Construction and Building Materials 40 (2013) 145–161

Contents lists available at SciVerse ScienceDirect

Construction and Building Materials

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

Experimental and numerical investigation for the flexural strengthening of RC beams using near-surface mounted steel or GFRP bars

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HIGHLIGHTS

- The worth of NSM bars for upgrading the flexural capacity of RC beams is investigated.
- A total of eight groups of 16 beams were tested under four-point bending till failure.
- The ACI 318-11 code and ACI 440.1R-06 guidelines were used for peak load prediction.
- Nonlinear finite element analysis was conducted using LS-DYNA software.
- NSM bars were found to be successful at upgrading the flexural capacity of RC beams.

ARTICLE INFO

Article history:
Received 9 June 2012
Received in revised form 9 September 2012
Accepted 25 September 2012
Available online 5 December 2012

Keywords:
Near surface mounting
FRP bars
Concrete beams
Flexural strengthening
Finite element modeling

ABSTRACT

In this paper, the effectiveness of NSM bars as a means of restoring or upgrading the flexural capacity of RC beams is experimentally and numerically investigated. The studied parameters included type of NSM bars: steel versus GFRP, and NSM reinforcement ratio (number and diameter of inserted NSM bars). A total of eight groups of 16 beams were tested under four-point bending. The two beams of the first group were reinforced with three main steel bars and were used as control specimens. The two beams of the second group were reinforced with three main GFRP bars and were utilized for comparison with control specimens. Assuming that one of the three main steel bars in the control specimen had corroded, three groups of six beams were designed in which one NSM steel or GFRP bar was inserted in the tension side. Yet, with the assumption of the corrosion of two main steel bars in the control beam, the last three groups of six beams were planned in which two NSM steel or GFRP bars were planted in the tension side. For NSM-upgraded beams, special type of epoxy paste was used as bonding agent. Test results showed that by using NSM steel or GFRP bars to compensate the difference in the main reinforcement, the original load capacity of the control beam was successfully restored. The ultimate capacity of the beams was predicted using the ACI 318-11 code and ACI 440.1R-06 guidelines. A numerical investigation utilizing nonlinear finite element (FE) analysis was also carried out using LS-DYNA software. A comparison was made between the experimental and numerical results and good agreement was obtained. Based on the validation of FE results, the numerical analysis was extended to include additional cases to study the effect of FRP reinforcement ratio on the flexural performance of NSM-upgraded beams.

1. Introduction

Reinforced concrete structures are suffering from different types of deteriorations. The paramount of all is the one due to steel corrosion. The damage due to corrosion or cracks due to combined mechanical and chemical factors implies the need for appropriate methodology of structural rehabilitation. Several techniques are now available to repair beams and columns. In the last few years, near surface mounting (NSM) technique has received more attention as an alternative for externally bonded FRP laminates in the flexural strengthening of concrete elements [1–3]. Due to the availability of high quality resins, NSM technique can offer an easy and efficient way of rehabilitation for many parts of the structures. Major innovative applications have been witnessed in this field to overcome the problems arising when externally bonded FRP composites are subjected to severe environmental conditions or mechanical damage [4–6]. Currently, prestressing is employed with the NSM-FRP strengthening technique to enhance the flexural performance of strengthened beams [7–9].

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0950-0618/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.conbuildmat.2012.09.107

In NSM strengthening technique, longitudinal grooves are first cut into the concrete cover of beams or slabs, then the reinforcing bars are inserted into these grooves and bonded with an appropriate binding agent; typically an epoxy paste or a cement grout. The first application of this technique was the implementation of steel bars into slots to strengthen a bridge deck slab in Lapland, Finland in 1940s [10]. The initial research work on NSM technique was reported by Blaschko and Zilch [11] using CFRP strips inserted into grooves cut at the surface of concrete specimens. The specimens were tested in a double shear configuration. Test results showed that strengthening using NSM CFRP strips has a greater anchoring capacity compared to externally bonded CFRP strips.

Based on the results of several applications [12], it has been concluded that the increase in the flexural capacity of strengthened beams applying NSM technique is greater than that using externally bonded systems for the same axial stiffness of the FRP

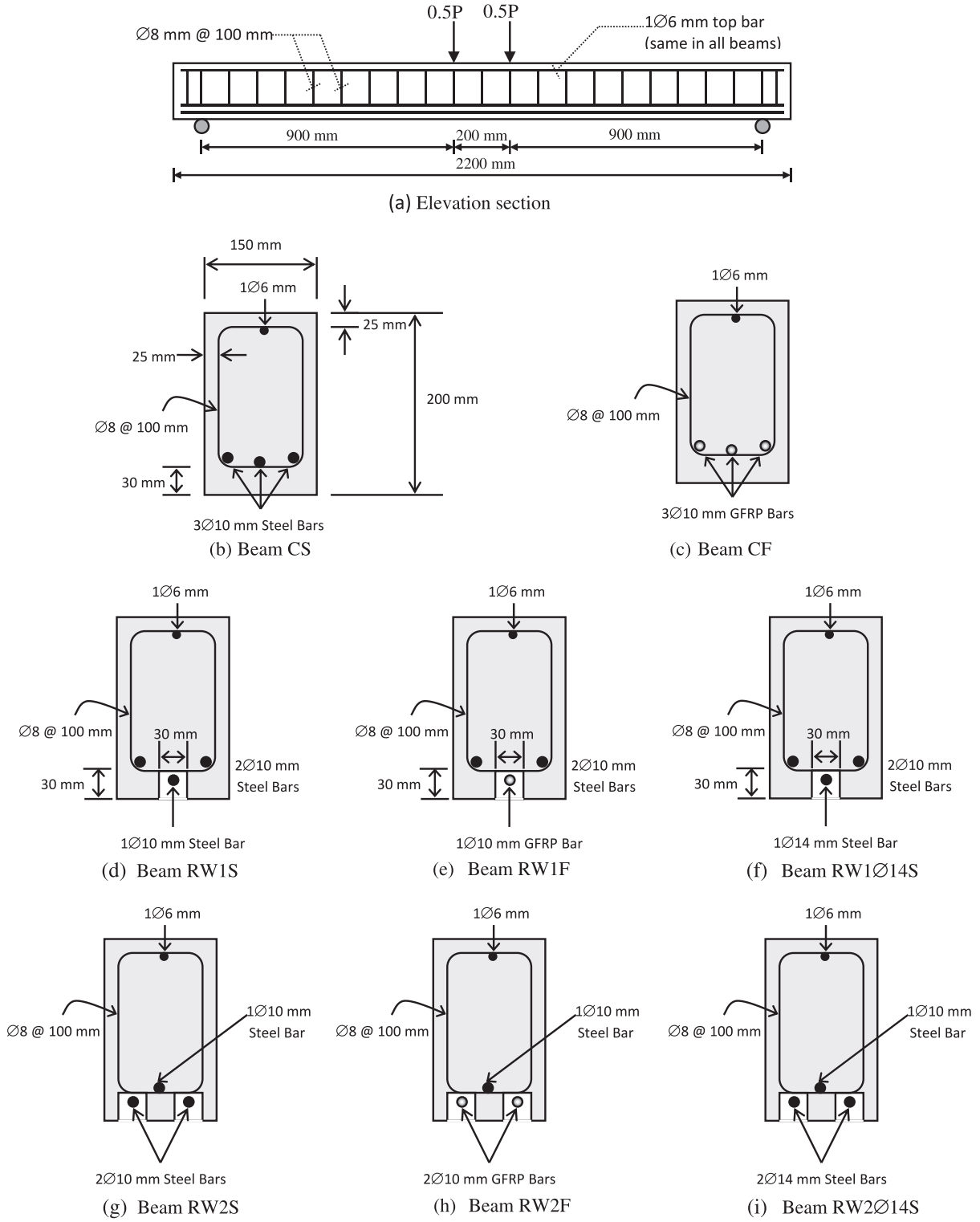

Fig. 1. Details of test beams.