AD 477: Transverse bending of composite slabs subjected to point loads

AD note 450[1] provides guidance on the design of composite slabs subjected to concentrated point loads. The present AD note provides further guidance on the topic. The method to calculate the applied transverse bending moment proposed by AD 450 is a simple approach[2]. The first reference to such a method may be traced back to 1994[3], where the author acknowledges that the method is conservative. The present note proposes a more sophisticated approach, as a supplement rather than a replacement for the approach in AD 450. This more advanced approach is particularly relevant for the UK market, where typically we rely on a single layer of reinforcement with a minimal cover to the top surface of the slab, for which the simplified method proposed by AD note 450 may result in an onerous requirement for the area of reinforcement required to resist transverse bending. Two layers of reinforcement, or a single layer placed lower in the slab, are typical in most other European countries. As we are seeing more use of deeper slabs in the UK, adding a second layer may be a sensible option.

Despite the fact that high point loads on completed composite slabs are normally only found in particular cases (such as a car park), during the construction stage of a building they are much more common, as the slabs may be required to resist high point loads due to temporary equipment such as mobile elevating work platforms (MEWPs). However, the coincident load level on the slab under such conditions is relatively low (self-weight of the slab, live load due to the construction stage and the equipment itself). Spare capacity is therefore expected, resulting in a low level of utilisation for the longitudinal slab design, for this temporary condition.

The applied transverse bending moment ($M_{Ed,t}$) is given in AD 450 as a function of b_{em}, a_m, b_m and Q_{Ed} as shown in Equation (1). The variables involved in the method are illustrated in Figure 1. The two main topics of discussion of this AD note are the variables b_{em} and a_{em}. The former has a direct influence on the level of applied transverse moment, and the latter determines the resistance to transverse bending, as will be seen below.

AD note 450 guidance:

AD 450 proposes a value for the applied moment $M_{Ed,t}$, which is supported by a transverse strip of width a_m. Variables are as defined below:

$$M_{Ed,t} = \frac{Q_{Ed}\,(b_{em} - b_m)}{8\,a_m} \text{(kNm/m)} \quad (1)$$

$$a_m = a_p + 2(h_c + h_f) \quad (2)$$

$$b_m = b_p + 2(h_c + h_f) \quad (3)$$

For a simply supported composite slab:

$$b_{em,max} = b_m = 2L_p\left[1 - \frac{L_p}{L}\right] \leq \text{slab width} \quad (4)$$

b_{em}:

Eurocode 4 provides maximum admissible values for the effective width b_{em} of the longitudinal strip of slab that is assumed to support a point load (as the Eurocode rules are based on maximizing the resistance of the slab in the longitudinal direction). The width b_{em} is a function of the transverse stiffness of the slab, the distance from the point load to the nearest support and the point load contact area. The ENV (so-called pre-standard) version of Eurocode 4[4], explicitly stated that if transverse bending of the slab is ignored, the width b_{em} could be taken as simply b_m (and no transverse reinforcement would then be needed). Intermediate values for the effective width of the longitudinal strip of slab b_{em}, between b_m and the value reported by Eurocode 4 (denoted from here on as $b_{em,max}$), may also be considered. Reducing the width $b_{em,max}$ given by Eurocode 4 would make the longitudinal slab design more onerous, but benefit the transverse slab design when compared with applying the simplified method proposed by AD 450. This benefit arises because the width of the longitudinal strip is also the span of the transverse strip, and the greater that span the more reinforcement is needed to resist a given load. Varying the assumed width of the longitudinal strip may be particularly helpful for the cited cases of composite slabs subjected to point loads during the construction stage, where the designer has very limited options.

a_{em}:

AD 450 assumes that the effective width of the transverse strip of slab over which the point load is carried is limited to a_m. The cited conservativism in the design method is mainly related to this assumption. The effective width of the transverse strip that may actually be mobilized (denoted from here as a_{em}) is greater than a_m. Given that the transverse stiffness of the slab is assumed to be sufficient to spread a point load over a longitudinal

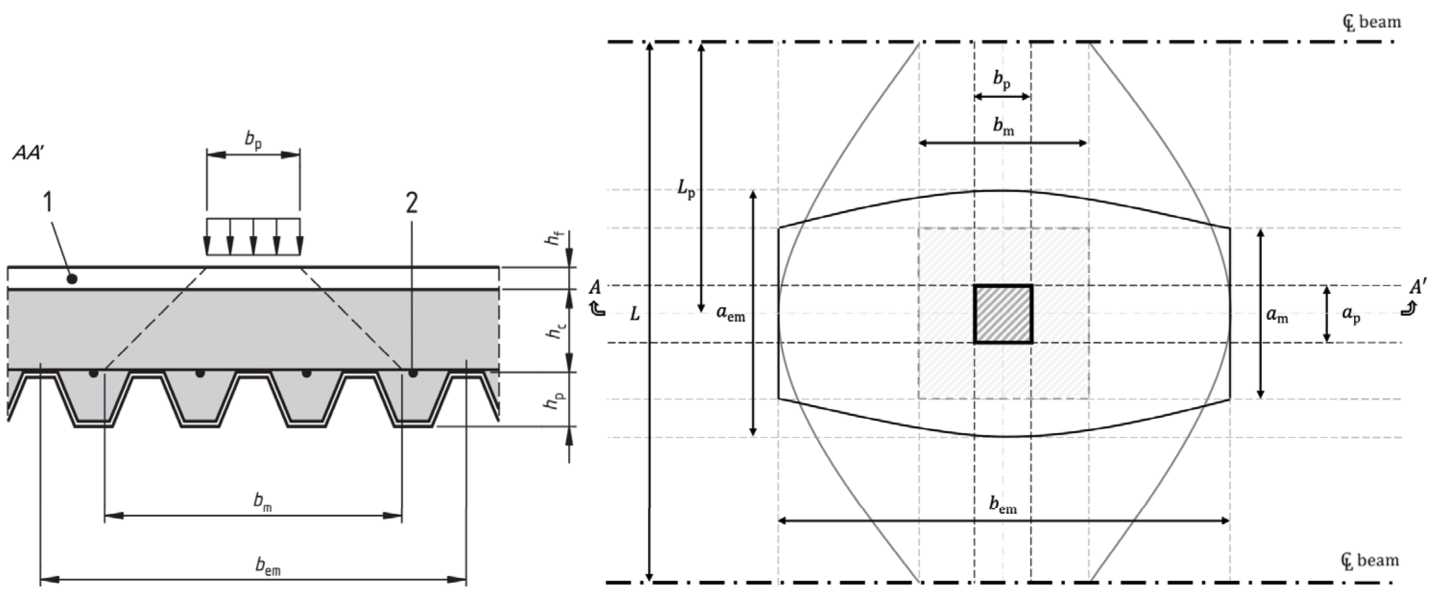

Figure 1: Widths associated with a concentrated load (1 indicates topping, 2 the slab reinforcement, noting that in typical UK practice it would not be placed as shown)

strip of width b_{em}, it is clear that a width greater than a_m can be mobilized for transverse bending. Equation (5) proposes a maximum value for the effective width of the transverse strip of slab subject to transverse bending ($a_{em, max}$). The applied moment per metre may therefore be determined using Equation (6). This leads directly to a specification of the area of transverse reinforcement needed per metre.

$$a_{em,max} = a_m + \frac{b_{em}}{3} \text{ but } a_{em,max} \leq \text{Slab span} \quad (5)$$

$$M_{Ed,t} = \frac{Q_{Ed}\,(b_{em} - b_m)}{8\,a_{em}} \text{(kNm/m)} \quad (6)$$

The transverse bending moment given by Equation (6) is applicable to composite slabs with $I_t/I_l \leq 0.50$, where I_t and I_l are the uncracked transverse and longitudinal second moment of areas of the slab, respectively.

Comments:

Using the limiting value of $a_{em} = a_m$ has the advantage that any other point load present in the direction of the slab span will not overlap (assuming a minimum point load spacing of a_m, which is sensible for practical cases). So, the design of transverse reinforcement for each point load can be treated independently. When assuming a_{em} greater than a_m, the designer may need to consider the overlapping effect of adjacent point loads that are trying to mobilise the same part of the slab. Reinforcement requirements would need to be additive. The designer should also consider the proximity of other point loads in the transverse slab direction, which may result in an overlapping of the attributed effective slab widths for longitudinal bending b_{em}. The definitions of $b_{em,max}$ and $a_{em,max}$ in Equations (4) and (5), respectively, are intended to provide a sensible compromise between competing demands.

Contact: **Ricardo Pimentel**
Tel: **01344 636555**
Email: **advisory@steel-sci.com**

1. AD 450: *Resistance of composite slabs to concentrated loads*, SCI, October 2020.
2. Johnson, R. P, Wang, Y. C., *Composite Structures of Steel and Concrete*, Fourth edition, 2019; Wiley Blackwell.
3. *Composite structures of steel and concrete* R.P. Johnson, Blackwell Publishing, 2nd edition 1994.
4. DD ENV 1994-1-1:1994, Eurocode 4. *Design of composite steel and concrete structures. General rules and rules for buildings (together with United Kingdom National Application Document)*, BSI, 1994.

New and revised codes and standards

From BSI Updates January 2022

BS EN PUBLICATIONS

BS EN ISO 15614-13:2021
Specification and qualification of welding procedures for metallic materials. Welding procedure test. Upset (resistance butt) and flash welding
supersedes BS EN ISO 15614-13:2012

NEW WORK STARTED

EN 17832
Thermal spraying. Determination of the feed rate with spray material in powder form
will supersede None

ISO 4931-1
Buildings and civil engineering works. Principles, framework and guidance for resilience design. Adaptation to climate change
will supersede None

ISO 4998
Continuous hot-dip zinc-coated and zinc-iron alloy-coated carbon steel sheet of structural quality
will supersede BS ISO 4998:2014

ISO 19735
Corrosion of metals and alloys. Corrosivity of atmospheres. Mapping areas of increased risk of corrosion
will supersede None

ISO PUBLICATIONS

ISO 834-1:1999/A2:2021
Fire-resistance tests. Elements of building construction. General requirements
Will be implemented as an identical British Standard

ISO 10675-1:2021
Non-destructive testing of welds. Acceptance levels for radiographic testing. Steel, nickel, titanium and their alloys
Will be implemented as an identical British Standard

ISO/TR 20413:2021
Fire safety engineering. Survey of performance-based fire safety design practices in different countries
Will be implemented as an identical British Standard