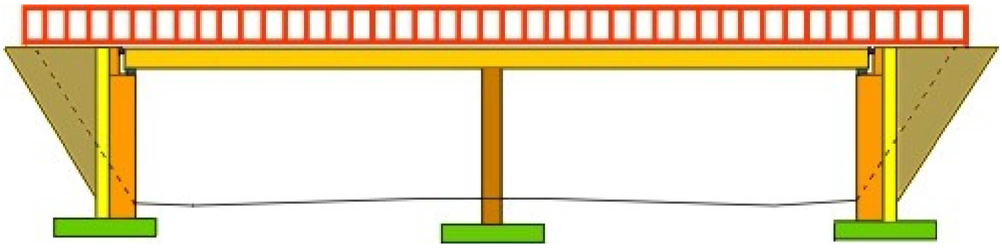
Bridge Components

Click onto the area of the bridge that you want details about.
If you are starting a design then click onto the 'Deck'
and read the section on 'Preliminary Design'.



Abutments | Bearings | Deck | Drainage | Footing/Foundations | Joints | Parapets | Piers | Wing Walls

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For more information:
Contact David Childs

Abutment Design Standards

Eurocodes

- EN 1991-1-1: Actions on Structures - General Actions
- EN 1991-1-5: Actions on Structures - Thermal Actions
- EN 1991-1-7: Actions on Structures - Accidental Actions
- EN 1991-2: Actions on Structures - Traffic Loads on Bridges
- EN 1992-1-1: Design of Concrete Structures - General Rules
- EN 1992-2: Design of Concrete Structures - Bridges
- EN 1993-5: Design of Steel Structures - Piling
- EN 1997-1: Geotechnical Design - General Rules
- EN 1998-2: Design of Structures for Earthquake Resistance - Bridges
- EN 1998-5: Design of Structures for Earthquake Resistance - Geotechnical Aspects
- *Each document is accompanied by a National Annex*

British Standards

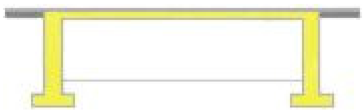
- BS 5400: Part 2: Specification for Loads
- BS 5400: Part 4: Code of Practice for the Design of Concrete Bridges
- BS 8002: Code of Practice for Earth Retaining Structures
- BS 8006: Strengthened/Reinforced Soils and Other Fills
- BS 8500: Concrete - Complementary British Standard to BS EN 206-1
- BS 8666: Specification for scheduling, dimensioning, bending and cutting of steel reinforcement for concrete

Design Manual for Roads and Bridges

- BD30: Backfilled Retaining Walls and Bridge Abutments
- BD37: Loads for Highway Bridges
- BA41: The Design and Appearance of Bridges
- BA42: The Design of Integral Bridges
- BD42: Design of Embedded Retaining Walls and Bridge Abutments
- BD57 and BA57: Design for Durability
- BD70: Strengthened/Reinforced Soils and Other Fills for Retaining Walls and Bridge Abutments

Choice of Abutment

Current practice is to make decks integral with the abutments. The objective is to avoid the use of joints over abutments and piers. Expansion joints are prone to leak and allow the ingress of de-icing salts into the bridge deck and substructure. In general all bridges are made continuous over intermediate supports, and decks under 60 metres long with skews not exceeding 30° are made integral with their abutments.



Full height integral abutments (DfT BA 42/96 call Frame Abutments) are generally used for the shorter spans (< about 20m).

Integral abutments with piled foundations (DfT BA 42/96 call Embedded Abutments) usually incorporate steel H piles in a single row; the H piles are orientated so that bending occurs about their weaker axis. These abutments are suitable for the larger span decks.

Integral abutments with spread footings (DfT BA 42/96 call Bank Pad Abutments) should only be used where settlement due to consolidation of founding strata is minimal.

Where decks exceed 60 metres long or have skews exceeding 30° then movement joints and bearings usually need to be provided.

Geometric Considerations

Open Side Span with Bank Seats

Solid Side Span with Full Height Abutments

Usually the narrow bridge is cheaper in the open abutment form and the wide bridge is cheaper in the solid abutment form. The exact transition point between the two types depends very much on the geometry and the site of the particular bridge. In most cases the open abutment solution has a better appearance and is less intrusive on the general flow of the ground contours and for these reasons is to be preferred. It is the cost of the wing walls when related to the deck costs which swings the balance of cost in favour of the solid abutment solution for wider bridges. However the wider bridges with solid abutments produce a tunnelling effect and costs have to be considered in conjunction with the proper functioning of the structure where fast traffic is passing beneath. Solid abutments for narrow bridges should only be adopted where the open abutment solution is not possible. In the case of wide bridges the open abutment solution is to be preferred, but there are many cases where economy must be the overriding consideration.

Design Considerations

Loads transmitted by the bridge deck onto the abutment are :

i. Vertical loads from self weight of deck.
ii. Vertical loads from live loading conditions.
iii. Horizontal loads from temperature, creep movements etc and wind.
iv. Horizontal loads from braking and skidding effects of vehicles.

These loads are carried by the bearings which are seated on the abutment bearing platform. The horizontal loads may be reduced by depending on the coefficient of friction of the bearings at the movement joint in the structure. However, the full braking effect is to be taken, in either direction, on top of the abutment at carriageway level.
In addition to the structure loads, horizontal pressures exerted by the fill material against the abutment walls is to be considered. Also a vertical loading from the weight of the fill acts on the footing.
Vehicle loads at the rear of the abutments are considered by applying a surcharge load on the rear of the wall.
For certain short single span structures it is possible to use the bridge deck to prop the two abutments apart. This entails the abutment wall being designed as a propped cantilever.

Bridge Components | Abutment Design Example

Bearing Design Standards

Eurocodes

- BS EN 1337: Structural Bearings
- PD 6703:2009 Structural Bearings - Guidance on their use

British Standards

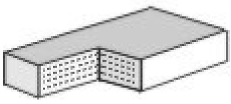
- BS 5400: Part 2: Specification for Loads
- BS 5400: Part 9: Code of Practice for Design of Bridge Bearings

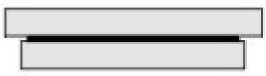
Design Manual for Roads and Bridges

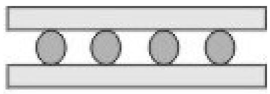
- BD37: Loads for Highway Bridges
- BA42: The Design of Integral Bridges
- BD20: Bridge Bearings, Use of BS 5400 Part 9

Choice of Bearings

Bridge bearings are devices for transferring loads and movements from the deck to the substructure and foundations. In highway bridge bearings movements are accommodated by the basic mechanisms of internal deformation (elastomeric), sliding (PTFE), or rolling. A large variety of bearings have evolved using various combinations of these mechanisms.


Elastomeric Bearing


Plane Sliding Bearing


Multiple Roller Bearing

Design Considerations

The functions of each bearing type are :

a. Elastomeric
   The elastomeric bearing allows the deck to translate and rotate, but also resists loads in the longitudinal, transverse and vertical directions. Loads are developed, and movement is accommodated by distorting the elastomeric pad.
b. Plane Sliding
   Sliding bearings usually consist of a low friction polymer, polytetrafluoroethylene (PTFE), sliding against a metal plate. This bearing does not accommodate rotational movement in the longitudinal or transverse directions and only resists loads in the vertical direction. Longitudinal or transverse loads can be accommodated by providing mechanical keys. The keys resist movement, and loads in a direction perpendicular to the keyway.
c. Roller
   Large longitudinal movements can be accommodated by these bearings, but vertical loads only can generally be resisted.

The designer has to assess the maximum and minimum loads that the deck will exert on the bearing together with the anticipated movements (translation and rotation). Bearing manufacturers will supply a suitable bearing to meet the designers requirements.

Bearings are arranged to allow the deck to expand and contract, but retain the deck in its correct position on the substructure. A 'Fixed' Bearing does not allow translational movement. 'Sliding Guided' Bearings are provided to restrain the deck in all translational directions except in a radial direction from the fixed bearing. This allows the deck to expand and contract freely. 'Sliding' Bearings are provided for vertical support to the deck only.

Bridge Components

Choice of Deck

Making the correct choice of deck will depend on many factors. Use the links below to find out about each type.

- Preliminary Design - Making the correct choice of bridge deck type.
- Reinforced Concrete
- Prestressed Concrete
- Composite
- Steel Box Girder
- Steel Truss
- Cable Stayed
- Suspension

Bridge Components

Design Standards for Preliminary Design

Eurocodes

- EN 1990: Basis of Structural Design
- EN 1991-1-1: Actions on Structures - General Actions
- EN 1991-2: Actions on Structures - Traffic Loads on Bridges
- EN 1997-1: Geotechnical Design - General Rules
- EN 1997-2: Geotechnical Design - Ground Investigation and Testing
- *Each document is accompanied by a National Annex*

British Standards

- BS 5400: Part 1: General Statement
- BS 5400: Part 2: Specification for Loads
- BS 5930: Code of Practice for Site Investigations

Design Manual for Roads and Bridges

- BA41: The Design and Appearance of Bridges
- BA42: The Design of Integral Bridges
- BD29: Design Criteria for Footbridges
- BD37: Loads for Highway Bridges
- BD57 and BA57: Design for Durability
- TD27: Cross Sections and Headrooms
- TD36: Subways for Pedestrians and Pedal Cyclists. Layout and Dimensions.

Preliminary Design

In selecting the correct bridge type it is necessary to find a structure that will perform its required function and present an acceptable appearance at the least cost.
Decisions taken at preliminary design stage will influence the extent to which the actual structure approximates to the ideal, but so will decisions taken at detailed design stage. Consideration of each of the ideal characteristics in turn will give some indication of the importance of preliminary bridge design.

a. Safety.
   The ideal structure must not collapse in use. It must be capable of carrying the loading required of it with the appropriate factor of safety. This is more significant at detailed design stage as generally any sort of preliminary design can be made safe.
b. Serviceability.
   The ideal structure must not suffer from local deterioration/failure, from excessive deflection or vibration, and it must not interfere with sight lines on roads above or below it. Detailed design cannot correct faults induced by bad preliminary design.
c. Economy.
   The structure must make minimal demands on labour and capital; it must cost as little as possible to build and maintain. At preliminary design stage it means choosing the right types of material for the major elements of the structure, and arranging these in the right form.
d. Appearance.
   The structure must be pleasing to look at. Decisions about form and materials are made at preliminary design stage; the sizes of individual members are finalised at detailed design stage. The preliminary design usually settles the appearance of the bridge.

Constraints

The construction depth available should be evaluated. The economic implications of raising or lowering any approach

embankments should then be considered. By lowering the embankments the cost of the earthworks may be reduced, but the resulting reduction in the construction depth may cause the deck to be more expensive.
Headroom requirements have to be maintained below the deck; the minimum standards for UK Highway bridges are given in TD 27 of the Design Manual for Roads and Bridges. The Eurocode Standard (EN 1991-1-7 clause 4.3.2(1) quotes clearances from roadway surfacing to the underside of the deck to avoid impact damage.
If the bridge is to cross a road that is on a curve, then the width of the opening may have to be increased to provide an adequate site line for vehicles on the curved road.
It is important to determine the condition of the bridge site by carrying out a comprehensive site investigation. EN 1997-2: 'Ground investigation and testing' covers the requirements for the Soil Survey. Other topics which need to be considered are:

i. Existing services (Gas, Electricity, Water, etc)
ii. Rivers and streams (liability to flood)
iii. Existing property and rights of way
iv. Access to site for construction traffic

Selection of Bridge Type

The following table is intended to be a rough guide to the useful span ranges of various types of deck.

Span	Deck Type
Up to 20m	Insitu reinforced concrete. Insitu prestressed post-tensioned concrete. Prestressed pre-tensioned inverted T beams with insitu fill.
16m to 30m	Insitu reinforced concrete voided slab. Insitu prestressed post-tensioned concrete voided slab. Prestressed pre-tensioned Y and U beams with insitu slab. Prestressed pre-tensioned box beams with insitu topping. Prestressed post-tensioned beams with insitu slab. Steel beams with insitu slab.
30m to 40m	Prestressed pre-tensioned SY beams with insitu slab. Prestressed pre-tensioned box beams with insitu topping. Prestressed post-tensioned beams with insitu slab. Steel beams with insitu slab.
30m to 300m	Box girder bridges - As the span increases the construction tends to go from 'all concrete' to 'steel box / concrete deck' to 'all steel'. Truss bridges - for spans up to 50m they are generally less economic than plate girders.
150m to 1000m	Cable stayed bridges.
350m to ?	Suspension bridges.

Preliminary Design Considerations

1. A span to depth ratio of 20 will give a starting point for estimating construction depths.
2. Continuity over supports
    i. Reduces number of expansion joints.
    ii. Reduces maximum bending moments and hence construction depth or the material used.
    iii. Increases sensitivity to differential settlement.
3. Factory made units
    i. Reduces the need for soffit shuttering or scaffolding; useful when headroom is restricted or access is

difficult.

ii. Reduces site work which is weather dependent.
iii. Dependent on delivery dates by specialist manufactures.
iv. Specials tend to be expensive.
v. Special permission needed to transport units of more than 29m long on the highway.

4. Length of structure
    i. The shortest structure is not always the cheapest. By increasing the length of the structure the embankment, retaining wall and abutment costs may be reduced, but the deck costs will increase.
5. Substructure
    i. The structure should be considered as a whole, including appraisal of piers, abutments and foundations. Alternative designs for piled foundations should be investigated; piling can increase the cost of a structure by up to 20%.

Costing and Final Selection

The preliminary design process will produce several apparently viable schemes. The procedure from this point is to:

i. Estimate the major quantities.
ii. Apply unit price rates - they need not be up to date but should reflect any differential variations.
iii. Obtain prices for the schemes.

The final selection will be based on cost and aesthetics. This method of costing assumes that the scheme with the minimum volume will be the cheapest, and will be true if the structure is not particularly unusual.

Bridge Components | Choice of Deck

Reinforced Concrete Design Standards

Eurocodes

- EN 1991-1-1: Actions on Structures - General Actions
- EN 1991-1-4: Actions on Structures - Wind Actions
- EN 1991-1-5: Actions on Structures - Thermal Actions
- EN 1991-1-7: Actions on Structures - Accidental Actions
- EN 1991-2: Actions on Structures - Traffic Loads on Bridges
- EN 1992-1-1: Design of Concrete Structures - General Rules
- EN 1992-2: Design of Concrete Structures - Bridges
- *Each document is accompanied by a National Annex*

British Standards

- BS 4449: Steel for Reinforcement of Concrete
- BS 5400: Part 2: Specification for Loads
- BS 5400: Part 4: Code of Practice for the Design of Concrete Bridges
- BS 8500: Concrete - Complementary British Standard to BS EN 206-1
- BS 8666: Specification for scheduling, dimensioning, bending and cutting of steel reinforcement for concrete

Design Manual for Roads and Bridges

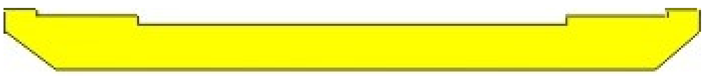
- BA24: Early Thermal Cracking of Concrete
- BD24: Design of Concrete Bridges
- BD28: Early Thermal Cracking of Concrete
- BD37: Loads for Highway Bridges
- BD43: Criteria and Materials for the Impregnation of Concrete Highway Structures
- BD57 and BA57: Design for Durability

Technical Papers

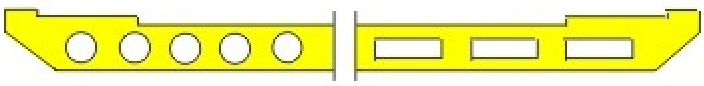
- CIRIA Report C660 - Early-age thermal crack control in concrete.

Reinforced Concrete Decks

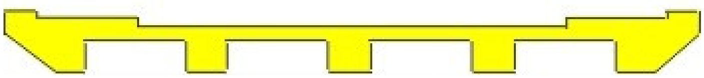
The three most common types of reinforced concrete bridge decks are :



Solid Slab



Voided Slab

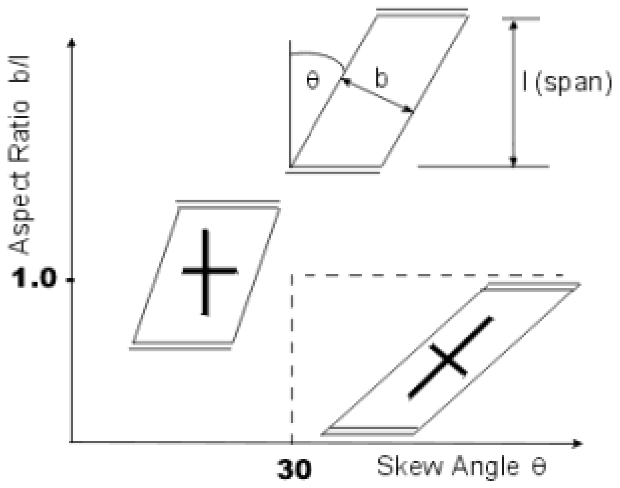


Beam and Slab

Solid slab bridge decks are most useful for small, single or multi-span bridges and are easily adaptable for high skew. Voided slab and beam and slab bridges are used for larger, single or multi-span bridges. In circular voided decks the ratio of [depth of void] / [depth of slab] should be less than 0.79; and the maximum area of void should be less than 49% of the deck sectional area.

Analysis of Deck

For decks with skew less than 25° a simple unit strip method of analysis is generally satisfactory. For skews greater than 25° then a grillage or finite element method of analysis will be required. Skew decks develop twisting moments in the slab which become more significant with higher skew angles. Computer analysis will produce values for Mx, My and Mxy where Mxy represents the twisting moment in the slab. Due to the influence of this twisting moment, the most economical way of reinforcing the slab would be to place the reinforcing steel in the direction of the principal moments. However these directions vary over the slab and two directions have to be chosen in which the reinforcing bars should lie. Wood and Armer have developed equations for the moment of resistance to be provided in two predetermined directions in order to resist the applied moments Mx, My and Mxy.
Extensive tests on various steel arrangements have shown the best positions as follows



Bridge Components | Choice of Deck

Prestressed Concrete Design Standards

Eurocodes

- EN 1991-1-1: Actions on Structures - General Actions
- EN 1991-1-4: Actions on Structures - Wind Actions
- EN 1991-1-5: Actions on Structures - Thermal Actions
- EN 1991-1-7: Actions on Structures - Accidental Actions
- EN 1991-2: Actions on Structures - Traffic Loads on Bridges
- EN 1992-1-1: Design of Concrete Structures - General Rules
- EN 1992-2: Design of Concrete Structures - Bridges
- *Each document is accompanied by a National Annex*

British Standards

- BS 5400: Part 2: Specification for Loads
- BS 5400: Part 4: Code of Practice for the Design of Concrete Bridges
- BS 5896: Specification for high tensile steel wire and strand for the prestressing of concrete
- BS 8500: Concrete - Complementary British Standard to BS EN 206-1
- BS 8666: Specification for scheduling, dimensioning, bending and cutting of steel reinforcement for concrete

Design Manual for Roads and Bridges

- BA24: Early Thermal Cracking of Concrete
- BD24: Design of Concrete Bridges
- BD28: Early Thermal Cracking of Concrete
- BD37: Loads for Highway Bridges
- BD43: Criteria and Materials for the Impregnation of Concrete Highway Structures
- BD57 and BA57: Design for Durability

Technical Papers

- CIRIA Report C660 - Early-age thermal crack control in concrete.

Prestressed Concrete Decks

There are two types of deck using prestressed concrete :

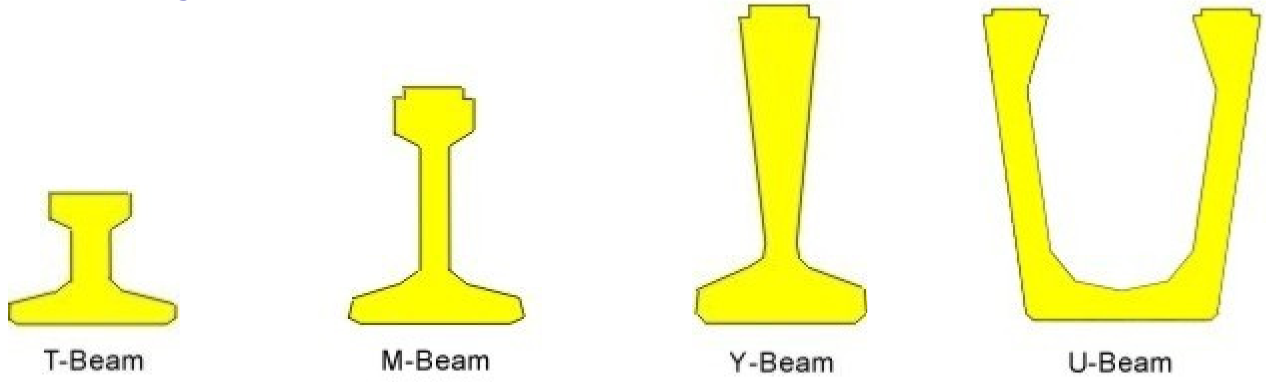
i. Pre-tensioned beams with insitu concrete.
ii. Post-tensioned concrete.

The term pre-tensioning is used to describe a method of prestressing in which the tendons are tensioned before the concrete is placed, and the prestress is transferred to the concrete when a suitable cube strength is reached.
Post-tensioning is a method of prestressing in which the tendon is tensioned after the concrete has reached a suitable strength. The tendons are anchored against the hardened concrete immediately after prestressing.
There are three concepts involved in the design of prestressed concrete :

i. Prestressing transforms concrete into an elastic material.
   By applying this concept concrete may be regarded as an elastic material, and may be treated as such for design at normal working loads. From this concept the criterion of no tensile stresses in the concrete was evolved.
   In an economically designed simply supported beam, at the critical section, the bottom fibre stress under dead load and prestress should ideally be the maximum allowable stress; and under dead load, live load and prestress the stress should be the minimum allowable stress.
   Therefore under dead load and prestress, as the dead load moment reduces towards the support, then the prestress moment will have to reduce accordingly to avoid exceeding the permissible stresses. In post-tensioned structures this may be achieved by curving the tendons, or in pre-tensioned structures some of the prestressing strands may be deflected or de-bonded near the support.

ii. Prestressed concrete is to be considered as a combination of steel and concrete with the steel taking tension and concrete compression so that the two materials form a resisting couple against the external moment. (Analogous to reinforced concrete concepts).
This concept is utilized to determine the ultimate strength of prestressed beams.
iii. Prestressing is used to achieve load balancing.
It is possible to arrange the tendons to produce an upward load which balances the downward load due to say, dead load, in which case the concrete would be in uniform compression.

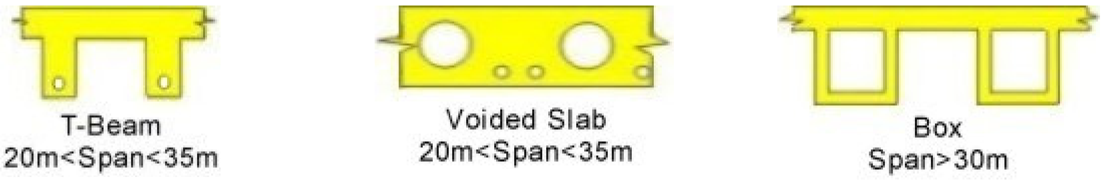
Pre-tensioned Bridge Decks



Types of beams in common use are inverted T-beams, M-beams and Y beams. Inverted T-beams are generally used for spans between 7 and 16 metres and the voids between the beams are filled with insitu concrete thus forming a solid deck. M-Beams are used for spans between 14 and 30 metres and have a thin slab cast insitu spanning between the top flanges with the aim of forming a voided slab type deck. The top face of the bottom flange of M-Beams cannot be readily inspected, also the limited access makes bearing replacement difficult. As a consequence of these restrictions the Y-beam was introduced in 1990 to replace the M-beam. This lead to the production of an SY-beam which is used for spans between 32 and 40 metres. The U-beam is used for spans between 14 and 34 metres and is usually chosen where torsional strength is required.

Post-tensioned Bridge Decks

Post-tensioned bridge decks are generally composed of insitu concrete in which ducts have been cast in the required positions.



When the concrete has acquired sufficient strength, the tendons are threaded through the ducts and tensioned by hydraulic jacks acting against the ends of the member. The ends of the tendons are then anchored.
Tendons are then bonded to the concrete by injecting grout into the ducts after the stressing has been completed.
It is possible to use pre-cast concrete units which are post-tensioned together on site to form the bridge deck.
Generally it is more economical to use post-tensioned construction for continuous structures rather than insitu reinforced concrete at spans greater than 20 metres. For simply supported spans it may be economic to use a post-tensioned deck at spans greater than 20 metres.

Bridge Components | Choice of Deck

Composite Bridge Design Standards Eurocodes

- EN 1991-1-1: Actions on Structures - General Actions
- EN 1991-1-4: Actions on Structures - Wind Actions
- EN 1991-1-5: Actions on Structures - Thermal Actions
- EN 1991-1-7: Actions on Structures - Accidental Actions
- EN 1991-2: Actions on Structures - Traffic Loads on Bridges
- EN 1994-1-1: Design of Composite Steel and Concrete Structures - General Rules
- EN 1994-2: Design of Composite Steel and Concrete Structures - Bridges
- *Each document is accompanied by a National Annex*

British Standards

- BS 5400: Part 2: Specification for Loads
- BS 5400: Part 3: Code of Practice for the Design of Steel Bridges
- BS 5400: Part 4: Code of Practice for the Design of Concrete Bridges
- BS 5400: Part 5: Code of Practice for the Design of Composite Bridges
- BS 8500: Concrete - Complementary British Standard to BS EN 206-1
- BS 8666: Specification for scheduling, dimensioning, bending and cutting of steel reinforcement for concrete
- BS EN 10025 Parts 1 to 6: Hot rolled products of structural steels

Design Manual for Roads and Bridges

- BD13: Design of Steel Bridges
- BD16: Design of Composite Bridges
- BD24: Design of Concrete Bridges
- BD28: Early Thermal Cracking of Concrete
- BD37: Loads for Highway Bridges
- BD57 and BA57: Design for Durability

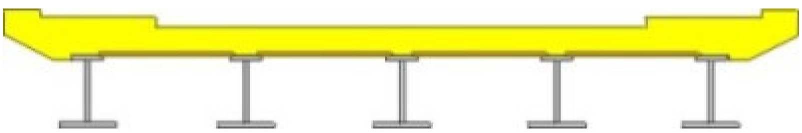
Technical Papers

- CIRIA Report C660 - Early-age thermal crack control in concrete.

Composite Decks

Composite Construction in bridge decks usually refers to the interaction between insitu reinforced concrete and structural steel.
Three main economic advantages of composite construction are :

i. For a given span and loading system a smaller depth of beam can be used than for a concrete beam solution, which leads to economies in the approach embankments.
ii. The cross-sectional area of the steel top flange can be reduced because the concrete can be considered as part of it.
iii. Transverse stiffening for the top compression flange of the steel beam can be reduced because the restraint against buckling is provided by the concrete deck.



Typical Composite Deck

Construction Methods

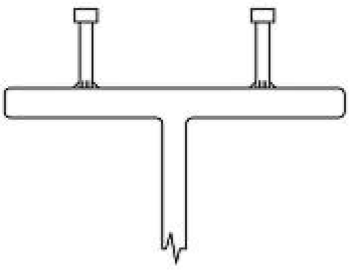
It is possible to influence the load carried by a composite deck section in a number of ways during the erection of a bridge.
By propping the steel beams while the deck slab is cast and until it has gained strength, then the composite section can

be considered to take the whole of the dead load. This method appears attractive but is seldom used since propping can be difficult and usually costly.

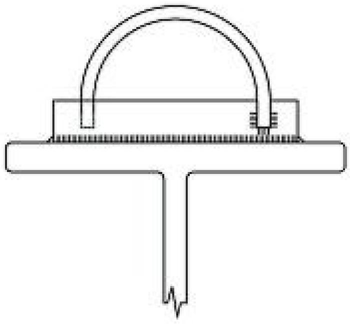
With continuous spans the concrete slab will crack in the hogging regions and only the steel reinforcement will be effective in the flexural resistance, unless the concrete is prestressed.

Generally the concrete deck is 220mm to 250mm thick with beams or plate girders between 2.5m and 3.5m spacing and depths between span/20 and span/30.

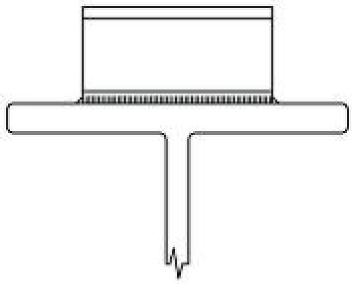
Composite action is developed by the transfer of horizontal shear forces between the concrete deck and steel via shear studs which are welded to the steel girder. Typical types of connectors are shown below, the stud connector being the most commonly used.



Stud Connector



Bar Connector



Channel Connector

Bridge Components | Choice of Deck

Steel Deck Design Standards

Eurocodes

- EN 1991-1-1: Actions on Structures - General Actions
- EN 1991-1-4: Actions on Structures - Wind Actions
- EN 1991-1-5: Actions on Structures - Thermal Actions
- EN 1991-1-7: Actions on Structures - Accidental Actions
- EN 1991-2: Actions on Structures - Traffic Loads on Bridges
- EN 1993-1-1: Design of Steel Structures - General Rules
- EN 1993-1-5: Design of Steel Structures - Plated structures without transverse loading
- EN 1993-1-7: Design of Steel Structures - Plated structures with out-of-plane loading
- EN 1993-1-8: Design of Steel Structures - Joints
- EN 1993-1-9: Design of Steel Structures - Fatigue
- EN 1993-1-10: Design of Steel Structures - Material toughness
- EN 1993-1-11: Design of Steel Structures - Tension members
- EN 1993-2: Design of Steel Structures - Bridges
- *Each document is accompanied by a National Annex*

British Standards

- BS 499: Welding terms and symbols
- BS 4395: Specification for high strength friction grip bolts and associated nuts and washers for structural engineering metric series
- BS 5400 Part 2: Specification for Loads
- BS 5400 Part 3: Code of Practice for the Design of Steel Bridges
- BS 5400 Part 10: Code of Practice for Fatigue
- BS EN 10025 Parts 1 to 6: Hot rolled products of structural steels

Design Manual for Roads and Bridges

- BA9: Use of BS5400 Part 10
- BD13: Design of Steel Bridges
- BD37: Loads for Highway Bridges
- BA53: Bracing Systems for the Use of U-Frames in Steel Highway Bridges

Steel Box Girders

Box girders have a clean, uninterrupted design line and require less maintenance because more than half of their surface area is protected from the weather. The box shape is very strong torsionally and is consequently stable during erection and in service; unlike the plate girder which generally requires additional bracing to achieve adequate stability.

The disadvantage is that box girders are more expensive to fabricate than plate girders of the same weight and they require more time and effort to design.

Box girders were very popular in the late 1960's, but, following the collapse of four bridges, the Merrison Committee published design rules in 1972 which imposed complicated design rules and onerous fabrication tolerances. The design rules have now been simplified with the publication of BS5400 and more realistic imperfection limits have been set.

The load analysis and stress checks include a number of effects which are generally of second order importance in conventional plate girder design such as shear lag, distortion and warping stresses, and stiffened compression flanges. Special consideration is also required for the internal intermediate cross-frames and diaphragms at supports.

Bridge Components | Choice of Deck

Steel Deck Design Standards

Eurocodes

- EN 1991-1-1: Actions on Structures - General Actions
- EN 1991-1-4: Actions on Structures - Wind Actions
- EN 1991-1-5: Actions on Structures - Thermal Actions
- EN 1991-1-7: Actions on Structures - Accidental Actions
- EN 1991-2: Actions on Structures - Traffic Loads on Bridges
- EN 1993-1-1: Design of Steel Structures - General Rules
- EN 1993-1-5: Design of Steel Structures - Plated structures without transverse loading
- EN 1993-1-7: Design of Steel Structures - Plated structures with out-of-plane loading
- EN 1993-1-8: Design of Steel Structures - Joints
- EN 1993-1-9: Design of Steel Structures - Fatigue
- EN 1993-1-10: Design of Steel Structures - Material toughness
- EN 1993-1-11: Design of Steel Structures - Tension members
- EN 1993-2: Design of Steel Structures - Bridges
- *Each document is accompanied by a National Annex*

British Standards

- BS 499: Welding terms and symbols
- BS 4395: Specification for high strength friction grip bolts and associated nuts and washers for structural engineering metric series
- BS 5400 Part 2: Specification for Loads
- BS 5400 Part 3: Code of Practice for the Design of Steel Bridges
- BS 5400 Part 10: Code of Practice for Fatigue
- BS EN 10025 Parts 1 to 6: Hot rolled products of structural steels

Design Manual for Roads and Bridges

- BA9: Use of BS5400 Part 10
- BD13: Design of Steel Bridges
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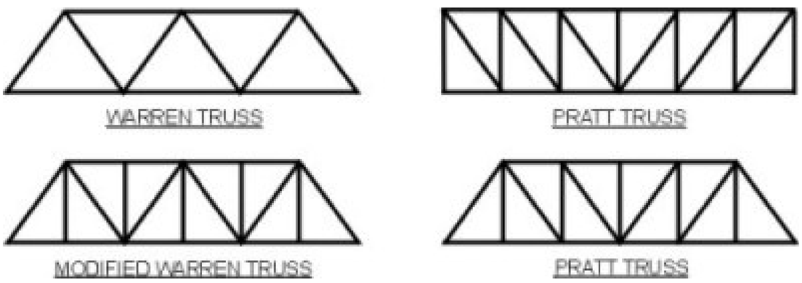
- BA53: Bracing Systems for the Use of U-Frames in Steel Highway Bridges

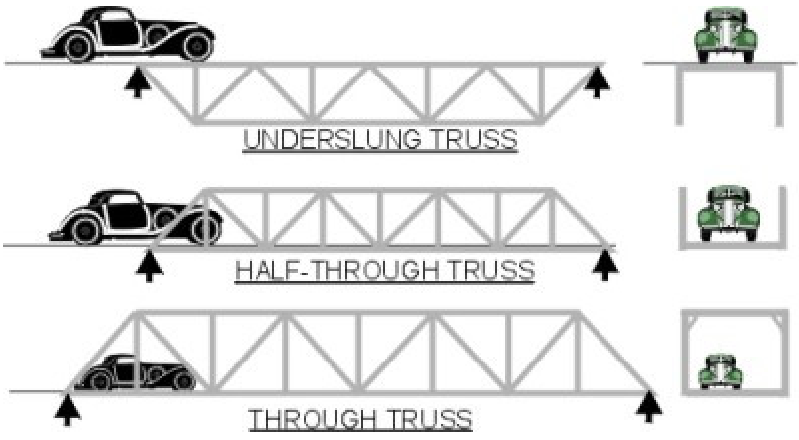
Steel Truss Decks

Trusses are generally used for bridge spans between 30m and 150m where the construction depth (deck soffit to road level) is limited. The small construction depth reduces the length and height of the approach embankments that would be required for other deck forms. This can have a significant effect on the overall cost of the structure, particularly where the approach gradients cannot be steep as for railway bridges.



High fabrication and maintenance costs has made the truss type deck less popular in the UK; labour costs being relatively high compared to material costs. Where material costs are relatively high then the truss is still an economical solution. The form of construction also allows the bridge to be fabricated in small sections off site which also makes transportation easier, particularly in remote areas.

Choice of Truss



The underslung truss is the most economical as the deck provides support for the live load and also braces the compression chord. There is however the problem of the headroom clearance required under the deck which generally renders this truss only suitable for unnavigable rivers or over flood planes.

Where underslung trusses are not possible, and the span is short, it may be economical to use a half-through truss. Restraint to the compression flange is achieved by U frame action.

When the span is large, and the underslung truss cannot be used, then the through girder provides the most economic solution. Restraint to the compression flange is provided by bracing between the two top chords; this is more efficient than U frame support. The bracing therefore has to be above the headroom requirement for traffic on the deck.

Bridge Components | Choice of Deck

Steel Deck Design Standards

Eurocodes

- EN 1991-1-1: Actions on Structures - General Actions
- EN 1991-1-4: Actions on Structures - Wind Actions
- EN 1991-1-5: Actions on Structures - Thermal Actions
- EN 1991-1-7: Actions on Structures - Accidental Actions
- EN 1991-2: Actions on Structures - Traffic Loads on Bridges
- EN 1993-1-1: Design of Steel Structures - General Rules
- EN 1993-1-5: Design of Steel Structures - Plated structures without transverse loading
- EN 1993-1-7: Design of Steel Structures - Plated structures with out-of-plane loading
- EN 1993-1-8: Design of Steel Structures - Joints
- EN 1993-1-9: Design of Steel Structures - Fatigue
- EN 1993-1-10: Design of Steel Structures - Material toughness
- EN 1993-1-11: Design of Steel Structures - Tension members
- EN 1993-2: Design of Steel Structures - Bridges
- *Each document is accompanied by a National Annex*

British Standards

- BS 499: Welding terms and symbols
- BS 4395: Specification for high strength friction grip bolts and associated nuts and washers for structural engineering metric series
- BS 5400 Part 2: Specification for Loads
- BS 5400 Part 3: Code of Practice for the Design of Steel Bridges
- BS 5400 Part 10: Code of Practice for Fatigue
- BS EN 10025 Parts 1 to 6: Hot rolled products of structural steels

Design Manual for Roads and Bridges

- BA9: Use of BS5400 Part 10
- BD13: Design of Steel Bridges
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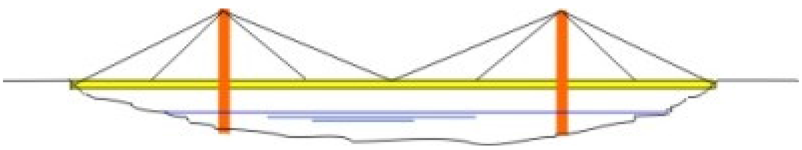
- BA53: Bracing Systems for the Use of U-Frames in Steel Highway Bridges

Cable Stayed Decks

Cable stayed bridges are generally used for bridge spans between 150m and 1000m. They are often chosen for their aesthetics, but are generally economical for spans in excess of 250m.



Cable stayed girders were developed in Germany during the reconstruction period after the last war and attributed largely to the works of Fritz Leonhardt. Straight cables are connected directly to the deck and induce significant axial forces into the deck. The structure is consequently self anchoring and depends less on the foundation conditions than the suspension bridge.
The cables and the deck are erected at the same time which speeds up the construction time and reduces the amount of temporary works required. The cable lengths are adjusted during construction to counteract the dead load deflections of the deck due to extension in the cable.

Most early cable-stayed bridges have an orthotropic deck, mainly because the long span bridges were usually built by steel companies. It was considered economical to use composite slabs for spans up to about 250m. Developments in concrete technology have now allowed higher grade strenghs to be used. This development, combined with the

increased cost of steel, has seen longer composite deck spans being used economically. Spans in excess of 600m are now being built using a steel-concrete composite box girder constuction.
Either box girders or plate girders (for the shorter spans) can be used in the deck, however if a single plane of cables is used then it is essential to use the box girder construction to achieve torsional stability.

Steel Deck Design Standards

Eurocodes

- EN 1991-1-1: Actions on Structures - General Actions
- EN 1991-1-4: Actions on Structures - Wind Actions
- EN 1991-1-5: Actions on Structures - Thermal Actions
- EN 1991-1-7: Actions on Structures - Accidental Actions
- EN 1991-2: Actions on Structures - Traffic Loads on Bridges
- EN 1993-1-1: Design of Steel Structures - General Rules
- EN 1993-1-5: Design of Steel Structures - Plated structures without transverse loading
- EN 1993-1-7: Design of Steel Structures - Plated structures with out-of-plane loading
- EN 1993-1-8: Design of Steel Structures - Joints
- EN 1993-1-9: Design of Steel Structures - Fatigue
- EN 1993-1-10: Design of Steel Structures - Material toughness
- EN 1993-1-11: Design of Steel Structures - Tension members
- EN 1993-2: Design of Steel Structures - Bridges
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British Standards

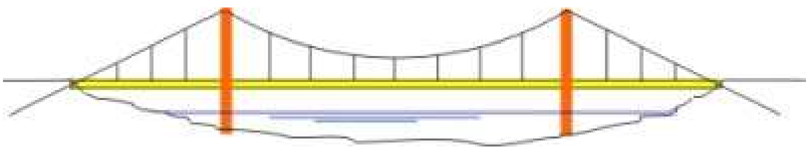
- BS 499: Welding terms and symbols
- BS 4395: Specification for high strength friction grip bolts and associated nuts and washers for structural engineering metric series
- BS 5400 Part 2: Specification for Loads
- BS 5400 Part 3: Code of Practice for the Design of Steel Bridges
- BS 5400 Part 10: Code of Practice for Fatigue
- BS EN 10025 Parts 1 to 6: Hot rolled products of structural steels

Design Manual for Roads and Bridges

- BA9: Use of BS5400 Part 10
- BD13: Design of Steel Bridges
- BD37: Loads for Highway Bridges
- BA53: Bracing Systems for the Use of U-Frames in Steel Highway Bridges

Suspension Bridges

Suspension bridges are used for bridge spans in excess of 350m.



Some of the world's longest bridge main spans are:

Bridge Name (Country)	Main Span
Akashi-Kaikyo Bridge (Japan)	1990m
Nansha Bridge (China)	1688m
Xihoumen Bridge (China)	1650m
Great Belt Bridge (Denmark)	1624m
Osman Gazi Bridge (Turkey)	1550m
Yi Sun-sin Bridge (South Korea)	1545m

Runyang Bridge (China)	1490m
Dongting Lake Bridge (China)	1480m
Nanjing Fourth Yangtze Bridge (China)	1418m
Humber Bridge (UK)	1410m
Yavuz Sultan Selim Bridge (Turkey)	1408m
Jiangyin Suspension Bridge (China)	1385m
Tsing Ma (Hong Kong)	1377m
Hardanger Bridge (Norway)	1310m
Verrazano Narrows (USA)	1298m
Golden Gate (USA)	1280m
Yangluo Bridge (China)	1280m
Höga Kusten Bridge (Sweden)	1210m
Aizhai Bridge (China)	1176m
Mackinac Bridge (USA)	1158m
Ulsan Grand Harbor Bridge(South Korea)	1150m
Hålogaland Bridge (Norway)	1145m
Qingshui River Bridge (China)	1130m
Huangpu Bridge (China)	1108m
Minami Bisan-Seto Bridge (Japan)	1100m
Xingkang Bridge (China)	1100m
Fatih Sultan Mehmet Bridge (Turkey)	1090m
Balinghe Bridge (China)	1088m
Taizhou Bridge (China)	1080m
Ma’anshan Bridge (China)	1158m
Bosporus Bridge(Turkey)	1074m
George Washington Bridge(USA)	1067m
Fuma Bridge (China)	1050m
Third Kurushima-Kaikyõ Bridge (Japan)	1030m
Second Kurushima-Kaikyõ Bridge (Japan)	1020m
25 de Abril Bridge [formerly Salazar Bridge] (Portugal)	1013m
Forth Road Bridge (UK)	1006m
Kita Bisan-Seto Bridge (Japan)	990m
Severn Bridge (UK)	988m
Yichang Bridge (China)	960m

A number of early suspension bridges were designed without the appreciation of wind effects. Large deflections were developed in the flexible decks and wind loading created unstable oscillations. The problem was largely solved by using inclined hangers.

The suspension bridge is essentially a catenary cable prestressed by dead weight. The cables are guided over the support towers to ground anchors. The stiffened deck is supported mainly by vertical or inclined hangers.

Bridge Components | Choice of Deck

Drainage Design Standards British Standards

- BS 5400: Part 2: Specification for Loads
- BS 8002: Code of Practice for Earth Retaining Structures
- BS 8004: Foundations

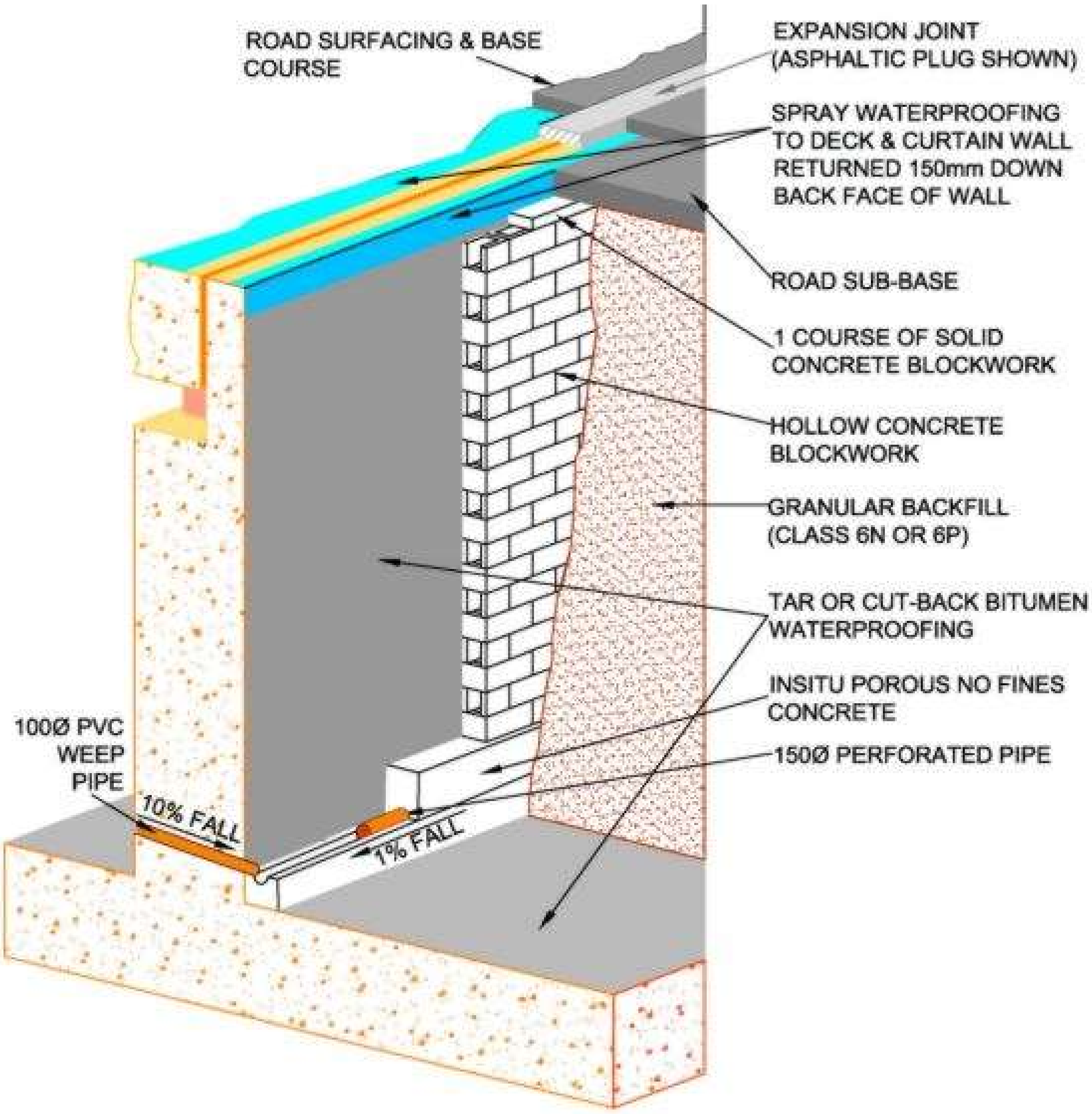
Design Manual for Roads and Bridges

- BD30: Backfilled Retaining Walls and Bridge Abutments
- BD37: Loads for Highway Bridges
- BA42: The Design of Integral Bridges

Drainage Systems

Back of Wall Drainage

The Design Manual for Roads and Bridges BD 30/87 requires surface water to be drained away from earth retaining structures or backfill. This will normally allow the retaining wall or abutment to be designed with zero ground water pressure on the back of the wall above the perforated drainage pipe level; this leads to a considerable cost saving. An instance where hydrostatic pressures will need to be considered is where there is a possibility of a burst water main in the vacinity of the wall.



Any water percolating through the fill is collected in a perforated drainpipe, not less than 150mm diameter, which is located at the rear of the vertical stem of the wall at the level of the top of the footing. Access to the pipe should be provided for rodding purposes from inspection manholes positioned at the foot of the wall. Weep holes are often provided as a safeguard in the event that the drainpipe is blocked; they also provide a visual check that the system is working.

Unless the backfill to the wall is highly permeable then a vertical drainage layer is provided at the rear of the wall and is connected with the perforated drainpipe.

The vertical permeable layer shown in the diagram above consists of hollow concrete blockwork, however it may also take the form of:

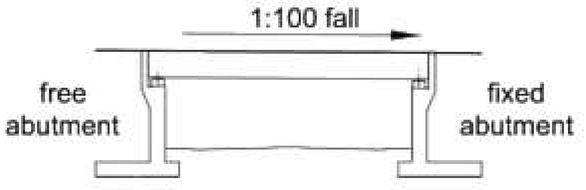
1. Cast insitu porous no fines concrete
2. or
3. Granular drainage layer.

There are also proprietary systems on the market, such as Terram Geocomposite Drains, but they will need DfT approval to be used on a highway structure.

Special consideration to the drainage layer is required when the backfill contains materials susceptible to piping such as silt, chalk or PFA. Under these conditions then a granular drainage layer only is recommended; hollow blocks or no fines concrete are unsuitable.

Deck Drainage

Ideally the road alignment should have a continuous fall from one abutment to the other. Also decks should be made integral with the abutments to avoid any joints in the carriageway. If decks cannot be made integral then the fixed abutment should be positioned at the low end to minimise any surface water leakage through the deck joints.



The DMRB document CD 358 "Waterproofing and Surfacing Concrete Bridge Decks"says that the longitudinal gradient on the deck should be a minimum of 1 in 100.

Road gullies should be positioned at the rear of the abutment at the high end of the deck to intercept any water from flowing onto the deck. Gully spacing should be determined using DMRB document HA 102 although every effort should be made to avoid putting gullies on the deck. It is crucial to be involved in the early planning stages of the road alignment to advise on the benefits of providing adequate longitudinal fall to avoid providing gullies on the bridge.

Bridge Components

Footing and Foundation Design Standards

Eurocodes

- EN 1991-1-1: Actions on Structures - General Actions
- EN 1991-1-4: Actions on Structures - Wind Actions
- EN 1991-1-5: Actions on Structures - Thermal Actions
- EN 1991-1-7: Actions on Structures - Accidental Actions
- EN 1991-2: Actions on Structures - Traffic Loads on Bridges
- EN 1992-1-1: Design of Concrete Structures - General Rules
- EN 1992-2: Design of Concrete Structures - Bridges
- EN 1993-5: Design of Steel Structures - Piling
- EN 1997-1: Geotechnical Design - General Rules
- EN 1997-2: Geotechnical Design - Ground Investigation
- EN 1998-2: Design of Structures for Earthquake Resistance - Bridges
- EN 1998-5: Design of Structures for Earthquake Resistance - Geotechnical Aspects
- *Each document is accompanied by a National Annex*

British Standards

- BS 5400: Part 2: Specification for Loads
- BS 5400: Part 3: Code of Practice for the Design of Steel Bridges
- BS 5400: Part 4: Code of Practice for the Design of Concrete Bridges
- BS 8500: Concrete - Complementary British Standard to BS EN 206-1
- BS 8002: Earth Retaining Structures
- BS 8004: Foundations

Design Manual for Roads and Bridges

- BD10: Design of Highway Structures in Areas of Mining Subsidence
- BA25: Piled Foundations
- BD32: Piled Foundations
- BD37: Loads for Highway Bridges
- BD42: Design of Embedded Retaining Walls and Bridge Abutments
- BD74: Foundations

Technical Papers

- CIRIA Report C660 - Early-age thermal crack control in concrete.

Choice of Foundation

Foundation types depend primarily on the depth and safe bearing pressures of the bearing stratum, also restrictions placed on differential settlement due to the type of bridge deck. Generally in the case of simply supported bridge decks differential settlements of about 20 to 25 mm can be tolerated, whereas multi-span continuous decks 10 mm is usually considered as a maximum.
Bridge foundations generally fall into two categories:

i. Strip footings, one for each pier and abutment. However, it is sometimes convenient to split the deck into two halves longitudinally along the centre line, this is then continued to the footing.
ii. Piled foundations.

It is possible to have a combination of both (i.e. piers being piled with abutments on strip footings).

Design Considerations
The design of foundations comprise of the following stages :

i. From the site investigation report decide upon which stratum to impose the structure load and its safe bearing pressure.

ii. Select the type of foundation, possibly comparing the suitability of several types.
iii. Design the foundation to transfer and distribute the loads from the structure to the ground. Ensure that the factor of safety against shear failure in the soil is not reached and settlement is within the allowable limits.

Strip Footings

The overall size of strip footings is determined by considering the effects of vertical and rotational loads. The combination of these two must neither exceed the safe bearing capacity of the stratum or produce uplift. The thickness of the footings is generally about 0.8 to 1.0 m but must be capable of withstanding moments and shears produced by piers or abutments.
The critical shearing stress may be assumed to occur on a plane at a distance equal to the effective depth of the base from the face of the column.
Cover to reinforcement should never be less than values given in BS 5400: Part 4: Table 13, and crack control calculation must be carried out to ensure the crack width is less than 0.25mm (Table 1). Cover to reinforcement will need to be increased to comply with BS 8500 requirements.

Piled Foundations

The type of piles generally used for bridge foundations are :

a. Driven Piles; preformed piles of concrete or steel driven by blows of a power hammer or jacked into the ground.
b. Preformed Driven Cast In-Situ Piles; formed by driving a hollow steel tube with a closed end and filling the tube with concrete.
c. Driven Cast In-Situ Piles; formed by driving a hollow steel tube with a closed end and filling the tube with concrete, simultaneously withdrawing the tube.
d. Bored and Cast In-Situ Piles; formed by boring a hole and filling it with concrete.

a. to c. are known as displacement piles, and the problems of calculating the load carrying capacity and settlement require a different approach to that for bored piles.
Driven type piles can, depending on the strata, be either end bearing or friction piles; sometimes a combination of both.
Bored piles are generally end bearing and are often of large diameter. To increase their bearing capacity the bottom can be under-reamed to produce a greater bearing area. However, additional safety precautions are required with larger diameter piles.
A specialist form of pile consisting of stone aggregate consolidated by water or air using the 'Vibroflotation' technique is suitable in some granular soils.
Choice of pile type depends largely on the strata which they pass through, none of them however give the most economic and satisfactory solution under all conditions.
The art of selecting the right sort of pile lies in rejecting all those types which are obviously unsuited to the particular set of circumstances and then choosing from those which remain, the one which produces the most economical solution.
Concurrently with the choice of pile type must go the choice of the strata which will carry the main loads from the structure, because this very often influences the choice. In most all cases the rejection of conventional pad or strip foundations arises because the computed settlement is more than the structure can safely withstand and hence the main purpose of the piled foundation will be to reduce this settlement. It follows, therefore, that if more compressible strata exists within reasonable distance of the surface, it is very desirable that a high proportion of the foundation load should be carried by this more stable strata; the ideal solution is where piles support the load wholly in end bearing on hard rock where the settlement will be negligible. It follows that piles wholly embedded in the same soil that would under-lie a conventional foundation has very little effect in reducing settlement. With soft normally consolidated alluvial clays, the remoulding effect of driven piles may well increase the settlement of the soil under its own dead weight and thus increase the settlement of the foundation itself.

Aspects of design of piled foundations which influence choice of pile type

All foundations must satisfy two criteria, no shear failure in the soil and no excessive settlement; piled foundations also have to meet this criteria. There are well established methods for ensuring that the first criteria is met, but the second presents more of a problem. The working load of an individual pile is based on providing an adequate factor of safety against the soil under the toe failing in shear and the adhesion between the shaft and the soil surrounding it passing its ultimate value and the whole pile sinking further into the ground. There are basically four methods for assessing this effect :

i. Through soil parameters i.e. summing shaft friction and bearing capacity. The ultimate bearing capacity is usually modified to compensate for the driving effect of the pile.
ii. By means of test piles.
iii. By means of dynamic formulae i.e. Hiley formulae which equates the energy required to drive the pile with its ultimate bearing capacity.
iv. Piling contractors 'know how'.

Bridge Components

Deck Joint Design Standards

Eurocodes

- EN 1991-1-1: Actions on Structures - General Actions
- EN 1991-1-5: Actions on Structures - Thermal Actions
- EN 1991-2: Actions on Structures - Traffic Loads on Bridges
- *Each document is accompanied by a National Annex*

British Standards

- BS 5400: Part 2: Specification for Loads

Design Manual for Roads and Bridges

- BA26: Expansion Joints for Use in Highway Bridge Decks
- BA42: The Design of Integral Bridges
- BA57 & BD57: Design for Durability
- BD33: Expansion Joints for Use in Highway Bridge Decks
- BD37: Loads for Highway Bridges

Technical Papers

- SR 479 Bridge Temperature for Setting Bearings and Expansion Joints. By M.Emerson of TRRL

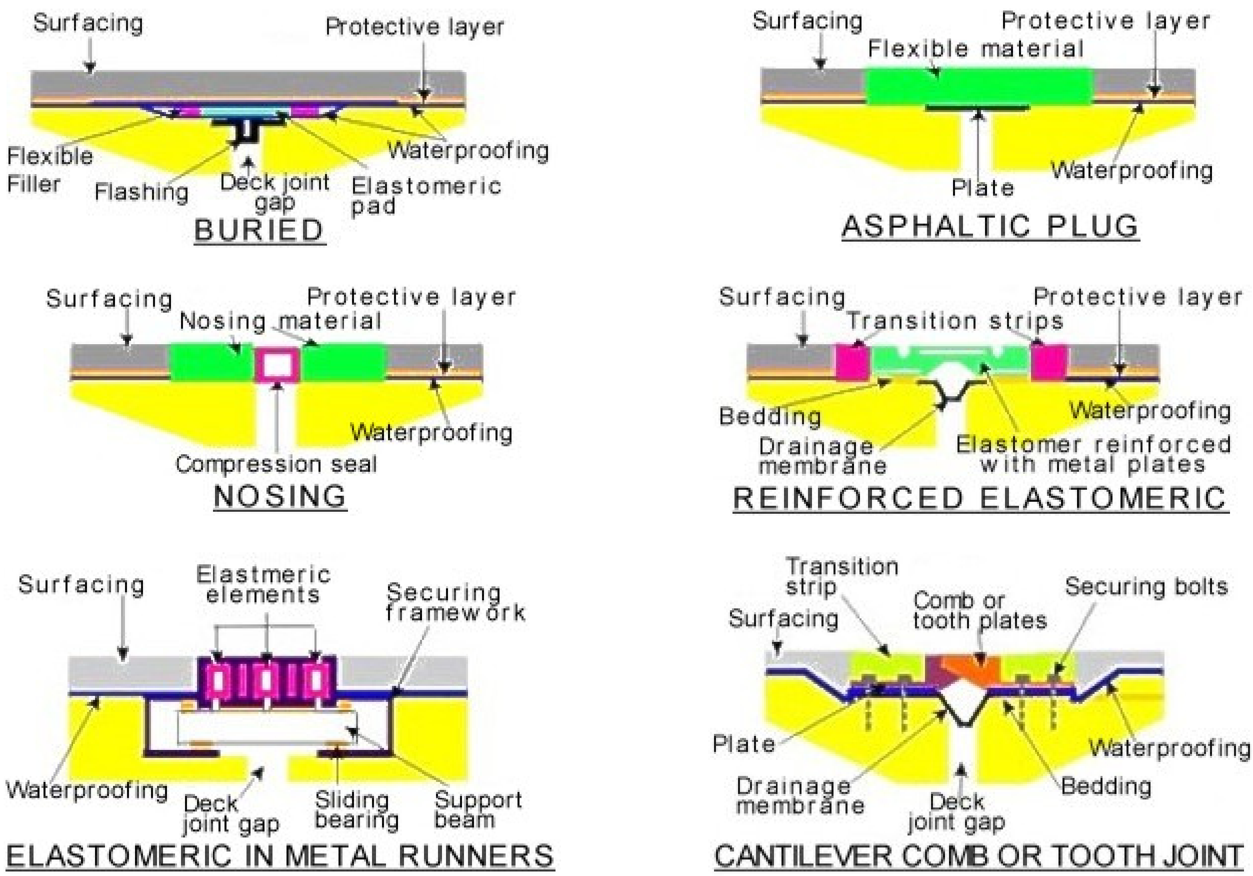
Choice of Deck Joint

Current practice is to make decks integral with the abutments. The objective is to avoid the use of joints over abutments and piers. Expansion joints are prone to leak and allow the ingress of de-icing salts into the bridge deck and substructure. In general all bridges are made continuous over intermediate supports and decks under 60 metres long with skews not exceeding 30° are made integral with their abutments.
Where it is intended not to use road salts, or the deck and substructure have been designed to incorporate deck joints then the following guidance is given in BD 33/94 for the range of movements that can be accommodated by the various joint types:

JOINT TYPE	TOTAL ACCEPTABLE LONGITUDINAL MOVEMENT		MAXIMUM ACCEPTABLE VERTICAL MOVEMENT BETWEEN TWO SIDES OF JOINT (mm)
	Min (mm)	Max (mm)	
1. Buried joint under continuous surfacing.	5	20	1.3
2. Asphaltic Plug joint.	5	40	3
3. Nosing joint with poured sealant.	5	12	3
4. Nosing with preformed compression seal.	5	40	3
5. Reinforced Elastomeric.	5	*	3
6. Elastomeric in metal runners.	5	*	3

7. Cantilever comb or tooth joint.	25	*	3

The minimum of the range is given to indicate when the type of joint may not be economical.
* Maximum value varies according to manufacturer or type.



Thermal Movements

BS 5400 Part 2 Chapter 5.4 specifies maximum and minimum effective bridge temperatures which have to be accommodated in the bridge structure.

The width of joint between the end of the deck and the abutment is set during construction of the bridge; usually when the concrete curtain wall is cast. The maximum expansion of the deck is therefore determined from the minimum effective temperature at which the curtain wall is allowed to to be cast; usually 2°C. Hence if a maximum effective temperature of 40°C is calculated from BS 5400 Part 2 then a joint width will have to be provided at the end of the deck to allow for an expansion caused by a temperature increase of (40-2)=38°C.

The maximum contraction of the deck is determined in a similar manner, but using a nominal effective temperature at which the joint is set.

Having determined the range of movement at the joint then the type of joint can be specified. The nominal effective temperature used in the calculations will also have to be specified to enable the correct adjustments to be made on site when the joints are set.

Joint Manufacturers

An overview of the various types of bridge joints, together with a list of suppliers can be obtained from the Bridge Joint Association.

Parapet Design Standards

Eurocodes

- EN 1317: Parts 1 to 6: Road Restraint Systems

British Standards

- BS 5400: Part 3: Code of Practice for Design of Steel Bridges
- BS 5400: Part 4: Code of Practice for Design of Concrete Bridges
- BS 6779: Parts 1 to 4: Highway Parapets for Bridges and Other Structures
- BS 7818: Specification for Pedestrian restraint systems in metal.

Design Manual for Roads and Bridges

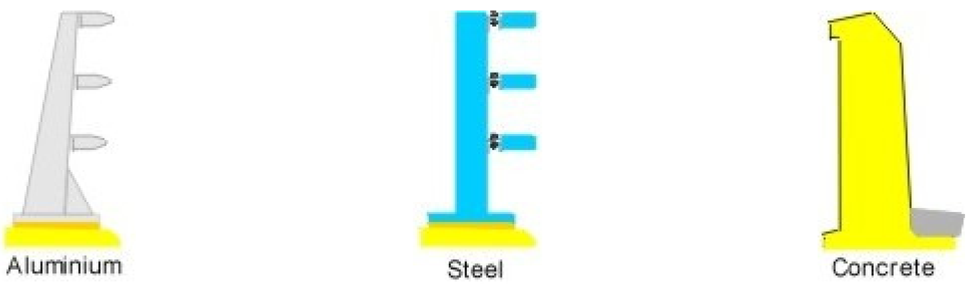
- BD37: Loads for Highway Bridges
- TD19: Requirement for Road Restraint Systems

Technical Papers

- Guidance Note for the Assessment and Design of Unreinforced Masonry Vehicular Parapets. Produced by the County Surveyor's Society, Vol.1

Choice of Parapet

BS EN 1317-1:1998 describes a Vehicle Parapet as a safety barrier that is installed on the edge of a bridge or on a retaining wall or similar structure where there is a vertical drop, and which may contain additional protection and restraint for pedestrians and other road users.



Manufacturers have developed and tested parapets to meet the containment standards specified in the codes. Much of the earlier testing work was involved with achieving a parapet which would absorb the impact load and not deflect the vehicle back into the line of adjacent traffic. The weight of vehicle, speed of impact and angle of impact influence the behaviour of the parapet. Consequently a level of containment has been adopted to minimise the risk to traffic using the bridge (above and below the deck).
BS EN 1317-2 1998 specifies criteria for vehicle impact tests on parapets for various containment levels. The containment levels adopted by TD 19/06 (Design Manual for Roads and Bridges Volume 2, Section 2, Part 8) require testing to be carried out for various vehicles impacting the parapet at an angle of 20^o.
The vehicle impact test criteria for various containment levels as follows :

Parapet Containment Level	Test Vehicle	Impact Speed
N1 Normal Containment (Formerly P2{80})	1.5t car	80 km/h
N2 Normal Containment Level (Formerly P1, P2{113} & P5)	1.5t car	110 km/h
H2 Higher Containment Level	13t bus	70 km/h
H4a Very High Containment Level (Formerly P6)	30t Rigid HGV	65 km/h

Metal Parapets are designed and tested by manufactures who apply to the Highways Agency to be included on an Approved List. A copy of the "Highways Agency's Approved Road Restraint System List" can be obtained from their website http://www.dft.gov.uk/ha/standards/tech_info/en_1317_compliance.htm
TD19/06 is the current design standard which requires carrying out a risk assessment to identify the hazards and minimise the risks to the road users.
The risk assessment is documented by using an Excel spreadsheet, a copy of which can be obtained from the Highways Agency's website http://www.dft.gov.uk/ha/standards/tech_info/rrrap.htm
A user-guide is also available on the same web-page.

TD 19/06 also directs the designer to use BS 6779 and BS 7818 for the design of specific elements of parapets.
BS 6779: 1998 - Highway Parapets for Bridges and Other Structures.
Part 1: Metal Parapets for the provision of infill to parapets (see TD 19/06 clause 4.29, 4.39, 4.40)
Part 2: Concrete Parapets for the design of reinforced concrete parapets with some amendments (see TD 19/06 clauses 4.56 to 4.60)
Part 4: Reinforced and Unreinforced Masonry Parapets to assess the containment capacity of existing masonry parapets (see TD 19/06 clause 4.62)
BS 7818: 1995: Pedestrian Metal Parapets
This Standard is required for the manufacture and installation of pedestrian restraint systems until such times as the drafting of prEN 1317-6 is completed (see TD 19/06 clause 9.3).

Design Considerations

Information required to be supplied to metal parapet manufacturers is listed in TD19/06, namely:

- Containment Level (*N1, N2, H2, H4a*);
- Impact Severity Level (ISL) (*Normally Class B*);
- Working Width Class (*W1 to W5*);
- The height;
- The length;

Concrete parapets are ideal for very high containment parapets due to their significant mass.
Steel parapets are generally the cheapest solution for the normal containment. This is significant if the site is prone to accidents and parapet maintenance is likely to be regular. The steelwork does however require painting and is usually pretreated with hot-dip galvanising.
Aluminium parapets do not require surface protection and maintenance costs will be reduced if the parapet does not require replacing through damage. The initial cost is however high and special attention to fixing bolts is required to

prevent the parapets from being stolen for their high scrap value. Aluminium also provides a significant weight saving over the steel parapet. This is sometimes important for parapets on moving bridges.

Bridge Components

Pier Design Standards

Eurocodes

- EN 1991-1-1: Actions on Structures - General Actions
- EN 1991-1-5: Actions on Structures - Thermal Actions
- EN 1991-1-7: Actions on Structures - Accidental Actions
- EN 1991-2: Actions on Structures - Traffic Loads on Bridges
- EN 1992-1-1: Design of Concrete Structures - General Rules
- EN 1992-2: Design of Concrete Structures - Bridges
- EN 1993-5: Design of Steel Structures - Piling
- EN 1997-1: Geotechnical Design - General Rules
- EN 1998-2: Design of Structures for Earthquake Resistance - Bridges
- EN 1998-5: Design of Structures for Earthquake Resistance - Geotechnical Aspects
- *Each document is accompanied by a National Annex*

British Standards

- BS 5400: Part 2: Specification for Loads
- BS 5400: Part 4: Code of Practice for the Design of Concrete Bridges
- BS 8500: Concrete - Complementary British Standard to BS EN 206-1
- BS 8666: Specification for scheduling, dimensioning, bending and cutting of steel reinforcement for concrete

Design Manual for Roads and Bridges

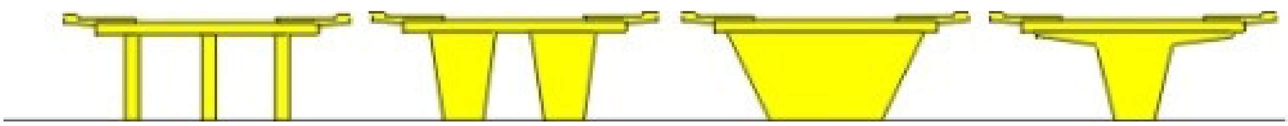
- BD37: Loads for Highway Bridges
- BA41: The Design and Appearance of Bridges
- BA42: The Design of Integral Bridges
- BD57 and BA57: Design for Durability

Technical Papers

- CIRIA Report C660 - Early-age thermal crack control in concrete.

Choice of Pier

Wherever possible slender piers should be used so that there is sufficient flexibility to allow temperature, shrinkage and creep effects to be transmitted to the abutments without the need for bearings at the piers, or intermediate joints in the deck.
A slender bridge deck will usually look best when supported by slender piers without the need for a downstand crosshead beam. It is the proportions and form of the bridge as a whole which are vitally important rather than the size of an individual element viewed in isolation.



Different Pier Shapes

Design Considerations

Loads transmitted by the bridge deck onto the pier are :

i. Vertical loads from self weight of deck
ii. Vertical loads from live loading conditions
iii. Horizontal loads from temperature, creep movements etc and wind
iv. Rotations due to deflection of the bridge deck.

The overall configuration of the bridge will determine the combination of loads and movements that have to be designed for. For example if the pier has a bearing at its top, corresponding to a structural pin joint, then the horizontal movements will impose moments at the base, their magnitude will depend on the pier flexibility. Sometimes special requirements are imposed by rail or river authorities if piers are positioned within their jurisdiction. In the case of river authorities a 'cut water' may be required to assist the river flow, or independent fenders to protect the pier from impact from boats or floating debris. A similar arrangement is often required by the rail authorities to prevent minor derailments striking the pier. Whereas the pier has to be designed to resist major derailments. Also if the pier should be completely demolished by a train derailment then the deck should not collapse.

Bridge Components

Retaining Wall Design Standards

Eurocodes

- EN 1991-1-1: Actions on Structures - General Actions
- EN 1991-1-7: Actions on Structures - Accidental Actions
- EN 1991-2: Actions on Structures - Traffic Loads on Bridges
- EN 1992-1-1: Design of Concrete Structures - General Rules
- EN 1992-2: Design of Concrete Structures - Bridges
- EN 1993-5: Design of Steel Structures - Piling
- EN 1997-1: Geotechnical Design - General Rules
- EN 1998-2: Design of Structures for Earthquake Resistance - Bridges
- EN 1998-5: Design of Structures for Earthquake Resistance - Geotechnical Aspects
- *Each document is accompanied by a National Annex*

British Standards

- BS 5400: Part 2: Specification for Loads
- BS 5400: Part 4: Code of Practice for the Design of Concrete Bridges
- BS 8002: Code of Practice for Earth Retaining Structures
- BS 8006: Strengthened/Reinforced Soils and Other Fills
- BS 8500: Concrete - Complementary British Standard to BS EN 206-1
- BS 8666: Specification for scheduling, dimensioning, bending and cutting of steel reinforcement for concrete

Design Manual for Roads and Bridges

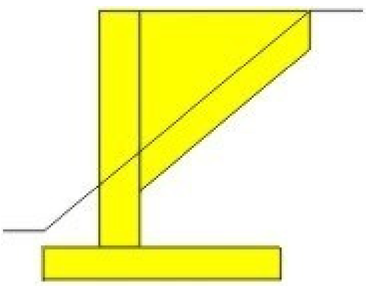
- BD30: Backfilled Retaining Walls and Bridge Abutments
- BD37: Loads for Highway Bridges
- BA41: The Design and Appearance of Bridges
- BD42: Design of Embedded Retaining Walls and Bridge Abutments
- BD57 and BA57: Design for Durability
- BD68: Crib Retaining Walls
- BD70: Strengthened/Reinforced Soils and Other Fills for Retaining Walls and Bridge Abutments

Technical Papers

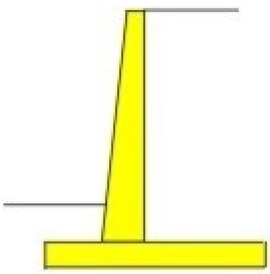
- CIRIA Report C660 - Early-age thermal crack control in concrete.

Choice of Wing Wall

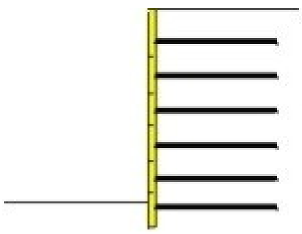
Wing walls are essentially retaining walls adjacent to the abutment. The walls can be independent or integral with the abutment wall.



Wing Wall Cantilevering from Abutment

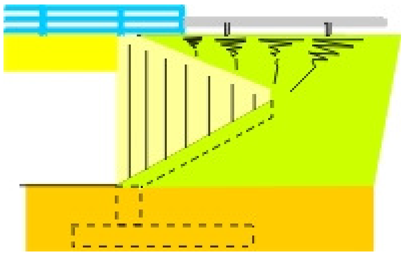


Free Standing Cantilever Retaining Wall



Strengthened/ Reinforced Soil

Providing the bridge skew angle is small (less than 20°), and the cutting/embankment slopes are reasonably steep (about 1 in 2), then the wing wall cantilevering from the abutment wall is likely to give the most economical solution.



Splayed wing walls can provide even more of an economy in material costs but the detailing and fixing of the steel reinforcement is more complicated than the conventional wall.

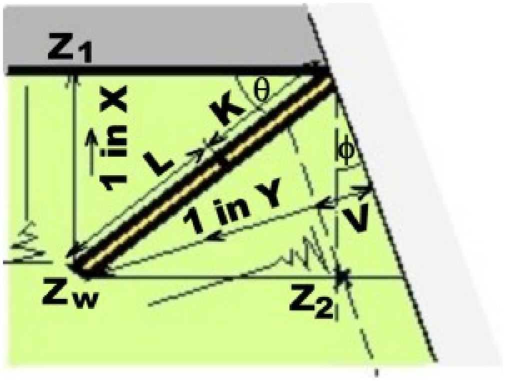
Design Considerations

Loads effects to be considered on the rear of the wall are:

i. Earth pressures from the backfill material.
ii. Surcharge from live loading or compacting plant.
iii. Hydraulic loads from saturated soil conditions.

The stability of the wall is generally designed to resist 'active' earth pressures (Ka); whilst the structural elements are designed to resist 'at rest' earth pressures (Ko). The concept is that 'at rest' pressures are developed initially and the structural elements should be designed to accommodate these loads without failure. The loads will however reduce to 'active' pressure when the wall moves, either by rotating or sliding. Consequently the wall will stabilise if it moves under 'at rest' pressures providing it is designed to resist 'active' earth pressures.

Geometry for splayed wing walls



Plan on Wing Wall

X = slope to road under bridge
Y = slope from road over bridge
L = length of sloping wall
K = length of horizontal wall
V = verge width to end of wall
Z_1 = level at bottom of embankment
Z_2 = level at back of verge on road over bridge
Z_w = ground level at end of wall
θ = angle of wall to road under bridge
φ = skew angle (-ve if < 90°)

$Z_w = Z_1 + {}^1/_X\,[(L+K)\sin\theta]$
$Z_w = Z_2 - [(L+K)\cos\theta + (L+K)\sin\theta\tan\varphi - {}^V/_{\cos\varphi}\,]^{\cos\varphi} / _Y$

$L + K = [\ X\ Y\ (Z_2 - Z_1) + V\ X\ ] / [\ X \cos(\theta - \varphi) + Y \sin\theta]$ ....eqn.(1)
For minimum length of wall ${}^{dL}/_{d\theta} = 0$
ie. $\tan\theta = \tan\varphi + {}^Y / {}_{X \cos\varphi}$

For known lengths of wall (L+K) two values of θ can be obtained from eqn.(1).
From eqn.(1) $-(A+B)\tan^2(\theta/_2) + 2(C+Y)\tan(\theta/_2) + (B-A) = 0$
Where $A = [XY(Z_2 - Z_1) + VX] / [L + K]$, $B = X\cos\varphi$, and $C = X\sin\varphi$

Example

Wall	Z_1	Z_2	V	X	Y	φ	Level at top of wall	(L+K)	Max & Min θ	θ	Z_w	K_{max}
N/E	56.6	63.6	2.2	2.0	2.0	10.5	63.0	11.0	68.1 to 32.4	32.5	59.6	4.1
S/E	56.9	64.2	2.0	2.0	2.0	-27.0	63.6	15.9	31.5	31.5	61.1	10.8
S/W	57.2	64.4	0.8	2.6	2.0	27.7	63.8	12.2	89.3 to 18.5	30.0	59.6	3.8

Minimum Lengths :-

N/E Wall : L+K = 10.437 @ θ = 50.25°

S/E Wall : L+K = 15.889 @ θ = 31.5°

S/W Wall : L+K = 9.996 @ θ = 54.37°

Bridge Components