Journal of Constructional Steel Research 100 (2014) 108–121

Contents lists available at ScienceDirect

Journal of Constructional Steel Research

Non-linear models for steel–concrete epoxy-bonded beams

B. Jurkiewiez *, C. Meaud [1], E. Ferrier [1]

Université de Lyon, Université Lyon 1, LGCIE, 82 Boulevard Niels Bohr, F-69622 Villeurbanne cedex, France

ARTICLE INFO

Article history:
Received 4 April 2013
Accepted 2 April 2014
Available online 8 May 2014

Keywords:
Steel–concrete composite beam
Bonding
Bending test
Non-linear models

ABSTRACT

The main objective of this article is to propose and validate two non-linear models suited for steel–concrete epoxy-bonded composite beams: the first is a multi-layered beam model, and the second uses a finite element model (FEM). We first completed experimental data available in the literature for test results on a steel–concrete beam. In this study, the slab consisted of both a precast part and a part that had been cast in-situ. The test results indicate that a beam fabricated in this way behaves similarly to beams made of steel–concrete with studs and significant ductility. The results from the proposed models were later compared to the aforementioned tests results, as well as to the measurements of four other steel–concrete epoxy-bonded composite beams discussed in the literature that were made from different materials and were constructed using varying methods. For all five beams, both models provided numerical results close to the measurements for the failure load and failure mode, deflection and strain. The state of stress and the damage were analysed, and these results also support the observed results. In particular, these findings show that the shear stress along the bonding joint is neither uniform within the width of the concrete slab nor constant along the span.

1. Introduction

Bonding precast concrete slabs is one possible method for fabricating steel–concrete composite structures [1–4]. The slabs are concreted in a factory, which decreases cost and increases quality. Moreover, concrete shrinkage is unrestricted before bonding, which reduces the cracking that occurs at an early age, thereby increasing the durability of the final product. In the case of bridges, bonding connection simplifies and accelerates construction, as heavy and expensive self-launching formwork may be avoided.

In previous studies [5–7], it was shown that a bonding connection is compatible with the prefabrication of a slab over its entire thickness. In the first part of this article, we intend to demonstrate, from an experimental standpoint, that a bonding connection is also possible if a slab is built in two phases: a pre-slab is first bonded onto the steel girder, and the compression slab is subsequently concreted. The testing device and measurement methods are also presented in this report.

The second part of the paper is devoted to the modelling of steel–concrete bonded beams. The non-linear behaviour of the constitutive materials is accounted for either within the thin multi-layered beam theory (generalised variables) or solid FEM (local variables). The numerical results are compared with the measurements presented in the first part of the paper but also with experimental data available in the literature and obtained for other steel–concrete bonded composite beams, which were made of different concrete types and fabricated using various methods. Both proposed models characterise the state of stress and the damage in the concrete slab, and in the final section, the results are discussed.

2. The experimental study

2.1. Geometry and reinforcements

The beam designated AB3 was composed of an IPE 160 S275 steel girder and a 400 × 80 mm^2 concrete slab. The slab consisted of 5 pre-slabs, each with a length of 875 mm, reinforced with ST35 S500 welded wire mesh and a compression slab (see Fig. 1). The beam had a span of 4 m and was tested using a 3-point bending scheme.

2.2. Material properties

Tensile tests were conducted according to the ISO 527-2 standard on 6 coupons cut from an IPE 220 S275 steel beam: 3 in the web and 3 in the flange. The results indicate that the failure strength was approximately 441 ± 9 MPa for all of the samples. However, the linear elastic limit strain was approximately 1.6 ± 0.1‰ in the web and 2.4 ± 0.7‰ in the flange. The yield strength was also slightly different: 289 ± 13 MPa in the flange and 304 ± 12 MPa in the web.

---

* Corresponding author. Tel.: +33 472692130; fax: +33 478946906.
E-mail addresses: bruno.jurkiewiez@univ-lyon1.fr (B. Jurkiewiez), charlottemeaud@gmail.com (C. Meaud), emmanuel.ferrier@univ-lyon1.fr (E. Ferrier).

[1] Tel.: +33 472692130; fax: +33 478946906.

http://dx.doi.org/10.1016/j.jcsr.2014.04.005
0143-974X/

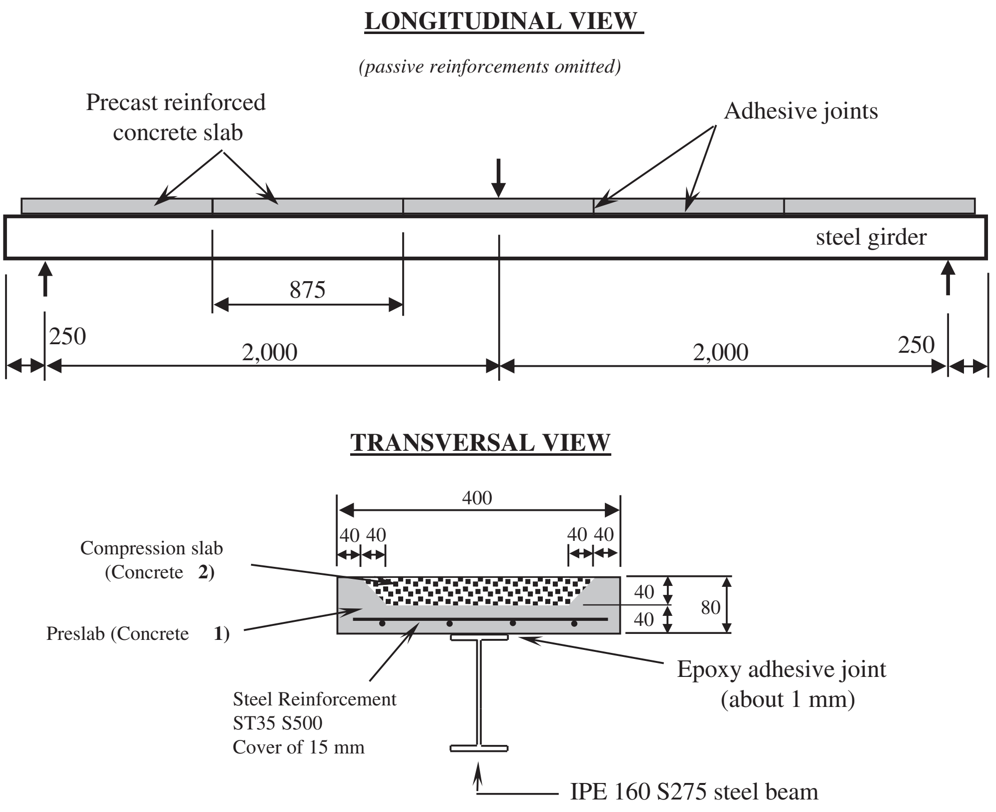

Fig. 1. Beam geometry and reinforcements [in mm] (AB3).

Table 1
Concrete properties.

		Preslab	Compression slab
28 days	fc (MPa)	38.8 ± 1.7	30.4 ± 1.6
	f_t (MPa)	2.8 ± 0.1	2.0 ± 0.2
Bending test day	Age (days)	60	28
	f (MPa)	42.7 ± 3.0	30.4 ± 1.6
	f (MPa)	2.9 ± 0.2	2.0 ± 0.2

f_c: compression strength (NF P18-406).
f_t: tensile strength (NF P18-408).

The adhesive used for all of the beams was epoxy mixed with silica (SIKADUR 30). Tensile tests were performed on 5 coupons according to the NFT 17-301 standard. The results showed that the resin exhibited high strength but was brittle. The failure stress, the secant elastic modulus and the ultimate strain were approximately 25.4 ± 7.4 MPa, 11,760 ± 1374 MPa and 2.2 ± 0.7‰, respectively.

The concrete used for the pre-slabs and the compression slab was a C25/30 WEBER concrete with a maximum aggregate size of

Fig. 2. Phases of construction (AB3).