Engineering Structures 33 (2011) 2870–2878

Contents lists available at ScienceDirect

Engineering Structures

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

Enhancing the fire resistance of composite floor assemblies through the use of steel fiber reinforced concrete

Rustin Fike, Venkatesh Kodur *

Department of Civil and Environmental Engineering at Michigan State University, 3580 EB, East Lansing, United States

ARTICLE INFO

Article history:
Received 22 April 2010
Received in revised form
3 June 2011
Accepted 6 June 2011
Available online 12 July 2011

Keywords:
Steel fiber reinforced concrete (SFRC)
Tensile membrane action
Beam–slab assembly
Steel frames
Fire resistance
Fire protection

ABSTRACT

This paper presents a strategy for achieving the required fire resistance in composite floor systems through the use of steel fiber reinforced concrete (SFRC). Both experimental and numerical studies were carried out to evaluate the fire performance of floor systems comprising unprotected steel beams and concrete/SFRC deck slabs. The results from these studies show that SFRC composite deck slabs develop significant tensile forces (through tensile membrane action) that transfer load from fire-weakened steel beams to other cooler parts of the structure. Preliminary results indicate that the combined effect of composite construction, tensile membrane action, and the improved properties of SFRC under realistic fire, loading, and restraint conditions can provide sufficient fire resistance in steel beam–concrete deck slabs without the need for external fire protection on the floor assembly.

1. Introduction

Steel offers many advantages when used as a primary structural framing material in buildings. These advantages include high ductility, ease of fabrication, and speed of construction. However, like all building materials, steel loses strength and stiffness when exposed to fire, and hence, steel structures are required to be provided with appropriate fire protection measures to maintain structural stability and integrity in the event of fire. A series of fire incidents in high-rise buildings, such as that at One Meridian Plaza [1] and the Broadgate Phase 8 fire [2] (UK), in which steel-framed structures did not collapse even under extreme fire conditions, prompted researchers to study the performance of steel-framed structures under realistic loading, fire, and restraint conditions, and to explore the possibility of unprotected steel structures. The culmination of this was a series of fire tests on a full-scale steel-framed building built at the Cardington large building test facility in the UK, collectively known as the Cardington tests.

Results from Cardington fire tests offer considerable insight into the response of a real steel-framed building under realistic fire exposure conditions. Of the seven fire tests conducted at Cardington, the tests that have the greatest implications to the research presented here are the "restrained beam" test, "plane frame" test, "corner" test, and "demonstration" test. The primary observation from these tests is that the steel-framed structure (which incorporated unprotected steel beams) did not collapse under fire exposure despite steel temperatures exceeding 900 °C [3,4]. During fire exposure, the composite floor system used in the Cardington test building underwent large deflections (more than 640 mm) but still supported the load and survived burnout conditions. Though the steel beams lost most of their strength due to extreme temperatures, loads from the beams were transferred through the concrete slab via tensile membrane action. Following the Cardington tests, many researchers initiated research programs to study various aspects of composite construction and their contribution to fire resistance. The early experimental studies were reported in [5–7].

Bailey et al. [5] investigated the possible failure patterns in concrete floors experiencing tensile membrane action under fire conditions. The research was based on the premise that an unprotected ribbed steel deck supporting a concrete slab offers no contribution to strength due to the high temperatures (in the region of 900 °C) rapidly achieved in the steel decking. Based on this assumption, Bailey et al. [5] removed the steel deck from the bottom of a series of floor slabs and loaded them to failure at ambient temperature. Using these tests as the basis, Bailey et al. [5] concluded that the failure load of a slab experiencing tensile membrane action is well above that predicted using typical yield line theory. Based on this experimental work and the work of Hayes [8], Bailey [9] developed an equilibrium-based method for predicting the ambient temperature load capacity of a slab without the supporting metal deck.

* Corresponding author. Tel.: +1 517 353 9813.
E-mail address: Kodur@egr.msu.edu (V. Kodur).

0141-0296/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.engstruct.2011.06.011