Shear Behavior Of Existing RC T-Beams Strengthened With CFRP

Stefania IMPERATORE
PHD
University of “Roma Tre”
Rome, Italy
simperatore@uniroma3.it

Davide LAVORATO
PHD
University of “Roma Tre”
Rome, Italy
dlavorato@uniroma3.it

Camillo NUTI
Full Professor
University of “Roma Tre”
Rome, Italy
cnuti@uniroma3.it

Silvia SANTINI
Associate Professor
University of “Roma Tre”
Rome, Italy
silvia@uniroma3.it

Lorena SGUERRI
Research Assistant
University of “Roma Tre”
Rome, Italy
sguerri@uniroma3.it

Summary

This paper presents the experimental behaviour of two reinforced concrete T-beams strengthened in shear with CFRP. The beams were extracted from an important building of the mid-'30s in Rome. The goal of this research was to evaluate the shear strength of the retrofitted beams with the simultaneous occurrence of a negative bending moment. The tests were performed at the Experimental Laboratory of the Structural Department of the University “Roma Tre”. In the meantime the two beams were modelled with the software ATENA in order to perform numerical simulations of the tests. The numerical results seem to be in good agreement with the experimental data in terms of load–displacement response, strain state, crack pattern and failure mode.

Keywords: building, r.c. structures, shear strengthening, CFRP, FEM analysis.

1. Introduction

A typical problem regarding the retrofitting of existing RC structures, is related to the insufficient shear reinforcement due to deficient code requirements, construction defects (irregular stirrups spacing and lack of concrete cover) and increased loads. In these cases, it has been shown that shear strengthening of a RC elements can be attained applying FRP sheets. International and national guidelines and codes give design tools for FRP reinforcement on the base of experimental studies that often refer to simply supported beams with FRP shear strengthening in positive moment region while the behaviour of FRP shear reinforcement in negative moment region is not clear yet. This is the case of continuous beams, when large shear forces are combined with large negative bending moments and shear cracks start from the top of the section, with the consequent less effectiveness to enhance the shear capacity. The main aim of the present research is to fill this gap.

2. Experimental program

The experimental tests are conducted on two RC T-beams extracted from a building in Rome dated the mid-'30s. In order to reproduce a beam behavior as in a framed structure with negative moments at the ends and positive moment inside the span, a cantilever is added to one beam end (Fig. 1).
The retrofit of the beams consists in the application of CFRP strips for the strengthening in shear and the construction of a new slab for the flexural strengthening. This slab is executed in two different ways: with (beam TM1a) and without (beams TM1b and TM2) some construction defects in order to evaluate their influence on the beam behaviour.
The experimental evidence shows that shear strengthening of RC beams by externally bonded FRP sheets is effective in providing additional shear resistance to existing members. However when shear and negative bending develop simultaneously, shear cracks start from the beam extrados, supporting the FRP debonding if this is not adequately anchored. It is to be noted that the occurrence of some construction defects significantly affect the final results [1].

https://doi.org/10.2749/222137813806501443

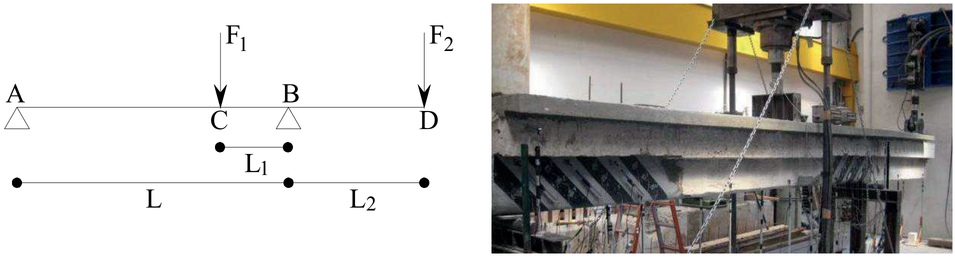

Fig. 1: Test static scheme and test setup for the retrofitted beams.

3. Numerical analyses and comparison with experimental evidence

Numerical analyses are performed to model the nonlinear behavior of the tested beams by the FEM software ATENA [2]. In order to simulate the behavior of beams without construction defects three-dimensional models are built, while to simulate the beam with defects a plane model is used. In this case, as experimentally found out, the beam behavior is governed by the construction defects and the stress state is very modest for the CFRP strips so that the CFRP bond law can be neglected.
Proper material models are used for CFRP strips, existing concrete, new concrete, steel rebars and construction joints interfaces and appropriate bond laws are used for different type of steel reinforcement: perfect bond for new ribbed rebars and Bigaj's model for the existing rebars [3].
The analytical results show that the proposed models fit the experimental results in absence of local phenomena. Further efforts should be made to improve the model in terms of beam stiffness.
The numerical results on the beam TM1a present some differences with respect to the experimental ones that can be attributed to the ineffectiveness of the model in capturing the effects of local phenomena due to construction defects. Nevertheless results highlight the influence of construction details such as the absence of the connectors between the slab and the beam.
The comparison between the experimental and the analytical results of the beams without defects shows a good fit in terms of vertical deflection.

4. Conclusions

Two existent beams extracted from a RC structure in Rome dated the mid-'30s are retrofitted in bending and reinforced in shear with CFRP strips. The beams are tested to investigate the shear strengthening capacity of beams in framed structures and the main factors that affect it.
The results show that the externally bonded FRP sheets are effective in providing additional shear resistance to existing members. However when shear and negative bending develop simultaneously, shear cracks start from the beam extrados, causing the FRP debonding if not adequately anchored.
In order to predict the behaviour of RC structures, the two beams are modelled with the finite elements software ATENA too. A 2D model, requiring minor computational effort, is used to simulate premature failure due to local phenomena associated to the construction defects. A 3D model, including accurate bond slip model for CFRP and concrete, are used for all other beams.
Proper material models are used for CFRP strips, existing concrete, new concrete, steel rebars, and appropriate bond laws are used for new or existing steel reinforcement.
The numerical results show that the proposed beam models reproduce well the experimental results not affected by local phenomena while further efforts should be made to improve the numerical approach in terms of beam stiffness.

References

[1] IMPERATORE S., LAVORATO D., NUTI C., SANTINI S. and SGUERRI, L., "Shear performance of existing reinforced concrete T-beams strengthened with FRP", *CICE 2012 - Conference on Composites in Civil Engineering*, Rome, 13th - 15th June 2012.

[2] CERVENKA V., JENDELE L. and CERVENKA, J., *ATENA Program Documentation, Part 1 – Theory*, Cervenka Consulting, Prague, 2007.

[3] IMPERATORE S., LAVORATO D., NUTI C., SANTINI S. and SGUERRI, L., "Numerical modeling of existing r.c. beams strengthened in shear with FRP U-sheets", *CICE 2012 - Conference on Composites in Civil Engineering*, Rome, 13th - 15th June 2012.