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Hollowcore Flooring in Composite Steel

Introduction

This article presents the design procedures for the use of precast hollowcore slabs in steelconcrete composite construction. The paper also summarises the recent and on-going work on the transfer of this knowledge into the Australian construction industry. Whilst it is common practice to use precast concrete planks in Australian building construction, the benefits of composite behaviour with steel beams have not yet been fully realised with these systems, (National Precast Concrete

Association of Australia, 2003). The use of precast hollowcore slabs in steel composite construction has seen rapid growth in popularity since it was first developed in the 1990s. The main advantages of this form of construction are that precast hollowcore slabs can span up to 15 metres without propping. The erection of 1.2 metre wide precast concrete units is simple and quick, shear studs can be pre-welded on beams before delivery to site thereby offering the savings associated with shorter construction times.

Summary of design considerations

Generally a maximum of 250 mm deep units, including any topping is used although tests have been conducted up to 300mm depth units. Full scale tests on 400 mm deep units are planned.

- Shear connectors are generally 100mm x 19mm diameter headed studs. The use of other shear connectors are possible, but horizontal push tests Lam & Uy (2003) must be conducted to obtain the shear capacity of the shear connectors. For deeper units, 125mm height studs are recommended.

- The minimum effective width of approximately 1.05m (1.0 m + the gap between the units) of compression width for internal beams can be assumed in design, more accurately, the effective width can be calculated using the formula proposed by Lam (2005).

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- The minimum beam flange width used inthe UK is 140mm for construction purposeswhile a minimum beam flange width of 180mm is required for the Australian practice. (National Precast ConcreteAssociation of Australia, 2003)
- The transverse reinforcement required forbeam / unit interaction is recommended as N16 at 300mm centres to enable sufficient slip capacity for the shear connectors inpartial interaction.
- The shear connector strength is related to the interaction of the concrete strength andproperties, the geometry of the unit andtransverse reinforcement.
- Research is currently being conducted at the University of Wollongong to consider the shear connection issues for typical Australian profiles.

Design procedures

Extensive research and design provisions have been carried out in the UK and this has resulted in the development of a joint industry (Precast Flooring Federation – Steel Construction Institute) design document being developed (Hicks and Lawson, 2003). This section presents the salient points relating to strength provisions in this document. Furthermore, suggestions on how these provisions may be used in light of Australian codes of practice are given here in:

1. Calculate effective width of hollowcore slabs:

Lam (2005) proposed the effective width for composite beam with precast panels as

(1)

$$b_{eff} = \frac{\sqrt{f_{ck,i}}}{35} \times \frac{32\phi_r}{500} \times \frac{f_{sd}}{460} \times 1000 + 2.5g$$

where,
Fck,i is the in-situ infill concrete cylinder strength in MPa.

Φr is the diameter of the transverse reinforcement in mm.

fsd is the characteristic strength of the transverse reinforcement in N/mm2.

g is the gap between the precast units in mm.

The effective width, beff of the concrete flange for positive bending in AS2327.1 – 2003 for a solid slab in a beam for a regular floor system is determined as the minimum of the following

(2)

$$b_{eff} = min.\left(\frac{L_{ef}}{4}, b, b_{sf} + 16D_c\right)$$

where,
Lef is the effective span, b is the spanning distance between consecutive beams, bsf is the steel flange width and Dc is the concrete slab depth. The effective width determined from Equation 1 however can not exceed that determined from Equation 2.

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2. Calculate the shear connectors' capacity:

The design shear resistance of an automatically welded headed stud with a normal weld collar using the Eurocode 4 (British Standards Institution, 1994) approach should be determined from:

(3)

$$P_{RD} = 0.8 f_u (\pi d^2 / 4)$$

or

(4)

$$P_{RD} = 0.29 \alpha \beta \varepsilon d^2 \sqrt{\omega f_{cp} E_{cp}}$$

whichever is smaller,

where

d = is the diameter of the shank of the stud;

fu = is the specified ultimate tensile strength of the material of the stud but not greater than 500 N/mm2;

= 0.2[(h/d) + 1] for 3 ≤ h/d ≤ 4 or

= 1.0 for h/d > 4;

= a factor which takes into account the gap width g (mm) and is given as 0.5 (g/70 + 1) ≤ 1.0, and g ≥ 30 mm;

e = a factor which takes into account the diameter f of transverse high tensile tie steel (N500) and is given by 0.5 (Φ/20 + 1) ≤ 1.0, and f ≥ 8 mm;

w = transverse joint factor = 0.5(w/600 +1), w = width of hollow core unit

fcp = average concrete cylinder strength of the in-situ and precast concrete in MPa;

Ecp= average value of elastic modulus of the in-situ and precast concrete.

Thus, expressions for the shear capacity for an individual shear stud used in Australian construction (Standards Australia, 2003) could be augmented to account for the reductions in capacity experienced in hollowcore units and thus could be expressed as the lesser of fvs in Equations 5 and 6 as outlined by Uy and Bradford (2005).

(5)

$$f_{vs} = 0.63 d_{bs}^{2} f_{uc}$$

(6)

$$f_{vs} = 0.31 d_{bs}^{2} \beta \varepsilon \sqrt{\omega f'_{cj} E_c}$$

where dbs is the diameter of the shear stud, fuc is the ultimate tensile strength of the stud, f'cj and Ec is the mean concrete compressive strength and modulus at the time in question and b, e and w are parameters to account for the gap, tie steel and transverse joint respectively.

3. Calculating the moment capacity of composite beam:

For composite beams with precast hollowcore slabs, similar rigid plastic theory is applied. The only limitation applied for this form of construction is that the plastic neutral axis is below the steel – concrete interface. Figure 1 shows the plastic stress distributions under sagging bending with full shear connection.

The moment resistance of the composite sections where neutral axis is within the web is given below:

(7)

$$M_{pl,Rd} = M_{pl,a} + N_{c,f}\frac{(D + D_{slab})}{2} - \frac{D}{4}\left(\frac{N_{c,f}^2}{N_{a,w}}\right)$$

Where

Mpl,a is the moment resistance of the steel section

D is the steel section depth

Dslab is the concrete slab depth

Nc,f is the compressive resistance of the concrete flange

Na,w is the resistance of the web of the steel section

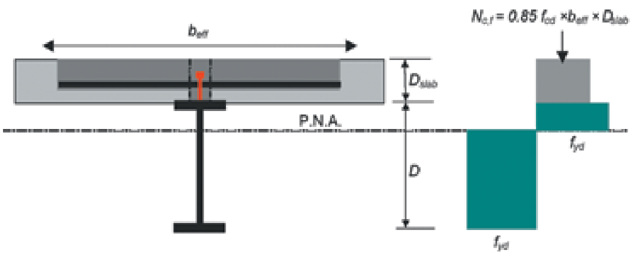

Figure 1: Plastic stress distribution under sagging moment.

Conclusions:

This article has presented the status quo for the use of hollowcore flooring in composite steel – concrete construction. Design provisions for strength have been presented as they appear in existing UK pseudo codes of practice. Research is on-going to provide for the transfer of knowledge from the UK to Australia taking account of the subtleties that exist in relation to hollowcore manufacture between the two nations.

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