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Study of the behavior of corroded steel bar and convenient method of repairing

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Abstract This paper presents an experimental investigation into the residual strength and mechanical properties of corroded reinforcing bare bars. An attempt has been made to describe firstly the impressed current technique which is commonly used for accelerating reinforcement corrosion. The study compared between two methods of repairing the corroded steel bar, the first one which mostly used by painting the half surface area of corroded bar; and the another one by coating the full surface area of corroded bar. The experimental results show that, the corrosion process alters the external surface of steel bar due to pitting, the residual cross-section of the corroded bar is no longer round and varies considerably along its circumference and its length so the residual diameter is better defined by loss of weight. The rate of corrosion has been calculated by two terms, the term of mass loss rate (MR) and the term of penetration rate (CR). The mass loss rate decreased for fully coated bars by 1.7–2 times than half coated bars showing the importance of fully coating bars in corrosion repair. Finally, the reliability of using the galvanostatic method in research work was represented by comparing between the real time and the accelerated time to reach a certain degree of corrosion.

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Introduction

Corrosion of steel reinforcement is one of the major causes inducing deterioration of reinforced concrete structures. Corrosion is considered to initiate when the chloride concentration around the reinforcement reaches a threshold to cause dissolution of the protective film. When the corrosion of steel bars develop significantly, it not only affects the structural serviceability by cracking, or even spalling of the concrete cover, but also has an impact on the structural safety by decreasing the load-bearing capacity of reinforcement concrete members, which is of great concern to both owners and users of the structural building. The corrosion of steel bars in concrete is an electrochemical process that; involves both chemical reaction and current flow with anode and cathode occurring simultaneously on the reinforcement surface. A series of subsequent

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oxidation reactions converts the ferrous hydroxide into hydrated ferric oxide (rust). It is clear that, since the corrosion of reinforcement starts transforming the iron into rust, it must affect the residual capacity of corroded steel bars.

The majority of the previous researches mainly concerned with the mechanism of corrosion and its local effects on bond with concrete, rather than its effect on the mechanical properties of corroded reinforcement. Relatively little attention has been devoted to the residual capacity of corroded reinforcement. In all reported experimental investigations, either a single bare bar or bars embedded in concrete were adopted as test specimens. On the basis of experimental results from tension tests, Maslehuddin et al. [1] reported that up to 1.1% corrosion in air hardly changed bar strength. By using the measured smallest sectional area of corroded bars, Palssom and Mirza [2] also reported that the average nominal yield and ultimate stresses of reinforcement with less than 10% loss of cross-sectional area were similar to those with more than 30% sectional loss, and that even a slight increase in the yield strength was noted in pitted specimens.

In contrast to Maslehuddin et al. and Palssom and Mirza, Andrade et al. [3] proved that corrosion decreased bar strength significantly. By using the average cross-sectional area determined by the measured weight loss, it was noted that 10% corrosion decreased the yield and ultimate strength by 4.5% and 3.3%, respectively. Although the conclusions of Andrade et al. were obtained from a single bare bar, they were still supported by experimental results of Lee et al. [4], Saifullah [5], Morinaga [6] and Zhang et al. [7], whose test specimens were corroded reinforcement embedded in concrete. Du et al. [8] argued that, for corroded steel bars up to 16% corrosion, their residual yield and ultimate strengths decrease more rapidly than their average cross-sectional area and, therefore, their residual strength decreases significantly. They concluded also, for the same corrosion, the residual capacity of bare reinforcement and that corroded while embedded in concrete are similar. As a result of the long duration of the corrosion process in nature, Yuan et al. [9] compared between two techniques for accelerating the corrosion process; and reported that the corrosion characteristics of the steel bar under artificial climate environment or by using the galvanostatic method are similar to that of corrosion under natural environment.

Research significance

Repairing of corroded steel in concrete structures includes the following basic steps; cover removal, exposing the whole bar

Fig. 1 Universal testing machine.

Fig. 2 The data logger.

surface, rust removal and coating with suitable epoxy. Sometimes, in practical cases the concrete cover was removed and only exposes the half surface of the bar and is treated as before. This study presents an experimental investigation into the residual capacity and mechanical properties of corroded reinforcement with different diameters exposed to different degrees of corrosion. In addition comparing the efficiency of repairing the corroded steel bars treated by anti corrosive epoxy, either for coating the whole surface area of the bar or coating the half exposed surface area of the steel bar as may be done in practice.

Experimental program

A total of 48 single bare bar specimens were corroded and examined under tension test. The experimental program for the reinforced steel ribbed bars is divided into two groups. The first (Group A) consists of 36 test specimens; they were 27 corroded and 9 non-corroded control specimens. The variables investigated were reinforcement diameter and degree of corrosion. The test specimens were corroded to 10%, 20% and 30% corrosion degree with diameters 10 mm, 12 mm with specimen length of 500 mm and 16 mm with length 600 mm. Each corrosion degree has three samples of each diameter.

The second group (Group B) consists of 12 reinforcement steel specimens with diameters 10 mm, 12 mm with length 500 mm and 16 mm with length 600 mm. The steel bars were corroded firstly to 10% and 30% corrosion degree; each corrosion degree has two samples of each diameter. Then the corroded bars were cleaned of rust and coated with commercial coating material (Epozinc) for repairing the corroded steel bars. For the same diameter, one of the specimens is fully coated and the other one is partially coated with the same coating material via painting the half surface area of the steel bar for the same degree of corrosion. After that the fully and partially coated bars are exposed again for the same corrosion time. The uniaxial tension tests of the reinforcement specimens were performed using a Universal Testing Machine (Fig. 1). The load cell, electrical strain gauges glued to the bars were connected to the Data Acquisition System to collect readings every five second by means of a computer program that runs under the "PCD-30A" software (Fig. 2). The technique of accelerated and simulated corrosion was employed into groups.

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