

Fire Resistance of Composite Beams with Profiled Steel Decking

Author: Kevin Cowie
 Affiliation: Steel Construction New Zealand Inc.
 Date: 23rd August 2011
 Ref.: FIR1003

This article was first published in HERA Design and Construction Bulletin 12 (Clifton, 1995). Revisions have been made to the article to be consistent with current standards.

Key Words

Fire resistance, composite beams, metal deck, trapezoidal deck, voids

Introduction

When a composite beam is constructed using a profiled steel deck, a void is created between the deck and the top flange of the beam. With open trapezoidal steel decks this void is comparatively large while with a 'closed dovetail' deck the void is much smaller. In the case of the open trapezoidal deck the fire resistance of the composite beam may be reduced because of the effects of additional heat entering the steel beam through the top surface of the flange. This article presents the background to determining the fire resistance of composite beams with profiled steel decking and recommendations for how to modify fire protection of beams supporting steel decking where voids occur.

Background

When a structural steel member must achieve a specified Fire Resistance Rating (FRR), calculation of the member's Period of Structural Adequacy (PSA) is typically undertaken in accordance with NZS 3404 (SNZ, 2007) Section 11. The PSA must equal or exceed the specified FRR. If the FRR is such that some kind of passive fire protection must be applied to the member, then calculation of the PSA is typically undertaken to Clause 11.7. This clause specifies a general method for determining the amount of passive fire protection material required for a given limiting steel temperature and Section Factor. The clause has been written to "tap into" the performance of a given fire protection system determined by the Standard Fire Test applied in accordance with the Australian (SA, 2005) and British standards (BS, 1987), all of which are recognised by the New Zealand Approved Documents for Fire Safety (DBH, 2010).

For intumescent paints, the limiting steel temperature is taken as 620°C. For board, sprayed, blanket or similar insulation materials having a dry density less than 1000 kg/m³, the Australian testing regime is more comprehensive than the British testing regime, and allows the results to be applied for a limiting steel temperature range that can be as wide as 500°C to 750°C, depending on the range of testing undertaken. Both testing regimes use the same standard fire test time-temperature curve and furnace set-up, however the British regime requires a narrower range of testing, based on establishing the performance of the system at a limiting steel temperature of 550°C for board or spray materials and 620°C for intumescent paints.

It is important to give this background in setting the scene for the rest of this article, which presents the results of a study undertaken (under the British testing regime) by the UK Steel Construction Institute into the fire resistance of composite steel beams. These beams involve a concrete slab cast on profiled steel decking and sitting on the top flange of a supporting steel beam. This is the most common composite beam configuration. The study looked at the difference in fire resistance of composite (and non-composite) steel beams obtained by either filling or leaving unfilled the voids above the top flange caused by the ribs of the profiled decking.

Fig. 11.9(b) of NZS 3404 shows an example of a dovetail deck profile with the voids filled (blocked); the SCI study investigated both dovetail and trapezoidal profiles.

When the voids of a trapezoidal profile are unfilled, significant extra heat can reach the top flange of the steel beam compared with the voids filled situation. This causes the top flange to increase in temperature in the standard fire test (and in natural fires) more rapidly than the fully protected bottom flange. In a non-composite

Disclaimer: SCNZ and the author(s) of this document make no warrantee, guarantee or representation in connection with this document and shall not be held liable or responsible for any loss or damage resulting from the use of this document

beam, both flanges contribute equally to the resisting moment and so the PSA is significantly reduced. In a composite beam under inelastic fire induced conditions, the top flange is typically near the plastic neutral axis and so contributes little to the composite section moment capacity. Its more rapid temperature rise when the voids are unfilled therefore has little reducing effect on the PSA for composite members.

The SCI study looked at establishing guidelines for applying voids filled test results to a voids unfilled situation, by increasing the amount of passive fire protection material applied to the remainder of the steel section.

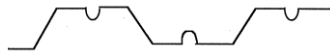
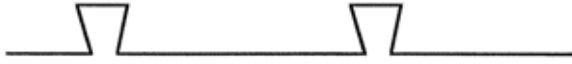
A full description of the tests undertaken and design recommendations obtained are presented in the SCI Technical Publication 109 (Newman, 1991).

Recommendations

The SCI recommendations are for application under the British testing regime, which uses a limiting temperature of 550°C for board or spray applied materials. This is expanded for application in New Zealand, by (Clifton, 1995), to give appropriate advice for applications under NZS 3404 which use a calculated limiting temperature from NZS 3404 Clause 11.5 that is higher than 550°C and which then takes advantage of this higher limiting temperature, through application of Reference 11.2 from NZS 3404:Part 2. The limiting steel temperature from (Clifton, 1995) has been modified to reflect the latest Loadings standard coefficients. A summary of the recommendations is presented in Table 1.

The effect of voids, due to trapezoidal decks, is to reduce the limiting temperature. The extent of this reduction is given in section 2.3 of (ASFP, 2010).

Table 1: Recommendation for voids for composite and non-composite beams supporting profiled steel decking

Trapezoidal Deck				
Construction	Fire Protection on Beam	Fire Resistance (minutes)		
		Up to 60	90	Over 90
Composite Beams	BOARD or SPRAY (Assessed for limiting steel temperature ⁽²⁾ of below 553°C)	No increase in thickness ⁽¹⁾	Increase thickness ⁽¹⁾ by 10% (or use thickness ⁽¹⁾ appropriate to beam $hp/A + 15\%$ whichever is less)	Fill voids
	BOARD or SPRAY (Limiting steel temperature ⁽²⁾ of above 553°C)	Fill voids or use unfilled void test results ⁽³⁾	Fill voids or use unfilled void test results ⁽³⁾	Fill voids
	INTUMESCENT (Assessed at 620°C ⁽⁴⁾)	Increase thickness ⁽¹⁾ by 20% (or use thickness ⁽¹⁾ appropriate to beam $hp/A + 30\%$ whichever is less)	Increase thickness ⁽¹⁾ by 30% (or use thickness ⁽¹⁾ appropriate to beam $hp/A + 50\%$ whichever is less)	Fill voids
Non-Composite Beams	All types	Fill voids		
Dovetail Deck				
Construction	Fire Protection on Beam	Fire Resistance (minutes)		
		Up to 60	90	Over 90
Composite or Non-Composite Beams	All types, up to a limiting temperature of 650°C ^(2,5)	Voids may be left unfilled for all fire resistance periods		

Notes:

1. Thickness is the board, spray or intumescent thickness given for 30, 60 or 90 minutes rating in *Fire Protection for Structural Steel in Buildings* (see Reference 11.19 in NZS 3404:Part 2).
2. Limiting steel temperature is as calculated from NZS 3404 Clause 11.5, or, if applying the results from Reference 11.19 - see note 1 above - is taken as 550°C.
3. This is in accordance with NZS 3404 Clause 11.9(b).
4. This is in accordance with the NOTE to NZS 3404 Clause 11.7.3.2(a).
5. For sections with a limiting steel temperature above 650°C - see note 2 above - use unfilled void test results in accordance with NZS 3404 Clause 11.9(b).

References

ASFP, Fire Protection for Structural Steel in Buildings, 4th Edition, ASFP, www.asfp.org.uk

BS, Fire tests on building materials and structures, BS 476 Parts 20-23, British Standards, 1987

Clifton, G. C., HERA Steel Design & Construction Bulletin No. 12, HERA, Manukau City, 1995

DBH, Compliance Document for New Zealand Building Code Clauses C1, C2, C3, C4 Fire Safety, Department of Building and Housing, 2010

Newman, G.M.; Fire Resistance of Composite Beams; SCI Technical Publication 109, The Steel Construction Institute, Ascot, England, 1991,

SA, AS 1530.4-2005 Methods for fire tests on building materials, components and structures - Fire-resistance test of elements of construction, Standards Australia, Sydney, 2005

SNZ, Steel Structures Standard (Incorporating Amendments 1 and 2), NZS 3404:1997, Standards New Zealand, Wellington, 2007