RESPONSE OF NSM CFRP RODS STRENGTHENED CONCRETE BEAMS INCLUDING SERVICEABILITY STATE

Firas Al-Mahmoud (1)*, Arnaud Castel (2), Amjad KREIT (2) and Raoul François (2)

(1) Institut Jean Lamour, Dpt CP2S, Equipe Matériaux pour le Génie Civil, Nancy Université, UMR 7198, IUT de Nancy-Brabois, CS 90137, F54601 Villers-lès-Nancy Cedex, France
E-mail: firas.almahmoud@iutnb.uhp-nancy.fr

(2) Université de Toulouse UPS, INSA; L.M.D.C (Laboratoire Matériaux et Durabilité des Constructions), 31077 Toulouse, France
E-mail: (castel, francois)@insa-toulouse.fr

*corresponding author: Fax: (0033) 3 83 68 25 32 Tel: (0033) 3 83 68 25 30 E-mail: firas.almahmoud@iutnb.uhp-nancy.fr

Keywords: FRP rods, NSM reinforcement, service loading, non-linear Macro-Finite-Element, tension stiffening

Summary
Under-performing structures are usually strengthened by Fibre-Reinforced Polymer (FRP) sheets or plates bonded on the external surface. This type of strengthening may be difficult or impossible to implement for some structures or parts of structures, e.g. cantilever parts subjected to particular kinds of environmental attacks or structures that present corrosion cracks.
For these particular cases, it is possible to envisage strengthening the structure by embedding a composite rod in a pre-sawn groove in the concrete cover. Known as NSM (Near Surface Mounted reinforcement), this technique has attracted extensive research in recent years. Although this technique seems to be relatively simple from a technological point of view, several points remain to be clarified, because we are dealing with a multiple-material structure (concrete, steel, FRP composite and filling material). On the one hand, the association of concrete, FRP composite and filling material makes the bond mechanism more complex to apprehend because there are two interfaces concerned: between the FRP composite and filling material and between filling material and the old concrete. On the other hand, the behaviour of the strengthened structures is more complex than that of the reinforced concrete structures because the failure modes can be different, as can the prediction of displacements in service. The serviceability of CFRP strengthened concrete, and particularly the deflection of structural members, needs to be analysed before and after cracking and, in the post-cracking phase, should take into account the tension stiffening effect of the concrete due to the bond between reinforcing bars and CFRP rods and the concrete.
The model proposed in this paper calculates the deflection of CFRP strengthened beams. Here, beams are strengthened before being loaded, so in an uncracked state. The calculation before cracking uses conventional existing models. The originality of the model lies mostly in the calculation of CFRP strengthened beam deflection after cracking. The calculation of
deflection after cracking is based on a Macro-Finite-Element (M.F.E.). This M.F.E., initially developed for reinforced concrete structures, is extended to the case of CFRP strengthened concrete structures in this paper. It is a BEAM Finite Element characterised mainly (for bending problems) by its homogeneous average inertia. In a cracked cross-section, the propagation of flexural cracks versus loading and the resulting increase in stress in the reinforcing bars and the CFRP rods are calculated. The average inertia of the M.F.E. is then deduced, including the tension stiffening effect resulting from the tension load transfer between the conventional reinforcing steel bars and the CFRP rods and the concrete between two cracks, which greatly enhances the bending stiffness of the beams. Finally, M.F.E.s are used in an elastic structural analysis to calculate the deflection.

The ultimate loading moment is calculated considering a conventional failure mode of the beams. The model is validated experimentally on two CFRP strengthened concrete beams with two sections of CFRP rods subjected to four-point-flexure under repeated loading cycles after cracking and then a constant loading rate until failure.