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NCCI: Modified limitation on partial shear connection in beams for buildings

This NCCI gives minimum degree of shear connection rules that may be used when the characteristic slip capacity of the shear studs can be demonstrated to be significantly greater than required by BS EN 1994-1-1, 6.6.1.1(5). These rules differentiate between propped and unpropped construction.

Contents

1. General

BS EN 1994-1-1, 6.6.1.1(14)P states that for Class 1 or Class 2 cross sections, partial shear connection may be used for beams, in which case the "number of connectors shall then be determined by a partial connection theory taking into account the deformation capacity of the shear connectors".

According to BS EN 1994-1-1, 6.6.1.2(1), headed stud shear connectors within certain dimensional limits may be considered ductile within given limits for minimum degree of shear connection. Clause 6.6.1.1(5) states that ductile connectors are those which have a characteristic slip capacity of at least 6 mm and thus the limits in 6.6.1.2 are appropriate to that level of slip capacity. In addition, it is understood that the expressions in 6.6.1.2 for minimum degree of shear connection have been calibrated for beams in propped construction; such calibration ensures that the expressions are valid, if somewhat conservative, for unpropped construction.

Recent tests have shown that in some circumstances significantly higher deformation capacity (characteristic slip capacity) can be achieved. For 19 mm diameter headed stud shear connectors through deck welded into transversely oriented trapezoidal decking profiles, characteristic slip capacities in excess of 10 mm are achievable. Based on the results of those tests and a parametric study using FE analysis, additional rules for the minimum degree of shear connection have been developed, for specific geometric limits. These rules, presented in Section 2, allow a lower degree of shear connection, taking advantage of this higher deformation capacity.

In addition, as a result of further parametric studies, the effect of unpropped construction has been considered and modified rules developed. In this case, as the steel section carries most of the permanent actions before the shear connectors are loaded, there will be less deformation required of the shear connectors at the ultimate limit state for a beam constructed without props compared to an equivalent beam constructed with props. Additional rules for unpropped construction, allowing a lower degree of shear connection, are also given in Section 2.

2. Minimum degree of shear connection

2.1 General limits for unpropped construction

Where a composite beam is unpropped at the construction stage (see BS EN 1994-1-1. 1.5.2.1 for the definition of an unpropped member) and the design value of the uniformly distributed imposed load on the floor (i.e. $\gamma_Q q_k$) does not exceed 9 kN/m², the following limitation on the use of partial shear connection may be applied. (Alternatively, the more conservative limits given in BS EN 1994-1-1. 6.6.1.2 may be applied.)

Headed studs with an overall height after welding not less than 4 times the diameter and with a shank of nominal diameter not less than 16 mm and not greater than 25 mm may be considered as ductile within the following limits for the degree of shear connection, which is defined by the ratio $\eta = n/n_f$.

For steel sections with equal flanges or with an area of the top flange greater than the area of the bottom flange:

$$\eta \geq 1 - \left(\frac{355}{f_y}\right)(0.802 - 0.029L_e), \quad \eta \geq 0.4$$

For steel sections having a bottom flange with an area equal to three times the area of the top flange:

$$\eta \geq 1 - \left(\frac{355}{f_y}\right)(0.322 - 0.014L_e), \quad \eta \geq 0.4$$

Where L_e is as defined in BS EN 1994-1-1, 6.6.1.2

For steel sections having a bottom flange with an area exceeding the area of the top flange but less than three times that area, the limit for η may be determined by linear interpolation between the values given by above expressions.

2.2 Limits for beams with trapezoidal decking transverse to the supporting beams

The limits in Sections 2.2.1 and 2.2.2 apply where a composite beam comprises a steel beam interconnected with a composite slab formed by the use of trapezoidal decking with its ribs transverse to the steel beam and the shear connection is achieved with headed studs through-deck welded to the beam. Where the overall height of the studs after welding is not less than 95 mm and the shank diameter is 19 mm, the studs may be considered as ductile within the following limits for the degree of shear connection, which is defined by the ratio $\eta = n/n_f$.

The resistance of headed studs in this situation is given in PN001.

2.2.1 Limits for propped construction

Where the composite beam with transverse decking is propped at the construction stage (see BS EN 1994-1-1. 1.5.2.9 for the definition of a propped member) the minimum degree of shear connection may be taken as:

For steel sections with equal flanges:

$$\eta \geq 1 - \left(\frac{355}{f_y}\right)(1.433 - 0.054L_e), \quad \eta \geq 0.4$$

For steel sections with unequal flanges, the limits given by BS EN 1994-1-1, 6.6.1.2 should be used.

2.2.2 Limits for unpropped construction

Where the composite beam with transverse decking is unpropped at the construction stage (see BS EN 1994-1-1. 1.5.2.1 for the definition of an unpropped member) and the design value of the uniformly distributed imposed load on the floor (i.e. $\gamma_Q q_k$) does not exceed

9 kN/m², the following limitation on the use of partial shear connection may be applied. (Alternatively, the more conservative limits given in 2.1 or those in BS EN 1994-1-1. 6.6.1.2 may be applied.)

For steel sections with equal flanges or with an area of the top flange greater than the area of the bottom flange:

$$\eta \geq 1 - \left(\frac{355}{f_y}\right)(2.019 - 0.070 L_e), \quad \eta \geq 0.4$$

For steel sections having a bottom flange with an area equal to three times the area of the top flange:

$$\eta \geq 1 - \left(\frac{355}{f_y}\right)(0.434 - 0.011 L_e), \quad \eta \geq 0.4$$

For steel sections having a bottom flange with an area exceeding the area of the top flange but less than three times that area, the limit for η may be determined by linear interpolation between the values given by above expressions.

2.3 Spacing of shear connectors in beams for buildings

With respect to uniform spacing of the shear connectors, BS EN 1994-1-1, 6.6.1.3(3), the rules presented in Section 2.1, 2.2.1 and 2.2.2 may be considered to satisfy the requirements for minimum degree of shear connection in the same way as BS EN 1994-1-1, 6.6.1.2.

3. Effect of partial interaction on deflection

When the limitations on degree of shear connection given in Sections 2.1, 2.2.1 or 2.2.2 are used, the requirements of BS EN 1994-1-1, 7.3.1(4) will not be met. Therefore the effects of incomplete interaction should be considered when calculating beam deflections. The effect of partial interaction on the deflection of the composite beam may be determined as follows:

For propped construction:

$$\delta = \delta_c + 0.5(1 - \eta)(\delta_s - \delta_c)$$

For unpropped construction:

$$\delta = \delta_c + 0.3(1 - \eta)(\delta_s - \delta_c)$$

where:

δ_s is the deflection for the steel beam acting alone

δ_c is the deflection of a composite beam with full shear connection for the same loading.

Creep and shrinkage may be accounted for by using an appropriate value of modular ratio, in accordance with BS EN 1994-1-1, 5.4.2.2(11).

4. Commentary

There is no upper limit to the degree of shear connection. In long-span beams, the central shear connectors do not develop their full resistance before the outermost shear connectors exceed their ductility limit. This means that the above equations may predict degrees of shear connection greater than 100%, which means a greater number of shear connectors are required to achieve full shear connection in practice. This number of connectors should be used.

This NCCI may be used in conjunction with PN001 Resistance of headed stud shear connectors in transverse sheeting.

For construction to be categorised as unpropped the steel beams must support the self-weight of the wet concrete and other construction loads. Where the steel decking is propped off temporary staging supported on the steel beams the construction may also be considered to be unpropped for the purposes of this NCCI. However, where propping to the steel decking or steel beams allows construction loads to be directed via alternative load paths, the shear connection rules for propped construction must be applied.

This document also supersedes the guidance given in SCI advisory desk notes AD148 and AD266 insofar as these relate to the minimum degree of shear connection rules given by BS EN 1994-1-1. Whilst the benefits of reduced beam utilisation, as covered in AD148, still exist, their application to the rules given in this NCCI is a subject for further research.

The minimum degree of shear connection rules in Section 2 have been developed from a parametric study of finite element models covering a range of typical composite beams using shear connector properties developed from push tests. These models have been calibrated against the results of full-scale beam tests, and have been used to confirm the validity of the existing rules in BS EN 1994-1-1, 6.6.1.2 as well as to develop the extended rules.

5. References

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Quality Record

RESOURCE TITLE	NCCI: Modified limitation on partial shear connection in beams for buildings		
Reference(s)			
ORIGINAL DOCUMENT			
	Name	**Company**	**Date**
Created by	Andy Smith	The Steel Construction Institute	23/10/09
Technical content checked by	Ian Simms	The Steel Construction Institute	12/1/10
Editorial content checked by	David Iles	The Steel Construction Institute	13/1/10
Technical content endorsed by:	Graham Couchman	The Steel Construction Institute	27/1/10