

**TECHNICAL USER MANUAL
for
STANDARD HALF THROUGH UNDERBRIDGES Z-TYPE**

Standard Detail and Design Drawings

Summary

This technical user manual is applicable to the standard Z-type half through underbridges. It provides guidance on the selection and application of Network Rail's suite of standard drawings. The standard designs and details within these drawings will generally be used for new-build structures, and part replacement e.g. deck replacement.

Issue record

This technical user manual will be updated when necessary by distribution of a complete replacement. A vertical black line in the margin will mark amended or additional parts of revised pages.

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GLOSSARY

Abutment	Part of the bridge structure that supports the bearings at the end of a deck and often supports and retains the approach embankment.
Bearing	The elements between the impost / cill and the main girders on which the deck is supported.
Bridge	A deck and its supporting structure (e.g. impost / cill, abutment or piers).
Cill	Alternative name for impost. The (usually) concrete beam on which the lower part of the bridge bearings are located.
Deck	A pair of main girders and a floor.
Deep Girder	A main girder located within the area for fixed infrastructure (platforms) in the lower sector structure gauge. May act as a robust kerb.
Designer	The person responsible for selecting the relevant standard designs and details to suit the specific requirements for a particular scheme.
Filler Beam	A steel and concrete floor arrangement comprising transverse spanning steel sections encased within and acting compositely with a concrete slab.
Floor	The transverse element that supports the ballast and track. May comprise filler beams composite with concrete slab, or steel transverse ribs and steel plate.
Gauging Diagram	A diagram showing the clearances between the lower sector structure gauge and the proposed structure.
Impost	Alternative name for cill. The (usually) concrete beam on which the lower part of the bridge bearings are located.
Main Girder	The primary load sustaining element that spans between bearings and supports the floor. Comprises a pair of flanges, possibly flange doubler plates, a web, web stiffeners and bearing stiffeners. The flanges are offset and resemble a Z shape.

Pier	Part of the bridge structure that supports the bearings at the end of a deck. Generally used where more than one span, in between abutments.
Protective Treatment	A treatment applied to structural elements to protect them from environment.
Scheme	Any planned work that involves the replacement of an existing bridge or deck.
Shallow Girder	A main girder located either below the lower sector structure gauge or within the area reserved for items intended to come in close proximity to trains (up to 110mm above rail and between 730mm and 558mm from the rail horizontally) allowed in GE/GN8573-2.
Transverse Rib	A steel transverse member formed of a tee rib.
Trimmer Beam	The first cross member adjacent to the main girder bearings. May or may not support the trimmed ends at adjacent cross members.
TUM	Technical User Manual
SDD	Standard Designs and Details
Walkway	A standard detail comprising brackets attached to web stiffeners and longitudinal spanning members positioned to allow railway personnel traverse the bridge away from the track.
Waterproofing	Measures applied to handle and remove water off the deck and away from structural elements.
Z Type	A standard underbridge arrangement comprising a pair of Z shaped main girders, a floor and four bearings.

1 INTRODUCTION TO STANDARD DESIGNS AND DETAILS

The development of the Standard Designs and Details (SDD) has been undertaken by Network Rail to improve safety, asset reliability and increase efficiency. Their development is linked to Network Rail's overall business objectives, to improve reliability of the railways and reduce the funding requirements for on-going management and maintenance of the network. The basis of the SDD focuses on two main areas that derive from these issues:

- Ensuring that the design meets Network Rail's requirements
- The design is as successful as the designs of previous railway engineers, who built and maintained bridges that have given good service for approaching 150 years.

The use of the SDDs is promoted from the highest level within Network Rail. Alternatives to the SDDs will only be considered where it can be demonstrated that a SDD cannot be used and must be agreed with Network Rail's professional head of civil engineering. Failure to use a SDD may lead to project authority being withheld.

1.1 Network Rail's Requirements

Network Rail's requirements are split between two areas, delivery and function:

1.1.1 Delivery Requirements

The SDDs have been taken to a stage where Form As and Form Bs for each aspect covered (underbridge design, ancillaries etc.) have been submitted and approved. This leads to the following benefits:

- A reduction in the design development timescales and costs.
- Minimising contractor and sub-contractor costs associated with uncertainties in detailing requirements.
- Streamlining the technical approval process for commonly used designs and details.

1.1.2 Functional Requirements

The SDD have been designed to ensure satisfactory performance of the asset under both normal operations and abnormal operations (both planned and unplanned). A further consideration has been Network Rail's requirement to reduce the volume of maintenance and management costs through the adoption of good practice. This leads to a number key design drivers including:

- Failure modes: Critical failure modes should give warning, and alternative load paths should be provided for potential local failures.

- No hidden details: All main structural elements should be visible from at least one side.
- Robustness: It is desirable for elements of the structure to have a degree of robustness so that they are not damaged by unforeseen events disproportionate to the cause.
- Capability to support load.
- Acceptable deformations.
- Structure gauge requirements: The underbridges have been designed to cater for a range of positions of the structure gauge allowing their wide use.
- Safe working environment: The bridges have been designed to minimise the risk to people on or about the bridge.
- Resistance to “bridge bash”: The bridges have been designed to minimise the risk of catastrophic failure in the event of a “bridge bash”.
- Resistance to derailment: The bridges have been designed to cater for the codified derailment loads, as well as protecting the structure whilst mitigating damage to the surrounding structures.

These functional requirements are requirements of draft Network Rail standard NR/L2/CIV/020. Draft 012 of this standard has been used and the requirements therein met in designing the standard Z-type details.

A library of standard designs and details for a range of half through underbridges forms meeting these requirements has been produced. This document contains guidance on the use of these standard drawings, including advice on the following:

- The elements and options contained within the suite of standard designs and details.
- Instruction on configuring a design using the standard designs and details
- Specific design restrictions and design assumptions
- Installation guidance
- Safety / CDM / environmental issues

The library will be maintained and distributed by Network Rail to its stakeholders and key external suppliers for adoption across the network at a national level.

2 GUIDANCE FOR USE OF NETWORK RAIL STANDARD DESIGNS AND DETAILS

The underlying philosophy of this standard is that a single standard deck design is provided, together with general details of the other components (i.e. main girders, bearings, walkways, protective treatment, waterproofing etc.) which go to make up a standard Z type bridge superstructure.

This allows the designer to produce a specific bridge design to suit the particular span, skew, track geometry, cable ducting and walking route requirements of any particular location with the minimum of design and drawing time, so long as they are within the limits of validity of the standard.

The flowchart in Figure 2-1 demonstrates the use of the technical user manual and standard drawings. The designer should analyse the constraints and requirements that exist for the specific project site. This information should be used in conjunction with the design advice contained within the technical user manual, to decide which elements can be taken from the suite of standard designs and details and which items, if any, need bespoke design. This designer output, and the series of standard drawings can be combined to produce the final Z type underbridge solution.

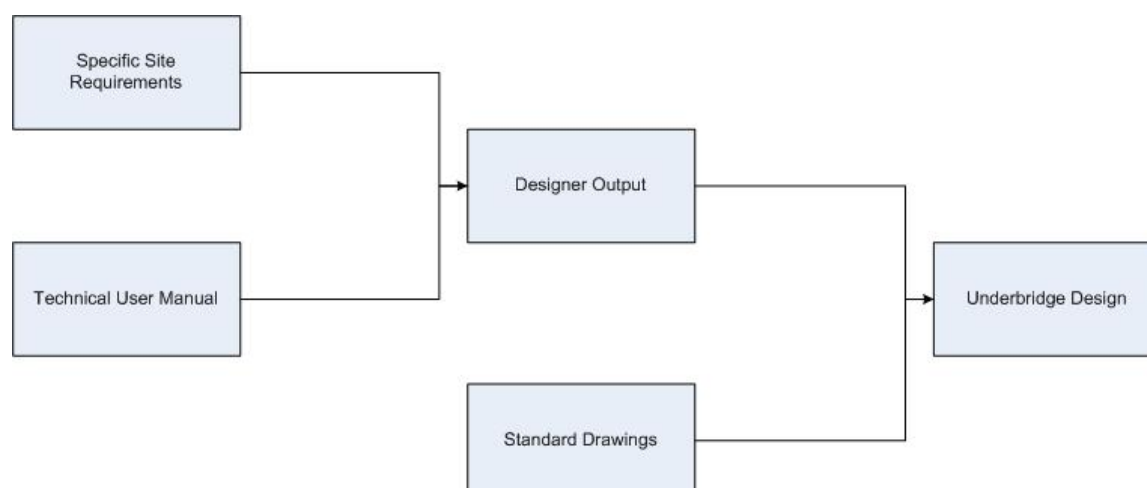


Figure 2-1: Flowchart to show the use of Network Rail's Standard Details and Designs

This manual describes the 2009 standard for rail underbridges using a half through construction arrangement of Z-type main girders with either a filler beam floor or a steel floor. It is intended to be read in conjunction with the set of standard drawings listed in Appendix A and aid the designer in producing an individual bridge design using this standard, or in comparing these

standard designs and details with other solutions. The manual discusses issues that will need to be covered in a contract specification for a bridge of this type.

The designer is required to determine the bridge steelwork layout and produce a scheme specific deck steelwork general arrangement drawing. The designer will also have to produce survey, proposed general arrangement, substructure detail, track layout and levels and setting out drawings, as necessary, plus detailed reinforced concrete drawings and schedules. A list of the standard drawings used that define the required works shall be included on the general arrangement drawing.

The standard drawings shall not be redrawn or modified. Any required changes (e.g. when defining geometry or facilitating construction methodology) shall be shown on a separate drawing that clearly identifies the affected details.

The deck and other components have been designed to cater for a wide range of spans, skews and track geometry. For situations outside these parameters, the standard cannot be assumed to be applicable. Equally it will be obvious that the design here, in catering for such a wide range of circumstances, will inevitably involve conservatism on specific aspects and for specific bridge arrangements. Thus it may be possible to use the existing design in whole or part outside the given limits without modification, or to achieve a less substantial design (e.g. lower weight) within those limits: In both cases they will need approval, full re-design, and an appropriate check. These are matters that will need discussion with Network Rail's project sponsor and Network Rail's professional head of civil engineering if such a course of action is favoured.

2.1 Approval of Schemes Using Standard Designs & Details

The SDDs for each half through underbridge form have been submitted and approved by Network Rail at both Form A and Form B (including a Category III Check) stages of the Network Rail approvals process in accordance with NR/CIV/SP/003. The flowchart in Figure 2-2 demonstrates the general process of using the SDDs and TUMs. The blue shaded boxes assist the designer to select the appropriate details or confirm the suitable options available. A list of typical site parameters to consider in determining the appropriate details or confirm the suitable options available is included in section 4.13.

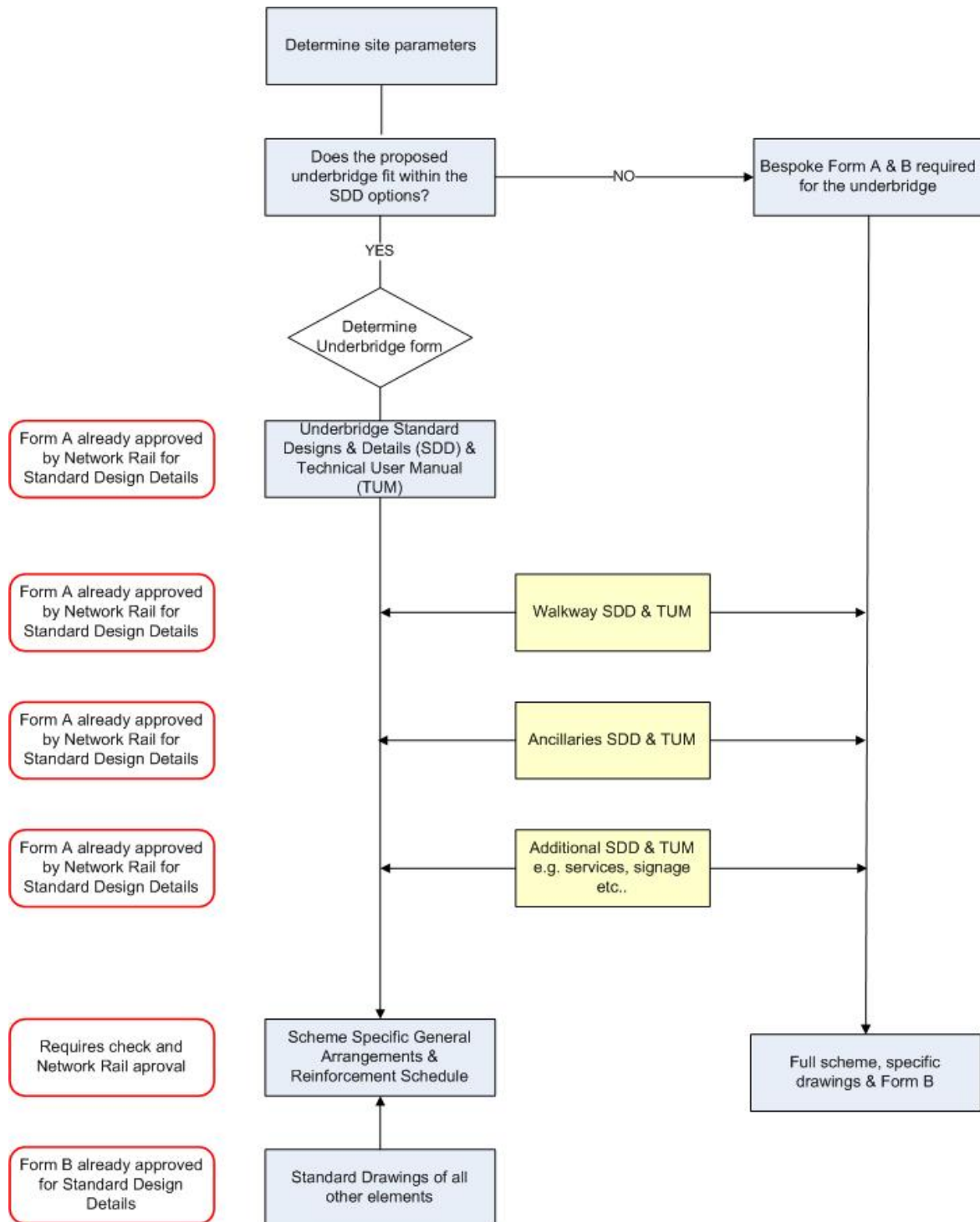


Figure 2-2: Process using the Standard Drawings and Technical User Manuals

The designer will need to produce a scheme specific Form A for the site under consideration. This Form A will detail the site specific parameters, include a gauging diagram and a list of the SDDs that will be used. As discussed previously the SDD Form As have been approved and a site specific Form A is to be produced to gain approval for use of the particular SDDs selected on the scheme.

Following Form A approval the designer will need to produce general arrangement drawings and reinforcement schedules only for the scheme. As discussed previously the SDDs have been approved (Form B), and include a Category III Check. Therefore the checking required for each specific scheme will be of the general arrangement and reinforcement details and schedules to ensure they are suitable in meeting the scheme requirements.

The level of checking required is:

- Category I Check of the application of the standard designs and details
- Category II Check of the general arrangement (including site survey information) and bar bending schedules

2.2 Modifications to Standard Designs & Details

Modifying the standard designs and details will only be accepted by Network Rail where the modifications can be justified technically and where it can be demonstrated that the modifications will not incur any significant additional whole life cost to Network Rail. Any modification invalidates the Standard Designs and Details Form As and Form Bs. In the event that modification is proposed the following justification must be provided:

- Technical justification considering structural capacity, longevity with respect to fatigue and reserves for future corrosion allowance:
 - Form A documentation.
 - Form B documentation.
- Cost justification
 - Estimate of the increased cost of maintaining non-standard assets.
 - Estimate of the increased cost of managing non-standard assets.
 - Estimate of the increased cost of additional Network Rail approval and review costs.

2.3 Drawing Selection Flowchart

The following flowchart assists the designer in deciding the options to select and which drawings to use in detailing a standard walkway and approach:

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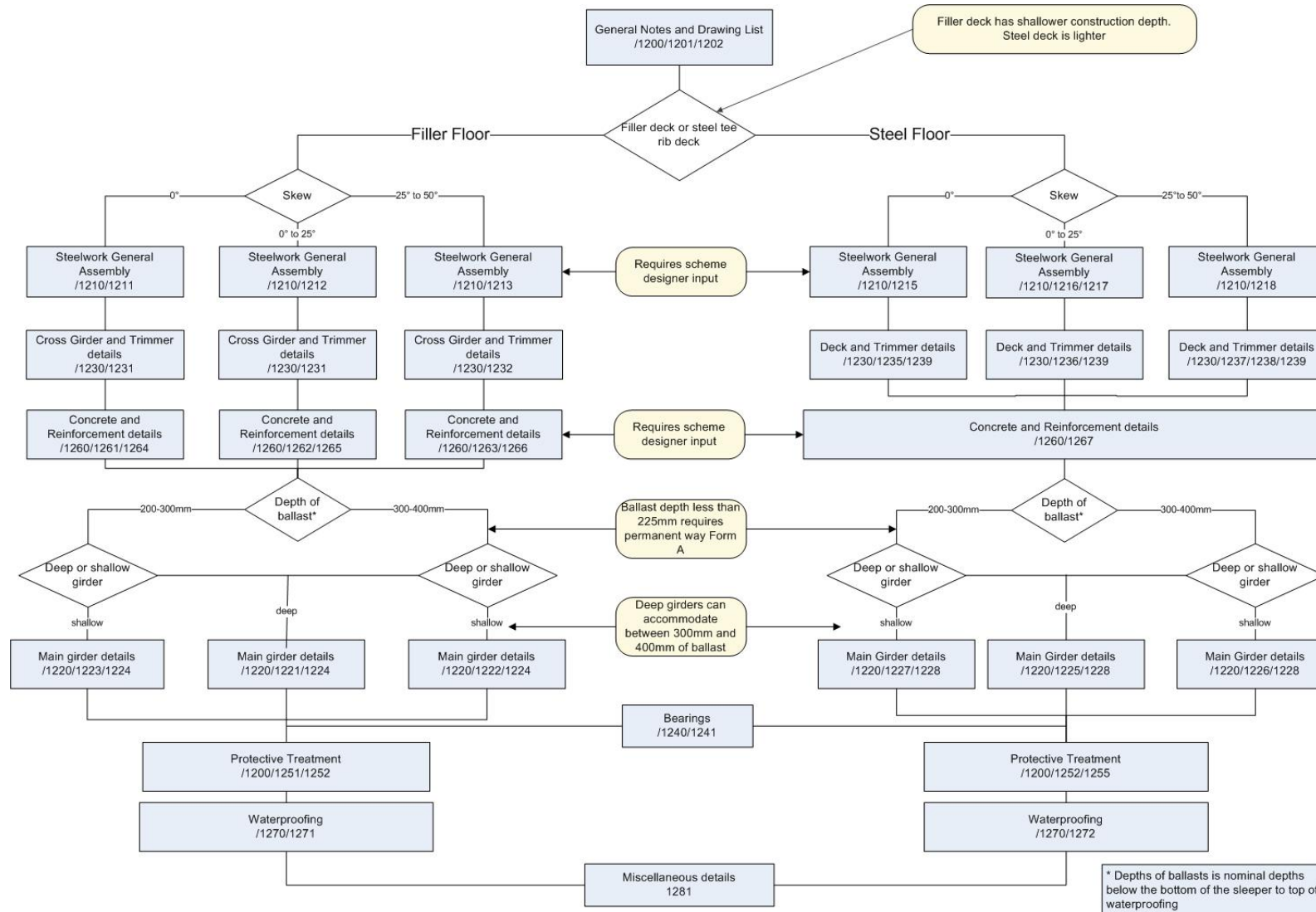


Figure 2-3: Process to determine the Standard Details and Designs to use in detailing a Standard Z-type Underbridge

3 Z-TYPE UNDERBRIDGE APPLICATION DETAILS

The standard Z-type design may be used at any suitable location in UK and complies with The Railways (Interoperability)(Amendment) Regulations 2007 (S.I No. 3386) with the following exception:

The use of shallow girders (refer to 4.7.2 for definition) within the zone up to 110mm above rail and between 730mm and 558mm from the rail horizontally (allowed in GE/GN8573-2) is not permitted on the UK parts of the High Speed Trans European Network (TEN). Note that the use of shallow girders within the zone up to 110mm above rail and between 730mm and 558mm from the rail horizontally is permitted on the UK part of the Conventional Rail Network.

The standard drawings provide a complete set of details for the superstructure including the bearings. For a particular bridge, the designer needs to determine the specific layout, choose the appropriate drawings, add the necessary dimensions and exercise specific options on these standard drawings.

It is intended that only those standard drawings relevant to the specific contract are issued to the contractor as part of the contract drawings, together with general arrangement drawings particular to the specific bridge. The general arrangement drawings prepared by the designer will specify all principal dimensions and sizes, including material grades. Standard drawings relevant to the particular bridge should be listed on the general arrangement drawing.

The standard drawings allow for skew spans between 6m and 17m for three skew related ranges:

- Square spans.
- Spans for bridge skews in the range 0° to 25° .
- Spans for bridge skews in the range 25° to 50° .

Where skew affects the design details (e.g. cross girder / transverse rib details), there are three separate standard drawings, one for each range. For other details which are not skew related (e.g. bearings) there is a single drawing.

The designer should therefore choose the relevant drawings for his particular bridge skew range from the full set of standard drawings. Refer to flowchart in Figure 2-3. To simplify details and fabrication, the designer should make low skew decks square where possible.

For skew bridges, the drawings are drawn for one (unstated) particular skew and span, which may not match the particular bridge under design. The standard design has considered all skew variations and the details shown can be rotated to suit the required skew.

4 DETAILS OF STRUCTURAL FORM

The standard Z-type deck comprises a single track half-through deck with two z-shaped steel main girders and either a filler beam floor or a steel floor. The main girders are simply supported on short rocker bearings. Trimmer girders are supported on the inside edges of the main girder bottom flanges. Refer to the figures in Appendix D for general arrangement details.

4.1 Geometry and Configuration

The designer will need to utilise the following Railway Group Standards (or their successors, where appropriate):

- GE/RT8073 – Requirements for the Application of Standard Vehicle Gauges.
- GC/RT5112 – Loading Requirements for the Design of Bridges.
- GC/RT5203 – Infrastructure Requirements for Personal Safety in Respect of Clearance and Access.
- GC/RT5212 – Requirements for Defining and Maintaining Clearances.
- GE/GN8573 – Guidance on Gauging
- NR/L2/CIV/020 – Design of Bridges and Culverts (a copy of draft 12 appended to this TUM)
- GC/RC5510 – Recommendations for the Design of Bridges.

4.2 Span

The span range of the standard Z-type underbridges considered in the SDD is the span measured between centres of bearings and is 6.0m to 17.0m. Limitations apply to the maximum span when considering shallow girders with a ballast range of 200mm to 300mm.

4.3 Skew

The skew range, measured between the bearing centre line and perpendicular to the track centreline, is 0° (square) to 50° (maximum).

4.4 Floor Type

There are two Z-type floor arrangements, a filler beam floor option and a steel floor option. The filler beam floor option is suitable for the majority of schemes with the exception where lifting weights or the loads on existing abutments are to be minimised. In this situation, the steel floor option is advantageous at the detriment of the construction depth which is greater than the equivalent filler beam floor. The steel floor standard detail includes a maintenance gap between the transverse rib flange and main girder flange. This gap must not be reduced without the agreement with Network Rail's professional head of civil engineering. There are further advantages of using the filler beam floor, including less long term maintenance and a lower capital cost. As such the filler beam floor is the preferred option.

4.5 Floor Width

The upper deck width limit of 3300mm between main girder web centres allows the deck to be wide enough to accommodate DC traction cables without the need for an adjacent cable bridge. This carries a weight penalty for lifting in a new bridge compared to narrower decks. The narrow deck width is that required for straight track with ± 25 mm tolerance on track lateral positioning. Where shallow girders are specified (refer to section 4.7.3) a 2588mm wide sleeper is considered and a 50mm minimum clearance between the structure and sleeper end required.

At the narrower end of the deck width range, shallow depth main girders must be utilised to comply with clearance requirements to the structure gauge. Where narrower deck widths are proposed, due attention must be paid to the electrical clearance requirements where conductor rails are present.

Deck widths and the position of any cess walkways will also be affected by the cant, curvature and track alignment of each particular bridge location. Consideration must also be given to existing abutment width and adjacent structures, walkway positions and bridge end access requirements. The minimum track radii that can be accommodated by the standard designs and details are given indicatively in Table 4.1. The designer is responsible for confirming scheme specific details and ensuring the maximum lateral force limits (refer to Appendix C) are not exceeded:

Floor width	3.300m	2.900m	3.300m	3.165m	3.300m	2.900m	3.300m	3.165m
Span	6m	6m	6m	6m	17m	17m	17m	17m
Girder type	Shallow	Shallow	Deep	Deep	Shallow	Shallow	Deep	Deep
Speed	50kph	200kph	60kph	200kph	50kph	200kph	70kph	200kph
Radius	200m	∞	250m	∞	250m	∞	350m	∞

Table 4.1: Indicative Minimum Track Radii on a Standard Z-Type Deck

4.6 Construction Depth

The construction depth for each Z-type floor type varies with span ranges and ballast depth, with a minimum of 913mm and a maximum of 1153mm. Refer to drawing NR/CIV/SD/1201 for specific details. The construction depth has been determined assuming the following: depth of track (rail, rail pads and sleeper) of 368mm, the nominal ballast depth, waterproofing (assumed as 15mm thick) and the chosen floor type depth.

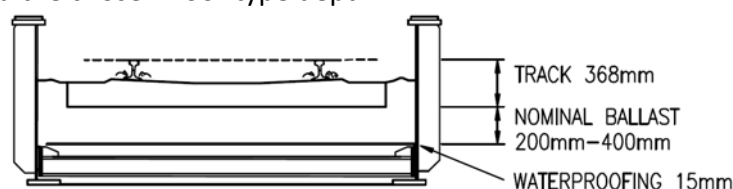


Figure 4-1: Construction Depth

4.7 Clearances

4.7.1 Structure Gauge Clearances

The designer should:

- Ensure that adequate clearance is provided between existing and proposed vehicles and the structure.
- Consider the maximum offset of the rail centre line and bridge centre line.
- Ensure that the structure gauge considered (to include cant and end throw allowances) is suitable for the line considered for each specific scheme, in accordance with current Network Rail and Railway Group Standards.
- Ensure that the required track radius (if any) will not result in encroachment on the structure gauge by any part of the deck or walkway. See earlier comment

The limits that the standard designs have been designed within are discussed in section 4.8 noting that the bridge structures are straight and the allowances for track offset small. Equally the effect of cant on maximum girder depths and on ballast top relative to shallow girder top must not be overlooked. The maximum cant of 150mm (super elevation + track) was derived to alleviate this problem.

4.7.2 Static Electrical Clearances

Where conductor rails are present, the designer should:

- Ensure that adequate clearance is provided between the conductor rail and the structure

4.7.3 Clearances Limits Affecting Design.

There are three basic cases to consider:

a) Bridges with shallow girders.

In case a), the tops of the main girder are low enough to avoid any interference with the kinematic envelope and are placed in the zone up to 110mm above rail level and between 558mm and 730mm from the running edge of the rear rail (allowed in GE/GN8573-2). Therefore the only potential clearance conflict is with the hand railing on any walkways. This aspect is addressed by making the walkway width large enough to meet the clearance requirements (See Section 6.1). The limiting criteria on track position in this case is the need to provide an adequate distance from sleeper end to the main girder top flanges or webs. An absolute minimum distance of 50mm is recommended and, where possible, should be increased to provide tolerance for track positioning. Where a conductor rail is present, the designer must ensure adequate static electrical clearance between the conductor rail and the structure.

Note that shallow girders with the top flange above rail level cannot be used on the UK parts of the High Speed Trans European Network (TEN) where the Railways (Interoperability)(Amendment) Regulations apply.

Decks with shallow girders only should not generally be used unless protected by adjacent decks (i.e. multiple track situations) or structures that act as or provide robust kerbs.

b) Bridges with deep girders.

For case b), the deep main girders may act as robust kerbs. This arrangement has the additional limitation of the clearance from the compression flange inside edge to the kinematic envelope. An absolute minimum clearance of 25mm has been assumed. The maximum distance between the rail and flange level considered in the standard designs is 350mm. Note that the designer should assess if this is acceptable for specific bridges, i.e. permanent way clearances and requirement to maintain gauge, or construction and installation tolerances, as a minimum clearance of 50mm is desired for possible future works. On the standard deck (3300mm wide) this leaves an allowance of 92.5mm to cater for the effects of cant, end and centre throw, track curvature and positional tolerance. Cant throw effects can be countered by offsetting the track. If this is done then the minimum radius of curvature that can be achieved at the

maximum span range of 17.0m is in the order of 350m at 70kph. This limiting criterion has been used in arriving at the 3300mm standard deck width.

In case b) the sleeper end position will not be critical. Walkway widths however must be determined, as in case a), to be wide enough to clear the upper part of the kinematic envelope with particular attention paid to canted or curved track arrangements. The designer must also confirm the deep girders can be located within the space available in the six foot. Typically there is insufficient space in the six foot for a pair of deep girders and an outer, deep girder acting as a robust kerb and a shallow inner six foot girder is provided.

c) Bridges with one deep and one shallow girder.

Where appropriate, case c), a deep and a shallow girder may be used on a single deck. In this case the outer deep girders will act as a robust kerb. Note that the deck centreline and the straight track centreline will not be coexistent for the minimum deck width.

(Note: deep girders are as defined as girders that act as a robust kerb, i.e. 350mm above rail level (deep) and shallow girders are those below the structure gauge. Refer to drawing NR/CIV/SD/1201.

4.8 Track Arrangement

A minimum distance of 50mm is assumed between the edge of the top flange and sleeper. A lateral positioning tolerance of 25mm is then provided to ensure the 50mm between the edge of the top flange and sleeper is maintained. Therefore 25mm is the total minimum lateral tolerance for positioning the track and deck where shallow girders are used.

A minimum distance of 25mm is assumed between the edge of the top flange and the structure gauge. This distance is the total minimum lateral tolerance for positioning the track and deck where deep girders are used.

The total lateral tolerance for track and deck installation assuming straight track, relative to the centre line of the deck, is as follows:

- Deep girders $\pm 92.5\text{mm}$ on a 3300mm wide deck reducing linearly to 25mm on a 3165mm wide deck.
- Shallow girders $\pm 226\text{mm}$ on a 3300mm wide deck reducing linearly to 26mm on a 2900mm wide deck.

For bridges with deep girders a lower maximum offset will apply due to the need to keep the inside edges of the main girder compression flange clear of the kinematic envelope of the design traffic.

The designer should check that the effects of curved track (end and centre throws) does not cause the structure gauge to foul the structure and that sufficient installation tolerances are provided.

4.9 Positioning

An absolute minimum lateral positioning tolerance of 25mm has been assumed although it is recommended that where possible, a minimum clearance of 50mm should be provided for possible future track slues.

The minimum vertical tolerance for the rail position in relation to a shallow girder is 13mm, noting the assumed track depth in section 4.5. Note that where possible, the vertical tolerance should be maximised as the typical tolerance on vertical track position is + 10mm, - 25mm (depending on line speed) and datum plates will be needed to control the position.

4.10 Cant

The absolute maximum cant permitted on the standard design is 150mm. This is made up of track cant and deck super elevation. The designer should ensure that the effects of cant, such as cant throw do not cause the structural gauge to foul the structure. The limits of the cant components can be seen in figure 4.2.

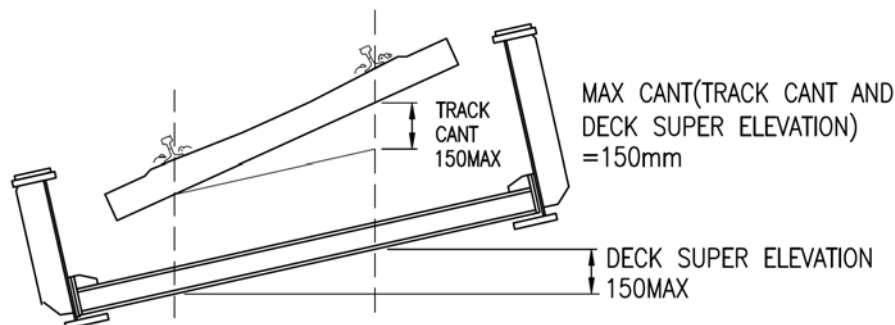


Figure 4-2: Cant Effects

4.11 Ballast Depth

The desired ballast depth is 300mm at mid span under the low rail. Shallower ballast depths may be used, to a minimum of 200mm, however permanent way approval will be required. The absolute maximum ballast depth below the sleeper shall be 400mm averaged over the span.

4.12 Sleeper and Rail Details

The total depth of the rail, chair and sleeper has been taken as 368mm. The designer should check that the chosen rail and sleeper combination will not cause the structural gauge to foul the main girders and sufficient distance is provided between the sleeper ends and the main girders.

Where narrow decks with steel floors and a shallow ballast depth are required, in order to avoid the ballast plates within the ballast layer, narrow wooden sleepers at close spacing may be required to ensure adequate clearance (50mm minimum) is provided between the ballast plate and the sleeper.

4.13 Site Constraints

The designer will need to consider the site constraints, including but not limited to: OLE, existing abutments, S&T, location of cess etc. Headroom above highways or waterways should be maximised where possible and appropriate signage fixed to the structure (ideally to the bash beam or web stiffener. Refer to ancillary details in NR/CIV/SD/1800 series). Note that the signs will be the responsibility of the Local Authority, Highways Agency or similar authority.

4.14 Direct Fastening Systems

The standard Z-type design has not been developed specifically to accommodate direct fastening systems but the use of the standard drawings does not limit their use to ballasted track. Where a direct fastening system is required for a specific scheme, the designer shall select the suitable standard design with the required track / structure performance. Additional design checks will be required to ensure suitability of the chosen detail as the intensity of the railway loads will be greater than for ballasted track. Form A and Form B submission and approval will be required.

5 INSTALLATION GUIDANCE

The standard Z-type has been designed to be lifted by cranes (mobile road cranes and rail cranes, size to be determined by the designer), or rolled or slid in while supported at the bearings or jacking points.

Specific calculations will be required of the designer if any other erection method is proposed.

The bridges can be installed with up to 300mm of clean ballast in place, though the designer should ensure it's stability and that the ballast is suitably retained. It is suggested that the density of ballast is taken as 18kN/m^3 when calculating the lift weight.

5.1 Trial Erection

As stated on drawing NR/CIV/SD/1202 the bridge should be fully trial erected: The trial erection should include all superstructure and ancillary items such as walkways, impost / cill beams, ballast walls and cover plates. This is particularly important for skew bridges. During the trial erection all bolts should be hand tightened. Any HR bolts fully torqued should be marked and discarded.

No trial lifts shall be undertaken until the bridge deck is structurally complete in accordance with standard and scheme drawings.

5.2 Installation Tolerances

The tolerances assumed in the standard design are for installation of the decks by crane. The standard designs were developed assuming the decks could be positioned within 10mm and the track placed within 15mm of the design position on plan. Vertical positioning tolerance of 10mm has been considered appropriate as it is assumed the track profile could be locally adjusted on site if necessary. Installation by alternative methods will require these tolerances to be reviewed.

5.3 Lifting Guidance

Where the decks are installed by lifting them into position by lifting brackets attached to the main girder top flanges, the designer should ensure that lifting points on one girder are located perpendicularly opposite to the lifting points on the opposite girder. Details are given on the standard drawings and assume that the standard 25t or 50t lifting brackets are used (refer to ancillary drawings NR/CIV/SD/1800 for details of the brackets).

Lifting brackets should be located at the web stiffener locations and the web stiffener increased in thickness to 30mm. Where the web stiffener arrangement is such that web stiffeners are not perpendicularly opposite, an additional 30mm thick lifting web stiffener may be inserted in the appropriate location as detailed. Care must be taken when determining the curtailment of any top flange doubler plates to ensure the lifting bracket is in full contact with the flange doubler plate.

It is recommended that the decks lifter demonstrated lifting slings to ensure equal loading on each lifting bracket.

The lifting points should ideally be located between the quarter and third points of the span and the lift arrangement should ensure no transverse force is applied to the main girder top flange, unless a suitable temporary bracing system has been installed for the lift. In all cases the designer must ensure that during the lift, the stresses (a safety factor of 2.0 is recommended) in the main girder top flange does not exceed the theoretical stresses at the end installation from permanent loads, unless lift specific stress checks are undertaken.

Specific calculations will be required of the designer if any other erection method is proposed.

5.4 Check List for Non-Standard Arrangements and Non-Standard Items

The following check list (not exhaustive) lists non-standard arrangements and items to be designed or checked by the designer for the particular scheme. Where appropriate, a separate Form C will be required.

- Capacity and stability of the bearing lifting bracket if the imposts / cill beams are to be attached to the deck during installation.
- The effect of the proposed lifting / support arrangement on;
 - o the lifting lugs (where applicable),
 - o the load distribution to each lifting / support point,
 - o the effect on the main girder if not lifted in accordance with Section 5.3 or supported in accordance with Section **Error! Reference source not found..**
- The suitability of the substructure:
 - o check the load effects from the new deck including pressure at base and under the impost / cill beam,
 - o check overturning and sliding stability with and without the new deck in place.
- Undertake suitable geotechnical investigation to determine soil properties.
- Check that the differential settlement predicted does not exceed the value the standard designs have been designed to accommodate (At SLS, 1 in 1000 along the abutment subject to a maximum 5mm difference between bearings).
- Check the effects of supporting the deck at any point other than assumed for lifting (refer to section 5.3). Note that alternative methods of installation may be more suited

for installation in short (8 hour) possessions but may require additional installation tolerances (refer to section 5.2).

5.5 Check List for Installation Options

The following check list (not exhaustive) lists typical issues to be considered by the designer for the particular scheme when deciding on the available options to install the deck.

- Access to site
 - Clearances to street furniture, overhead cables, low headroom or weight restricted bridges etc.,
 - Road profile (horizontal and vertical): Proximity to hump back bridges, tight curves etc. that may restrict access to site or plant movement.
 - Location for site compound.
- Services: Highway / waterway.
 - Services in or alongside the highway or waterway must be protected from bridge installation activities.
- Services: Railway.
 - Services may restrict or complicate installation of new bridge decks. Some methods of installation will be more suited for sites with numerous railway services, e.g. if services cannot be raised, this may preclude installation with SPLV.
- Access around site
 - Consider size of compound to rig cranes, store plant and materials, store bridge elements, staff accommodation and welfare provision.
- Site properties
 - Strength of ground (ground reinforcement or piling for cranes or temporary works),
 - Access to site (haul roads and access agreements with land owner),
 - Environmental issues (minimise damage to habitat, restrictions due to the presence of rare or protected fauna and flora, relocation of rare or protected fauna and flora, limitations on time of year to do the work to minimise impact on flora and fauna).
 - Working over water.
- Available possessions
 - Minimise all possession times.
 - Railway possessions. Strive for an 8 hour railway possession. Installation with SPLV is usually quicker, thus minimising railway possessions, but will need larger installation tolerances (refer to Section 5.2) and will not be suitable for all sites.
 - Highway and waterway possessions may be limited at certain times of the year, depending on the site location, e.g. a highway possession will be unlikely in December if the site adjacent to a retail outlet, and a waterway possession unlikely in July and August if heavily trafficked with recreational vessels.

6 GUIDANCE FOR USE OF THE Z-TYPE STANDARD DESIGNS AND DETAILS

6.1 General Arrangement Drawing

General arrangement drawings should be produced in line with Network Rail's requirements for the specific site. However it is expected that these drawings should normally include the following:

- Plan, bridge elevation and a cross-section through the bridge including the elevation of one abutment and the bridge seating arrangement.
- Geotechnical information, details of services (railway and other), details of land ownership and details of adjacent infrastructure,
- Principal dimension information such as span, skew, clearances from rail to main girders and walkway parapets, six foot gap (where applicable), bearing, bridge soffit, rail, walkway and parapet levels, clearance to road (or river or rail as applicable).
- List of drawings forming the complete bridge design.
- Scheme specific deck steelwork general arrangement drawing.

6.2 General Assembly Drawings

The setting out and arrangement of cross girders / transverse ribs, trimmers and main girders will be unique in most instances and dependent upon many variables including, bridge span, abutment skew, clearance requirements, main girder stiffener design and compliance with minimum and maximum spacing requirements of cross girders.

Where decks are to be positioned side by side, the designer should ensure web stiffener positions are staggered to enable future access for inspection and maintenance.

It should be noted that the trimmer skew will be different to the bridge skew in all instances except that of a square bridge deck as the trimmer is supported inboard, on the main girder bottom flanges. The floor overhangs the trimmer so that the floor skew equals the deck skew. For setting out of the trimmer see drawings NR/CIV/SD/1235-1237 and Figure 6.1.

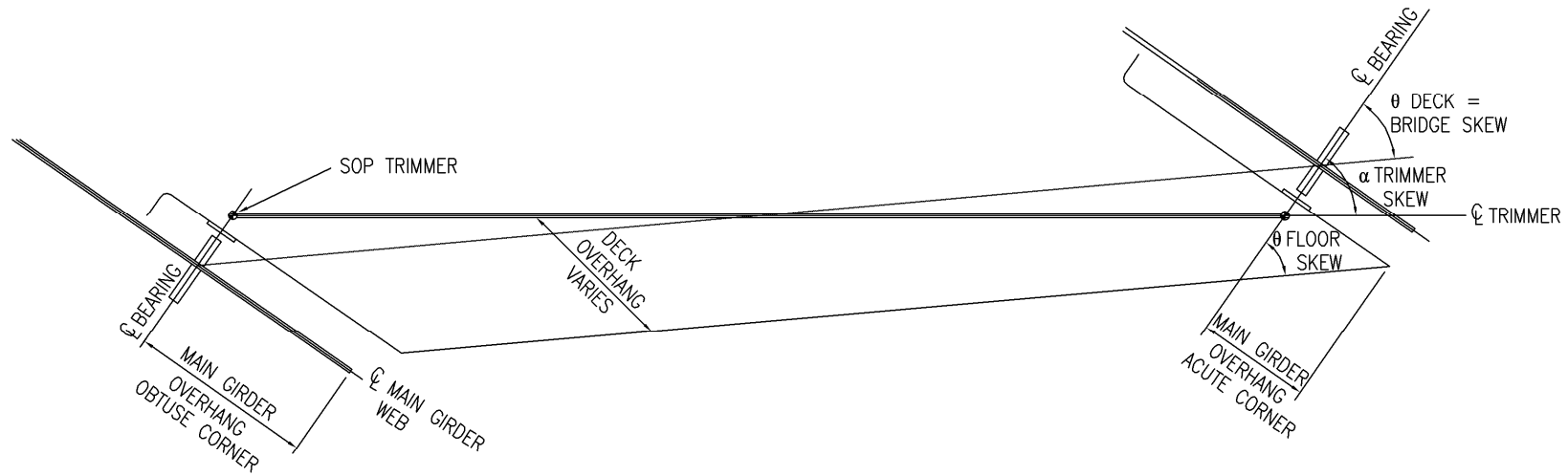


Figure 6.1: Definition of Skews

For deck skews up to and including 25° skew, a fanned cross girder / transverse rib arrangement is required at the deck ends as acute connections into the trimmer are neither desirable nor practical. Fanning of the last few cross girders is usually all that is necessary on low skew bridges. As the skew increases and the required number of fanned cross girders / transverse ribs increase, fabrication details may become excessively complicated. In these instances there is an option to skew all or some of the cross girders / transverse ribs by the same amount through the middle of the bridge to allow duplication of fabrication details. For shorter spans, fanned cross girders/transverse ribs are not practicable: Insufficient length is available to fan the cross girders / transverse ribs perpendicular to the main girder. For these cases cross girders / transverse ribs should remain parallel to the trimmer girder. For details refer to standard drawings NR/CIV/SD/1201.

For deck skews between 25° and 50° a trimmed cross girder / transverse rib arrangement is shown at the deck end. All cross girders / transverse ribs are square to main girders. Where cross girders / transverse ribs connect into the trimmer, there are alternative details for both filler beam and steel floor types.

Setting out of the cross girders / transverse ribs shown on the standard drawings considers the setting out point as the intersection at the main girder web and a line perpendicular to the web at the point the cross girder / transverse rib centre line meets the inside of the web. Where required, the centreline at the web stiffener goes through the setting out point. Refer to figure 6.2.

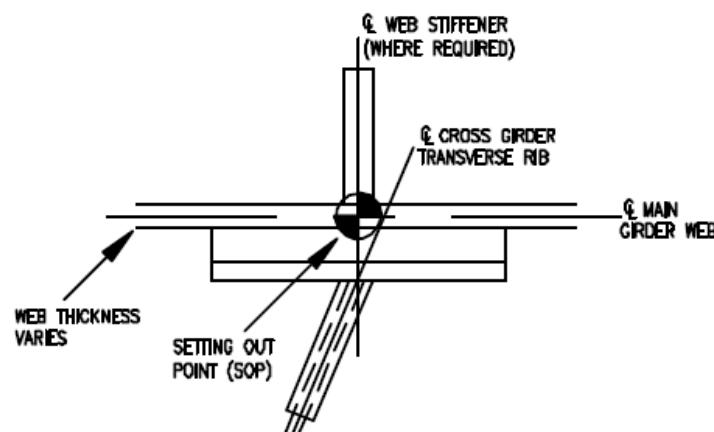


Figure 6-2: Cross Girder / Transverse Rib Setting Out

6.3 Details Drawings

Details are provided for all spans and skews. In a number of cases, to avoid any conservative designs, the details depend also on the traffic type and annual tonnage. This section gives guidance on how the required details should be selected.

6.3.1 Span

The standard details drawings give details for particular span ranges. Where the span required (measured between bearings, parallel to the main girders) is not included on the standard drawings, the details for the next span are to be used.

e.g. if span required is 11.7m, the main girder details for the next span, i.e. the 12m, are to be used.

6.3.2 Skew

The standard details and drawings give details for particular skews ranges. Where a skew of 17.4°, the details for deck skews (i.e. between main girder bearings) between 0° and 25° are to be used. Where skews are 0° or 25°, the designer may choose the drawings to be used, but must ensure they are used consistently. For very low skew angles, the designer should, where practicable, make the bridge square as this will simplify many of the details.

6.3.3 Traffic

The standard designs and drawings give details that may vary depending on the railway traffic anticipated at the particular site. Where details vary, e.g. main girder flange, doubler plate and web details and steel floor deck plate thickness, the detail to be used is either classified HEAVY or LIGHT in the table given on the particular drawing and replicated below in figure 6.3.

ANNUAL TONNAGE x10 ⁶	42-27	27-18	18-12	12-7
TRAFFIC				
25t axles	HEAVY GIRDERS		LIGHT GIRDERS	
EC Mix				
Type 9 MUs				

Figure 6-3: Traffic Type and Detail Classification

e.g. for a detail subject to 15 million tonnes of traffic per annum and medium EC mix traffic type, the details to be used are the LIGHT details, as shown above.

Where the annual tonnage is stated in two columns, the column to the left shall be used, e.g. if the detail is subject to 18 million tonnes of traffic per annum and EC mix traffic type, the details to be used are the HEAVY details.

6.3.4 Main Girder Length and Floor Overhang Past Trimmer

The length of the main girder will be determined by the designer: To simplify the ancillary details and arrangements (e.g. ballast walls, impost / cill units, refer to series NR/OIV/SP/1800) the deck skew will not equal the trimmer skew except for square decks. The floor skew is kept equal to the deck skew by varying the floor overhang past the trimmer. The allowable overhang is given as the standard drawings and should not be exceeded. The depth of deep main girders should be determined by the designer to suit the required ballast depth.

e.g. a filler beam floor, deep main girder for a 12.4m span with 335mm of ballast and track make up of 365mm will have the following details if traffic is 40 million tonnes per annum and EC mix traffic.

Main girder span: use 14m span details on NR/CIV/SD/1221

Main girder type: read where 42 – 27 million tonnes per annum column crosses the EC mix traffic type row in the table in the notes column. This table requires HEAVY girder details, i.e. use left hand side details on NR/CIV/SD/1221.

Girder depth stated is for 300mm ballast and track make up at 368mm. Therefore need to increase girder depth by $(335 - 300) = 35\text{mm}$, i.e. main girder now $1365 + 35 = 1400\text{mm}$ deep from top of bottom flange to top of top flange doubler to provide a robust kerb 350mm (to top of top flange) above rail assuming rail make up in section 4.6.

e.g. a steel floor, shallow main girder for a 10.4m span with 225mm of ballast and track make up of 350mm will have the following details if the traffic is 18 million tonnes per annum and Type 9 MU traffic.

Main girder span: use 11m span details as NR/CIV/SD/1227

Main girder type: read where 27 - 18 million tonnes per annum column crosses Type 9 MU traffic row in the table in the notes column. This table requires LIGHT girder details, i.e. use right hand side details on NR/CIV/SD/1227.

Girder depth stated is for 200mm and track make up at 368mm. Therefore increase girder depth by $(225 - 200) = 25\text{mm}$ for ballast depth. And decrease girder depth by $(368 - 350) = 18\text{mm}$ for track make up. Thus the net increase in girder size is $25 - 18 = 7\text{mm}$, i.e. girder now $995 + 7 = 1002\text{mm}$ from top of bottom flange to top of top flange doubler. This allows for 13mm tolerance for positioning the deck and the track vertically and ensuring the lower structure gauge is not compromised. If this is insufficient, the girder can be reduced in size but must not be less than the value stated on the drawing, i.e. in this case it must be $\geq 995\text{mm}$ from top of bottom flange to the top of the top flange doubler.

6.4 Concrete and Reinforcement Drawing

Reinforced concrete is required to act compositely with the steel cross girders in a filler beam floor and cantilever from the trimmer beam to achieve the required deck skew and support for ballast plates in both filler beam floors and steel floors. The standard details provide a floor skew to match the bridge skew. This will generally ensure that the deck end is roughly parallel to the line of the abutment and also enables the possibility of aligning adjacent bridge decks with spans up to 25° skew.

The reinforced concrete standard drawings require tailoring to suit specific skew arrangements. In doing so the designs should maintain the size and spacing of the bars to ensure adequacy of the reinforcement, and to ensure the minimum steel is present in any face to prevent early thermal cracking. Guidance is given on the standard drawings.

Floors should be detailed to allow easy placement of reinforcement as well as meeting all relevant design requirements.

If it is required to change the dimensions of the floor and cantilever this should be done with care and the following points should be taken into account:

- Reinforcement and cover to steelwork should be maintained.
- Adequate room should be provided around the trimmer for location of reinforcement and placing concrete.
- The floor end cantilever should not be increased above the maximum values stated on the standard drawings as this will increase loadings on the trimmer, trimmer end restraints, floor overhang and inward moments on the bearings. It may also exceed the allowable upward deflection at the end of the deck.

6.5 Bar Bending Schedules

Production of deck specific bar bending schedules to accompany the deck drawings are necessary in all instances.

6.6 Protective Treatment and Waterproofing

6.6.1 Basic Principles and General Comments

The basic principles are as follows:

- All buried surfaces beneath or at the sides of the track are protected by a waterproofing arrangement designed to ensure water and other train related pollutants do not come into contact with the bridge superstructure and support / end units.
- Drainage arrangements, such as providing a longitudinal fall (recommended minimum fall 1 in 250, noting deck camber to be considered), are incorporated in the overall bridge design to minimise maintenance requirements.
- Other steel surfaces permanently exposed in the final structure are specified as receiving a protective treatment. Refer to standard drawings for details.

Both protective treatment and waterproofing should be carried out as far as possible in shop conditions to ensure the maximum integrity and quality. Details are shown on the standard drawings of the residual site joint protection involving hand applied protective treatment and waterproofing system. It is envisaged that some remedial site painting will be required, to be carried out in accordance with the Network Rail Specification.

6.6.2 Protective Treatment

The standard steelwork protective treatment specified is a type N1 system in accordance with NR/SP/CIV/039. The standard drawings show details in accordance with NR/GN/CIV/002. Where no guidance is provided the requirements of NR/GN/CIV/002 shall apply. Points to note are include:

- Areas encased in concrete (e.g. Filler floor trimmer beams, filler beams) should remain untreated, only loose rust or mill scale removed.
- Areas partially encased in concrete (e.g. lower part of inner main girder, trimmer end blocks, steel floor trimmer beams, bearing stiffeners within concrete) should be blast cleaned and primed only.
- Where the concrete finishes the protective treatment for the adjacent area should be extended not less than 25mm into the concreted area and a sealant applied in a rebate in the concrete to minimise the risk of water ingress at the steel / concrete interface.
- Faying and bearing surfaces (e.g. bolted connections, trimmer support positions) are blast cleaned and metal sprayed only, to maintain optimum friction conditions with minimum protection. Subsequent layers of protective treatment to be stepped back.
- Joints carried out on site will need completion of protective treatment after bolting up.

- Exposed areas inaccessible after erection (e.g. around bearings and the back of bearing stiffeners in the '6 foot' where two spans are erected to each other) are painted with the N1 system.
- Concrete surfaces that may be exposed to chlorides (e.g. filler floors above highways) should receive a hydrophobic pore lining impregnant in accordance with Highways Agency Document BD43/03.

The use of weathering steel was not developed as a standard design. Where the use of weathering steel has been assessed favourable, the standard designs and details may be considered as a basis for design but the design will be classed as a modification (refer to Section 2.2). Approval for the use of weathering steel is required from Network Rail's professional head of civil engineering. If weathering steel is to be used, the designer must (list not exhaustive):

- Follow requirements of Highways Agency standard BD7/01, including increasing the plate thicknesses. The designer must
 - o Check the bridge deflection are within the limits set in BS EN 1990:2002 and NR/CIV/L2/020.
 - o Check the availability of components, in particular nuts and bolts (generally supplied in imperial sizes) and may not be available in the sizes called up on the standard designs.

6.6.3 Waterproofing

The waterproofing system shown is based upon an acrylic spray system protected with a protective layer against local damage. The waterproofing details are shown on drawing NR/CIV/SD/1270, 71 & 72. Deck ends are waterproofed to ensure water drains from the deck to the back of deck drainage.

6.7 Drainage

Positive drainage should be considered where possible. Details of drainage provision options are given on the standard drawings and details in the series NR/CIV/SD/1800. Generally, drainage locations and thus the profile of the back of the impost / cill unit may be governed by the abutment thickness. A narrow abutment invites a simple arrangement of deck end and upstand aligned vertically with the rear of the abutment. Ideally the drainage pipe should be located below the final top of the existing abutment. This should ensure that water will not permeate along the underside of the impost and then down the abutment face.

Where the existing abutment is much wider and the new deck stops short then providing drains in the impost at the deck end and below impost / cill to the rear of the abutment is often preferred even to the extent of terminating the waterproofing at the impost / cill drain.

6.8 Substructure and Ancillary Items

Within the standard detail suite of drawings, details are provided for underbridge ancillary items (drawing series NR/CIV/SD/1800 and associated technical user manual). The Z-type superstructure details refer to these and the details regarding assumptions are contained therein.

To ensure a smooth transition from the stiffness of the bridge approach to the stiffness of the deck and then the stiffness of the deck to the stiffness of the approach, the designer should consider the use of a suitable transition detail.

Where an existing substructure is being reused the scheme design should ensure that there is no significant change in the loads or points of application, and also the acceptability both the re-use of the existing substructure and foundations.

The design of the standard deck details covered in this TUM have assumed a maximum abutment differential settlement at SLS of 1 in 1000, but not exceeding 5mm under a single bearing. The load applied shall be in accordance with BS EN 1990:2002 and include railway loads. The designer shall determine the soil parameters and ensure that the maximum design settlement under a single bearing is not exceeded. Refer to the check list in Section 5.4 for guidance and limits on differential settlement allowed for in the standard designs.

6.9 Bonding / Stray Current / Insulation

The designer must ensure that suitable details are provided to ensure that the structure is adequately bonded / insulated / protected from stray current effects.

7 FABRICATION AND CONSTRUCTION

The standard details have been developed from previous Z-type designs (refer to the history of the Z-type development in Appendix B). The details are generally straightforward and a competent fabricator or contractor should be able to determine their own procedures for ensuring the required quality is achieved. The areas where the details require particular attention are discussed below.

7.1 Fabrication

Along with the continuous shaping and straightening of the Z shapes main girders, the most difficult detail in the fabrication process is the machining and fitting of the cross girders / transverse ribs. It is intended that the end plates to the cross girders / transverse ribs are attached and then machined down to the exact thickness required for fit noting that the plate thicknesses shown on the standard drawings are the minimum thicknesses required at the end of machining. Alternatively the cross girders / transverse ribs could be machined to the correct length.

The fabricator must ensure that all faces are in full contact to make the HR bolted connections effective. This is particularly important for the shear key details on the steel floors where two separate faces must be in contact.

The fabricator must also pay due attention to the reinforcement location and orientation to ensure holes in trimmer beams and cross girders (filler beam floors) and shear studs (steel and filler beam floors) are suitable to facilitate the accurate fixing of reinforcing bars and concreting.

On standard drawing NR/CIV/SD/1210, the camber required for the main girders is that required at the end of steelwork fabrication, with steel ancillary items such as walkways attached. The designer shall consider construction stages and calculate allowable deflections or camber requirements for the scheme specific fabrication and construction sequence.

7.2 Construction

When constructing the concreted areas of the standard Z-type decks, the contractor must be careful to ensure suitable clearance between reinforcing bars is provided to allow concrete to surround all reinforcing bars. This is particularly relevant where the cross girders in the filler beam floors are fanned and the reinforcement will bunch in the narrow end. The designer should determine which bars can be curtailed in this situation.

The contractor should consider the use of vibrating shutters where the reinforcement is congested and limited access for pokers, such as casting the concrete behind the trimmer beam on steel floors. A suitable concrete slump shall be specified by the contractor to ensure the required quality of concrete is provided and to suit his concrete methodology.

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8 SAFETY / CDM AND ENVIRONMENTAL

The general (non site specific) risks associated with the bridge design, construction and operation are listed on drawing NR/CIV/SD/1202. In addition there may be others arising from site-specific considerations, such as the presence of overhead line equipment (OHLE) or vulnerable services.

Environmental issues can only be determined on a site by site basis, bridge aesthetics including its colour, should be considered also.

The effect of renewing the protection scheme on the environment, particularly any watercourses, should be taken into consideration during the selection of the elements of the protection scheme.

Appendix A SCHEDULE OF STANDARD DRAWINGS

Description	Drawing
NR/CIV/SD/1200	Index of Drawings
NR/CIV/SD/1201	Key to Types
NR/CIV/SD/1202	General Notes and H&S Risk Register
NR/CIV/SD/1210	Steelwork General Assembly - Notes
NR/CIV/SD/1211	Steelwork General Assembly Details for Square Filler Beam Floor
NR/CIV/SD/1212	Steelwork General Assembly Details for 0° to 25° Skew Filler Beam Floor
NR/CIV/SD/1213	Steelwork General Assembly Details for 25° to 50° Skew Filler Beam Floor
NR/CIV/SD/1215	Steelwork General Assembly Details for Square Steel Floor
NR/CIV/SD/1216	Steelwork General Assembly Details for 0° to 25° Skew Steel Floor 1 of 2
NR/CIV/SD/1217	Steelwork General Assembly Details for 0° to 25° Skew Steel Floor 2 of 2
NR/CIV/SD/1218	Steelwork General Assembly Details for 25° to 50° Skew Steel Floor
NR/CIV/SD/1220	Main Girder Details - Notes
NR/CIV/SD/1221	Main Girder Sizes Filler Beam Floor - Deep Girders
NR/CIV/SD/1222	Main Girder Sizes Filler Beam Floor - Shallow Girders 300mm Ballast
NR/CIV/SD/1223	Main Girder Sizes Filler Beam Floor - Shallow Girders 200mm Ballast
NR/CIV/SD/1224	Main Girder Steelwork Details Filler Beam Floor
NR/CIV/SD/1225	Main Girder Sizes Steel Floor - Deep Girders
NR/CIV/SD/1226	Main Girder Sizes Steel Floor - Shallow Girders 300mm Ballast
NR/CIV/SD/1227	Main Girder Sizes Steel Floor - Shallow Girders 200mm Ballast
NR/CIV/SD/1228	Main Girder Steelwork Details Steel Floor
NR/CIV/SD/1230	Floor Steelwork and Trimmer Details - Notes
NR/CIV/SD/1231	Details of Cross Girder and Trimmer Girder 0° to 25° Skew Composite Floor
NR/CIV/SD/1232	Details of Cross Girder and Trimmer Girder 25° to 50° Skew Composite Floor
NR/CIV/SD/1235	Details of Transverse Ribs and Trimmer Girder Square Steel Floor
NR/CIV/SD/1236	Details of Transverse Ribs and Trimmer Girder 0° to 25° Skew Steel Floor
NR/CIV/SD/1237	Details of Transverse Ribs and Trimmer Girder 25° to 50° Skew Steel Floor Sheet 1 of 2
NR/CIV/SD/1238	Details of Transverse Ribs and Trimmer Girder 25° to 50° Skew Steel Floor Sheet 2 of 2
NR/CIV/SD/1239	Details of Transverse Ribs to Trimmer Girder Connections. All Skews
NR/CIV/SD/1240	Bearings – Notes
NR/CIV/SD/1241	Standard Bearings Details
NR/CIV/SD/1250	Steelwork Protective Treatment - Notes
NR/CIV/SD/1251	Filler Beam Floor Main Girder and Floor Protective Treatment Details
NR/CIV/SD/1252	Bearing Protective Treatment Details

NR/CIV/SD/1255	Steel Floor Main Girder and Floor Protective Treatment Details
NR/CIV/SD/1260	Concrete and Reinforcement Details - Notes
NR/CIV/SD/1261	Concrete Details for Square Filler Beam Floor
NR/CIV/SD/1262	Concrete Details for 0° to 25° Skew Filler Beam Floor
NR/CIV/SD/1263	Concrete Details for 25° to 50° Skew Filler Beam Floor
NR/CIV/SD/1264	Reinforcement Details for Square Filler Beam Floor
NR/CIV/SD/1265	Reinforcement Details for 0° to 25° Skew Filler Beam Floor
NR/CIV/SD/1266	Reinforcement Details for 25° to 50° Skew Filler Beam Floor
NR/CIV/SD/1267	Concrete Details for Steel Floor
NR/CIV/SD/1268	Reinforcement Details for Steel Floor
NR/CIV/SD/1270	Waterproofing Details - Notes
NR/CIV/SD/1271	Waterproofing Details for Filler Beam Floor
NR/CIV/SD/1272	Waterproofing Details for Steel Deck
NR/CIV/SD/1281	Ballast Plate and Filler Rail Details

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Appendix B HISTORY

The Z-type girder and filler beam floor has been in use for over 40 years on the former British Rail network.

Although its history is not fully documented, it is understood that it derived from the old standard A Type, in use since the 1950s, which consisted of traditional I section main girders, with steel cross-girders with a concrete infill between them to provide a floor to support ballasted track and for local distribution purposes. Cross girders soffits in the A Type were exposed. The outside faces of the main girders in the 'six foot' zone were infilled with brickwork. Decks were either not waterproofed, or poorly waterproofed.

It then evolved into the Z-type during the 1960s as a result of experience and identification of shortcomings with the A Types in use. The introduction of the Z shaped girders allowed the brick infilling to be deleted and proper access to be provided to the outside girder faces in the very constrained situation between adjacent bridges placed in the standard 'six foot' gap between adjacent tracks on two track lines. It also reduced deck widths, and hence weight. Cross girders were fully encased to allow longitudinal cracking reinforcement to be placed above and below cross girders, to get over corrosion and cracking problems at the concrete / steel interface along cross girder soffit edges. Deck waterproofing was incorporated, or improved. Changes from fixed trimmers bolted on to main girder end plates, to the principle of the present arrangement also occurred. Standard Drawings B/18/1 and /2 were issued in 1967.

The issue of cracking of concrete soffits and other general problems with concrete and floor reinforcement, meant that floor reinforcement was increased on at least two occasions in the early 1970s and late 1970s in response to these issues and to the greater knowledge of reinforced concrete reflected in new and amended design codes.

Design continued on the basis of the Z girders being individually designed on each bridge (using various versions of the British Railways Board (BRB) Plate Girder Design Programme (PGDES)) with decks based on the standard arrangement with a limited design / check calculation to the BRB Technical Note 27 (1976).

Different regions, whilst working within the above framework, did evolve and vary the designs, with differing regional standards coming into existence in the 1980s. Use of the standard was extended to longer spans also.

In 1996 the Z-type Bridge Standard drawings were completely redesigned to meet new design codes and other new or revised requirements. The deck was completely redesigned to meet BS 5400 requirements (for the first time), subject to certain departures which were agreed with

Railtrack. The main girder design arrangements were also re-evaluated in the light of BS 5400: Part 3. This has involved some substantial background work and the evolution of appropriate departures from the code. Since the 1996 update, BS 5400-3:1982 was superseded with BS 5400-3:2000. The revised standard incorporated the departures. The 2009 Z-type Design update (revision A), was completed in accordance with the current standard with no departures as described. The 2009 update (revision B) also included verification of the design to the structural Eurocodes.

Summary of Details Updated Since The 1996 Z Type Standard Detail

The following items have been modified since the 1996 design. Explanation is given.

Steel Floor

An alternative floor arrangement has been developed, based upon the Tee Rib floors adopted for the Western Region Boxes. The steel floor has been developed to reduce the weight of the bridge and allow easier installation. It is intended for use only where weight must be kept to a minimum.

Bearings and Uplift Detail

The modified bearing design has been based upon details used and implemented successfully on a number of projects. The modified design consists of a single machined line rocker bearing block, welded to the bearing set. Uplift restraint is provided by a clevis plate, welded to the bottom flange and separate base plate. The modified design is more robust and requires less fabrication and welding than previous bearings. The modified design allows for easier replacement of components, with allowance for the replacement of the uplift details or bearing set individually. The details and arrangement of the uplift bracket components allow the bearings be lifted in one piece, already attached to the main girders.

Bearing Stiffeners

The modified bearing stiffener design has been developed following discussion with a number of bridge fabricators, and has been based upon details used and implemented successfully on a number of projects. The modified design consists of three full height fin bearing stiffeners fillet welded to the main girder web and flanges, with three shorter inner load spreading stiffeners. A number of issues with the previous bearing stiffener have been eliminated through the modified design. Fabricators highlighted the issues with the former detail, including distortions due to butt welding of the stiffener, and a number of complex and awkward welds. The modified design has been designed on the basis of the sole use of fillet welds. Fabricators highlighted issues with the use of bent plates which has been eliminated through the use of fins requiring flame cutting and localised machining to fit the bottom flanges.

The walkway connection to the bearing stiffener has also been simplified through the use of the fin arrangement.

Flange Curtailment Detail

A modified flange curtailment detail was developed to reduce the effect of welded details on the ductility and fracture classification of the flanges. The modified detail gave a detail type of 2.6 (from BS5400-10:1980 Table 17 (b)) allowing the use of thicker plates and negating the necessity to carry the bottom flange doubler through to the bearing, which would complicate the bearing detail unnecessarily. Where the top flange curtailment point is close to the end the main girder, the doubler plate should continue to the end the main girder and the square curtailment detail be used. The Eurocode (BS EN 1993-1-9:2005) does not differentiate between the width of attachments (referred to as cover plates) but the detail developed to satisfy the BS 5400-10 rules has been retained. The lowest detail category in accordance with BS EN 1993-1-9:2005 Table 8.5, detail 6, was verified.

Cross Girder / Transverse Rib Connection with Main Girder Web

To simplify the fabrication of the cross girder / transverse rib connection with the main girder web, lap joints were considered but rejected as:

- It could not be demonstrated that they had sufficient capacity to resist longitudinal shear effects.
- Network Rail have historically had problems with such details and requested that they are not developed as a standard design.

Appendix C DESIGN ASSUMPTIONS

Structural Models

The proposed new decks have been analysed using a linear elastic model of a complete deck. One corner of the deck was fixed in position. The bearings in the other corners allow rotation and movement longitudinally, laterally or in both directions. A quasi-static approach was used.

The trimmer beam was supported on the bottom flanges for all skews and the end of the trimmer free to rotate. The main girder bearings are line rockers and positioned to ensure restraint at the bearings is provided by the bearing stiffeners acting as cantilevers.

The simple approach to fatigue assessment (without damage calculation) was used.

Loading

The following is a summary of the Eurocode design loads and draft Network Rail standard, NR/L2/CIV/020 (draft 12):

Permanent Actions

Item	Density / Load	Load Factor (γ_G)
Concrete	25 kN/m ³	1.35
Steel	77 kN/m ³	1.20
Ballast	21 kN/m ³ – depth 575mm over full floor area between webs of main girders (appropriate to 300mm depth under sleepers with additional average 100mm allowance for variations in ballast depth due to cant, track gradients, deflections etc). The weight of the top 300mm of ballast was factored by $\pm 30\%$ in accordance with NA BS EN 1991-1-1.	1.35
Track	6 kN/m (per track, includes sleeper and rail only, no allowance for ballast between sleepers)	1.35
Waterproofing	0.36 kN/m ² over floor area (equivalent to 15mm thickness at 24 kN/m ³)	1.35
Trackside Cables	1.0 kN/m (equivalent to 7 no. solid 40mm diameter lead cables)	1.35

Variable Actions

Load	Reference	Notes
LM71	BS EN 1991-2:2003 NR/L2/CIV/020	An additional a factor of 1.1 has been applied to provide adequacy in accordance with TSIs for high speed lines, or γ_{det} for standard lines. The total alpha factor used where applicable, $\alpha = 1.21$.
Dynamic Effects	BS EN 1991-2:2003	Factor taken as 2.0 for shorter span bridges, as detailed below.
Centrifugal Force*	BS EN 1991-2:2003	Value based upon $V = 120\text{kph}$, $r = 654\text{m}$ Maximum line speed 200kph.
Fatigue	BS EN 1993-2:2006	Damage equivalence method adopted Maximum traffic 42 MTPA
Walkways ⁺	NR/L2/CIV/020 – Draft 12	Uniformly Distributed load: 5.0 kN/m^2 Single Point Load: 2.0 kN Parapet Lateral Load on top rail: 0.74 kN/m
Longitudinal	BS EN 1991-2:2003	The track is assumed not continuous over the bridge for the purpose of distributing longitudinal live loads off the bridge, i.e. all longitudinal load resisted by the bridge.
Crane Loading (temporary case)	KIROW KRC1 200UK Rail Mounted Crane	Refer to NR/L2/CIV/020 for Axle Distribution, and reduced partial load factors apply.

Notes:

* - Maximum Centrifugal Force Factor (defined as the vertical effect of the centrifugal force on a girder expressed as a fraction of the static LM71 load): $0.2Q_{vk}$. Note that the designer must determine the minimum track radius a deck can accommodate, considering clearances, tolerances etc.

⁺ - These loads are used for the walkway, parapet, walkway bracket and main girder intermediate stiffener design.

Design of Main Girders

The Girders have been designed in two main forms, shallow and deep:

Shallow: Standard shallow girders are those whose tops are at a level no greater than 110 mm above rail level and are intended to fit below the structure gauge. Note that shallow girders above rail level cannot be used on the UK parts of the High Speed Trans European Network (TEN) where the Railways (Interoperability) regulations apply.

Deep: Standard deep girders are those whose top flange (not doubler) tops are at a maximum 350 mm above rail level, to provide a robust kerb on bridges where the main girders are outside the structure gauge (as apposed to below for shallow girders). They cannot be used in standard 'six foot' or on narrow (<3165 mm) decks as they would otherwise infringe clearance

requirements. The requirements for the robust kerb and maintainable flange thicknesses have limited the minimum thicknesses to 30mm for flange plates, to sustain light vehicular impact.

Main girder geometry has been designed to allow for the minimum construction depth whilst maintaining adequate maintenance spaces. Refer to Annex 2 for details.

The flange plate thickness ranges are from 30mm to 80mm. The doubler plate thickness ranges are from 20mm to 75mm. The absolute maximum flange thickness is 155mm including the doubler plate. Web thickness ranges are 20mm to 25mm. Based on these thickness and the requirements for ductility the following grades of steel have been specified for thicknesses:

- J2, max thicknesses permitted are 45mm (tension) and 80mm (compression).
- K2, max thicknesses permitted are 55mm (tension) and 95mm (compression).
- NL, max thicknesses permitted are 80mm (tension) and 140mm (compression).

These thicknesses are appropriate for a design minimum bridge effective temperature at -24°C and are not adjusted for the detail category. Where the detail category is significant (refer to NA BS EN 1993-1-10) the allowable thicknesses are reduced.

Where flange and doubler thicknesses allow for differing grades, the thinner plate has been specified as per the thicker plate to avoid confusion.

For the short span decks, the decks are too stiff to satisfy upper bound frequency requirements, i.e. their natural frequency too high and exceed the upper bound values in figure 6.10 in BS EN 1991-2:2003. A dynamic factor of 2.0 was therefore applied. A dynamic analysis was not undertaken as studies have shown that for half through structures the high frequency dynamic effects are not significant.

The main girders have been designed in accordance with BS EN 1993-2:2006, with no departures (although some aspects not covered as noted below). The following assumptions have been made during the design:

- The girders have been design as 'I' Girders, with an additional F_H force applied at the shear centre to account for the eccentricity of the top flanges.
- When calculating the properties and strength of the main girder no benefit from the longitudinal floor reinforcement (and concrete) or floor plate has been taken.
- Fatigue on shallower girders, especially for 25t axle traffic, was found to be the governing criteria, in cases where the maximum readily available plate sizes were used and fatigue criteria were not met, limits have been indicated on the drawings.
- U-Frame spacing has been taken as 1800mm. The designer will need to determine the U-Frame spacing, based upon the overall geometry of the specific structure, using the limits specified on the drawings of 1200mm minimum to 1800mm maximum.

- For the purposes of calculating U-Frame restraint the rotational capacity of the U-Frame six-bolt connections was taken as follow: Filler beam – 0.2×10^{-10} rad/Nmm, transverse rib floor – 0.5×10^{-10} rad/Nmm.
- The main girders have been assumed to be restrained by cantilevered bearing stiffeners at their ends.

Design of U-Frames

Neither the Eurocodes nor the NCCI give explicit rules for the design of half through structures where the compression flange is restrained by U-frames. Therefore the rules in BS EN 1993-1-1:2005 were complied with and the restraint forces from the U-frames calculated from first principles, replicating the rules in BS5400-3:2000 Clause 9.12, and specifically Clause 9.12.2 and Clause 9.12.3.3. The only aspect not covered in the code is the inclusion of the F_H as detailed below.

The connections have been designed to take the worst fatigue loading of 25t axles Traffic in the range 42 MTPA.

In addition to the F_R and F_C forces for intermediate stiffeners, U-Frame connections have been designed to carry an additional F_H force as detailed in the 1996 Z-type User manual. The F_H force has been determined based upon the following formula, taken from Network Rail Assessment code discussion (taken from ongoing work, not yet published, by Cass Hayward and Partners):

$$F_H = \left[\frac{A_f \sigma_f e}{M_x} \right] W_u \left(\frac{\Delta_y}{\Delta_y + \delta_R} \right)$$

where:

- A_f is the area of the top or bottom flange of the beam.
- σ_f is the average stress in the flange arising from the bending moment M_x .
- e is the horizontal eccentricity of the top or bottom flange of the beam with respect to the centre line of the web.
- M_x is the maximum bending moment in the beam about the x axis.
- W_u is the load carried by or transmitted to the beam including its self weight over a length equal to the spacing of U-Frames l_u at the location of M_x .
- D_y is the free lateral deflection of the top flange of the beam at the location of M_x assuming that it is disconnected within the span under a loading equivalent to a unit lateral force applied at the location of each U-Frame. For a uniform spacing of U-Frames D_y may be taken as:

$$\Delta_y = \frac{5L^4}{384EI_c l_R}$$

- L is the span of the beam

- I_c is the second moment of area about the y-y axis of the flange remote from cross members, plus one third of the height of the web.
- d_R is the deflection of the U-Frame under a unit horizontal load.
- l_R is the spacing of the U-Frame.

The F_H force is assumed to act outwards only.

The connections have been designed to take the combination of F_R , F_C , F_H and walkway loads, combined with associated local moments generated.

Design of Bearing Stiffeners

The bearing stiffener has been modified as described previously. The bearing stiffener has been designed in accordance with BS EN 1993-2:2006 with no departures from the standards.

The bearing stiffener loads have been conservatively assumed to be transferred through the welds only, with sections locally machined as shown on the drawings. Revised bearing centre lines have been considered due to the modified bearing detail as discussed below.

No effect of the trimmer cross girder on the bearing stiffener was considered. The Trimmer is assumed to be supported separately, bearing directly onto the main girder bottom flange.

Design of Bearings

The bearing design has been modified to that of a short line rocker bearing in order to improve robustness and simplify fabrication by reducing the weld requirements. The bearings have been designed to be used in all fatigue and skew situations. Effects of the trimmer end blocks on the bearing have also been considered. In order to avoid confusion and simplify the drawings, only one bearing size has been specified.

The designer, in determining the setting out, should determine the design installation levels to minimize the potential for twisting the decks and generate significantly uneven bearing loads.

The bearings have been designed in accordance with BS EN 1993-2:2006 and BS EN 1337-1:2000. The bearings have been designed to accommodate movement of the structure from thermal expansion / contraction. This has been achieved via keep strips allowing guided movements longitudinally / transversely as required. Maximum longitudinal expansion/contraction allowed is 12mm, maximum transverse expansion / contraction allowed for is 2mm.

Longitudinal (braking/traction) and transverse (nosing/centrifugal) loads have been assumed to be taken by the keep strips and welds. The load effects are assumed to be applied to the bridge at least 0.5 m away from any particular bearing centre line.

The trimmer is kept in position by a pair of steel blocks welded to the main girder bottom flange. These blocks also resist the horizontal couple force from the trimmer concrete overhanging the deck end and subject to axle loads.

The bearing has been designed as a short rocker, required to ensure the bearing stiffeners act as a cantilever in restraining the main girder. To do this the bearing is set in board of the main girder web so that the vertical force through the web, acting eccentrically to the bearing, offsets the moment due to the bearing stiffener actions. The bearing reaction is retained within the middle third of the bearing block at all times to ensure stability.

Jacking points for the standard designs are located at the position of the uplift restraint. Uplift restraint lower plates will require removing and the exposed base plate then used as a jacking platform. Jacks used should be at least 100mm in diameter and should be positioned under the main girder flanges in line with the main girder web. An offset of 50mm from the centre of the pack to the centre of the web can be accommodated. Spreader plates are required if the jack is less than 100mm diameter. Jacking can take place with the full permanent load on the deck. The designer must check the jacking arrangement.

Grade S460 NL Bearing Plates

The bearing plates attached to the main girder ends and in contact with the bearing block are specified in a higher grade material to avoid problems of local yield and grooving (to ensure the bridge does not lock up and start to carry loads from expansion and contraction effects).

The choice of grade is dictated by the need to avoid any overlap of the yield stress range of the two parts. The upper side of the bearing plate is shown machined on the drawings to ensure the underside of the bearing plate is level (under dead loads only) on top of the bearing upstand – so significant gradient, deck tilt and camber effects are taken out, and any tendency for a tilted deck to creep against the side stops (and seize up longitudinally) is minimised.

The designer should ensure that the client's attention is drawn to the need for pre-ordering these plates which are generally less readily available.

Collision Loads.

The Z-type bridges and bearing arrangements shown have been designed in accordance with the requirements of NA BS EN 1991-1-7.

Following discussion between Network Rail and the standard designs designer, a qualitative assessment was made for the minimum flange thickness, taken as 30mm, to provide suitable robustness against light impact. The weld between the main girder bottom flange and the web