Main girder make-up

No. 2.01

Scope

This Guidance Note covers the make-up of bridge girders. Whilst the Note is written principally with I-section steel bridge girders in mind, much of the information is equally applicable to steel box girders for short and medium spans.

The selection of the configuration of the bridge and its structural arrangement is part of conceptual design and is outside the scope of this Note. Brief mention of typical arrangements is made below, and some guidance on highway bridge arrangements is given in Reference 1.

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 abutments and intermediate supports (if more than one span) and aesthetics. For bridges of more than one span, variable depth girders may be chosen, if appropriate.

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 highway bridge construction the two arrangements that are most commonly used are:

- multiple longitudinal main girders with the deck slab spanning transversely
- a 'ladder deck' comprising two longitudinal main girders with the deck slab spanning longitudinally between cross beams.

For railway bridges, the requirement to minimise construction depth below track level may necessitate the use of half-through construction, in which the deck is supported by cross girders spanning between a pair of main girders. Typical examples are given in GN 1.10. When there is no requirement to minimise construction depth, the deck (of steel or composite construction) may be supported on longitudinal main girders. In this case, the main girders are normally located directly under each rail, to minimise transverse bending effects.

Main girder make-up

Once the structural configuration of the bridge and the number of girders in the deck cross section has been selected, the designer will determine the required sizes of top and bottom flanges at the critical sections, namely those at the positions of maximum moment. Similarly, the maximum shear forces are critical for determining the required thickness of the web at the supports.

In order to make the most economical use of material, flange sizes and the web thickness should be reduced away from the critical sections (except for short spans, under about 25 m). The make-up of the main girder is determined by consideration of the available sizes of steel plate of the required width and thickness, the lengths of the spans and the maximum length/weight that can be transported to site and erected.

In the UK, the Tata Steel plate products catalogue (available from tatasteelconstruction.com) provides information on the range of sizes that is available for plates. Generally, plates of the thickness most commonly used in bridge girders are available in lengths up to 18.3 m, although on some occasions longer lengths may be available by arrangement. Hence, the flanges and webs of girders will normally (except for short single spans) be fabricated from a number of plates arranged end to end. Long girders must be subdivided into a number of erection pieces for handling and transport. Girder lengths up to around 27.4 m can be transported by road without a movement order (see GN 7.06), although fabricators often transport longer lengths. This is also the case for individual erection pieces.

The plates making up a girder or erection piece may either be joined in the fabrication shop (a shop splice), which usually means a full penetration transverse butt weld, or at site. A site splice (sometimes known as a field splice) can be either a bolted connection or a transverse butt weld. (Note that some site splices are made at ground level, to join several components before erection.)

Transverse butt welds are expensive so it may be more economical to continue a thick flange plate over a longer length. The optimum girder make-up will usually result from:

- minimising the number of transverse butt welds made in the shop (particularly in the flanges)

- maximising the length transported to site, thereby minimising the number of connections made at site
- positioning site splices to suit the method of erection.

For multiple span bridges, erection by crane typically involves pieces that cantilever to the point of contraflexure in the next span, with a bolted site splice at the connection (see Figure 1). For long spans one or more site splices may be made on the ground before the girder is lifted and placed onto the substructure. The make-up of the girder and the locations of the site splices need to be considered together.

Flange and web sizes
Variations of the flange size affect the cross section geometry, with implications for the fabricator and the erector.

Flange width
Where possible, the designer should choose a combination of width and thickness that provides a balance between a wide, thin plate that would be likely to distort or ripple and a narrow thick plate that might be difficult to weld (for various reasons).

For design to EN 1993-2, (Ref 2) the limits on outstand flanges in compression are in Table 5.2 of EN 1993-1-1 (Ref 3). For a Class 2 cross-section, which can develop the plastic moment resistance, the outstand c is limited to $10t\varepsilon$ (= $8.1t$ for f_y=355). For a Class 3 section, which reaches the elastic yield strength but will not develop plastic resistance, the outstand c is limited to $14t\varepsilon$ (=$11.3t$ for f_y=355). Tension flange outstands are not limited by EN 1993 but designers may wish to continue to observe previous practice and limit the tension flange outstand to $16t$. (If a wide flange were to go into compression during handling or erection it would buckle at a very low stress.) Commonly used proportions for the overall width of flange are therefore in the range of $12t$ to $32t$.

Note that compression flanges need to be kept as wide as possible to increase their resistance to lateral torsional buckling, particularly the top flanges in midspan regions (for the construction condition). This may preclude the choice of compact proportions for the bare steel beam.

Some rolling mills produce material in the form of ‘wide flats’ in rounded dimensional sizes. The material standards cover these products.

In composite construction a constant flange width may be chosen for the top flange as this simplifies the geometry of slab soffit and the detailing of the reinforcement. A constant width top flange is also preferable when proprietary permanent formwork is used for the slab. A constant flange width is sometimes chosen for the bottom flange for appearance. A constant width within a girder piece also avoids difficulties with automatic girder welding machines (it is difficult to accommodate a sudden change of flange width). Where flange widths do change, designers usually make the change at a splice position.

In railway bridges, flange plate widths are usually kept constant for fatigue design reasons. The width of the top flange may also be influenced by its use as a walkway across the bridge.

Flange thickness
Where the thickness of the flange varies, the designer should keep the overall girder depth constant and vary the web depth (see Figure 2). However, prevention of water traps in weathering steel girders sometimes makes it better to vary the bottom flange thickness downwards (keeping the top surface at the same level).

Steps in the web can easily be made when they are cut from plate. If the web were constant depth, the step in girder depth would be more difficult to accommodate in an automatic girder welding machine.

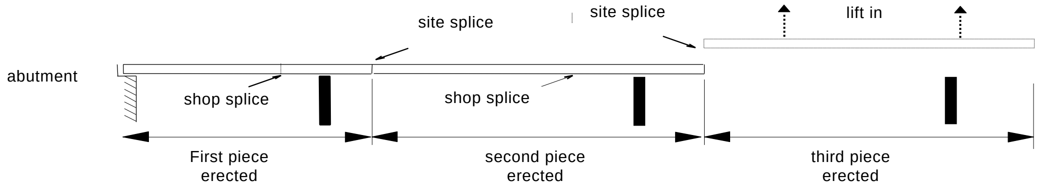


Figure 1 *Erection sequence of pieces*

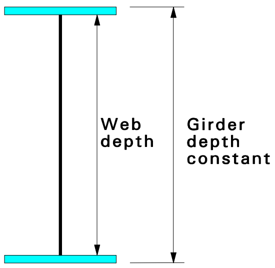


Figure 2 *Girder section*

Doubler plates
Network Rail limits the flange plate thickness in railway bridges to a maximum of 75 mm. Thicker flanges are obtained by welding on doubler plates; the doubler plate thickness is generally slightly less than the primary flange plate (the plate attached to the web). Doubler plates are often curtailed short of the girder ends. See GN 2.02 for comment on detailing doubler plate details.

Web thickness
Whilst the thickness of web needed in midspan regions is often quite low, a minimum thickness for robustness should be observed. A minimum of 10 mm is commonly adopted in highway and railway bridges (and 8 mm, or possibly even 6 mm, in footbridges). The possible effects of erection conditions on thin webs should also be considered carefully when selecting the make-up (particularly where girders are launched).

Attachments
The make-up of a girder includes all the pieces that are attached to the girder in the fabrication shop. The principal attachments to plate girders are web stiffeners and shear connectors. On large girders there may be longitudinal stiffeners, and in box girders there are also diaphragms and/or ring frames.

Web stiffeners
The size of any web stiffeners, their locations and their orientation (e.g. whether transverse stiffeners are square to the top flange or truly vertical) should be given on the make-up sheet. See GN 2.04 and GN 2.05 for comment on attachment of stiffeners.

Shear connectors
In composite construction, the spacing of the shear connectors should be selected to avoid clashing with the transverse reinforcing bars in the bottom mat of the deck slab; the spacing is often varied in groups along the spans. The spacing and number in each group should be given on the drawings. The starting point for measurements should be clear (avoid appearing to locate the first group at the very end of the girder), as should the line of measurement (whether in horizontal plan or along the top of the steelwork, for example).

Site connected attachments
Details of other attachments, such as bracing, diaphragms, etc. are usually given separately, but the make-up sheet is often used to give references to indicate which attachment will be made where.

Material grade
Whilst it is usually good practice not to mix grades of material in made-up girders (to avoid risk of using the wrong grade), where there is little risk of confusion, for example for thick flange material, the selection of different grades (e.g. sub-grade K2 rather than J2) is normal.

If material with through thickness properties is required in particular locations, this should be noted. It is better not to make this a general requirement; only those locations that require the enhanced properties should be so specified. See GN 3.02 for guidance on through thickness properties.

Information about make-up
Make-up information is usually communicated in graphic and tabular form (e.g. typical cross sections plus separate make-up sheets)

Two typical make-up sheets from actual projects are included at the end of this Guidance Note. Each includes many, though not all, of the aspects mentioned above. They should be considered as illustrative only, and not taken as definitive.

Electronic methods of information transfer are increasingly being used. Whilst this carries many benefits, drawings are still of great assistance in illustrating the designer's needs, in review and in approving proposals made by the fabricator. Dialogue between designer and fabricator is important to make sure that all the necessary allowances (for cutting and weld shrinkage effects, allowance for permanent deformation, etc.) have been made by the appropriate party.

Guidance Note

No. 2.01

Geometrical information

It is common for geometrical information, particularly relating to the vertical profile, to be included on drawings showing the girder make-up. This information is of particular relevance to the make-up of the web, since it completes the information needed when ordering material and cutting out the webs.

Note that any allowances for permanent deformation need to be associated with the vertical profile. See GN 4.03 for guidance on allowances for permanent deformations.

References

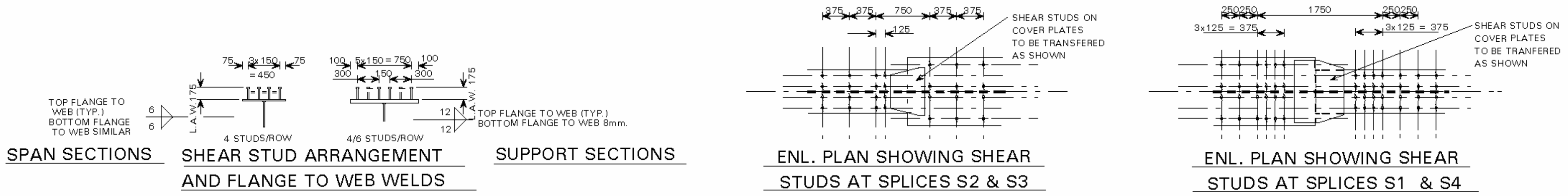
1. Composite Highway Bridge Design (P356), SCI, 2010
2. EN 1993-2:2006 Eurocode 3 – Design of steel structures – Part 2: Steel bridges
3. EN 1993-1-1:2005 Eurocode 3: Design of steel structures – Part 1-1: General rules and rules for buildings

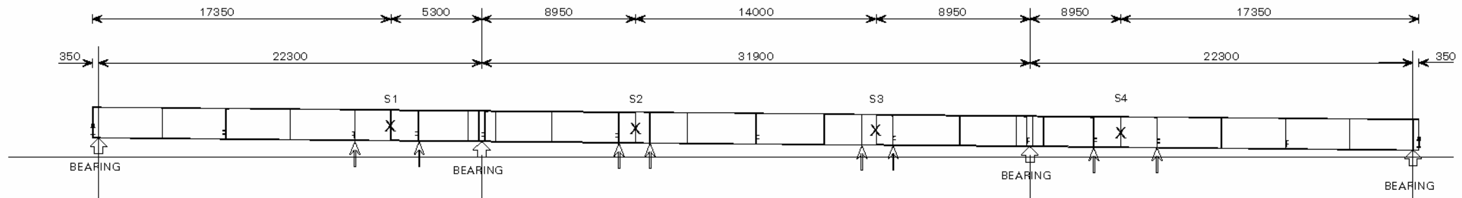
Sample make-up sheets

The following fold-out sheets present typical examples of make-up sheets. The examples are:

(1) A 3-span composite railway bridge, with each track carried by two girders and with a concrete slab acting compositely with the top flange.

(2) A 3-span haunched composite box girder highway bridge. There are four open-topped steel boxes and the bridge is curved and tapered in plan.





DOWN LINE DECK-OUTER GIRDER
(DOWN LINE-INNER, UP LINE-OUTER, UP LINE-INNER SIMILAR)

SCALE 1:200

SHEAR STUDS - 22 DIA. LAW 175														
4 No. /ROW @ 250 PITCH 37.5	4 No. /ROW @ 375 PITCH 375 375	SEE DETAIL S1 ABOVE	1000	SEE DETAIL S1 ABOVE	6 No / ROW @ 250 PITCH 250 250	SEE DETAIL S2 ABOVE	4 No. /ROW @ 375 PITCH 375 375	SEE DETAIL S3 ABOVE	6 No / ROW @ 250 PITCH 250 250	SEE DETAIL S4 ABOVE	1000	SEE DETAIL S4 ABOVE	4 No. /ROW @ 375 PITCH 375 375	4 No. /ROW @ 250 PITCH 37.5

TOP FLANGE	600 x 20	950 X 50	600 x 20	950 x 50	600 x 20
WEB	20 x 1725	25 X 1680	20 x 1725	25 x 1680	20 x 1725

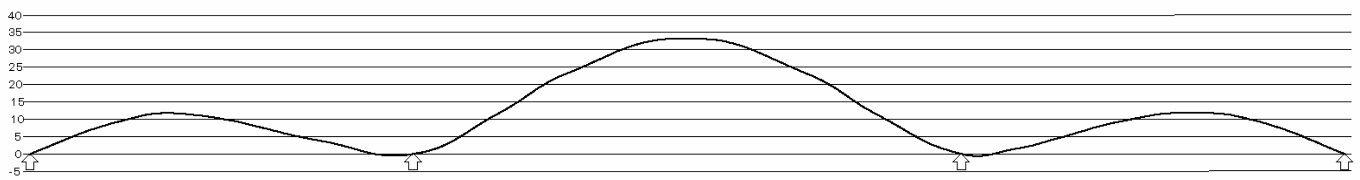
CROSS BRACING POSITION											
7750	7500	3700	3875	7800	7975	7975	7800	3875	3700	7500	7750

BEARING & INTERMEDIATE STIFFENERS: 350, 3700, 3700, 3750, 3750, 3700, 2900, 625, 350, 625, 3275, 3900, 1800, 2188, 3987, 3987, 2188, 1800, 3900, 3275, 625, 625, 350, 2900, 3700, 3750, 3750, 3700, 3700, 350

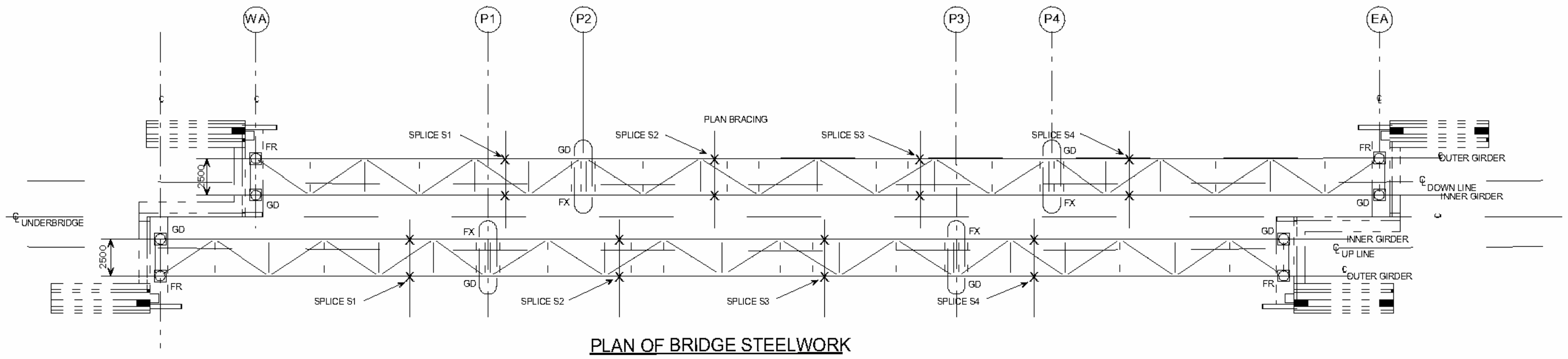
BOTTOM FLANGE	700 x 35	950 x 50	700 x 35	950 x 50	700 x 35

PRECAMBER LOCATION (M)		0	5	9	17	22.3	27.25	31.25	38.25	45.25	49.25	54.2	57.5	59.5	63.5	67.5	71.5	76.5
INNER GIRDER	PERMANENT	0	3.7	4.3	0.3	0	5.6	11.7	17.3	11.5	5.5	0	-0.3	0.5	2.9	4.6	3.9	
	50% LIVE LOAD	0	2.8	3.9	2.5	0	3.6	6.3	8.2	6.3	3.5	0	1.6	2.5	3.8	3.9	2.7	
	TOTAL	0	6.4	8.2	2.8	0	9.1	17.9	25.5	17.8	9.0	0	1.3	3.0	6.7	8.5	6.6	
OUTER GIRDER	PERMANENT	0	6.6	7.9	1.4	0	8.2	17.3	25.6	17.1	8.1	0	0.2	1.7	5.9	8.3	6.8	
	50% LIVE LOAD	0	2.6	3.7	2.3	0	3.4	5.9	7.9	5.9	3.4	0	1.4	2.3	3.5	3.6	2.5	
	TOTAL	0	9.1	11.6	3.7	0	11.6	23.2	33.4	23.1	11.5	0	1.6	4.1	9.4	11.9	9.3	

DOWN LINE DECK-GIRDERS



PRE-CAMBER PROFILE-OUTER GIRDERS



PLAN OF BRIDGE STEELWORK

SCALE 1:200

NOTES

Rev.	Date	By	Description	Ckd	Apvd PE	Apvd EM

Drawing Status

Drawing Title

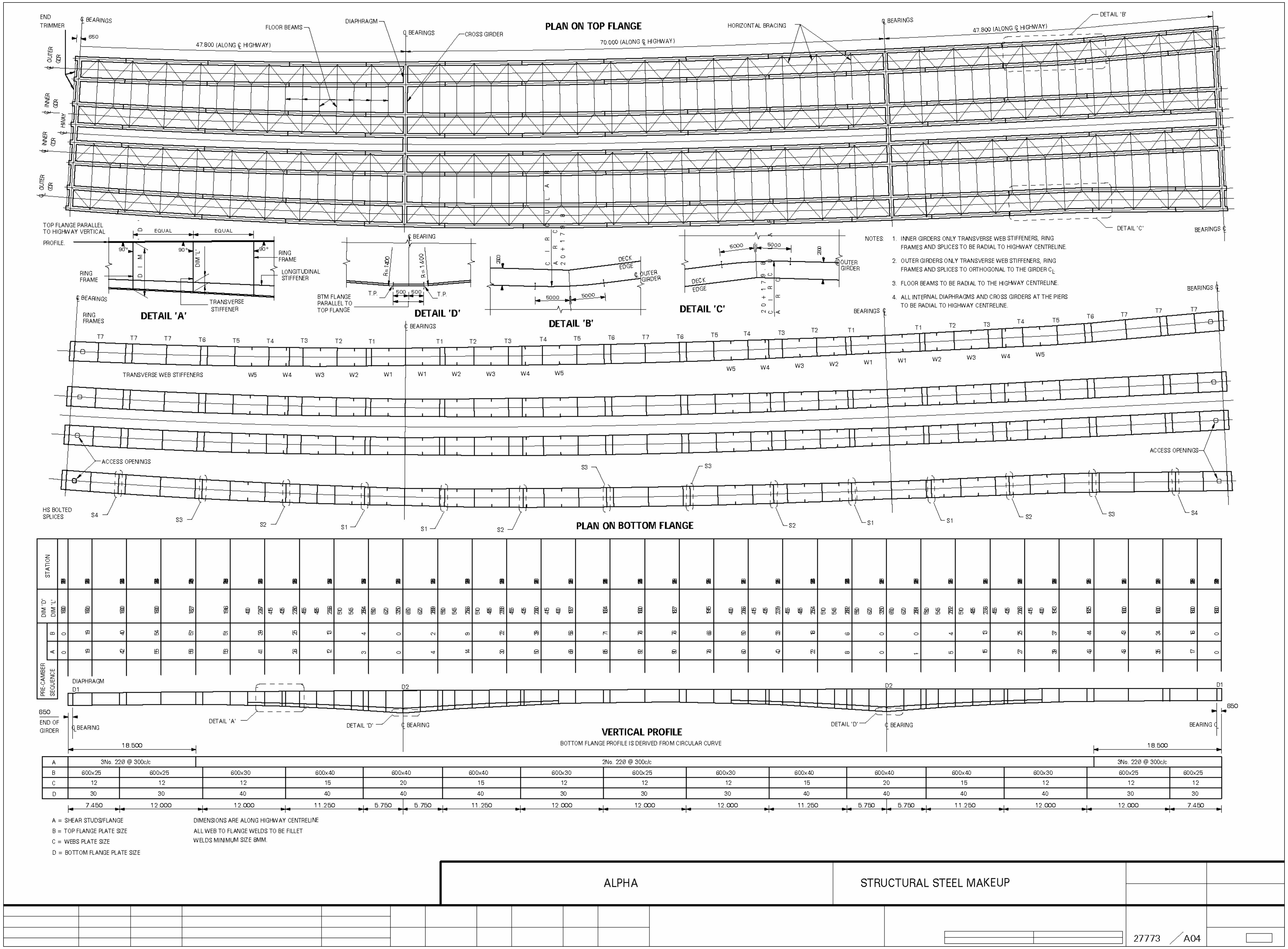
Drawn By | Date | Checked By | Date

Approved By Project Engineer | Date

Approved By Eng. Manager / Manager of Const. | Date

Scale | Sheet Size A1

Drawing No.


PLAN ON TOP FLANGE
FLOOR BEAMS
DIAPHRAGM
CROSS GIRDER
HORIZONTAL BRACING
47.800 (ALONG ℄ HIGHWAY)
70.000 (ALONG ℄ HIGHWAY)
DETAIL 'A'
DETAIL 'D'
DETAIL 'B'
DETAIL 'C'
NOTES: 1. INNER GIRDERS ONLY TRANSVERSE WEB STIFFENERS, RING FRAMES AND SPLICES TO BE RADIAL TO HIGHWAY CENTRELINE.
2. OUTER GIRDERS ONLY TRANSVERSE WEB STIFFENERS, RING FRAMES AND SPLICES TO ORTHOGONAL TO THE GIRDER ℄.
3. FLOOR BEAMS TO BE RADIAL TO THE HIGHWAY CENTRELINE.
4. ALL INTERNAL DIAPHRAGMS AND CROSS GIRDERS AT THE PIERS TO BE RADIAL TO HIGHWAY CENTRELINE.
TRANSVERSE WEB STIFFENERS
ACCESS OPENINGS
HS BOLTED SPLICES
PLAN ON BOTTOM FLANGE
STATION
PRE-CAMBER SEQUENCE
VERTICAL PROFILE
BOTTOM FLANGE PROFILE IS DERIVED FROM CIRCULAR CURVE
A = SHEAR STUDS/FLANGE
B = TOP FLANGE PLATE SIZE
C = WEBS PLATE SIZE
D = BOTTOM FLANGE PLATE SIZE
DIMENSIONS ARE ALONG HIGHWAY CENTRELINE
ALL WEB TO FLANGE WELDS TO BE FILLET WELDS MINIMUM SIZE 6MM.
ALPHA
STRUCTURAL STEEL MAKEUP
27773 A04