## Bridge Design Requirements

<table>
<thead>
<tr>
<th>Revision</th>
<th>Date</th>
<th>Issued for/Revision details</th>
<th>Revised by</th>
</tr>
</thead>
<tbody>
<tr>
<td>P01</td>
<td>01/07/2015</td>
<td>Initial Issue</td>
<td>Ewan Jones</td>
</tr>
<tr>
<td>P02</td>
<td>04/12/2015</td>
<td>Retitled and coordinated with other docs.</td>
<td>Ewan Jones</td>
</tr>
<tr>
<td>P03</td>
<td>08/04/2015</td>
<td>Retitled and minor update</td>
<td>Ewan Jones</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOI / EIR</td>
<td>None</td>
</tr>
<tr>
<td>Document type</td>
<td>Standard</td>
</tr>
<tr>
<td>Directorate</td>
<td>Technical</td>
</tr>
<tr>
<td>MPL &amp; Deliverables Ref</td>
<td></td>
</tr>
<tr>
<td>Keywords</td>
<td>Architecture, Aesthetics, Specification, Civil Engineering</td>
</tr>
<tr>
<td>Authors</td>
<td>Oliver Moen</td>
</tr>
<tr>
<td>Checker</td>
<td>Ewan Jones</td>
</tr>
<tr>
<td>Approver</td>
<td>Andy Tye</td>
</tr>
<tr>
<td>Owner</td>
<td>C227 Atkins</td>
</tr>
<tr>
<td>Review Directorate</td>
<td>Technical, Built Environment</td>
</tr>
<tr>
<td>Employer’s Lead Reviewer</td>
<td>Tomas Garcia</td>
</tr>
<tr>
<td>Authorised for use</td>
<td></td>
</tr>
</tbody>
</table>
High Speed 2
BRIDGE DESIGN REQUIREMENTS
April 2016

Code 2 - Accepted with Comments
<table>
<thead>
<tr>
<th>Document number</th>
<th>HS2-HS2-BR-STD-000-000004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revision</td>
<td>P04</td>
</tr>
<tr>
<td>Author</td>
<td>C227 Atkins / Grimshaw</td>
</tr>
<tr>
<td>Date</td>
<td>04 April 2016</td>
</tr>
<tr>
<td>Revision details :</td>
<td>For acceptance</td>
</tr>
</tbody>
</table>
Foreword

Great design is essential to HS2 and great civil engineering design will be pivotal to its success. The design of HS2’s bridges is crucial to the performance of the high speed train system. Great design will ensure that HS2 achieves its full potential and delivers Britain’s long term economic plans but also safeguards and enhances our natural and cultural environment for this century and beyond.

Bridges are significant elements in the landscape and they will be some of the most visible parts of HS2. The array of new bridges and viaducts needed will include major new landmark structures as well as many straightforward crossings meeting the local needs of roads, footpaths, railways and waterways. Every new structure shall be sensitive to its place and well designed. Even the simplest bridge should clearly demonstrate great care and attention to detail in its design and construction.

HS2’s bridges will be designed to maximise opportunities for off-site construction. Systemisation and pre-fabrication will increase construction quality and efficiency. Off-site construction is safer and will minimise disruption to HS2’s neighbours and the users of existing routes.

This design requirements document provides the framework and inspiration to deliver bridge design beyond ‘business as usual’, setting new standards of design and efficiency for an infrastructure project.
Contents

Foreword 03

Introduction
Purpose of this document 08
High Speed 2 10
Bridge design 12
Design requirements 14

Bridge design vision
HS2 design vision 18
People : Place : Time 20
Bridge design approach 26
What success looks like 28

Bridge scenarios
Introduction 32
Underbridges 34
Viaducts 38
Pedestrian underpasses 42
Overbridges 46
Green bridges 50
Footbridges 54

Bridge design library
Introduction 60
Landscape 62
Deck structures 66
Piers and bearings 70
Parapets 74
Abutments and walls 78
Materials and maintenance 82
Steelwork 86
Concrete 90
Rainwater management 94
Services and rail systems 98
Mandatory clauses

Unlike the convention used in HS2 technical standards this document does not differentiate mandatory clauses from main text by the use of a ‘black box’. Instead, mandatory requirements will contain the word ‘shall’ to indicate their status as a requirement. Guidance is defined by the use of the words ‘should’, ‘consider’ or ‘may’.
Introduction

Code 2 - Accepted with Comments
Introduction

<table>
<thead>
<tr>
<th>Purpose of this document</th>
<th>08</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Speed 2</td>
<td>10</td>
</tr>
<tr>
<td>Bridge Design</td>
<td>12</td>
</tr>
<tr>
<td>Design Requirements</td>
<td>14</td>
</tr>
</tbody>
</table>
Introduction

Purpose of this document

This document provides guidance and requirements for the design of bridges and associated civil engineering throughout HS2. It defines design principles and best practice to be applied to future design development of the bridges for HS2. The design approach defined here embraces the HS2 vision and reflects the project’s commitment to exemplary design.

The scope of design and construction work considered here encompasses the majority of civil engineering structures within HS2 Phase One. Although this guidance excludes tunnels, tunnel portals and stations, many of the considerations in this document are applicable to tunnel portals and major structures within stations.

This document shall be read with, and be part of, the “Common Design Approach: Open Route Elements.” The adjacent diagram shows how these design requirements integrate with other HS2 design documentation, including design approaches for landscape and architecture. When read together this suite of documents provides comprehensive guidance for HS2’s designers.
The Bridges Design Requirements are presented in three sections as follows:

**Bridge design vision**

This section presents the bridge design vision for HS2 and shows how this embraces the HS2 Vision and HS2 Design Vision. The bridge design vision aims to demonstrate the highest standards of design and construction, a world class railway that creates a positive lasting legacy and provides a benchmark for the civil engineering design of major infrastructure projects.

**Bridge scenarios**

The bridge scenarios present a range of typical HS2 bridges, illustrating the range of structures that will be required along the route. Drawing from the bridge design vision these demonstrate the design approach required for HS2. Clear design principles, with associated guidance for each type of structure, implement the bridge design vision and thus the HS2 Vision.

**Bridge design library**

The bridge design library contains detailed advice for elements of design that are common across all bridge types. Some key aspects of bridge design (e.g. response to landscape) are covered in more detail in other design guides (e.g. Landscape Design Approach). This document defines how bridge design will be influenced by those key issues.
Introduction

High speed 2

HS2 is the largest infrastructure project ever undertaken by the UK Government, and construction is expected to commence in 2017.

Phase One of HS2 will run from London to Birmingham, a total length of 225km. Stations are proposed at Old Oak Common and Birmingham Interchange in addition to termini at London Euston and Curzon Street, Birmingham. The route will connect to the West Coast Main Line at Lichfield.

The maximum design speed for Phase One is 400kph. It will carry up to 18 trains per hour, each train being 400m long.

Phase Two of HS2 forms a ‘Y’ shape extending from the West Midlands towards Manchester and the North West, with a proposed station at Manchester Airport; and towards Leeds and the North East with proposed stations in the East Midlands and South Yorkshire.
Introduction

Bridge design

Bridges will be an abundant and prominent element of High Speed 2. In place for 120 years, they should provide a legacy of excellence for future generations.

Bridge aesthetics shall be considered, from the outset, as an integral part of design and procurement processes. Bridge design will not be successful if aesthetics are considered only in an attempt to mitigate the impact of decisions that have already been made.

Bridges are engineering but also architecture. There is a need to be constantly aware of the aesthetic implications of design decisions. A talent for, and understanding of, aesthetics is essential for excellent bridge design. This places a strong emphasis on the need for integrated design within a clear overall vision.

HS2’s civil engineering designers are encouraged to include architects, ideally with experience of bridge design, within their teams: architects’ training can reinforce a focus upon integrated design.

Some bridges and viaducts, due to their scale or location, will be symbolic landmark structures, naturally attracting special attention. The aesthetic principles defined in this document shall be applicable to all of HS2’s bridges, the minor structures as well as the special one-offs. Even the humblest of HS2’s bridges should have good manners and a degree of finesse.

This document does not provide a formula for good bridge design and there are always exceptions to design ‘rules.’ Unlike technical standards, hard and fast rules for appearance are not easily defined, but there is substantial and useful guidance that should be followed. The intent is to define principles and considerations that will eliminate the worst aspects of bridge design and encourage the best.
Maillart's Salginatobel bridge, Switzerland produced the lowest tender in a design/construct competition © Rama / Wikimedia Commons
Introduction

Design requirements

High speed railways

High speed rail is a relatively new type of infrastructure in the UK, with only one line currently in operation. Experience from this line, HS1, has been a key source in consideration of standards for HS2. In addition, there are established International, European and British Standards that the works shall comply with.

Whilst many of these standards deal with ‘technical’ matters, some will have a significant impact upon appearance and user experience. For example, requirements for the height and construction of highway and footbridge parapets.

Civil engineering design

Compliance with the UK Highways Agency’s Design Manual for Roads and Bridges (DMRB) shall be used as the core bridge design standard for HS2. As design progresses there may be scope to either reduce or increase the requirements where this can be demonstrated to be appropriate and justifiable.

Guidance in the following core reference documents shall be applied to all HS2 bridge design:

- DMRB Volume 1, Section 3, Part 11: The Design and Appearance of Bridges (BA 41/98, 1998)
- The Appearance of Bridges and Other Highway Structures (Highways Agency, 1996).

HS2 alignment

HS2’s horizontal (plan) and vertical (level) alignment is now substantially fixed, along with existing highway and footway levels. Alignment is largely defined by design for the Hybrid Bill, including a series of amendments.

Limits of deviation will leave some scope for very minor changes to alignment. Therefore, bridge structures which could significantly affect the alignment can no longer be considered.
HS2 requirements

The HS2 spatial requirements are defined within HS2-HS2-CV-STD-000-000001 ‘Technical Standard, Spatial Arrangements’. It sets out the required dimensions for generic cross sections along the full route, including bridges and viaducts. In addition, there are various span and headroom clearance requirements for overbridges. These are detailed in Sections 5 and 6 of the Requirements for Spatial Arrangements document.

The design of structures shall comply with the technical specification for interoperability (TSI) for dynamic performance.

All structures shall have a design life of 120 years.

HS2’s preference is to minimise future maintenance requirements. Accessibility for maintenance is a critically important consideration and needs to be considered throughout. This needs to include consideration of whether it is practicable to eliminate maintenance altogether in critical locations, i.e. those that would require track possessions.

Build off-site

HS2’s Efficiency Challenge Programme has led to a strategy to maximise off-site construction. On site construction should only be adopted as the exception or to support an off-site solution.

To pursue this agenda, HS2 has identified two distinctive routes to maximise off-site construction:

- Systematised: asset types that include repetition but need a degree of tailoring for their context.
- Standardised: specific proprietary products and standard product designs

Bridges, viaducts, wing walls and retaining walls have all been identified as asset families appropriate for having systemised designs and design rules. The objective is to avoid repeated design activities and provide supply chains with the greatest scope for improving productivity.

HS2’s current view is that there will be a need for limited customisation of some of these to accommodate alternative planning contexts.

It is important to recognize the significance of some asset types being very directly linked to the performance of the high speed train system itself. Within HS2, there is a strong presumption in favour of systemisation for viaducts and underbridges because the performance of the high speed train system needs to be thoroughly validated, including these elements. Verification can be complex and there is a clear case for only doing this once and having a standard design concept for each asset that forms part of the system. Once the design and design rules have been established they will need to be applied rigorously.

Standard designs may be developed for components that repeat throughout the HS2 system. Any standard designs may need multiple suppliers for commercial or capacity reasons, whilst minimising the need to retest or certify multiple designs. Elements of the bridges works could become standard designs, for example, a family of precast concrete parapet panels or precast concrete beams.
Bridge design vision

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS2 design vision</td>
<td>18</td>
</tr>
<tr>
<td>People : Place : Time</td>
<td>20</td>
</tr>
<tr>
<td>Bridge design approach</td>
<td>26</td>
</tr>
<tr>
<td>What success looks like</td>
<td>28</td>
</tr>
</tbody>
</table>
**Bridge design vision**

**HS2 Design Vision**

The HS2 Design Vision sets out the role that design can play in making High Speed Two a catalyst for growth across Britain. It sets out our aspiration for designing the UK’s new national high-speed rail network. It focuses on those things that will lift us beyond the ordinary and provides us with the means to constantly critique and check that we are on course.

HS2 is a project that will set designers, from the widest range of disciplines, the challenge of reaching new heights of creativity and innovation in everything they design.

Given the scale and importance of HS2 to the nation, every design task is critical. The system will be delivered through all the designed elements coming together. All the fundamental principles of good design shall apply. It all has to look good and work well and that means meeting rigorous requirements. But we are looking to achieve even more – something transformational – and this will call for great ingenuity.

"We aim to enhance the lives of future generations of people in Britain by designing a transformational rail system that is admired around the world."

*HS2 Design Vision, 2015*
The HS2 Design Vision

**People**
Design for everyone to benefit and enjoy

1. Design for the needs of our diverse audiences
2. Engage with communities over the life of a project
3. Inspire excellence through creative talent

**Place**
Design for a sense of place

4. Design places and spaces that support quality of life
5. Celebrate the local within a coherent national narrative
6. Demonstrate commitment to the natural world

**Time**
Design to stand the test of time

7. Design to adapt for future generations
8. Place a premium on the personal time of the customers
9. Make the most of the time to design

Code 2 - Accepted with Comments
Bridge design vision

People

User experience

Whilst passengers are the obvious “users” of HS2, many other people will be affected by the design of HS2’s bridges. The needs of all of them shall be considered, especially key impacts upon:

• neighbours
• views and the visibility of structures
• those travelling on routes crossing HS2
• maintenance and construction staff

The project’s neighbouring communities will, initially, be affected by construction and then by impact upon views and/or noise once the line is operational.

Many people will be affected by the way roads, footpaths, railways and waterways cross the HS2 route. The bridges that provide these crossings will have a significant influence.

Those working to build and maintain HS2 shall be considered. Bridges and viaducts shall be safe to build, maximising off-site construction and pre-fabrication. Structures shall be simple to maintain with convenient secure access and space to work safely.

Stakeholders

Multiple stakeholders will be affected by the design and construction of HS2’s bridges and viaducts. The HS2 Design Vision strongly advocates stakeholder consultation informing design development.

Discussions with stakeholders may also reveal areas where HS2 designs could be modified to the benefit of both parties. Stakeholders should be encouraged to describe and define their key concerns for people and their environment, including any special characteristics of their locations.
Grand Union Canal users at the site of HS2's Longhole viaduct, © Canal and River Trust

Delivery of pre-fabricated 7th Street bridge arch, Fort Worth, © Infinity Engineering (infinity-engineers.com)
Bridge design vision

Place

Context

HS2 passes through a broad variety of locations, from dense urban sites in London and Birmingham to valued open countryside. A number of locations are considered to be especially environmentally or visually sensitive.

The context for each bridge shall be thoroughly analysed through a landscape assessment, including urban design in built-up areas. Bridge design shall be informed by place, with a sensitive response to local character, history and future needs and plans. The scale of the structure and its visibility shall be considered. Bridges shall be integrated with the surrounding landscape and shall not be examples of engineering design in isolation.

In designing and constructing HS2’s bridges and viaducts, particularly special care shall be taken where:

- users are passing by slowly
- it is possible to get close to the structures
- many people can see the structures
- they are in a landscape acknowledged to be of visual importance

All of these places require special attention to design because of the higher levels of scrutiny that their structures will be subject to.

Uniformity or variety

There is potential tension between HS2’s aim for standardisation and systemisation for off-site construction and the HS2 Design Vision which seeks “design for a sense of place.”

In creating identity, HS2’s Design Vision aims to “celebrate the local within a coherent national narrative” where “local projects reflect their context but contribute to HS2’s overall identity.” It is clear that local variation will be necessary and appropriate but a consistent linewide approach will also have value.

Careful design exploration is now needed to define the appropriate balance between overall systematic linewide repetition and local variation. This shall be defined for each individual structure or location based upon clear analysis of place.
Grade 2 listed Lawley Street viaduct to be crossed by new HS2 viaduct structure, Birmingham © source info needed

Site for HS2 viaduct crossing meandering route of the Oxford canal, Wormleighton © Canal & Rivers Trust
**Bridge design vision**

**Time**

**Design life**

High Speed 2 has a design life of 120 years. Within this overall lifespan, trains and railway equipment will be renewed at regular intervals. Experience strongly suggests that the stations will also be subject to significant change over their lives.

In this context the landscape and civil engineering structures that define and support the HS2 alignment will be the longest lasting parts of the project. Bridges and viaducts will be the most visible of these structures throughout HS2. The significance of this legacy for future generations demands great care and attention to the quality of design, construction and maintenance for HS2’s bridges. They shall be of exemplary quality: a model of the very best practice.

**Construction time**

HS2 is the UK’s biggest infrastructure project. Its construction will take significant time, inevitably affecting the line’s neighbours and users of existing infrastructure crossing the route. Off-site manufacturing, maximising the use of prefabrication, has significant potential to reduce the amount of time spent on site with benefits for the construction workforce, neighbours and local stakeholders. HS2’s bridge designs shall consider modern methods of construction and design for manufacture and assembly to reduce the disruption that construction may cause to communities along the line.

**Durability**

HS2’s design life is an onerous requirement for bridge structures and materials. Long term durability is a fundamental design requirement. In addition to structural performance, and the impacts of corrosion and deterioration, long term visual ‘performance’ shall be considered. Structural forms, details and materials shall be designed to weather well over time.

Maintenance and inspection regimes have the potential to disrupt regular operation of the railway, affecting the reliability of train timetables and operations. This impact upon the valuable time of HS2’s passengers shall be controlled and minimised.

Bridge structures shall be designed to reduce the need for inspection and maintenance to minimum levels without affecting durability or safety. This requires maintenance to be considered from the very earliest design stages. Where elements that require inspection or maintenance cannot be eliminated, they should be located so that access does not require track possessions.
120 year design life: Forth Rail Bridge now 126 years since its completion in 1899, © George Gastin / Wikimedia Commons

Minimised maintenance time will be crucial: track maintenance team at work, © Network Rail
Bridge design vision

Bridge design approach

Design process

Appearance shall be a major design imperative alongside strength, safety, construction and cost.

Aesthetics shall be considered at project conception and through each stage of design. Design quality cannot be added on at the end.

Bridges shall be designed by multidisciplinary teams, including engineers, landscape architects, urban designers and bridge architects, working as equals in a collaborative and integrated way.

Construction shall be considered at all design stages, with early contractor involvement. Remember that contractors’ expertise and equipment varies: different contractors may lead to different answers.

Client, designers and contractors shall all demonstrate a continuing commitment to design quality. Aesthetics shall be championed and adequately weighted in selection and assessment processes. This commitment shall be carried through to construction where poor workmanship and design variations place quality at risk.

Response to context

Each site is unique. The character of the local natural or urban landscape shall be appraised to inform the bridge design. Visibility and construction access shall be considered.

The visual significance of each bridge shall be defined: will it be a low-key structure, will it be a prominent landmark or within a sensitive setting? The built and natural environment shall be as visible as possible through the bridge.

The complexity of a bridge design should be minimised in a rural setting.

Natural vegetation should be protected and augmented, with existing vegetation retained to the maximum extent practicable without impact upon operation of the railway.

Designs shall minimise the footprint of bridges (piers, abutments) so that local vegetation is maximised.

Designs shall minimise the presence and extent of hard surfaces in rural landscapes.

Bridge design

Each bridge shall have a clear, understandable design concept with scale and proportions appropriate to its context.

Each structure shall be elegant aesthetic composition, with a consistent design language used for all of its components. Simple repetition of standard parts or designs is not adequate, broader thinking is required.

The design of a bridge should express its fundamental structural anatomy: the structural logic and flow of forces should be apparent. The shapes of the structural members should reflect the forces acting on them.

Construction shall contribute to the design concept: how a bridge is built and how it looks should work together not fight against each other.

Scale and proportion shall be carefully considered, including how these are affected by context and daylight and shadow.
Where an essentially symmetrical concept is proposed, the built result should be symmetrical in its setting out and in its detail. Where asymmetric designs are proposed they should be clearly and boldly asymmetric.

Simplicity is encouraged, but not crudity. Simplicity is seen as refinement, taking time and effort, it is not a lack of detail or articulation.

Bridges’ form and detail should reflect the flow of forces, honestly showing structure and materials.

Articulation, the quality and quantity of expressed detail, is critical to the character of a bridge. Articulation of detail shall be consciously manipulated and edited, choosing which elements or junctions to emphasise and which to hide or subdue.

The character of components and details shall be consistent and compatible with the overall design concept. This could include elements of contrast.

Where components repeat, order and rhythm shall be carefully considered. Modules and grids should be used to ensure that the relationships (sizes, locations and alignment) between all elements are coordinated.

Bridge design should not rely on colour, but may be enhanced by it. Self-finished materials are strongly preferred. There may be cases where pigmented concrete or painted steel could be considered.

Functional lighting shall be considered at the outset and discreetly coordinated with the structure. A few structures may justify feature lighting but the benefits, impact and maintenance costs shall be carefully considered.

Facilities for maintenance shall be discreetly integrated, not afterthoughts. The design, location and coordination of doorways, hatches, walkways and gantries shall be neat and unobtrusive.

Line-wide identity

HS2 bridges shall follow an identifiable pattern along the route. There should also be locations with special distinctive designs. This approach aligns with precedents from other major engineering projects, for example the M1.

Families of bridge types, and their requirements, shall be defined. Each family should have model designs with considerable flexibility for variation (span, width, height, etc.). This will enable family resemblance and systemised production of standard pieces. The model designs will provide clear design intent for contracting teams.

Designs for component families shall also be developed to provide a systemised kit of parts.

It is appropriate to have carefully located specials and one-off structures. Whilst having distinctive designs, they should adopt key components or characteristic from the families to provide a link to the broader line identity.

The HS2 bridges shall have family resemblance, with variety: family members not identical clones!
Bridge design vision

What success looks like

→ Each bridge shall have a clear, understandable design concept with scale, geometry and proportions appropriate to its context.

→ Each structure shall be an elegant aesthetic composition, with a consistent design language used for all of its components.

→ Civil engineering shall be fully coordinated with the surrounding landscape design.

→ The form and detail of spanning deck and beam structures shall be simple, continuous profiles, minimising bulk and visual impact.

→ Viaduct, underbridge and overbridge parapets shall have a consistent HS2 line-wide identity across a range of spans and structural forms.

→ Pier design shall be consistent within each structure and in groups of adjacent structures.

→ All water run-off shall be fully managed, controlled and collected.

→ The visible extent of concrete walls and abutments shall be minimised.

→ In rural locations the landscape form shall be used to conceal vertical concrete faces before considering cladding or screening.

→ The design of structures used by pedestrians and cyclists shall recognise the increased level of scrutiny that they will receive.

→ Green tunnels and green bridges shall be thoroughly integrated into their surroundings.

→ All materials, components and systems shall be capable of providing a 120 year design life, subject to appropriate maintenance.

→ The need for maintenance shall be minimised, especially where it requires permanent way access or line possessions.

→ Security and safety systems shall be fully coordinated with the civil engineering design.

→ All services and rail systems shall be fully coordinated with the civil engineering design.

→ Services and rail systems containment and routes shall be concealed from public view.
# Bridge scenarios

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>32</td>
</tr>
<tr>
<td>Underbridges</td>
<td>34</td>
</tr>
<tr>
<td>Viaducts</td>
<td>38</td>
</tr>
<tr>
<td>Pedestrian underpasses</td>
<td>42</td>
</tr>
<tr>
<td>Overbridges</td>
<td>46</td>
</tr>
<tr>
<td>Green bridges</td>
<td>50</td>
</tr>
<tr>
<td>Footbridges</td>
<td>54</td>
</tr>
</tbody>
</table>
Bridge design scenarios

Introduction

"Bridges are forms seen in light and by means of light."

*Design Manual for Roads and Bridges*

This section presents design scenarios for the six bridge types that will be required for HS2.

The drawings and photographs are not location specific. They illustrate the key design issues that shall be considered within design of each type of structure.
Bridge design scenarios

Underbridges

Underbridges are defined as structures supporting HS2 where it crosses above roads, railways, waterways and other obstacles that do not require multi-span solutions.

There are significant variations in types of underbridge to be developed, from short span crossings with limited construction depth available, to large, skew crossings requiring portal substructures to span over existing infrastructure.
Design considerations

- Assess what the appropriate minimum clearance should be below low underbridge decks. The landscape design or extents of embankments shall be adjusted to achieve a good result.

- Steel half-through decks will be used for some replacement under-bridges. Their design shall be sympathetic to their locations and any existing piers.

- The visual impact of junctions with, and adaptations to, existing structures shall be thoroughly considered. The resulting assemblies shall be well composed and visually coherent. Purely pragmatic adaptations are not acceptable.

- Where existing masonry abutments are used or extended, new works shall match and be sympathetic to design of existing.

- Where existing structures are to be adapted, design features of existing works should be respected if retained. The geometry of new works shall sit happily with the old and be adjusted to suit.

- High skew bridges with beams or boxes spanning perpendicular to the obstacle below create ‘redundant’ areas of deck at track level. These structures are difficult to integrate with surroundings and risk appearing awkward and poorly designed. If they cannot be avoided, special attention shall be paid to their design, including the use and appearance of the triangles of left over space at deck level.
Bridge design scenarios

Underbridges

Low clearance beneath underbridges and viaducts is a feature of the HS2 alignment and needs design care, © charentelibre.fr

The benefit of the interesting steel structure for this HS1 underbridge is lost because of poorly designed and visually dominant noise barriers, brighter colour may also have helped under this wide deck, © David Anstiss / Wikimedia Commons
Special structures may be appropriate for prominent underbridges, colour should be carefully considered, © TUC Rail

Haunched girder form reflects geometry of single central pier in the water, Val-d'Oise, France © Geralix / Wikimedia Commons
Bridge design scenarios

Viaducts

Viaducts are defined as structures with two or more spans carrying HS2 track alignment over flood plains or other obstacles, including other HS2 tracks in some cases, at bifurcations, junctions and spurs. They are essentially a specific type of underbridge, with more than a single span.

The majority of the viaducts will be in rural / open landscapes. Although typically arranged as twin parallel tracks, in some cases they are single track, paired parallel tracks (4 track) or specials with 5 or 3 tracks plus merging / splitting lines.

The appearance of viaducts is particularly important: they will be major features in the landscape, potentially dominating the nature of the existing environment.

HS2 will have a large number of ‘low-level’ viaducts, with limited clearance over the ground below. For aesthetic reasons, the height of the viaduct soffit above ground level will be crucial in determining appropriate spans.

Concrete motorway viaduct reinforced with steel for larger span, Meaux viaduct, France, © MOSSOT /Wikimedia Commons
Design considerations

- The spans within each viaduct should be rationalised and made equal. Shorter spans are permitted at abutments.

- Special long spans should only occur over significant special features, e.g. waterways, major roads.

- Assess what the appropriate minimum clearance should be below low viaduct decks. The landscape design or extent of embankments shall be adjusted to achieve a good result.

- Design proposals shall minimise the deck depth for low-level viaducts to maximise the views and clearance beneath them.

- The soffit of many viaducts, particularly those passing over canals, pathways and urban areas, will be easily visible to passengers or passers-by so it is a crucial design feature.

- Where viaducts are visible to the public at close range, care shall be taken to achieve neat joints between pre-cast segments.

- The ability to skew piers or use offset pairs of piers is crucial: to reduce long spans and to improve the relationship with routes, spaces and views below the deck. Where these issues are important, deck structures that allow skewed or offset piers shall be chosen.

- Special conditions may dictate the design for viaduct structures. For example, where two track viaducts divide into two single track structures twin box structures shall be used.

- Special junctions and components shall be handled neatly, junctions between forms shall be visually clean and well resolved.
Bridge design scenarios

Viaducts

Bold colour and flowing curved form of the Arsta railway viaduct, Stockholm, © Holger.Ellgaard / Wikimedia Commons

Haunched girders show flow of forces in TGV Viaduct, Avignon, © happypontist.blogspot.co.uk
Sculptural piers and very slim deck structure, Viaduc de la Savoureuse, France, © bmhmagazine.com

Combination of steel and concrete create distinctive aesthetic for Meaux viaduct, France, © MOSSOT / Wikimedia Commons
Bridge design scenarios

Pedestrian underpasses

Pedestrian underpasses are defined as a specific type of underbridge, conveying pedestrians or accommodation routes beneath the HS2 alignment and with fill material between the tracks and the underpass roof.

Pedestrian underpasses are notoriously one of the most unpleasant public environments and many authorities have policies to minimise their use. The design of pedestrian underpasses shall recognise these risks and provide an exemplary environment for users. High quality finishes are required.

Portal and wing wall design will be a prominent part of the underpasses’ appearance but secondary features shall be considered too. In particular, handrails around or above wing walls / portals and continuity of security fencing to the HS2 track.

Extensive use of glazed brick within upgraded pedestrian underpass beneath Reading Station, © Jim Stephenson
Design considerations

- Underpass cross-sections have a significant impact on user experience. Although minimum cross section sizes are defined, consideration should be given to more generous dimensions, particularly for long structures.
- A rectangular cross-section is best suited to users’ needs, arched cross sections are not preferred.
- Approach routes and plan geometry have a significant impact upon pedestrian safety. Clear lines of sight are important for pedestrians to feel confident that they will not be vulnerable. Use of mirrors to provide views around blind corners should be considered as a failure. This applies to fenced approaches as well as to underpasses.
- Separate ‘lanes’ for pedestrians and cyclists are unlikely to be effective, with potential for conflict at crossing points. An environment that is clearly shared is more likely to be understood by all users.
- Barriers to prevent vehicle access may be required in some locations. These need to be carefully designed if they are to prevent motorcycle access but not disrupt cyclist use. Consider landscape design and use of street furniture to discourage motorcycle use.
- Frequency and intensity of use shall be established to define maintenance requirements, e.g. commuter route v country footpath v local farm access.
- Consider vandalism risks, including litter, graffiti, malicious damage (e.g. to luminaires), theft (e.g. of surface mounted metal components) and arson.
- Large areas of plain finishes can be a more attractive target for graffiti. Higher quality or patterned finishes shall be considered, especially in more intensely used locations. Finish options could include: brick, glazed brick, ceramic tile, self-finished metals.
- Wall finishes are likely to suffer from graffiti. They shall be easy to clean. Exposed concrete should have an anti-graffiti coating.
- Structural water-proofing will affect the quality of the pedestrian environment. Water penetration and staining of finishes shall be prevented. Special attention should be paid to any construction or movement joints.
- Floor finishes shall be compatible with the surrounding footpaths. They shall provide good slip resistance and be well drained, with consideration to mud or ice build-up. (Note that most underpasses will incorporate buried services routes, including piped drainage).
- In rural locations, it is assumed that footpaths and underpasses will not be lit at night. In urban locations illumination levels shall be carefully considered to avoid strong contrast or glare when moving between underpasses and surrounding environments.
Bridge design scenarios

Pedestrian underpasses

Wider underpasses are desirable for safety and overall user experience, © Lombard North Group

Well lit spaces and textured walls reduce likelihood of vandalism, © halfrain / Flickr.com
Clear lines of sight increase sense of safety for pedestrians, © mick lobb / Wikimedia Commons

Blind corners and graffiti: typical underpass problems to be considered in design proposals, © Szilas / Wikimedia Commons

Patterned tiles create bright environment and deter graffiti in Elephant and Castle underpass, © classicalmusicmagazine.org
Bridge design scenarios

Overbridges

Overbridges are defined as all crossings over the HS2 alignment. There is a wide range of types of overbridge from small accommodation bridges carrying existing or diverted highways to broad green bridges.

Design issues applicable to all overbridges are considered under this heading, with the additional issues specific to green bridges and footbridges dealt with on subsequent pages.
Design considerations

- 3 span overbridges with bank seats shall be used in slope-sided cuttings to promote an open appearance.
- In three span overbridges, the central span should larger than the side spans. The side spans should be equally sized.
- The appearance of single spans with substantial concrete or earth abutments / walls is not preferred, except for green bridges within green slope sided abutments.
- Where overbridges have more than three spans, the spans should be rationalised and made equal. Shorter spans are permitted at abutments.
- Long single span structures across slope-sided cuttings, between bank-seat abutments, are also acceptable.
- Leaf piers to support multi-beam decks are acceptable for 3 span overbridges.
- Across vertical sided (retaining wall) cuttings, single span structures are preferred.
- Elaborately ‘shaped’ sculptural piers are not appropriate for overbridges piers within HS2 railway cuttings.
- Where bearings are unavoidable, integral piers are preferred with bearings at abutments where access is easier and less disruptive to rail operations.
Bridge design scenarios

Overbridges

Large concrete abutments interrupt continuity of open slope sided cutting, © Grimshaw

3 span overbridge maintains continuity of cutting and significantly reduces visible extent of concrete, © Grimshaw
3 span geometry preferred for typical highway and accommodation overbridges, © Grimshaw

Bank seat abutment maintains open continuity of cutting below overbridge, © Roads and Maritime Services NSW

Bold asymmetric overbridge design works with strongly with gradient of Snow Hill Lane crossing the M6, © David Humphreys
Bridge design scenarios

Green bridges

Green bridges will provide ecological connections across HS2 for mammals, including bats, and other fauna.

HS2 will have two types of green bridge:
• narrow green bridges with limited planting, typically in linear ‘troughs’
• wide bridges with significant intensive planting.

Intensively planted green bridges, and green tunnels, should be thoroughly integrated into their landscape surroundings, maximising connectivity of planting and animal habitats. These wide green bridges should, effectively, be perceived as short tunnels.

The narrower green bridges should follow the guidance established for other overbridges, including relevant footbridge design considerations. They should be clearly seen as bridges.

Green bridge over E25 highway with thoroughly integrated landscape design, Netherlands, © urbanarchnow.com
Design considerations

- The lightly planted green bridges, with hedge planting in linear troughs, should be treated like road overbridges, with 3 span structures.

- The intensively planted green bridges should be single span, recognising increased loads and the solidity of appearance that should complement the sense of this planting being in 'solid' earth.

- The single span length of intensively planted green bridges should be minimised with slope-sided earth embankments across the cutting leading up to the span.

- Adjacent slope angles should be matched and the junction between them radius to provide a smooth natural-looking transition.

- The "portals" for intensively planted green bridges should be coordinated as a family with tunnel and green tunnel portals, recognising their function to provide significant landscape continuity over the HS2 route.

- In rural locations, it is assumed that the footpaths passing over green bridges will not be lit at night.

- Green bridges shall have step free access. Steel or concrete ramps should be avoided in rural locations. Earthworks ramps should be designed to avoid the need for handrails and balustrades / guarding.

- Hard vertical abutment surfaces and retaining walls (e.g. concrete) are likely to be visually intrusive in rural locations and their use for green bridges shall be minimised and subject to specific justification in each location where they are proposed.
Bridge design scenarios

Green bridges

Excellent continuity of wildlife routes and planting, Kibeek Ecoduct, Netherlands, ©Yves Adams
Continuity of landscape more important than continuity of cutting profile, B38 Birkenau, Germany, © designweed.com

Green bridge over highway 464, Böblingen, Germany © KlausFoehl / Wikimedia Commons

A21 Lamberhurst bypass, © Fira

Code 2 - Accepted with Comments
Bridge design scenarios

Footbridges

Footbridges are defined as specific forms of overbridge carrying only footpaths, cycleways or bridleways over the HS2 alignment.

Footbridges will have a high impact upon their users, who will not be in the sheltered environment of a vehicle. The design of footbridges shall recognise the increased level of scrutiny that they will receive. Higher quality finishes are required.

There are three generic types of footbridge planned:
• typical 3 span structure, or adaptable to this format
• single spans between abutments or retaining walls
• long multiple span footbridges.
Design considerations

- Footbridge cross-sections have a significant impact on user experience. Although minimum cross section sizes are defined, consideration should be given to more generous dimensions, particularly for long structures.

- Footbridges shall have step free access. Steel or concrete approach ramps should be avoided in rural locations. Earthwork ramps should be designed to avoid the need for handrails and guarding.

- Approach routes and plan geometry have a significant impact upon pedestrian safety. Clear lines of sight are important for pedestrians to feel confident that they will not be vulnerable. Use of mirrors to provide views around blind corners should be considered as a failure. This applies to fenced approaches as well as to footbridges.

- In rural locations, it is assumed that footpaths and footbridges will not be lit at night.

- In urban locations illumination levels shall be carefully considered to avoid strong contrast or glare when moving between footbridges and surrounding environments.

- Continuous LED lighting, mounted within handrail profiles is preferred, to provide discrete and even illumination for footbridge decks. Light levels and light distribution shall be sufficient to identify the faces of other users.

- Separate ‘lanes’ for pedestrians and cyclists are unlikely to be effective, with potential for conflict at crossing points. An environment that is clearly shared is more likely to be understood by all users.

- Barriers to prevent vehicle access to footbridges may be required in some locations. These shall be carefully designed if they are to prevent motorcycle access but not disrupt cyclist use.
Bridge design scenarios

Footbridges

Weathering steel footbridge: structure and containment combined, © happypontist.blogspot.co.uk

Urban bridge over railway provides new place to meet within Verboekhoven Square, Brussels: steel fabrication installed in one piece, © NEY & Partners
1800mm parapets hinder pedestrian views from bridges, but mesh or perforation permitted at upper levels, © Grimshaw

Villetaneuse-University Station, footbridge form provides protection to pedestrians and tracks below, © Cyril Sancereau

Bridge truss structure provides integrated 'cage' to protect rail line below, La Roche sur Yon ©Hugh Dutton
## Bridge design library

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>60</td>
</tr>
<tr>
<td>Landscape</td>
<td>62</td>
</tr>
<tr>
<td>Deck structures</td>
<td>66</td>
</tr>
<tr>
<td>Piers and bearings</td>
<td>70</td>
</tr>
<tr>
<td>Parapets</td>
<td>74</td>
</tr>
<tr>
<td>Abutments and walls</td>
<td>78</td>
</tr>
<tr>
<td>Materials and maintenance</td>
<td>82</td>
</tr>
<tr>
<td>Steelwork</td>
<td>86</td>
</tr>
<tr>
<td>Concrete</td>
<td>90</td>
</tr>
<tr>
<td>Rainwater management</td>
<td>94</td>
</tr>
<tr>
<td>Services and rail systems</td>
<td>98</td>
</tr>
</tbody>
</table>

**Code 2 - Accepted with Comments**
Bridges design library

Introduction

The Bridges Design Library contains detailed design approach advice and requirements under 10 component headings. For each component, design principles are defined, accompanied by a series of design considerations.

Sir John Fowler and Benjamin Baker, who designed the Firth of Forth bridge, provide the supports. The central “weight” is Kaichi Watanabe, one of the first Japanese engineers who came to study in the UK, © Imperial College, London
Bridges design library

Landscape

Design Principles

Landscape design shall be fully and carefully integrated with the civil engineering design. Refer to HS2’s “Landscape Design Approach” for further guidance.

Security and safety systems shall be fully coordinated with the landscape and civil engineering designs.

“It is the landscape design that will provide the unifying design mechanism (the ‘glue’) to create a seamless and integrated scheme.”

HS2 Landscape Design Approach

Impact of long viaduct in Colne Valley: design shall be sensitive to place, character and nature of the site, needing thorough analysis to inform design, © Grimshaw / Ordnance Survey
Design considerations

- Each bridge location shall be subject to a landscape character analysis. This context analysis should inform the design of the civil engineering and the new landscape proposals.

- In locations where bridges are close or alongside each other, ensure that the bridge designs are considered together and coordinated as one composition.

- Identify particularly sensitive locations that will need special attention during design and construction. Identify opportunities for local engagement or variation.

- Extensive landscape works should be subject to comprehensive landscape architect designed proposals.

- Localised soft landscaping “repairs” should match existing species and planting arrangements.

- Localised hard landscaping “repairs” should match existing conditions and materials.

- Make landscape and embankment forms as simple and natural as possible.

- Where appropriate, extend and soften embankment slopes to blend with surrounding topography and create a more sympathetically natural appearance.

- Minimise use of hard surfaces in natural / rural locations. Where vegetation cannot flourish use finishes that are sympathetic to the natural environment, e.g. rip-rap.

- Surrounding landscape finishes should continue smoothly and continuously up to the face of piers without local variations to conceal foundations. The top of foundations shall be set deep enough below the surrounding surface level to allow this.

- In soft landscape provide sufficient soil depth for vegetation to flourish, without compromising operation of the railway.

- Areas below bridge decks may be inhospitable for natural vegetation. Assess where vegetation will flourish or struggle, and propose appropriate finishes.

- Do not place security fences at the top of embankments (i.e. on the horizon line).

- In sloped cuttings, side slopes below bridge decks should use riprap finishes in locations that cannot support vegetation. Concrete side slopes are not acceptable.

- Develop and integrate design proposals for security and safety elements, including:
  i) fencing
  ii) signage
  iii) security
  iv) gates
  v) bollards / access barriers
  vi) handrails, including guarding to tops of portals and wing walls
  vii) acoustic screens.
Bridges design library

Landscape

Bold use of colour in the landscape, Viaduc de Corcelles, France, © A.BourgeoisP / Wikimedia Commons

Pedestrian underpass in embankment: wing walls and fall protection are prominent features, © Grimshaw
Security fence should fit neatly below parapet panels to maintain security line at abutments, © Grimshaw

Soft landscape continues up to face of piers, Findhorn viaduct, Tomatin, © happypontist.blogspot.co.uk

Well integrated green bridge over HS1, © Arup
**Design Principle**

The form and detail of spanning structures shall be simple, continuous profiles modelled to minimise bulk and visual impact.

Continuous deck edge: uninterrupted deck structure provides consistent clean profile within the landscape, © Yee Associates
Design considerations

- Deck soffits should provide a clean, smooth continuous profile. Multi-beam decks are acceptable in this context.

- Deck edges should be cantilevered, with beams set back from deck edges, creating a shadow line to break up the bulk of the elevations. Set backs should vary to suit different beam depths and deck widths.

- Standardised pre-cast cantilever units should be used to form deck edges.

- Steel edge beams should be a J profile with the web over-sailing the lower flange to create drip profile.

- Visible down-stand crossheads are strongly discouraged and shall be subject to design review.

- If crossheads are required to link pier heads to multiple deck beams, the crosshead should be contained within the overall depth of the deck to maintain continuity of the bridge soffit line.

- Most HS2 bridges and viaducts will have spanning structures that are below deck level. Truss structures and other one-off specials shall be designed to suit their specific context and constraints, whilst adhering to any applicable rules in this document.

- Decks for bridges that are set-out to a curve in plan shall be designed to provide a continuous smoothly curved appearance. Whilst straight components may be suitable, the extent of any faceting shall be carefully assessed and controlled to achieve the required appearance. For example, 3m long pre-cast viaduct segments are acceptable on a curve. 30m long straight pre-cast beams would not be acceptable unless the curve was of very large radius.
Bridges design library

Deck structures

- Precast concrete deck edge: deck spine beam is cast into shadow, © merseygateway
- Cantilevered deck edge: deck spine beam is cast into shadow, © Grimshaw
- Exposed crossheads interrupt line of viaduct soffit, Pulandian Bay, China, © Jinzhou New District Information Center

Code 2 - Accepted with Comments
Precast pre-stressed concrete beams: poorly resolved interface between precast beams’ ends, © Rail Technology Magazine

Precast pre-stressed concrete beams: simple repetitive units provide neat clean appearance for soffit, © Grimshaw

Recessed crossheads maintain clean line of viaduct soffit, River Yare Viaduct, Norwich Bypass © Maunsell
Bridges design library

Piers and bearings

Design Principles

Piers design shall be consistent within each structure and comply with an overall HS2 line-wide identity.

Special central span: piers and deck structure respond to context, spanning over river, © Heiko Dassow
Design considerations

- Pier aesthetics and setting-out shall be consistent within each structure. The number of variants within any structure shall be minimised. Pier proposals will be subject to design review by HS2.

- Pier design should be proportionally elegant and must be able to accommodate significant variation in their heights.

- Pier sizes should be minimised and piers set back from the edge of deck structures.

- A clean, simple, uncluttered appearance is required. No handrails, ladders, pipes, cables, etc. are to be fixed to any piers (or portal structures).

- The use of leaf piers shall be minimised, especially where skewed geometry creates long leaf piers.

- Exposed pile caps, sheet piles and foundations are not permitted in any location.

- Where practicable, place piers outside train impact protection zone to avoid increased pier sizes.

- The pier surface area needed for bearing replacement / jacking should be defined to permit consistent maintenance procedures. There is an option for bolt on jacking frames to minimise pier top size, but this will need line-wide coordination across line to avoid multiple different solutions.

- Bearings shall be accessible for inspection, maintenance and replacement. A consistent bearing zone should be used across all piers.

- Do not place bearings directly under movement joints / vulnerable waterproofing details.

- Where bridges are close or alongside each other, ensure that the pier designs and locations are coordinated and aligned. Promote open views below the bridge decks.
Bridges design library

Piers and bearings

Elegant concrete piers: piers and deck structure designed as one coherent system, © Ferrovial

Pier functions expressed in design: slim integral piers with special piers to resolve braking and bracing forces, © Holger Althaus / SBP
‘Special’ pier design: pier form badly adapted to solve one-off condition, © Grimshaw

Wall of piers: oblique view provides no visibility through array of leaf piers, © TBC

Exposed concrete foundation: pile caps formed above surrounding ground surface level, © Grimshaw
Bridges design library

Parapets

Design Principles

Viaduct, underbridge and overbridge parapets shall have a consistent HS2 line-wide identity across a range of span lengths and structural cross-sections / forms.

Angled planar parapet matches aesthetic defined for viaduct girder and piers, © MOSSOT / Wikimedia Commons
Design considerations

- Parapet panels shall be a standardised design and sizes, used across the entire system.
- The parapet design shall be flexible enough to cope with structures that have curved setting-out, either in plan or camber in long section.
- Parapet lines shall be clean, simple and uninterrupted. Parapets shall be set-out to use whole panels only. ‘Blisters’ in the parapet line or special parapet panels are not permitted.
- Services and rail systems, including OHLE, shall be fixed on decks between and within the deck parapets only. Nothing should be mounted on the top, outer face or underside of parapets.
- Parapets should have a down-stand that extends below deck edge cantilever. The down-stand should incorporate drip grooves to control water discharge and the potential for staining structures below.
- Parapets shall prevent trespass by eliminating climbable ledges and toe-holds on the outer faces where they are accessible from embankments or adjacent structures.
- Viaduct and underbridge parapets providing guarding for personnel shall extend to at least 1100mm above the adjacent walkway surface.
- Road overbridges will require a minimum parapet height of 1500mm, increasing to 1800mm over the tracks and OHLE installation. 1800mm high parapets are required within 500mm of any live overhead equipment, including the return conductors.
- Where equestrian use is expected 1800mm high parapets are required for the full length of the bridge deck.
- Caged enclosures to footbridges shall not be installed unless a site specific risk assessment clearly demonstrates that they are needed.
Bridges design library

Parapets

Visual impact of H4a barriers plus pedestrian barrier and additional higher protection above track / OHLE, © Grimshaw

Closer view of H4a barriers plus pedestrian barrier and additional higher protection above track / OHLE, © Grimshaw

Pre-cast concrete parapets have potential to contribute to a line-wide identity for HS2, © Grimshaw
Concrete parapets should extend below the deck edge and use sloped faces to create light and shade contrast, © Grimshaw

Poorly designed acoustic barrier parapets, not coordinated with structure, M2 Sydney, © Roads and Maritime Services NSW

Canted girder parapet and perforated panels improve sense of space for pedestrians, Stratford, London © Knight Architects

Planning consents were granted in January 2010 following extensive consultation with stakeholders including the Olympic Delivery Authority, London Borough of Waltham Forest, Transport for London, Network Rail and High Speed 1 (Channel Tunnel Rail Link).
**Bridges design library**

**Abutments and walls**

**Design principle**

HS2 makes extensive use of retaining walls, typically with retained heights exceeding 3m. In visually sensitive locations, especially rural ones, the visible extent of concrete walls and abutments shall be minimised, before considering cladding or screening.

Walled abutments can reduce the slender appearance of the bridge, block the flow of the landscape and confine views.

Reducing the abutments can create a more refined and better looking bridge. It does however increase the span and therefore depth of the beam.

Continuing the superstructure of the parapet above the abutment allows the shadow line to reduce the dominance of the abutment, and makes the bridge appear longer and more elegant.

---

Diagrams from 'Bridge Aesthetics' by the New South Wales Government, Australia, © Roads and Maritime Services NSW
Design considerations

- Minimise and avoid the use of vertical walls (including abutments, wing walls, side walls and retaining walls) in rural areas where they will be visible to the public: they are an alien element.

- Wing walls for viaduct abutments shall be parallel to the HS2 track alignment.

- Underbridge wing walls in embankments should be aligned at approximately 45 degrees so that a slope continues in front of the wing wall, minimising the overall length of wall.

- Bank seats (or their appearance) should be used for overbridges across slope-sided cuttings, in preference to visible full height concrete abutments.

- Minimise hard landscape finishes around abutments in rural areas. Use vegetated earth slopes. Use riprap in areas where planting will not thrive.

- In urban areas with hard landscaping, vertical faces for abutments and wing walls are preferred.

- Design and detailing shall manage water flow to prevent leakage from drainage behind walls and prevent staining or poor weathering of front faces.

- Assess visibility from publicly accessible locations. There will be locations where cutting walls are visible, especially the upper most parts, walls near the ends of cuttings and in areas where the land form affords views into the cutting. In these locations, a higher quality finish shall be required.

- Assess impact upon passenger experience. High speed glimpses of walls through carriage windows will not be a concern. However, for retaining walls alongside a station and other locations easily visible to passengers, the quality of construction, finish and appearance shall be important.

- Design pre-cast wall units’ size, shape and finish to be in proportion and scale to the whole structure and sympathetic to the location.

- Details at edges / interfaces will have a considerable impact upon appearance and weathering. Careful coordinate copings, handrails, connections to other construction, access / inspection hatches, etc.
Bridges design library

Abutments and walls

Poor abutment design: substantial concrete abutments and retaining walls, © Grimshaw

Refinement of abutment design: bank seat abutments, visible extent of concrete abutment minimised., © Grimshaw

Secant pile embedded wall: not suitable for walls visible to the public, © Grimshaw
Side slope below bridge deck: concrete face to earth embankment, vegetated slopes preferred, © Grimshaw

Side slope below bridge deck: riprap face to earth embankment where vegetation will not thrive, © Grimshaw

Preferred single span deck with green slope sided abutments for green bridge across slope sided cutting, © Grimshaw
Bridges design library

Materials and maintenance

Design Principles

All materials, components and systems shall be capable of providing a 120 year design life, subject to appropriate maintenance.

The need for maintenance shall be minimised, especially where it requires permanent way access or line possessions.

Although there is an engineering presumption that structures should be accessible for inspection, some elements will inevitably be concealed, for example foundations and the back of retaining walls. Where cladding of structures is proposed pay special attention to durability of the structure and consider how the cladding may be removed for maintenance or repair of the structure.
Design considerations

- Self-finished materials are strongly preferred. If coatings are used, very long life factory applied coatings (e.g. galvanising, anodising) are preferred to paint, powder coating, etc.

- Do not use paint finishes where access for re-painting requires permanent way possessions.

- On-site cutting or drilling of coated (galvanised, painted, etc.) components is not permitted: this will require careful detailed design and fabrication.

- Movement joints should be minimised. Where they are essential, they should be properly detailed to be concealed or coordinated with the geometry and appearance of the whole structure.

- Detail structures, including piers and abutments, to avoid creating ledges which could be used by roosting birds or for climbing the structure.

- Netting or wires shall not be relied upon to prevent bird perching. They have poor durability, collect dirt and impede maintenance access.

- Deck finishes should be compatible with the surrounding environment. They shall provide good slip resistance and be well drained, with consideration to mud or ice build-up: overbridges are often more vulnerable to ice formation than their surrounding environments. Deck finishes should also be resistant to small scale fires.

- Large areas of plain finishes may suffer from graffiti: they shall be easy to clean. Consider anti-graffiti coatings for concrete, but there shall not affect the concrete's appearance. Higher quality finishes should be considered in intensely used locations.

- Assess and mitigate vandalism risks including litter, graffiti, malicious damage (e.g. to luminaires), theft (e.g. of metal components) and arson.

- Integrate design of secure access to bearing locations / abutments for inspection and maintenance. Maintenance access routes, steps and handrails should be included in the designs.

- Where exposed concrete finishes are not acceptable, consider:
  i) masonry cladding (brick, block or stone)
  ii) other cladding (timber, metal, mesh, etc.)
  iii) screening with vegetation.
Bridges design library

Materials and maintenance

Anti-graffiti coatings: testing coatings for use of Crossrail GRC panels, © Grimshaw

Facing materials for concrete: potential to make inspection of structures more difficult, © Matthijs Borghgraef / Flickr.com

Facing materials for concrete: opportunity to introduce local character, © NHSavage/Wikimedia Commons

Code 2 - Accepted with Comments
Concrete finishes: consistent finish used across all structural elements, © Schlaich Bergermann Partner

Precast concrete retaining walls: potential for texture and pattern in pre-cast panels, © Glen Waverley / urban.melbourne

Reinforced earth wall: potential for texture and pattern in pre-cast panels, © Prekast Beton
Bridges design library

Steelwork

Off-site fabrication: mast base for Newport City Footbridge at Rowecord works, South Wales, © Atkins
Design considerations

- Use weathering steel to minimise maintenance requirements in steel and steel composite structures.

- Note that weathering steel is produced as flat plate. Rolled hollow sections are not produced.

- Detail weathering steel structures to fully manage, collect and direct water run-off. Prevent staining of adjacent surfaces and finishes.

- Fasteners and accessories for weathering steel structures shall be in compatible materials.

- Consider weathering steel columns to mitigate the risk of concrete columns being stained by water run-off from weathering steel.

- All metalwork installations shall isolate dissimilar metals to prevent electrolytic corrosion. Water run-off from one type of metal to another shall also be carefully considered and managed.

- In urban locations, weathering steel may be felt to be inappropriate in pedestrian accessible locations due to risk of rust marking to clothing. Where necessary, physical separation by handrail and/or balustrade design or paint the inside face of weathering steel parapets.

- Cleaning of graffiti from weathering steel can remove part of the sacrificial surface layer. Define how this will be dealt with if the structure is located in a high risk area for graffiti.

- Smaller components could be galvanised or zinc coated (e.g. flame sprayed). Galvanised steel is unlikely to provide a service life of 120 years, therefore resolve how galvanised components will be replaced or painted.
Bridges design library

Steelwork

Weathering steel deck beams: Paint finish not required, © Commonwealth of Kentucky

Crisply detailed structural steelwork, St Elmo breakwater bridge, Valetta, © Hector Beade

Steel has potential for dramatic structural form, Stratford City Bridge 14, London © Knight Architects / Arup
Weathering steel column: form controls and directs rainwater run-off, © happypontist.blogspot.co.uk

Stained concrete pier: uncontrolled water run-off from weathering steel beam, © Z22 / Wikimedia Commons

Weathering steel footbridge: projecting handrail protects pedestrians from rusty surface, © Xavier Font / Dezeen.com
Bridges design library

Concrete

Off-site fabrication: installation of 300 ton arch segment for new West 7th Street bridge, Fort Worth, © equipmentworld.com
Design considerations

- Visible concrete should be Class F3: the finish should be smooth and of uniform texture and appearance.

- Concrete should be light grey. Ordinary Portland cement produces a beige colour. Ground granulated blast-furnace slag cements are preferred.

- Concrete colour shall be consistent within each structure. Concrete colour shall be consistent across all structures that can be seen together.

- Control aggregate choice and concrete batching to ensure colour consistency.

- Formwork lining shall not stain the concrete and shall be joined and fixed to prevent blemishes. Use one formwork type and source in each structure.

- Plan shuttering to define all joints and to prevent minor variations causing pattern staining.

- Do not use internal ties and embedded metal parts.

- Avoid horizontal construction joints. Where possible, pour walls and piers full-height or pre-cast.

- Unplanned cold / day-work joints are not acceptable in any visible works. If construction joints are unavoidable conceal with appropriate detailing.

- Matching pre-cast and in-situ concrete colours will be very difficult. Design structures and production methods to avoid visible differences in colour.

- Where pre-cast elements are joined end to end, in-situ concrete 'stitching' shall not be visible in the completed outer faces (e.g. edge beams).

- Prevent rust staining from temporarily exposed reinforcing bars and other mild steel components.

- Design pre-cast units’ size, shape and layout to be sympathetic in proportion and scale to the whole structure.

- Where the ‘rear’ face of pre-cast units will be visible to the public, ensure that the finish is high quality.

- Consider application of texture and patterning to concrete surfaces, especially to break up large surfaces. Patterning and applied finishes provide an opportunity for local customisation.

- Where a higher quality finish is required consider these concrete finishes before considering cladding:
  i) cast-in concrete finishes and / or patterns
  ii) post-casting finishes: e.g. acid wash, polish

- Where cladding is considered refer to the considerations defined in ‘Materials and maintenance’ above.


Bridges design library

Concrete

Pre-cast parapet panels: visible colour mis-match between adjacent panels, © Grimshaw

Pre-cast concrete finishes: buff coloured concrete, acid wash, machine polished raised areas, © Grimshaw

Pre-cast retaining wall panels: poor quality finish visible to rear, © Grimshaw
Concrete jointing: daywork joint between pours not aligned with recesses in formwork, © Grimshaw

Concrete daywork joints coordinated and expressed in finish, Viaduc de Corcelles, © A.BourgeoisP / Wikimedia Commons

Temporarily exposed reinforcement: concrete column stained by rainwater run-off from rebar, © The Masterbuilder
Bridges design library

Rainwater management

Design Principle

All water run-off, including from bridge decks, shall be fully managed, controlled and collected to prevent staining of finishes and damage to materials.
Design considerations

• All rainwater on bridge decks shall be collected and discharged remotely from the structures.

• Waterproofing systems shall be complete, and durable for their intended design life.

• All rainwater pipes shall be concealed within the normal structural profiles.

• Water collection points and deck falls shall be designed to facilitate concealed pipework.

• Structural lines shall be kept clean, clear and uninterrupted. 'Blisters' in the structure / soffit, special cover panels and other additions to conceal pipework are not permitted.

• Water shall not discharge over or onto bearings. Joints shall not be located directly over bearings.

• Manage water flow to stop leakage from construction and movement joints.

• Special attention shall be paid to waterproofing of movement joints. Water shall be collected at movement / expansion joints. Movement joints shall prevent the passage of moisture.

• The design shall allow any expected maintenance or replacement of water control elements to be carried out during HS2 engineering hours only.

• Access to drainage routes is to be at deck and ground level only. Access at ground level is to be through manhole pits not access panels in piers.

• Access hatches, rodding eyes, etc. are not permitted in the surface of piers.

• Service conduits and rainwater pipes should be fully recessed into the piers and completely concealed behind robust panels that are removable for access.

• Ensure that robust kerbs and OHLE mast bases are carefully detailed to avoid compromising deck waterproofing systems and drainage falls.

• Salt and grit will be used to prevent icing. Manage the impact of salted water run-off on materials and finishes, including potential staining.

• Flexible joint / funnel details in drainage pipework may be needed at movement / bearing locations.
Bridges design library

Rainwater management

Leaking joints: water leaking through deck joints will stain the pier below, © Grimshaw

Staining: concrete marked by rainwater leakage through joint above pier, © unknown

Viaduct expansion joint: poor / temporary waterproofing at structural joint, © Grimshaw
If simply supported structures are used, fit secondary rainwater collection below joints in deck, © Grimshaw

Viaduct rainwater collection: exposed rainwater collection pipes, ©Timothy Reichard / m-plex.com

Pier rainwater routes: pipework recessed into face of pier behind cover plate, © Grimshaw
Bridges design library

Services and rail systems

Design Principle

Services and rail systems routing and containment shall not be visible on any structures. Services shall be concealed from any location where there is public access, including where there is public access below bridges.

All services and rail systems shall be fully coordinated with the civil engineering design. A clean, simple, uncluttered appearance is required. No handrails, ladders, pipes, cables, earthing straps, etc. are to be fixed in any locations visible to the public.
Design considerations

• All service conduits and equipment shall be discreetly positioned and concealed within the normal structural profiles. Exposed conduit and pipes are not acceptable.

• Structural lines shall be kept clean, clear and uninterrupted. ‘Blisters’ in the structure / soffit, special cover panels and other additions to conceal pipework are not permitted.

• Designs shall be fully detailed and coordinated with local authorities, Highways Agency, utility suppliers and other stakeholders to ensure that services can be fully concealed whilst working to third party standards.

• Comprehensive details and interfaces shall be drawn and agreed with third parties to provide adequate control.

• Some overbridges have utility services routes built into the structures. Utility services shall be carefully integrated so that they do not project below the structure and they shall not be placed near or at the edge of the structure.

• Access to service conduits and drainage routes shall be at deck and ground level only. Access at ground level is to be through manhole pits not access panels in piers. Access hatches, rodding eyes, etc. are not permitted in the surface of piers.

• Avoid placement of highway lighting / lamp posts on bridge decks for shorter spans. Consider location carefully and coordinate with views of structure when required on longer decks to manage visual impact. Match existing lighting / lamp post designs where few new units are required.

• Pay special attention to continuity of cross-section for HS2 rail systems routes and containment from adjacent tracks, embankments and cuttings leading up to civil engineering structures. Changes of size or location are vulnerable to construction and maintenance problems. Wherever practicable walkways, OHLE, cableways and drainage should continue at same size and alignment in cuttings, on and below bridges and viaducts.

• OHLE masts, communications masts, etc. should not be mounted on short spanning structures (bridges). Where OHLE masts, communications masts, etc. are required on longer spanning structures (viaducts) their positions should be carefully considered and coordinated to manage visual impact.

• Any lighting for maintenance access on viaducts and under-bridges should default to off and only be switched on when required by staff. Automatic reset switching shall be used to ensure that it stays switched off after overnight use.

• Utilities cabinets and other third party equipment cabinets shall be carefully positioned, ideally off the bridges, and integrated into the surrounding landscape design.

• Cables between piers and bridge decks should ideally connect at fixed bearing points only.
Bridges design library

Services coordination

Deck drainage pipework: should be concealed from public view, © Grimshaw

Rainwater collection from deck surface: should be concealed from public view, © Grimshaw

Deck end movement / expansion joint: needs careful design and coordination of waterproofing system, © Grimshaw
**Earthing straps**: should be concealed from public view, © Grimshaw

**Utility and rail systems cabinets**: should be located neatly, out of public view and not on bridge decks, © Lyddrail / rmweb.co.uk

**Cable containment and OHLE mast**: needs careful design and coordination of waterproofing system, © Grimshaw
Document status
BRIDGE AESTHETIC DESIGN APPROACH

<table>
<thead>
<tr>
<th>Revision</th>
<th>Date</th>
<th>Issued for/Revision details</th>
<th>Revised by</th>
</tr>
</thead>
<tbody>
<tr>
<td>P01</td>
<td>01/07/2015</td>
<td>Initial issue</td>
<td>Ewan Jones</td>
</tr>
<tr>
<td>P02</td>
<td>04/12/2015</td>
<td>Retitled and coordinated with other docs.</td>
<td>Ewan Jones</td>
</tr>
<tr>
<td>P03</td>
<td>08/12/2015</td>
<td>Revis ed by HS2 to change document title to &quot;Bridge Design Requirements&quot;</td>
<td>Tomas Garcia, HS2</td>
</tr>
<tr>
<td>P04</td>
<td>15/03/2016</td>
<td>Text revised to clarify mandatory items</td>
<td>Ewan Jones</td>
</tr>
<tr>
<td>P05</td>
<td>04/04/2016</td>
<td>For acceptance</td>
<td>Ewan Jones</td>
</tr>
</tbody>
</table>

Name | Data
---|---
FOI / EIR | None
Document type | Report
Directorate | London West Midlands
MPL & Deliverables Ref | 
Keywords | architecture, aesthetics, specification, civil engineering
Authors | Oliver Moen
Checker | Ewan Jones
Approver | Andy Tye
Owner | C227 Atkins
Review Directorate | LWM TD
Employer’s Lead Reviewer | Tomas Garcia
Authorised for use | 