Engineering Structures 33 (2011) 1302–1315

Contents lists available at ScienceDirect

Engineering Structures

journal homepage: www.elsevier.com/locate/engstruct

Shrinkage effects on the flexural stiffness of composite beams with solid concrete slabs: An experimental study

Safat Al-deen [a], Gianluca Ranzi [a,*], Zora Vrcelj [b]

[a] *School of Civil Engineering, The University of Sydney, Sydney NSW 2006, Australia*

[b] *School of Civil and Environmental Engineering, The University of New South Wales, Sydney NSW, Australia*

ARTICLE INFO

Article history:
Received 25 May 2010
Received in revised form
31 December 2010
Accepted 6 January 2011
Available online 15 February 2011

Keywords:
Composite steel-concrete beams
Creep
Shrinkage
Partial shear interaction
Partial shear connection

ABSTRACT

This paper describes the testing of three full-scale simply-supported composite steel-concrete beams. The specimens were representative of a typical secondary beam used in composite flooring systems and were designed in accordance with Australian guidelines with a degree of shear connection equal to 0.5. Two beams were cast unpropped while the third was prepared under propped conditions. The beams were loaded to failure 18 months from concrete casting by a point load applied at mid-span. During this period the specimens were monitored to collect information on their time-dependent behaviour. Extensive data was measured during the ultimate tests, i.e. deflection at quarter points, slip and strain readings. Standard coupon and cylinder tests provided the instantaneous material properties of the materials. Push-out tests were performed to obtain information on the response of the shear connectors. The measured ultimate strengths of the beams were greater than those calculated based on rigid-plastic analysis using the actual properties obtained from standard material tests. Although this information is very useful for the calibration of theoretical models and design recommendations, the main contribution of this paper is the recognition of the detrimental effects at service conditions of shrinkage in composite members incorporating a solid slab. This shrinkage was observed to cause the composite flexural stiffness to degenerate to the value calculated with no shear interaction for a certain range of loading.

1. Introduction

Composite steel–concrete beams are extensively used for building and bridge applications. They consist of a T-beam formed by a reinforced concrete slab, a steel joist and mechanical shear connectors between them. The popularity of this form of construction is related to its ability to combine well the advantages of both steel and concrete. Composite beams exhibit enhanced strength and stiffness when compared to the contribution of the slab and joist considered separately.

When a beam is subjected to external loading, the deformability of the connectors leads to relative movement between the slab and the joist, denoted as interface slip. This behaviour is referred to as partial shear interaction and its importance in predicting the composite response was originally pointed out in [1]. This formulation is usually referred to as the Newmark model. Its main assumptions require that no vertical separation occurs between slab and joist, and plane sections remain plane except for the discontinuity at the connection interface. Many researchers have further extended the Newmark model in the last few decades to account for the time-dependent behaviour of the concrete, material nonlinearities and geometric effects (e.g. [2–39]). Experimental work has focussed on either the service response (e.g. [40–45]) or the ultimate behaviour (e.g. [46–54]), while, to the knowledge of the authors, no studies have concatenated the service and ultimate tests. It is beyond the scope of this paper to provide a review of the current state of the art; useful reviews were presented in [55,56].

This paper presents the results of a set of experiments aimed at evaluating how time effects of the concrete influence the ultimate capacities of three full-scale composite beams. These specimens were tested to failure after 18 months from casting. During this period, the time-dependent behaviour of these beams was monitored to gain information on the effects of creep and shrinkage and the results of this long-term study are reported in [57]. The ultimate tests took place after the completion of the long-term experiments.

The initial part of this paper reports the ultimate tests carried out on the three 8 m long beams. These specimens were designed in accordance with Australian guidelines [58] with a degree of shear connection of 0.5, reflecting modern composite trends. Because of this, the dimensions and steel section are representative of a realistic secondary beam in a typical Australian floor system.

* Corresponding author. Tel.: +61 2 9351 5215; fax: +61 2 9351 3343.
E-mail address: gianluca.ranzi@sydney.edu.au (G. Ranzi).

0141-0296/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.engstruct.2011.01.007