FLEXURAL STRENGTHENING OF RC BEAMS WITH PRESTRESSED FRP LAMINATES APPLIED ACCORDING TO NSM TECHNIQUE

Inês G. Costa and Joaquim A. O. Barros
ISISE, Department of Civil Engineering, University of Minho
E-mail: ines.costa@civil.uminho.pt

KEYWORDS
Reinforced Concrete, Fibre Reinforced Polymer, Near Surface Mounted Reinforcement, Prestress.

ABSTRACT

A new technique for the flexural strengthening of Reinforced Concrete (RC) beams according to Near Surface Mounted (NSM) technique using prestressed Fibre Reinforced Polymer (FRP) laminates is being developed. This technique is expected to increase the flexural capacity of the beams to strengthen and to recover part of its existing deformation, reducing or even closing existing cracks, resulting in benefits in terms of structural durability and integrity. The possibility of using rapid stiffness and strength gain adhesives to bond the FRP in the structure in order to produce a simple, fast and efficient prestress strengthening technique demands the method of application to be easily placed and removed. The equipment to apply this new technique in job site, as well as the design of its critical components are presented in this paper.

INTRODUCTION

Tests on simply supported RC members strengthened using laminates according to the NSM technique (Barros and Fortes, 2005, Barros et al., 2007, Bonaldo et al., 2008) have shown that NSM laminates debond or fail at much higher strain than Externally Bonded Reinforcement (EBR) strengthening systems. Using NSM, premature debonding is no longer the predominant failure mode. In fact, delamination of the concrete cover is the most current failure mode. Due to the characteristics of the application of NSM technique, it seems to be specially adjusted to increase the negative bending moments of continuous RC elements. Indeed, the opening process of the slits can be executed by conventional equipment used to open the crack control joints in flooring applications.

Concerning the prestressed NSM reinforcement, bibliographic research shows that little work has been conducted in this scope. Most of the analysed authors (Wight et al., 2001, Nordin and Täljsten, 2006, Gaafar and El-Hacha, 2008) recognize that prestress presents benefits of extreme significance, namely: the closure or reduction of the width of existing cracks and retardation of the appearance of new fissures, resulting in benefits in terms of structural integrity and concrete durability. Other benefits are also reported such as: restitution of lost prestress to a structural member (Wight et al., 2001) or the unloading of the existing steel reinforcement (Nordin and Täljsten, 2006).

Currently, there is no NSM-based prestress technique that can actually be applied on job site. Most of the tested specimens were reinforced in the sagging region, but the reinforcement tasks were performed as if it was a hogging region (Nordin and Täljsten, 2006, Barros, 2009), i.e. the elements are turned over, reinforced, and finally turned over again in order to be tested. The scheme in which the hydraulic jacks are placed (in line with the FRP and beyond the boundaries of the structural element) is also impracticable in real cases. Only Gaafar and El-Hacha, (2008) claim to have a system that allows this technique to be applied in job-site. In this paper, a method for the application of the proposed technique is presented.

PROPOSED TECHNIQUE

The system suggested to apply prestress on FRP is depicted in Figure 1. The system will consist of a pair of telescopic tubes that converge in a steel plate, where the prestress load will be applied. On the other extremity of the telescopic tubes, the anchorage piece depicted in Figure 2 will be positioned. This system will be placed directly against the element to strengthen and stressed in place, using a common hydraulic jack.

The numerical analysis of the components evidences that relatively small and lightweight pieces can be used in this innovative strengthening technique. Note that the largest dimension of the designed anchorage piece is approximately 15 cm.

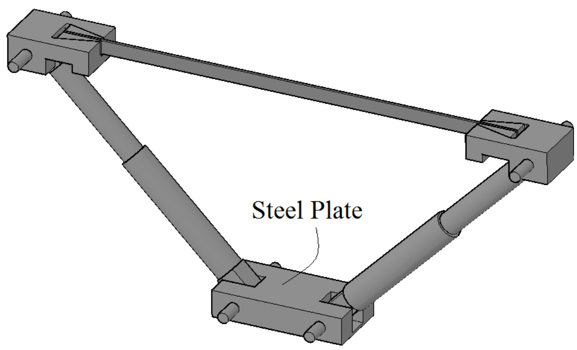

Figure 1: Assemblage scheme of the system

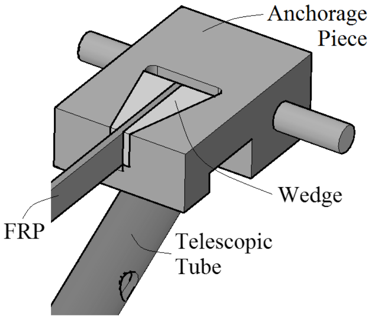

Figure 2: Detail of the anchorage steel piece

The deformed mesh represented on Figure 3 was produced using a scale factor of 100 when the applied load was 84 kN. This level of load was selected because it represents the ultimate load of the largest Carbon FRP frequently used for NSM reinforcement, although the prestress level will be most of the times limited to 60% of the ultimate stress. Based on the Von Mises stress criteria obtained in the Finite Elements Analysis (Figure 4) a common steel grade can be selected to manufacture the anchorage pieces.
The possibility of changing the wedges is an advantage of this system. Although the system is designed to apply prestress on FRP laminates, more suitable wedges can be adopted to prestress FRP rods. The design of the telescopic tubes is currently being carried out, but the most recent estimates point out to portable tube dimensions. Once the design of this system is finished, the effectiveness of prestressed FRP according to the NSM technique will be assessed.

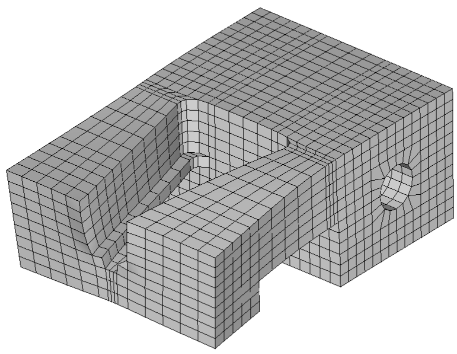

Figure 3: Deformed mesh

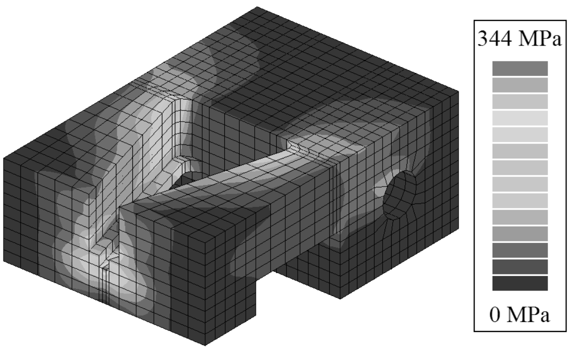

Figure 4: Von Mises stresses

CONCLUSIONS

In this paper, a method for the application of prestress on FRP according to the NSM technique is presented. The system proposed reveals to be not only feasible, but also portable, allowing the goal of producing a simple, fast and efficient prestress technique for the flexural strengthening of RC beams and slabs to be fulfilled.

ACKNOWLEDGEMENTS

The study reported in this paper is a part of the research currently being carried out in the scope of the author's PhD thesis, supported by FCT, SFRH/BD/61756/2009.

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AUTHOR BIOGRAPHIES

INÊS G. COSTA was born in Braga, Portugal and graduated in Civil Engineering by University of Minho in 2008. She is a researcher in ISISE, Department of Civil Engineering, University of Minho, Portugal since October 2007 and started her PhD in November 2009. Her research interests are essentially focused on structural analysis and modelling, fibre-reinforced composites behaviour and characterization, repair and retrofit of reinforced concrete structures. Her e-mail address is: `ines.costa@civil.uminho.pt`.