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Abstract

Traditional materials (steel, concrete, timber and masonry) still dominate the building industry. However new materials are constantly being explored by engineers and scientists due to their numerous advantages offered.

With the acronym FRP (Fibre Reinforced Polymers) we indicate a family of composite materials obtained by coupling a polymeric matrix and fibres. More specifically, high strength fibres (glass, carbon, aramid or ultra-thin steel wires) provide strength and stiffness while the resin (polyester, vinylester or epoxy) protects the fibres and guarantees the stress transfer between them. As a result, enhanced final properties are obtained with respect to those exhibited by the individual constituents.

Nowadays composite materials are widely used for the strengthening and repair of civil structures. This is due to their advantages such as light-weight, good mechanical properties and corrosion-resistance.

Composite materials are also appropriate for applications where the aesthetic preservation of the original structure is required (buildings of historic or artistic interest) or where traditional strengthening techniques cannot be effectively employed.

Composite materials are available in several geometries types ranging from laminates with regular surfaces to bi-directional fabrics that are easily adaptable to the shape of the member being strengthened.

The evolution and the study of these materials has also encouraged their use not only as structural reinforcements, but also as main structural elements made of pultruded profiles.

Within this context, glass fibre-reinforced polymers (GFRPs) are usually considered, due to the best match between expected costs and benefits.

Thick-walled tubular composite profiles with annular cross-section are focused in this study. They represent an optimal solution for a number of applications (large truss covers, large bridge decks or spatial frames) where the structural members are connected to standard co-axial nodal device by means adhesive bonding thus represent a standard, reliable, easy to make system for on site assembling modality.

Many factors affect the adhesive interface behavior at the ends of the tubular profile, the constitutive properties of device (metal, composite) and the tube, the type of the glue, the length and thickness of the bonding region and the loading path considered.

An useful approach for modelling the mechanical response of the adhesive interface refers to the cohesive fracture mechanics. In this view, the interfacial interactions come from appropriate potentials thus allowing a simple mathematical formulation of the bonding problem.

In the present study a parametric-numerical analysis has been carried out in order to investigate the strains and stresses within the tube (loaded in traction) accounting for the interfacial interactions distribution. Moreover, the maximum load provoking the adhesive failure is evaluated. In this view, a mechanical model based on an appropriate kinematics has been proposed in combination with a mixed mode cohesive failure criterion. The aim is to predict both the structural response at the service conditions and the ultimate strength of the joint allowing a refined structural analysis of the whole structure and accounting for the local shear strains too.

Moreover, the equations of motion are obtained, useful for investigating the dynamic response of tubular composite elements.

Finally, two experimental investigations were presented, concerning the characterization of the cohesive interfaces of GFRP / GFRP or GFRP / steel joints.

The work thesis has been focused on the study and analysis of adhesive joints made by means of tubular elements in fiber-reinforced composite material coaxially connected through nodal devices.

A brief review of the most significant civil structures made entirely or predominantly of composite material was firstly offered, in one with an overview of both national and international standards that manage the design and execution. Therefore, the possibility of modeling the behavior of adhesive joints with approaches related to the mechanics of cohesive fracture was presented, due to special formulations in mode I, mode II and mixed mode, which also include the "rate-dependent" behavior.
In this regard, a mechanical model based on appropriate kinematic hypotheses has been proposed for the study of composite profiles with annular cross section, which allows to examine also the cases in which the thickness of the tubular profile is "not thin", with consequent importance of the effects of the shear strains. As for the adhesive interface, a cohesive model with exponential law has been considered that includes the possibility of coupling normal and tangential displacements.

Several numerical analyses have been carried out in order to highlight the importance of shear strain that arise in the thickness profile.

As an extension of the static case, the free extensional vibrations of a tubular profile made of composite material connected to a cohesive substrate were investigated. Reference was made to a bilinear (elastic-softening) cohesive law and dispersion curves were obtained. Preliminary numerical analyses have been carried out which have shown how the shear modulus and the stiffness parameter of the joint influences the dynamic response.

Lastly the residual stiffness of the connection was investigated at the end of a cyclic loading by means of experimental tests on adhesive joints. It is useful for characterizing the residual mechanical parameters in the failure conditions (residual stiffness in the failure conditions).