STEEL INDUSTRY GUIDANCE NOTES

Long span composite beams

The introduction of steel composite design into the UK provided the specifier with an array of new possibilities. Not only was it possible to design shallower floors, but specifiers could now offer long span solutions with real tangible benefits for both the client and the end-user. Today, it is estimated that around 35% of steel-framed buildings incorporate long spans in excess of 12m. This guidance note reminds designers of the benefits of long span composite construction.

Why long span?

The principal benefit of a long span floor is column free space and the ease with which the interiors can be changed giving the building a longer life. Perhaps more important now in this age of sustainable development. There are also other secondary benefits. Compared to typical short span schemes long span solutions have fewer pieces. That means fewer connections, and so fabrication and erection times are reduced. Long span beams have more favourable H_p/A ratios (section factor) and are often more cost effective to fire protect. Furthermore, all long span solutions have the ability to accommodate services within the structural zone. Studies show that in a long span building where structure and service zones are combined, that the increased cost is less than 1% compared to the short span equivalent.

What are the options?

The composite revolution of the 1980s created an environment of experimentation within the consulting engineering sector. Engineers explored various long span structural schemes with integrated services. These included simple downstand composite beams with web penetrations, composite trusses, stub girders, tapered plate girders, the parallel beam approach, etc. Each of these solutions had its merits, all were used successfully, and all have relevance today. However in the 1990s the cellular beam, which replaced the castellated beam, gained prominence. Cellular beams are now estimated to have an 80% share of the long span market and are used in more than half the car parks built each year in the UK. This dominance is due to several factors including:

1. Compared to the other long span alternatives, the fabrication content is significantly less.
2. Asymmetric cellular beams allow greater design economy.
3. Regular service holes allow greater flexibility for service integration.

What constitutes a long span floor?

For the purpose of this guidance note long spans are considered to be in the range of 12m to 18m. Composite action between the concrete floor slab and the steel beam is achieved using shear studs welded to the top flange of the beam.

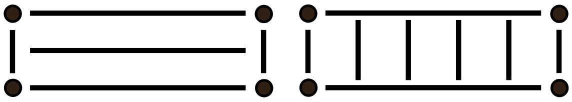
For short to medium spans a downstand composite UKB often provides the most cost effective solution. This approach uses standard components and products with which the industry is familiar. In the 10m to 12m span range this traditional solution starts to lose ground to cellular beam solutions but the precise point is dependent on weight savings compared with the manufacturing cost of a cellular beam. This can be further complicated by the need for service integration.

At spans up to 18m, economic, strength-governed solutions, are possible. Beyond 18m serviceability criteria will have an increasingly significant influence on design.

Long span primary or long span secondary, what's the answer?

In the case of cellular beam solutions, if minimum depth is key, the long span secondary approach will always yield the shallowest option. An efficient strength-driven design typically has a span/depth of 20 to 25. If depth is critical the ratio can rise to 35 plus, but at the expense of weight, as the design becomes serviceability driven. Therefore for a 15m long span the designer can consider a depth range of 400 - 750mm. Other benefits, compared to a long span primary option, include a lower piece count leading to quicker fabrication and erection.

The long span primary option offers a different kind of flexibility. Primary beams are more heavily loaded and rather than a UDL the load is applied as a series of point loads. Therefore there is limited scope for variation on depth. Shear and vierendeel effects become more significant and so typical span/depth ratios tend to be between 20 and 25. However, the greater spacing between the primaries and the differential beam depth between the deeper primary beams and the shallower secondaries offers opportunities for pre-fabrication of building services which can be lifted into place in each bay, so speeding up the M&E fit-out process.



Long span secondary (for shallowest depth) **Long span primary (for easier servicing)**

Through-deck stud welding

The standard stud diameter for through-deck stud welding is 19mm, and although 95mm LAW (length after welding) is standard, other lengths are available. The process on site requires a ceramic ferrule that concentrates the heat at the base of the stud and forms the weld profile. Ferrules are only available for 19mm diameter studs so designs requiring other stud diameters will not accommodate through-deck welding.

Dynamic Performance of long span floors

The measure of how well a floor performs dynamically has traditionally been determined by calculating the natural frequency. This measure is not entirely accurate, and research has shown that “response” provides a more appropriate guide to performance. The common misconception that longer span floors are inferior to their short span counterparts on the basis of frequency is often invalid. When the correct measure is used i.e., “response”, long span floors can often be shown to out-perform their short span counterparts. SCI guide P354 offers explicit guidance on the subject, and software is also available to assist designers.

Deflection

Construction stage deflections of long span beams can be relatively large and it is common practice to pre-camber beams to allow for this. The dilemma is by how much? In practice beams will not deflect as much as predicted because of connection stiffness amongst others factors. A rule of thumb commonly used is to allow 70-80% of the calculated deflection due to self-weight of steel, deck and concrete and apply that as a pre-camber. Also, to create a common plane for the top of the steel, a radius or a series of straight lengths or facets is often specified for the pre-camber. Pre-camber in cellular beams are often free of charge or at a nominal cost.

A steel composite floor is a live structure, as load is applied it will deflect. A common dilemma is whether to cast the slab to a level or to a thickness. From a design perspective the key criteria is to have the correct thickness of concrete at the point of maximum moment - mid-span of the beam. So, provided the flatness of the slab meets the specification, casting to thickness is acceptable. If casting to a level/datum then an appropriate allowance should be made in the loading for ponding effects.

Fire

The typical long span floor has fewer pieces than short span floors, leading to a smaller surface area to be fire-protected. This alone can often reduce fire-protection time and cost. Further saving can be achieved by using performance-based design approaches and the design guidance derived from the Cardington Fire Tests. In appropriate situations secondary beams do not require protection. See SIGNS SN22 02/2008.

Car parks

A car park is a special type of long span structure and often the structural depth is restricted due to the need to achieve appropriate gradients on access ramps and traffic flow models. Car parks are also modular and beam spacing is a multiple of 2.4m with 4.8m and 7.2m being the most common.

Recent developments in steel decking have led to the introduction of closed ends and pre-coated soffits. The deck can be used in unpropped single spans up to 3.6m with the closed ends providing stops for the concrete pour and composite action achieved by shear studs shop welded to the beams. Greater unpropped spans can be achieved by utilising the deck continuous over intermediate beams with the shear studs welded through deck on site. Careful consideration to detailing is paramount for the latter option to ensure adequate durability is maintained.

At 4.8m, thin pre-cast concrete type planks are commonly used with an insitu concrete topping and composite action is achieved with shop-welded studs.

At 7.2m spacing, deeper pre-cast units are typically used, with beam depths increasing accordingly. In this instance designers could consider the benefits of using UKB 533x312 series to limit beam depths in comparison to the more traditional 762x267 series.

Key Points

1. Consider a long span solution as an alternative to short span in serviced buildings or where current and/or future flexibility are key criteria.
2. If minimum structural depth is a driver opt for a long span secondary framing arrangement.
3. If though-deck stud welding is being used it should be noted that only 19mm diameter studs are supported, and the top flange must be left unpainted.
4. Consider pre-cambering for c.75% of the self-weight of steel, deck and concrete and specify an equivalent radius.
5. If the slab is being cast to a level or datum make an allowance for ponding in the design loads.
6. Secondary beams may not require fire protection if designed in accordance with SCI P288.

Further sources of Information

1. **Supporting the commercial decision (Corus publication)**
2. **Design of Steel-Framed Buildings for service integration (SCI P166)**
3. **Design of Floors for Vibration: A New Approach (SCI P354)**
4. **Composite Slabs and Beams Using Steel Decking: Best Practice for Design and Construction (SCI P300)**
5. **Precast Concrete Floors in Steel-Framed Building (SCI P351)**
6. **Fire Safe Design: A New Approach to Multi-storey Steel-Framed Buildings - 2nd Edition (SCI P288)**
7. **Cellular beam manufacturers' websites**

a. Fabsec: http://www.fabsec.co.uk/

b. Westok: http://www.westok.co.uk/ website