

Scope

This Guidance Note covers the structural arrangement of deck type composite bridges (concrete deck slab on top of steel girders). Whilst the Note is written principally with I-section steel bridge girders in mind, much of the information is also equally applicable where steel box girders are used for short and medium spans (see also GN 1.08). The information is presented generally in the order in which it will be considered during the course of the design.

Bridge arrangement

The designer will determine the span lengths of the bridge from consideration of the physical dimensions of the obstacle to be crossed, the required clearance envelopes, the available locations for the bridge abutments and intermediate piers (if more than one span) and aesthetics. The geometry of the crossing may require the bridge to be skewed (see GN 1.02).

Where there are three or more spans and the deck is simply supported at the end supports, end spans are normally proportioned to be 0.7 to 0.85 of the length of the adjacent interior span. With spans in this ratio, the end span sagging moment will be of similar magnitude to that in the adjacent span, and it is unlikely that there will be uplift at the end support.

For bridges of more than one span, variable depth girders may be used, although the saving in girder weight (at midspan) will usually only be significant for span lengths greater than about 40 to 45 m. On multi-span bridges with variable depth girders, care should be taken with the appearance. Whilst haunching the girders over the main span piers will give a satisfactory appearance, multiple haunched spans can be visually disturbing. Reference 1 gives guidance on the appearance of bridges.

Nowadays, with increased emphasis on durability and maintainability, unless particular circumstances such as mining subsidence warrant otherwise, multi-span bridges should be continuous over intermediate supports (see Ref 2 and GN 1.04). Steelwork for well designed continuous decks will invariably be more economic than that for the equivalent simply supported

spans. Continuity also offers robustness and redundancy in the event of damage to the supporting substructure.

Number of girders

The number of main girders in the deck cross section is determined principally by the required width of the deck and the economics of the steelwork. In composite construction the two arrangements that are most commonly used are:

- multiple parallel longitudinal main girders spaced at 3 to 4 m centres with the deck slab spanning transversely (see Figure 1)
- the 'ladder deck', comprising two longitudinal main girders with the deck slab spanning longitudinally between cross beams that are spaced at about 3 to 4 m centres (see Figure 2)

A span of 3.5 m is about the optimum for a 250 mm reinforced concrete deck slab and also allows the use of proprietary permanent formwork.

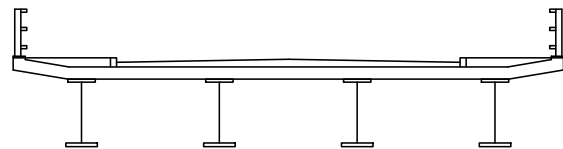


Figure 1 Multiple girder bridge

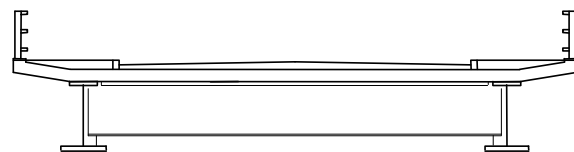


Figure 2 Ladder deck bridge

Where there are limitations on construction depth, multiple girders with a closer spacing may be required, or, if depth is severely limited, through or half through types of construction may be utilised (see GN 1.10). Ladder decks usually prove to be economical for spans upwards of 35 – 40 m, and are best suited to bridge decks up to about 12 m in width. Good examples are found in References 3 and 4.

The ladder deck arrangement can prove cost effective on wider decks, although the loading on the two main girders can become very heavy. Doubler plates may have to be used to provide flanges of the required size. Irre-

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spective of the width of the deck, ladder deck girders will usually have a greater section depth than those in a multiple girder arrangement because the individual girders carry heavier loads.

On bridges with spans greater than 45 m and with wide decks, by spacing the main girders wider than 4 m apart and by haunching the deck slab, fewer girders can be used, and a significant saving in material in the girder webs can be made (see Figure 3). For spans in the range 80-100 m, plate girder composite decks of this form can be very economical where a ladder deck arrangement cannot be used.

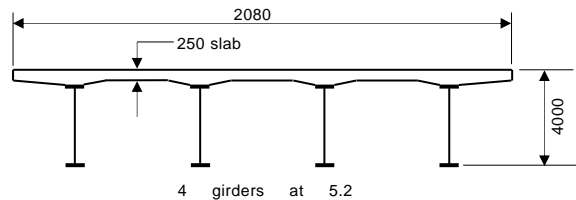


Figure 3 Deck with haunched slab

Whichever arrangement is chosen for the deck cross section, careful consideration should be given as to how best to provide required crossfalls or superelevation. Most commonly the levels of the girder top flanges are set to define the soffit level of the deck slab, either by setting the bridge bearings to varying levels or by varying the girder heights. Less commonly, and usually only on smaller decks, the thickness of the deck slab is varied (see Figure 4).

With I-section girders the deck cross section will invariably have the girder top flange horizontal.

With box girders, it is usual to vary the web heights to provide the slope (see Figure 5). Sometimes the whole girder may be tilted so that the top flange is sloped parallel to the upper surface of the slab (this keeps the box geometry orthogonal, which may have advantages during fabrication, particularly of closed boxes).

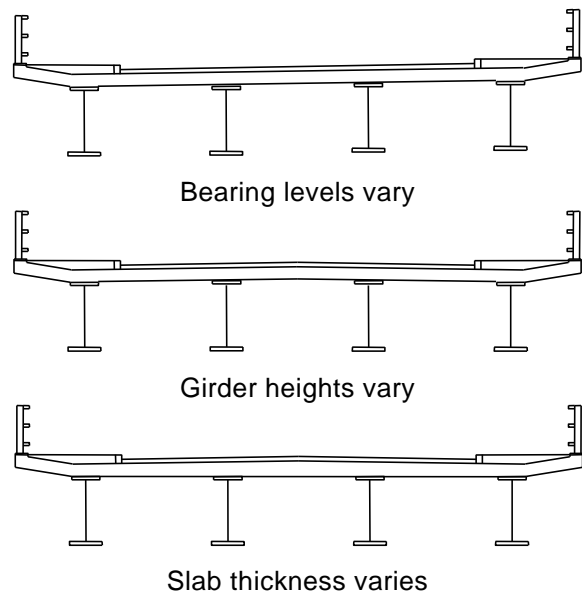


Figure 4 Superelevation and crossfall

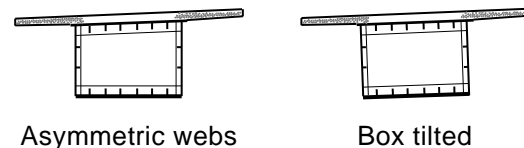


Figure 5 Crossfalls on box girders

The designer should always bear in mind the method of erection. An even number of girders will facilitate erection in pairs by crane. If the steelwork is to be erected by launching, then constant depth girders are virtually a necessity.

There may be particular constraints at the erection site that limit the transport, handling and erection of the girders. In such cases the erection cost of a small number of heavy main girders may outweigh the savings in material cost over a greater number of smaller girders.

Deck slab cantilever

With a multiple girder arrangement, the length of the deck slab cantilever will usually be about half the girder spacing. For both ladder deck and multiple girder arrangements, it is customary to limit the maximum length to not more than about 1.5 m for a 250 mm slab. A longer cantilever will require the deck slab at the cantilever root to be thickened, and with multiple girders will result in the outermost girder being more heavily loaded than the

inner girders. Generally, a short cantilever is to be avoided for aesthetic reasons and because the cantilever should have sufficient length to protect the edge girder from the elements. With a P6 high containment parapet, a short cantilever may, however, be unavoidable.

The designer should consider the stage at which the cantilever is to be constructed. From a construction point of view, casting the full width of the deck in one operation is generally preferred. This is usually done using a cantilever formwork system (see Figure 6) that is fixed to the outside face of the edge girder by bolting each temporary frame to a proprietary attachment that is welded to the upper surface of the top flange. The formwork system can be attached to the girder before erection, which is a particular advantage if the bridge has to be erected in a limited possession.

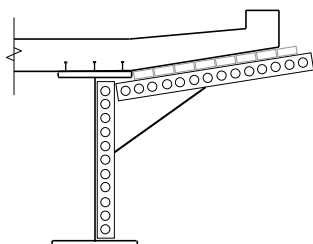


Figure 6 *Cantilever formwork*

Alternatively, the cantilevers can be cast as a second stage, after the slab over the girders has been constructed and is acting compositely (see Figure 7). Note that the arrangement shown in Figure 6 will put a large torsion on the edge girder when the cantilever is concreted, and this torsional loading should be taken into account in the design and detailing of the bracing system.

A two-stage construction sequence is particularly advantageous for long cantilevers, as the cantilever wet concrete dead load is carried by the composite deck rather than by the edge girder in the bare steel condition. Also, with two stage construction, it is easier to obtain the correct line and level of the cantilever tip and stringcourse. If a two-stage sequence has to be used, this should be stated on the drawings and provision for deflection allowance (precamber) made accordingly (see GN 4.03).

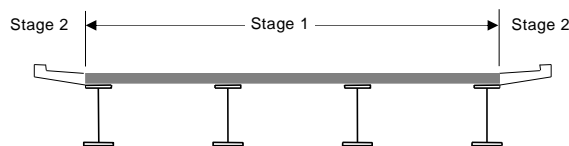


Figure 7 *Two stage construction*

Support to the deck

Generally, for a single span bridge deck the girders will be supported directly on the bridge abutment. A bearing is provided at each end of each girder, or in the case of integral bridges, the girders are built into the abutment wall.

Where there is more than one span the arrangement at the abutment will be similar to that for a single span and the girders will also be supported on the intermediate piers. Note that integral abutments are not appropriate where the thermal movement at the end of the deck exceeds 40 mm or skewed more than 30°.

With multiple girders the form of the substructure can be chosen so that either:

- each girder is supported on a bearing, usually in conjunction with leaf piers or, less frequently, on portal type piers or individual columns (see Figure 8)
- or
- there are fewer bearings than girders; this requires the use of integral (or lost) crossheads (see Figure 9)

Use of integral crossheads with haunched girders can be unsatisfactory visually, because the point of the haunch appears to be unsupported. The combination of haunching and integral crossheads is best avoided, especially where the supports are skewed.

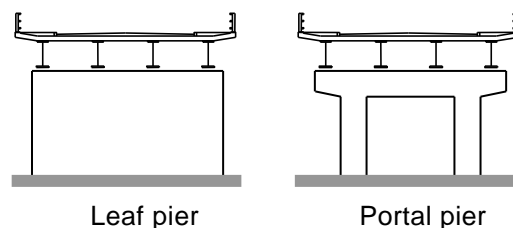


Figure 8 *Leaf and portal piers (all girders on bearings)*

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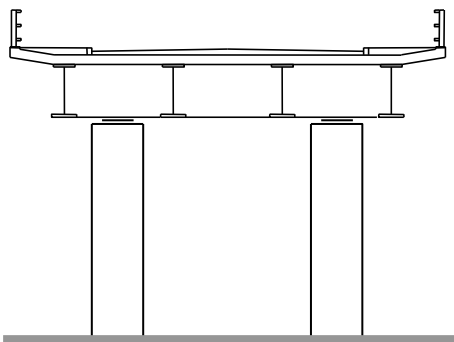


Figure 9 *Integral crosshead*

Where integral crossheads are used, the stability of the steelwork during erection must be considered. If the girders are erected one at a time, temporary propping/support will be required. If they are lifted in pairs the integral crosshead can be landed directly on the supporting pier. Appropriate restraint against sideways rotation should always be provided.

For relatively narrow decks (usually with just two girders) a single column intermediate support is often preferred for aesthetic reasons. A single column support may also have to be used at a skew crossing where there is insufficient space to accommodate an orthogonal leaf type pier – for example in the central reserve of a dual carriageway. In such instances the designer should ensure that torsional loading is adequately distributed by the deck.

Usually with a ladder deck arrangement each of the girders is supported on a bearing seated directly on column type piers (see Figure 10) or, less frequently, on leaf type piers. With this arrangement the main girders can be landed directly on the supporting pier. The cross beams are usually erected and bolted once both main girders have been erected. A deeper cross beam or additional bracing will often be required at the support positions (see GN 2.03).

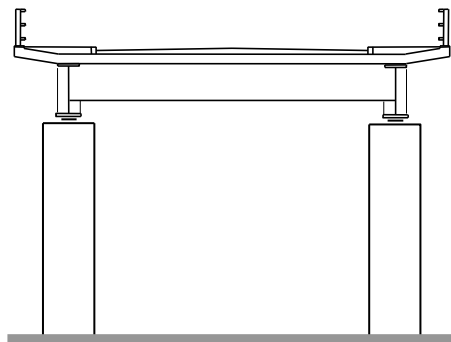


Figure 10 *Typical ladder deck pier*

References

1. BA 41/98 The design and appearance of bridges, Design Manual for Roads and Bridges, TSO, 1998
2. BA 57/01 Design for durability, Design Manual for Roads and Bridges, TSO, 2001.
3. The Structural Engineer, 1 August 1989
4. Bridged in Steel No 11, British Steel.