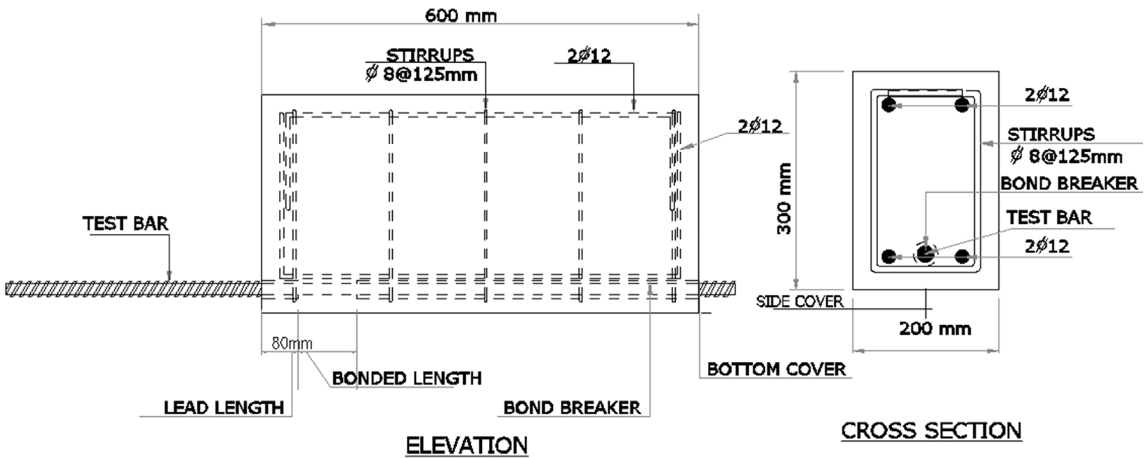


**Fig. 1.** Configuration of the test specimens.

behavior for heat-damaged elements considering the different parameters studied.

## 2. Experimental program

### 2.1. Test specimens

The experimental program consists of twenty-five beam-end specimens prepared and tested according to ASTM A944-10 [30]. The beam-end specimen, used in this investigation, where both reinforcing steel and concrete are in tension offers a good alternative to study the bond behavior. The test specimens sized 200x300x600 mm. Detailed dimensions of specimens are shown in Fig. 1. Each beam was reinforced with one tested steel rebar in tension side. To avoid a localized cone failure of the concrete, the first 80 mm of the test bar from the concrete surface at the loaded end were debonded using PVC pipe shall be used as bond breakers, as shown in Fig. 1. The bonded length was followed by a debonded length throughout the remaining part of the tested rebar. Compression and tension side of the specimen was provided with two 12 mm deformed steel rebars.

### 2.2. Material properties

The beam-end specimens concrete mix consists of Ordinary Portland Cement (CEM I 42.5R), natural sand, crushed stone with 10 mm nominal maximum size, Tap water, and Type G Superplasticizer. The mix proportions are given in Table 1. Reinforcing steel rebars with 16 mm diameter were used. The rebars have yield and tensile strength of 450 and 640 MPa respectively.

### 2.3. Repair materials

Two types of repair materials were used, namely concrete (C) and steel fiber reinforced concrete (SF). The mix proportions of the used repairing materials are shown in Table 2. Corrugated round steel fibers were used in this study, with 1% fiber volume fraction [31–36]. The properties of used fibers are presented in Table 3 and Fig. 2 shows the shape of steel fibers.

**Table 1**
Concrete mix proportions /m$^3$.

| Cement (kg) | Coarse aggregate (kg) | Fine aggregate (kg) | Water (kg) | Super plasticizer (kg) |
|---|---|---|---|---|
| 375 | 1135 | 615 | 190 | 6 |

**Table 2**
Repair materials' proportions /m$^3$.

| Repair material | Cement (kg) | Coarse aggregate (kg) | Fine aggregate (kg) | Water (kg) | Steel fibers (kg) | Comp. strength (MPa) | Tensile strength (MPa) |
|---|---|---|---|---|---|---|---|
| C | 400 | 1100 | 590 | 200 | – | 45.6 | 2.9 |
| SF | 400 | 1100 | 590 | 200 | 78.40 | 45.00 | 3.9 |

Download English Version:

https://daneshyari.com/en/article/10126916

Download Persian Version:

https://daneshyari.com/article/10126916

Daneshyari.com