STEEL REUSE IN BRIDGES

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ice

April 2025

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Thank you
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Expedition Engineering is part of the Useful Simple Trust. Our purpose is to blaze a trail in the integrated, intelligent and ethical provision within the human environment.

The Useful Simple Trust is a family of professional design practices driving change. Our experienced and committed engineers, architects, designers and strategists work side by side, and with our clients and users, to deliver valuable outcomes with positive impact. Our structure creates real value for our clients, beneficiaries and wider society.

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ice

The Institution of Civil Engineers (ICE) is a 97,000-strong global membership organisation with more than 200 years of history. It is a centre of engineering excellence, qualifying engineers and helping them to maintain lifelong competence, assuring society that the infrastructure they create is safe, dependable and well designed. Its network of experts offers trusted, impartial advice to politicians and decision-makers on how to build and adapt infrastructure to create a more sustainable world.

FOREWORD

We live in a world where the need to minimise the use of natural resources and avoid unnecessary waste is increasingly urgent and critical.

In the race to net zero, if we are to have any chance of slowing down the inexorable rise of global temperatures due to man-made greenhouse gases, the worldwide construction industry must abandon outdated and wasteful practices and adopt circular economy principles wherever possible. This includes the recycling, repurposing and reuse of existing materials, and requires a conscious and deliberate shift in priorities. It also demands changes to some current design and construction standards and protocols, as well as a thorough review of procurement practices.

This report addresses the principal challenges of applying such a circular economy approach to the reuse of steel materials and components in bridges. As such, it is a timely and very welcome resource for all bridge design and construction professionals, as well as bridge owners and those who plan and commission new bridge projects. It also speaks to those involved in the growing practice of urban mining, fuelling the supply chain for repurposed materials in construction. It does not pretend to be a detailed manual or design guide, but rather a useful summary of the issues, describing the benefits, difficulties and potential pitfalls, and pointing the way towards important future developments in this evolving field.

The reuse of existing materials demands a very different approach in the planning and design process. It introduces a new paradigm in which designers must work with what is available – a kit-of-parts approach, where the designer must effectively choose the structural materials from a catalogue of available components and design accordingly. Every child (or adult for that matter) playing with Lego is familiar with searching through the pile of available brightly coloured plastic bricks to find exactly the one that is needed next for his/her evolving structure. Bridge design using available components will require rather more rigorous planning and analysis than that, but the principle is similar!

For example, designing a new footbridge using steel members extracted from a 50-year-old building frame will demand extra care in the analysis and detailing, but this is surely an opportunity too good to miss as we strive to minimise waste and energy-use towards a greener future. This report is timely and very welcome, and it will help to make this approach to bridge design become a reality and more widely adopted across the industry.

Ian Firth
MSc, DIC, CEng, FREng, FICE, FIStructE, HonFRIBA

April 2025

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INTRODUCTION

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PURPOSE OF THE REPORT

Expedition Engineering, as part of the Useful Simple Trust, has a mission to 'blaze a trail in the regeneration of our built and natural environment to meet the needs of all people and the planet.'

This mission led us to apply for the ICE research fund and co-sponsor a study on steel reuse for bridges. Reused steel components are increasingly specified in the construction of new buildings. This project therefore aims to define the key steps required to successfully replicate this in bridge design.

The growth of a circular economy is a key factor in the built environment's pathway to net zero. However, there are significant barriers when applying the general principles of circular economy, such as reuse in infrastructure projects. This is due to concerns relating to compliance with current legislation, onerous design requirements, and a lack of research and case studies on this topic to guide the different stakeholders. The result is that clients, designers and contractors cannot practically engage with reusing steel because of the challenges in procurement, design, programme, cost and risk.

There are relevant and useful guidance documents on designing steel structures with reclaimed components such as: the SCI P427 *Structural steel reuse: assessment, testing and design principles guide*, the IStructE *Circular economy and reuse guidance for designers*, and the recently published PD CEN/TS 1090-201:2024 *Execution of steel structures and aluminium structures. Reuse of structural steel*.

This study aims to demystify steel reuse in bridges and collate existing information for reference purposes. The report is an introductory piece that will:

- describe the wider context
- define the different types of steel reuse
- review the challenges, opportunities and case studies for each type of reuse.
- propose some conclusions and recommendations for further research.

Technical addenda have been included in the report to cover specific points such as material testing, execution class and fatigue.

The approach

Our research approach consisted of:

- a desk study, to review existing information;
- interviews with experts (to review technical topics and gather different viewpoints);
- discussions of case studies with designers (to obtain their feedback);
- a roundtable (to review the draft report).

Disclaimer

Expedition takes responsibility for the writing of the report, which is neither a guidance document nor a standard. Every reader is required to comply with current legislation and standards and should apply engineering judgement when reviewing the information provided in this report.

BENEFITS OF REUSE

Reuse reduces carbon emissions and does not jeopardise biodiversity.
The carbon impact of steel production is decreasing due to greener methods like electric arc furnaces that use scrap steel. However, the embodied carbon in reclaimed components is significantly lower.

Embodied carbon in different steel sources[1]

Type of steel	A1-A3 embodied carbon
New steel	1,750 kgCO_2e/tonne
Recycled steel	330 kgCO_2e/tonne
Reused steel	30 kgCO_2e/tonne

In addition to requiring less energy, reuse helps prevent environmental impacts such as resource extraction, acidification, and ozone depletion, which can harm biodiversity.

While the market for scrap recycling is becoming increasingly competitive, with only 25% of the demand currently being met, reuse offers additional benefits.

Reused steel is cheaper and less volatile.
Global inflation and supply disruptions from events such as pandemics and wars generally drive up steel and energy prices. Countries are seeking better control over their material supply and considering relocating some supply chains.

Reclaimed steel, however, is a local resource less impacted by international events that affect prices. It is typically £300 per tonne cheaper than new steel, making it about 50% less expensive than new sections.

The challenge lies in sourcing high-quality reclaimed steel that can be reused to fully leverage this price advantage. High-quality reclaimed steel needs to be carefully dismantled, stored, and requalified. Some companies are already turning this process into a viable business model.

Reuse is key to reducing waste and demand for new steel.
Many bridges and buildings are demolished before reaching their theoretical end of life due to issues such as being unfit for purpose, change of use, or deterioration.

Construction waste accounts for an estimated third of the world's overall waste!

While there is a growing emphasis on extending the life of existing structures, there is also an opportunity to salvage components and repurpose them. For instance, a significant supply of reclaimed steel is available from 30–40-year-old commercial buildings, offering salvaged steel in good condition.

Pre-demolition audits are valuable, as they can identify opportunities for reuse.

It is time to align with more progressive industries.
Reclaimed steel is increasingly being used in building construction.

Numerous reuse case studies for buildings are featured in the IStructE Circular Economy and Reuse Guide. For example, 1,500 tonnes of steel was salvaged from 2 Aldermanbury Square, London, with 710 tonnes reused in a new commercial development in the West End of London.

There are key differences between buildings and bridges, such as design life, fatigue requirements, and loading. Bridges are also designed, fabricated, and constructed differently from buildings.

However, much of the approach to reusing steel is similar for both bridges and buildings, and is already well-documented in existing guidance.

1. Institution of Structural Engineers - Circular economy and reuse: guidance for designers

WHAT DO WE MEAN BY REUSE?

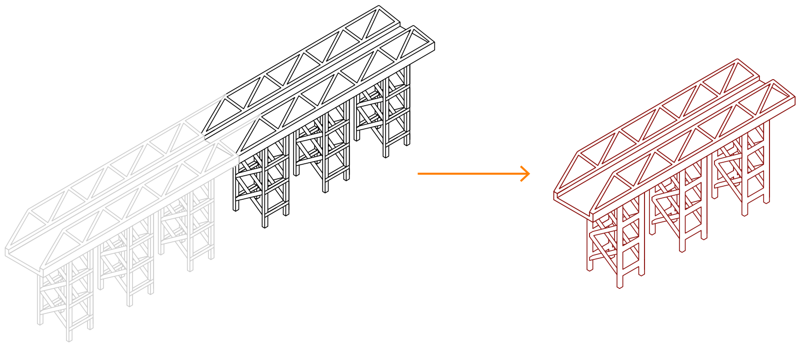
In this report, we will focus on three distinct ways of maximising use of existing materials in 'new' structures:

- reuse of a span or whole section
- repurposed steel
- reclaimed steel.

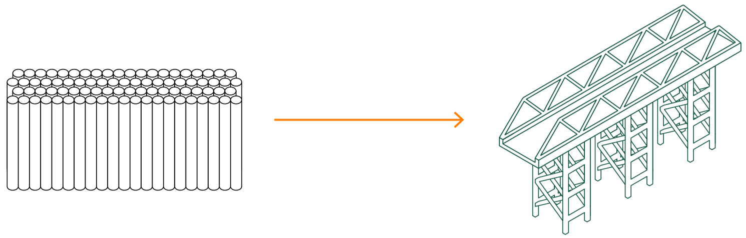
While the industry generally talks of 'reused steel', the definitions presented on this page are adopted throughout the report for clarity of discussion.

Note: Recycled steel is different from reused steel: it is new steel produced in an electric arc furnace that is supplied with scrap steel. It is not covered by the current report.

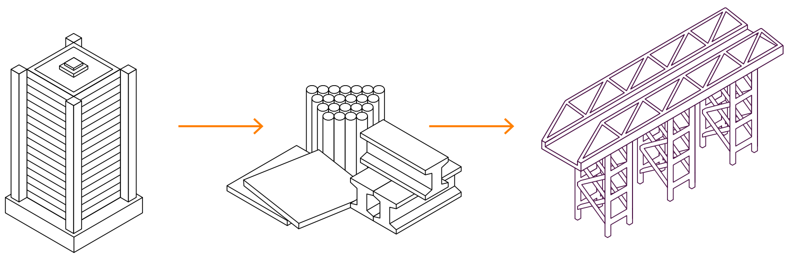
Click here to read more



Reuse of a span
Reuse of large sections of existing bridges. This can be on site, at the current location - or at another site.



Repurposed steel
New steel that was produced for other purposes (e.g. oil and gas industries) that was not used for its intended purpose (i.e. surplus steel).



Reclaimed steel
Steel elements salvaged from demolition or deconstruction projects, that have been reconditioned, tested, assessed and requalified, and are available for use in a new structure.

REUSE CASE STUDIES

Reuse of a span: *Front view of the completed Lucie Bréard footbridge. Copyright Michel Denancé. For more information,* *see page 19.*

Reuse of a span in situ: *Castlefield Viaduct (Manchester): the old railway viaduct has been turned in a public garden.*

Reclaimed steel: *Lower Thames Crossing footbridge competition: Useful Studio and Expedition Engineering.*

Repurposed steel: *Aerial image of the completed Tan House footbridge. Copyright Glen Crouch. For more information,* *see page 27.*

Reclaimed steel/reuse of a span: *Duncan Creek Bridge, Kansas, USA. Image copyright Robert Elder. The through truss bridge was constructed in 1935 and, due to the unusual form that does not comply with the codes of the time, it is believed that the bridge was constructed from components from a pre-1900 structure or that sections were relocated and reused.*

Reuse of a span steel: *Image of relocated bridge, courtesy of Acrow. In 2018 the Imperial Road Bridge in Port Bruce Ontario collapsed. Acrow installed a temporary steel bridge. When the new permanent bridge was completed the temporary structure was dismantled, reconfigured and transported to a permanent location 30km away.*

REUSE CASE STUDIES

Reuse of a span: *Keizersveer bridge in the Netherlands. Copyright CC BY-SA. The Keizersveer road bridge constructed in the late 1970s reused six trusses from the decommissioned Moerdijk road bridge built in the 1930s.*

Reuse of a span: *Spijkenisse bridge in the Netherlands. Copyright Connie Wang. The remaining four trusses from Moerdijk road bridge were used to construct the Spijkenisse bridge.*

Reuse of a span: *London Olympic Park. Fifteen temporary bridges were built as part of the London 2012 Olympics.*

Reclaimed steel: *Footbridge South of Wokingham Station. Copyright David Lovell. This 19th-century footbridge is an early example of steel reuse. It is made using reclaimed iron rails.*

Reclaimed steel: *Green Valley road bridge in the United States. Copyright Douglas R. Davis. Steel beams reclaimed from Pleasant Valley road bridge were used to construct the Green Valley road bridge in 2014. A cost saving of $51,000 was reported due to reusing steel in place of new steel. Two other road bridges were constructed using steel from Pleasant Valley, the North Branch and Rural Dale road bridges.*

Reuse of span: *Dane Road Bridge, Iowa, United States. Copyright Nathan Holth. The original bowstring bridge was constructed in the 1870s before being relocated in the 1990s.*

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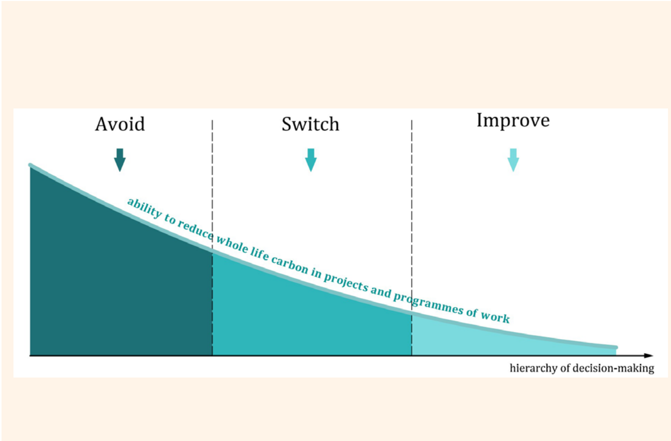
LOW CARBON REQUIREMENTS FOR BRIDGES

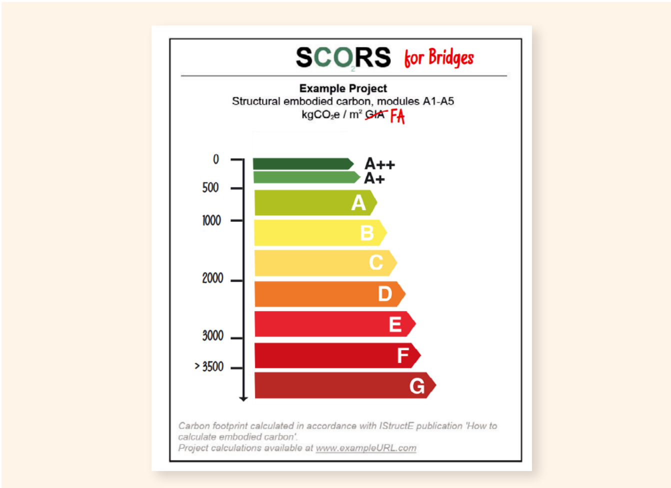
Bridges are critical, carbon-intensive assets. Their design and construction must adhere to stringent safety, robustness, and durability standards, while considering economic and social contexts. Importantly, they must also prioritise minimising carbon impact.



PAS 2080 Carbon Reduction Hierarchy

PAS 2080: reducing whole-life carbon

PAS 2080 is a whole-life carbon management framework adopted by most new infrastructure projects. It requires carbon assessments and reductions. It also advocates for a holistic approach, recognising co-benefits to the implications of reducing carbon, including biodiversity net gain, climate adaptation and increased resilience. Reuse is an essential part of this approach.



Carbon targets for bridges: a proposed SCORs-style rating scheme.
The Structural Engineer, Volume 99, Issue 10, 2021

SCORBs: carbon rating for bridges

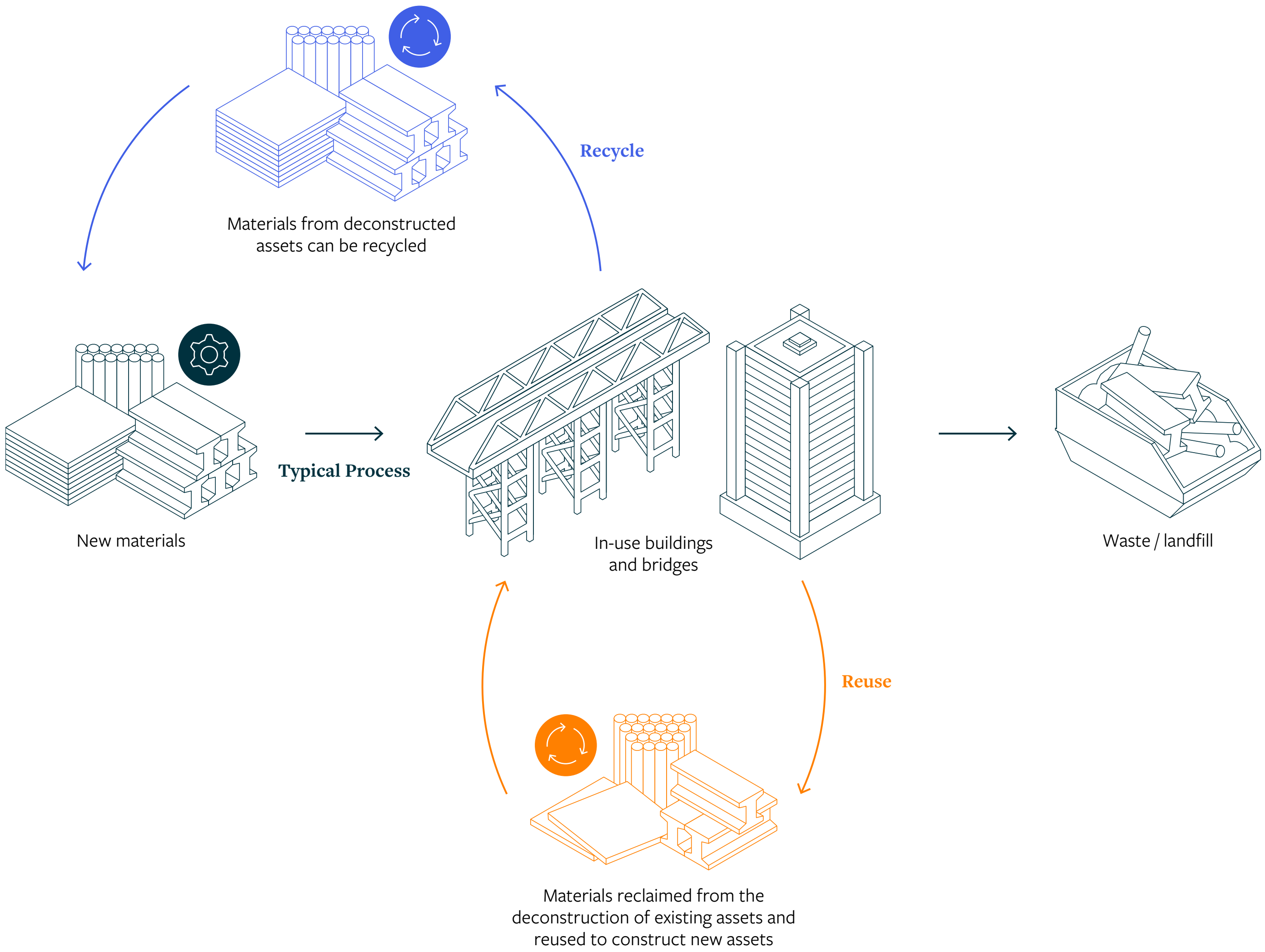
Although there is no specific requirement to rank new assets' carbon impact, clients, such as National Highways, are now asking for carbon assessments to be uniformised. For bridges, the UK industry uses the Structural Carbon Rating: SCORBS. This scheme ranks bridges from A++ to G, depending on the estimated A1-A5 emissions associated with the primary structure. Consensus in the industry suggests that all bridges should be targeting A (and A+ or A++ for footbridges). A way to achieve this ambition is to increase the implementation of circular economy.

CIRCULAR ECONOMY FOR BRIDGES

Circular economy principles can be applied to the bridges and infrastructure sector. The UK uses on average 35,000 tonnes of steel per year for the construction of new highway bridges[1]. There is an opportunity to reduce our future steel consumption by reusing bridges scheduled for demolition or by using reused steel from other sources.

Some suggestions for how bridges can be designed for future reuse are detailed on page 45.

> *Considering deconstruction, disassembly and future reuse is key to developing a circular economy for bridges.*



Steel life cycle, including reuse in bridges and recycling.

1. Tata Steel: M8 Footbridge case study

WHAT MAKES A BRIDGE DIFFERENT FOR REUSE?

Reused steel has been used in the building sector. It is therefore anticipated that similar principles can be followed for reused steel in bridge design. However, some key differences between buildings and bridges need be understood.

Characteristic	Buildings	Bridges	Impact
Execution Class	Typically, Execution Class 2.	Typically, Execution Class 3.	More stringent manufacturing and fabrication requirements, including more significant quality controls and traceability of material requirements. For further information, see page 56.
Loading	Typically designed for static loads. Accidental design load cases are determined on a project-by-project basis by assessing the risks. Loads may include explosions, impacts from vehicles etc.	Road and railway bridges are designed for moving loads. Accidental design load cases are determined on a project-by-project basis by assessing the risks. The accidental load case may include impacts from vehicles and trains.	Recurrent moving loads can cause fatigue in the structure. Fatigue life is a limiting factor for bridge design. For further information, see page 57.
Fatigue	Not typically designed for fatigue.	Road bridges and railway bridges are designed for fatigue. Pedestrian bridges are not typically designed for fatigue.	Guidance in SCI P427 does not allow for steel from a structure that has been subjected to fatigue to be reused. However published document PD CEN/TS 1090-201:2024 does not preclude steel from a structure subjected to fatigue from being reused. Guidance in SCI P427 and PD CEN/TS 1090-201 does not recommend that reused steel is used in structures that are subject to fatigue. Therefore, reused steel may not be used for the construction of road or railway bridges unless the appropriate technical appraisal has been undertaken. For further information on fatigue, see page 57.
Redundancy	Typically, several load paths.	Typically, one primary load path.	Refer to execution class.
Fabrication approach of steel structure	Typically, constructed out of small catalogue steel sections.	Typically, constructed out of bespoke fabricated elements (i.e plates, cables, etc.).	The components typically available on the reuse market are those from buildings or surplus from other industries. These sections are unlikely to be those typically used in bridge design. Reused sections may therefore be better suited for certain bridge typologies and designers may need to consider alternative structural solutions in order to incorporate reused steel into a project.
Materiality	Typically constructed out of S275 or S355 steel. Steel grade typically JR.	Typically constructed of S355 and often higher, such as S460. Steel grade typically J2.	The components typically available on the reuse market are those from buildings or surplus from other industries. The grade of material available may not match that typically used for bridges. Designers will need to assess the impact on a project-by-project basis. For further information, see page 44.
Design life	50 years	120 years.	The condition of the reused steel will need to be assessed, with a likelihood that 'reconditioning' will be necessary in order to meet the new bridge requirements.
Corrosion protection methodology	Typically painted.	Painted, galvanised or weathering steel.	
Environment	Structure is in a protected environment within the building envelope.	Structure is typically exposed.	

REUSED STEEL FOR BRIDGES: THE KEY POINTS

The following two pages summarise the essential information to be aware of when considering reused steel for bridges.

The key points are investigated per type of reuse (steel bridge reuse, repurposed steel and reclaimed steel) in the following sections of the report.

A different normative system applies.
BS EN 1090-2, *Execution of steel structures and aluminium structures*, which is the primary standard in the UK covering the requirements for the execution of steel structures, is also applicable for reused steel.

Two guidance documents (not yet adopted by the UK as standards) are currently available to support designers and fabricators:
- SCI P427 Structural Steel Reuse
- PD CEN/TS 1090-201:2024 *Execution of steel structures and aluminium structures. Reuse of structural steel*.

These documents detail the testing procedures required to qualify reused steel, and SCI P427 also introduces amended design procedures.

Both documents primarily focus on buildings, but can also be used for bridges. The restriction on fatigue makes the reuse case easier for footbridges, than for highway and railway bridges.

Compliance with clients' requirements (such as Design Manual for Roads and Bridges or National Rail Standards) is still necessary and derogations should be approved by the client.

Material qualification will require tests.
For the steel to meet the design requirements and the requirements in BS 1090-2, several parameters need to be qualified and quantified. The qualification and testing are not considered to be prohibitive in terms of cost or programme.

Provenance: It is essential to understand the history and previous life of the steel, as the provenance impacts the testing protocol that the steel is required to undergo to define its properties.

Component geometry: The shape and geometrical tolerances are set out in BS EN 1090-2 and in the product standards. If the geometrical tolerances are not met, then additional straightening activities may be required to ensure compliance.

Component condition: The geometrical properties of components may need to be modified if there are signs of damage such as plastic deformation, significant corrosion or existing holes. Detailed surveys are required to assess the condition.

Material properties: BS 1090-2 details the material properties such as the yield strength, the impact toughness and the ductility that need to be determined by destructive and non-destructive testing to enable a full characterisation of the steel. For further detail on the required properties, see page 53.

Previous and future fatigue life: Fatigue can significantly impact the design life of a structure. Current guidance is restrictive about reused steel from and for bridges subject to fatigue. However, with the right level of assessment, inspection and engineering judgement, some reuse is possible as is demonstrated by the case study on page 19.

Designers need to be aware of the necessary assessment, survey and testing requirements for reused steel, in order to specify them adequately.

> *Current guidance does not cover steel reuse when subject to fatigue. This results in restrictions for the application of the guidance in bridge design.*

REUSED STEEL FOR BRIDGES: THE KEY POINTS

Certification will require compliance with existing standards. Using reused steel is relatively novel and, although there are several case studies for steel reuse in buildings, it is uncommon in the infrastructure sector. Bridges are typically built to a higher execution class than buildings. It is crucial for designers to have a better understanding of the execution requirements and how the execution class impacts the fabrication and testing requirements. For further information on the execution class, see page 56.

According to BS EN 1090-2, reclaimed or repurposed elements themselves cannot be CE or UK marked, due to the absence of a Type 3.1 mill certificate that can only be provided by the mill. UK marking of steel assemblies or fabrications made of reclaimed or repurposed steel is, however, allowed by BS EN 1090-2. The overall certification will be based on tests demonstrating the properties.

Additional considerations.

New design life: Current guidance requires a 120-year design life for new bridges. This should remain the target for bridges with repurposed and reclaimed steel. However, in agreement with the client, the design life of a reused span could be reduced and/or the performance requirements reevaluated.

Costs: Existing steel is typically cheaper than new steel. However, additional costs can arise due to the additional testing and reprocessing requirements. Other costs that also need to be considered include logistics, certifications and insurances.

Uncertainty: Similarly to working with existing structures, uncertainty is a key parameter to manage when designing with reused elements. For reused steel the uncertainty relates to the type of components available, the condition and quantity.

Programme: Time implications should not be significant if the project is well planned and stakeholders are engaged early on in the process.

Sources of reused steel.

Repurposed and reclaimed steel are both available from stockists such as Cleveland Steel and EMR. Some stocklists are available online and detailed stocklists can be accessed by contacting the supplier directly. The stocklist contains information on the sections available, including the section size, length, key properties and condition. Designers can use this information to inform their design.

When reusing a span or using reclaimed steel directly from a existing asset, case studies have shown that this is typically more successful when the client owns both the new and existing asset enabling logistical and commercial goals to be aligned. For these types of projects to be successful, early geometrical and condition surveys are required.

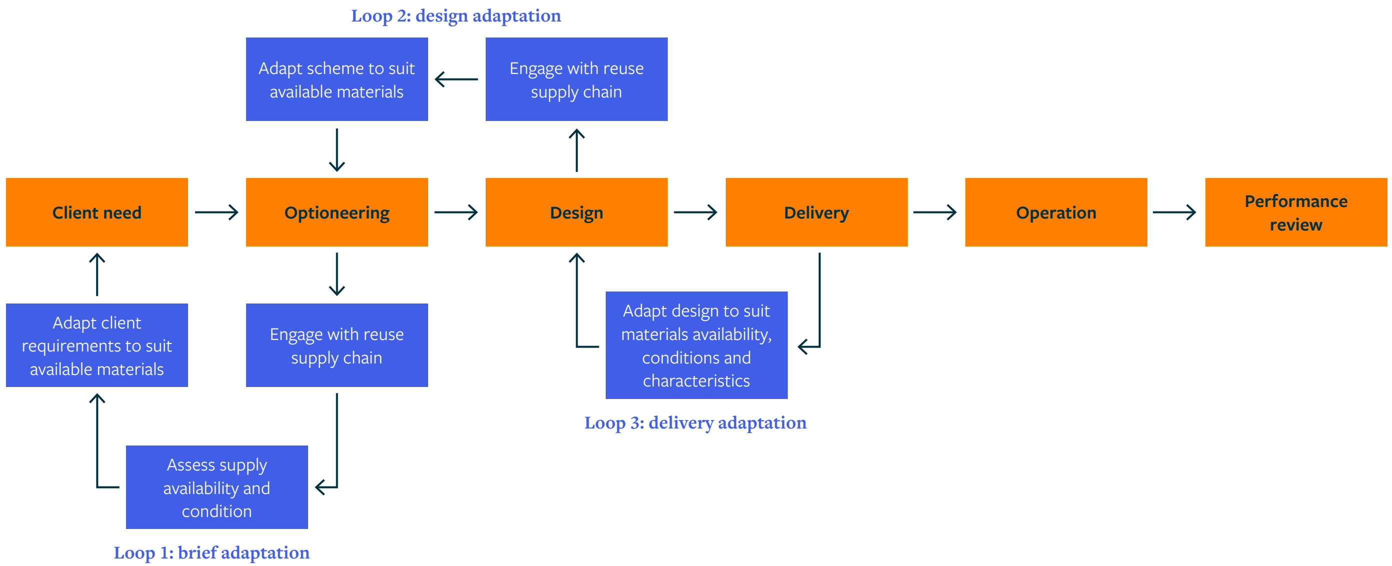
Aerial view of Cleveland Steel yard

> *It is crucial for designers to have a better understanding of the execution requirements and the impact of the execution class on fabrication and testing requirements.*

RESOURCE-LED DESIGN AND CONSTRUCTION PROCESS

Due to additional complexities involved in designing a bridge with reused steel, the project life cycle deviates from the typical bridge life cycle. This process is iterative and requires enhanced collaboration and iteration at all stages.

Three additional **project loops** have been identified.



Loop 1: brief adaptation

The design process usually starts with a client brief, defining the project requirements. To allow reuse to be a viable option, the requirements may need to be adapted. The adaptations to the brief could include authorising derogations from client standards or adapting the overall geometry to suit the dimensions of the existing components.

Loop 2: design adaptation

This second loop enables designers to optimise the use of reclaimed and reused materials by taking into account the components available on the reuse market. For example, the choice of the bridge typology will be dependent on the availability of the existing components. The use of reclaimed sections also needs to be justified to limit increase in tonnage: for an increase over 30%, it is best to use recycled steel[1].

Loop 3: delivery adaptation

Uncertainties relating to material availability, quantity and quality will remain until the materials have been procured and tested. The design should be flexible in order to reduce the risk related to the uncertainty. While the first two loops are measures to mitigate potential late changes during the fabrication phase, it is likely that some final adaptations will be required due to unexpected material supply issues. This would typically involve additional testing, changing section sizes or switching back to new steel.

1. Institution of Structural Engineers - Circular economy and reuse: guidance for designers

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TYPES OF REUSE

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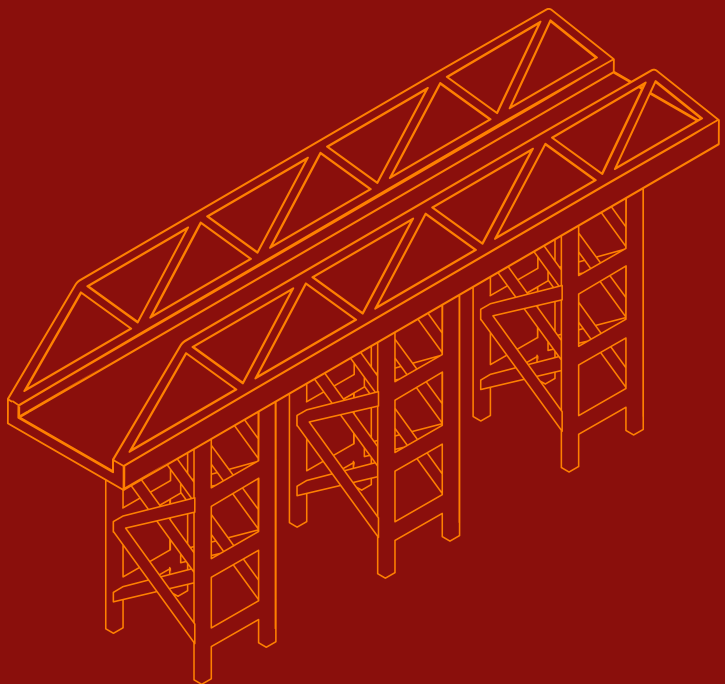
REUSE OF A SPAN



This section of the report focuses on reuse of a span, which is defined as the reuse of large sections of existing bridges (for example, a whole span). This can be on site, at the current location or off site in a new location.

Key facts:

- Steel bridge reuse is similar to extending the life of and refurbishing an existing structure, which is covered by assessment codes such as CS 456 *The assessment of steel highway bridges and structures*.
- As-built information, visual inspections and targeted testing will be critical in assessing the condition of the existing spans for reuse.
- The reuse of structures with a previous fatigue life is not permitted by SCI P427 but is permitted by PD CEN/TS 1090-201, provided that the future use is not subject to fatigue.

The resource-led process results in:

- the overall geometry matching the existing bridge
- the relocation operation being constrained by the existing bridge dimensions and the ability to segment it.

CASE STUDY 1
LUCIE BRÉARD FOOTBRIDGE

Project Team
Client: Plaine Commune
Designers and structural engineers: Schlaich Bergermann Partner
Architect: Explorations Architecture
Landscape architect: August
Steel contractor: Eiffage Métal
Civils and general contractor: Razel-Bec
Client advisor: Setec
External control: ADISS

The Paris 2024 Olympic games focused on improving accessibility for all. In that context, the creation of a new footbridge over the Canal Saint-Denis was required to replace a moveable bridge, whose rotating mechanism failed on a regular basis, and a staired arch footbridge which was not accessible for all. While the client's brief specified demolition of both structures and construction of a new 5m-wide footbridge with access ramps, the design team proposed reuse of the main span of the road bridge as the new pedestrian and cycle footbridge. The alignment would be altered and the level raised by 5.5m above water to allow for commercial navigation. The proposal was supported by the client, who was keen to meet its sustainability goals and to take a pragmatic approach to maximise existing resources.

Front view of the completed Lucie Bréard footbridge. Copyright Michel Denancé.

The reused span is a 52m-long and 13m-wide orthotropic steel box girder. A visual inspection and non-destructive tests confirmed that the structure was in good condition and, due to the limited in-use service life of only 20 years, the bridge was not near the end of its fatigue life. Parts of the foundations were also reused.

New parts included the ramps and stairs, as well as the replacement of the deck edges that were corroded and not adequate to support the new balustrade. Other areas with signs of corrosion were repaired.

The availability of the as-built drawings and justifications, the client's support and ownership, and the tight programme which pushed everyone to work proactively and collaboratively, all contributed to the success of the project.

A barge, jack-up system and self-propelled modular transporters (SPMTs) were used to install the 280-tonne bridge in two days. The Lucie Bréard footbridge opened to the public a month before the Paris 2024 Olympics, meeting an ambitious goal in terms of CO_2 emissions, an innovative design and construction process, and a very tight schedule.

CASE STUDY 1
LUCIE BRÉARD FOOTBRIDGE

Lifting and positioning of the Lucie Bréard footbridge. Copyright Sernavision/Razel-Bec.

Lucie Bréard footbridge completed. Copyright Michel Denancé.

> *A barge, jack-up system, and self-propelled modular transporters (SPMTs) were used to install the* ***280-tonne*** *bridge in* ***two days.***

NORMATIVE SYSTEM AND ASSESSMENT

Normative system: refer to assessment codes. The current Eurocode 3 is primarily intended for the design of new structures and does not explicitly cover existing structures. However, due to the increase in reuse projects the next generation of Eurocode (to be published in 2025) is expected to include a new technical section on the assessment and retrofit of existing structures, following recently published guidance: PD CEN/TS 17440:2020 *Assessment and retrofitting of existing structures*.

The point of reference in the UK for steel bridge assessments is CS 456 *The assessment of steel highway bridges and structures*, published by National Highways. While the document was developed to assess existing steel structures on motorways and trunk roads and was based on British standards BS 5400-3 and BS 5400-10, it provides a relevant and useful framework for considering reuse of a steel span.

Any strengthening or new sections are typically designed following the Eurocodes. This may raise some compatibility issues (in term of tolerances or durability). However, these can be overcome using engineering judgement and submitting justifications to the checker and the Approving Authority.

BS EN 1090-2 *Execution of steel structures and aluminium structures* remains an important document for use when assessing an existing structure's suitability for reuse. Not all sections of the standard will be applicable as the asset is already built. However, the criteria on geometric tolerances, for example, can be used to confirm that existing deformations are acceptable.


Design Manual for Roads and Bridges
Highway Structures & Bridges
Inspection & Assessment
CS 456
The assessment of steel highway bridges and structures
(formerly BD 56/10)
Revision 0
Summary

CS 456 The assessment of steel highway bridges and structures


PD CEN/TS 17440:2020
BSI Standards Publication
Assessment and retrofitting of existing structures

PD CEN/TS 17440 Assessment and retrofitting of existing structures

The availability of as-built information will inform testing requirements. The first source of information will be the as-built drawings and fabrication and quality pack. For more recent structures, a BIM model may also be available.

Information relating to the geometry, structural form of the bridge, element sizes, connection details and information on the material properties will be needed to complete a full assessment of the structure. Site surveys will also be required to verify the documented information.

The type and quality of the information available about the existing steelwork will influence whether additional testing is required. If no existing historical data is available, then a full geometrical survey of the structure will be necessary, along with testing of the materials.

QUALIFICATION OF STEEL ELEMENTS

Material quality should be assessed and documented. The reuse of an existing span or a large portion of the structure is likely to require a thorough inspection of the asset, similarly to a principal inspection to assess the condition of the structure. The primary characteristics to be assessed are surface condition, corrosion extent, pitting, cracks and weld condition. Additional non-destructive and destructive testing may be required. For example, ultra-sonic testing can be used to determine the thickness of plates and to assess the level of corrosion. Magnetic particle inspections and ultrasonic inspections may need to be completed on some welds to check for cracking.

Geometrical deformations and tolerances should be reviewed. If the existing bridge was built using Eurocodes and in accordance with BS EN 1090-2, then it may be sufficient to confirm that no large unexpected local or global deflections or deformations have occurred. For older structures, it may be necessary to confirm the geometrical tolerances of the bridge components and of the bridge as a whole. It is worth noting that measuring imperfections can bring benefits in some capacity assessments if they are less than the standard values.

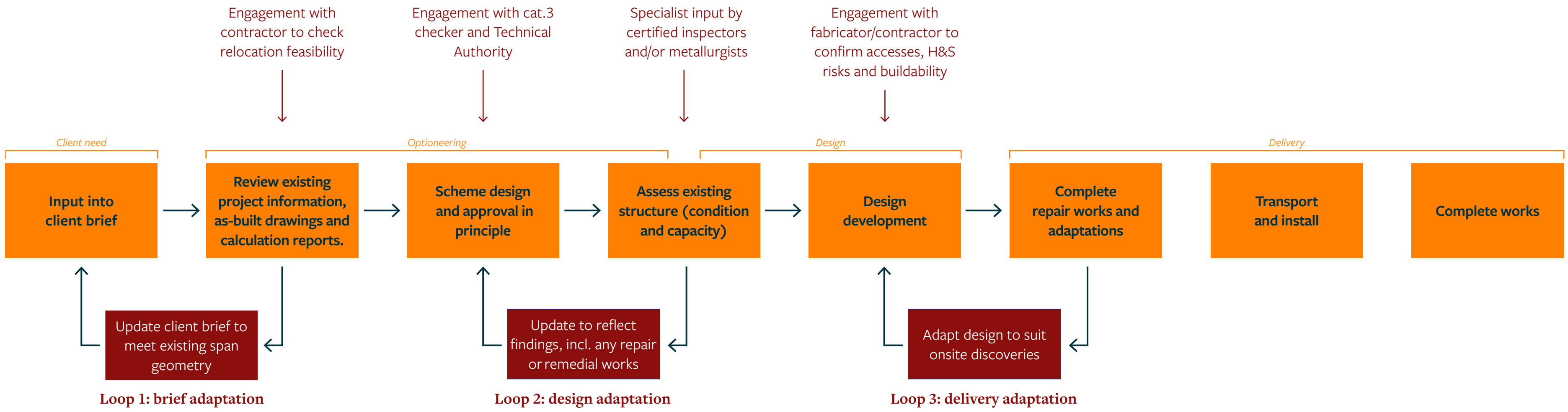
Material properties should be defined and documented. Where the appropriate documentation is provided, the material properties can be assumed to be those specified in the original design. In the absence of as-built information, material certificates and appropriate quality documentation, CS 456 and PD CEN/TS 17440:2020 allow for testing to be undertaken to establish the required properties. CS 456 also allows for conservative assumptions to be made regarding the material properties. For example, if the material properties are not known and no test information is obtained, the steel may be assumed to be a mild steel grade, with the minimum yield stress noted in BS 15 or BS 4360 appropriate to the date the original bridge was constructed. Tests are, however, likely to be required to determine the fracture toughness as older materials may have lower values than modern steels.

Remaining fatigue life should be determined, and at-risk details should be identified. If the existing bridge asset was subject to fatigue, it is essential to understand the fatigue history and to identify the at-risk details such as connections, welds, bolt holes and any corroded areas. Detailed inspections will need to be completed to ensure that there are no signs of fatigue cracks. If cracks are identified an appropriate repair procedure will need to be developed.

CS 456 details a method to numerically assess the remaining fatigue life of a structure, using the damage calculation procedures in BS 5400-10. To complete this assessment a prediction of past and future traffic volumes needs to be determined. CS 456 also allows for fatigue assessments, to be completed on the actual stress measurements for cases where the stresses cannot accurately be determined through analysis. Further information on fatigue is provided on page 57.

Testing is a requirement to characterise existing steel. It is also an opportunity to improve the level of information and refine conservative assumptions.

RESOURCE-LED DESIGN AND CONSTRUCTION PROCESS



Loop 1: brief adaptation to meet the existing span geometry.

Reusing or relocating an existing bridge will require significant client buy-in. The project brief may need to be altered to suit the constraints associated with the existing asset, including the geometry, architecture and structural form.

It should be noted that a span reuse scheme is likely to be more successful if the existing asset is part of the client's portfolio, as challenges associated with access, transfer of ownership and liabilities will be reduced.

Loop 2: design adaptation to consider existing condition and constraints.

Early assessment is necessary to inform the decision-making and to tune the scope of the design. Similarly, logistical constraints for relocation will dictate what is feasible. Engagement with the contractor at the early stages is important for establishing a feasible scheme.

Early support from specialist metallurgists or other experts such as welding engineers may be required for corrosion and fatigue assessments. Early engagement with the appropriate technical authorities and the CAT 3 checker is also recommended in order to reduce project risks.

Loop 3: delivery adaptation to mitigate unexpected defects or damage.

Once works commence, it is likely that additional issues will be identified on site, such as unexpected areas of corrosion which were previously difficult to access and assess. The design will consequently need to be adapted, requiring proactive engagement from the design team.

Relocation may also damage some elements, which will need to be inspected again and may require repair.

FURTHER CONSIDERATIONS

The new design working life depends on the condition and future use of the asset. Two main issues need to be taken into consideration when defining the design life: the magnitude of the load (which depends on the return period and impacts wind loads, temperature loads and flooding requirements) and durability measures, such as corrosion protection, and inspection and maintenance regimes. An existing bridge's previous life need not necessarily preclude it from having a future life.

Currently, the design working life of a bridge designed following the Eurocodes is 120 years in the UK and 100 years in some other European countries. As steel properties do not degrade over time, it is accepted that if the condition is proven to be good, the new design life can be defined with engineering judgement, and no systematic discount is required with regard to its previous life. This approach assumes that the structure is not subject to fatigue.

Recertification is usually not needed. Depending on the required execution class, certification to BS EN 1090-1 will be required. An existing span will not be subject to recertification as this cannot be done retrospectively. However, any new additions will require CE/UK marking.

The cost savings can be significant. It is typically expected that reusing a span will have significant cost savings compared with fabricating a new span, particularly if the existing asset is already owned by the client. A cost/benefit analysis may be necessary to prove the commercial case if poor condition necessitates significant repair works, or if significant logistical challenges are expected. This analysis should include any costs associated with the site constraints for demolition, access and relocation, as well as any financial benefits due to a reduction in programme length.

It is anticipated that there will be a reduction in programme length. Reusing a span is likely to be beneficial to the length of programme compared with fabricating a new span. This is due to a reduced procurement and construction phases. If the repair works are limited, then the construction phase will be governed by the relocation activities.
The repair strategy should review whether it is more efficient for modifications to be completed in the bridge's original position, in a fabrication yard or in the future location.

The biggest risk to the programme for a span-reuse project is the uncertainty relating to the condition of the existing structure. Detailed inspections can reduce the risk; however, it is challenging to eliminate the risk entirely.

Logistics may be the most significant challenge. The logistics challenge will depend on:

- size of the span
- access to existing and future site
- lifting/jacking opportunities
- transport constraints
- tolerances
- obstacles to be crossed: railways, highways, local roads, rivers, canals
- traffic disruption.

A typical span size that is transportable by road is approximately 4.5m wide and 18.5m long, with a maximum weight of 78 tonnes. Beyond these dimensions, special transport will be required. Self-propelled modular transporters (SPMTs), when used in conjunction with jacking systems, offer versatile lifting and manoeuvring solutions.

Transport along a waterway is easier as a barge can be used to lift/jack the existing bridge off its position and transport it to its new location. It can even rotate and accommodate a change in height. Rail-mounted cranes usually work in static positions for assembly and disassembly. They could potentially be used in combination with a delivery train to transport the span from one location to another.

IDEAL OPPORTUNITIES FOR REUSE

The ideal opportunities for reusing a span include small to medium spans, that require limited transportation or where transport is in an open environment. Continuity of client ownership between the donor and new structure is likely to increase project success rates.

Reuse of a span is likely to be most successful where the proposed bridge has less onerous design conditions than the donor bridge: for example, using an existing road or railway bridge as a footbridge.

The Lucie Bréard footbridge case study highlights the ideal conditions for span reuse: the client owned the existing and new bridges; the existing assets were in good condition; the new, future use was less onerous than the initial use; the relocation was close by and logistics were simplified by using a barge.

The ideal reuse targets for whole spans comprise:
- old railway or highway bridges to be turned into footbridges (with several case studies in the UK)
- bridges that have simple relocation requirements.

> *Reuse of a span is likely to be most successful where the proposed bridge has less onerous design conditions than the donor bridge.*

Castlefield Viaduct (Manchester): the old railway viaduct has been turned in a public garden.

REPURPOSED STEEL

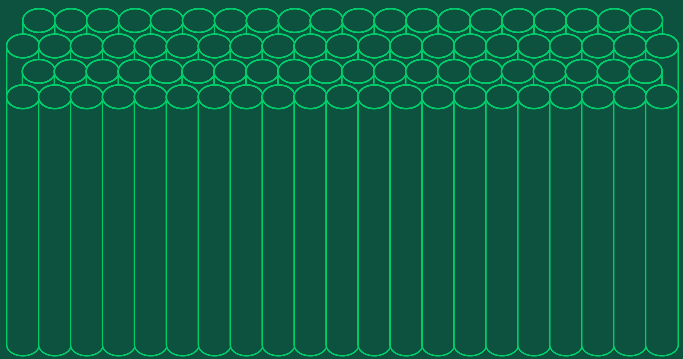
This section of the report focuses on repurposed steel that was originally produced for an alternative industry (e.g. the oil and gas industries). The components have no previous design life and are considered to be new.

Key facts:

- Repurposed steel mainly comes from the oil and gas industries and consists of circular hollow sections, originally intended to be used as pipes.
- There are limited suppliers of repurposed steel in the UK but they can engage proactively with designers and contractors to reduce risk.
- Fatigue is not a concern as the elements have had no previous service life.

The resource-led process requires:

- non-standard sections to be used
- design iteration to determine the balance between the minimum material use and maximum reuse (this balance depends on the types of repurposed sections available and how these sections align with the optimal structural solution)
- enough time for testing to characterise the steel properties
- contractors to secure repurposed sections as early as possible.



CASE STUDY 2
TAN HOUSE FOOTBRIDGE

Project Team
Client: Network Rail
Principal engineers: WSP
Designers and structural engineers: Format Engineers
Contractor: Balfour Beatty
Steel fabricator: SH Structures
Repurposed steel supplier: Cleveland Steel and Tubes Ltd
Repurposed steel tonnage: 14.3 tonnes of the superstructure
Embodied carbon A1–A5: Bridge (677kgCO_2e/m^2), stairs (883kgCO_2e/m^2)

Aerial image of the completed Tan House footbridge. Copyright Glen Crouch.

The final design taken forward following an early-stage conceptual design process was that which the project team believed would have the most potential for low-embodied energy through the specification of repurposed circular hollow steel tubes. Form and material optimisation was pursued at each design stage via digital optimisation techniques. The client and future owner, Network Rail, was committed from the outset to aligning Tan House footbridge with the aspirations of PAS 2080 and achieving a low carbon footprint.

The 53m-long structure comprises a triple-span bridge deck supported by steel-braced column frames with integrated steel stairs at each end of the bridge. The bridge structure is a composite ‘U-frame’ through-deck frame, with the two parapets laterally restrained by regularly spaced vertical plate members which also pass beneath the deck. Both parapets are splayed outwards from the verticals. The U-frames are part hung from and restrained by splayed compression struts. The U-frames also double as tension members hung from the compression struts.

Repurposed steel tubes were used for all column elements and their cross-bracings, and the fan members supporting the deck. The requirement for the contractor to use repurposed steel was defined in the tender drawings and specifications.

Repurposed steel was chosen as it does not have a previous loaded design life. Sizes and grades of repurposed members were taken in consultation with Cleveland Steel and Tubes Ltd of Thirsk. Embodied carbon was tracked through life cycle stages A1 to A5 from the scheme comparison exercise at GRIP 3 until completion. The bridge was also benchmarked against the IStructE SCORBS ratings for bridges and it achieved a SCORBS A rating.

CASE STUDY 2
TAN HOUSE FOOTBRIDGE

Although the required documentation was unavailable for several repurposed sections, testing enabled steel properties to be demonstrated promptly.

Fabrication of the Tan House footbridge. Copyright Glen Crouch.

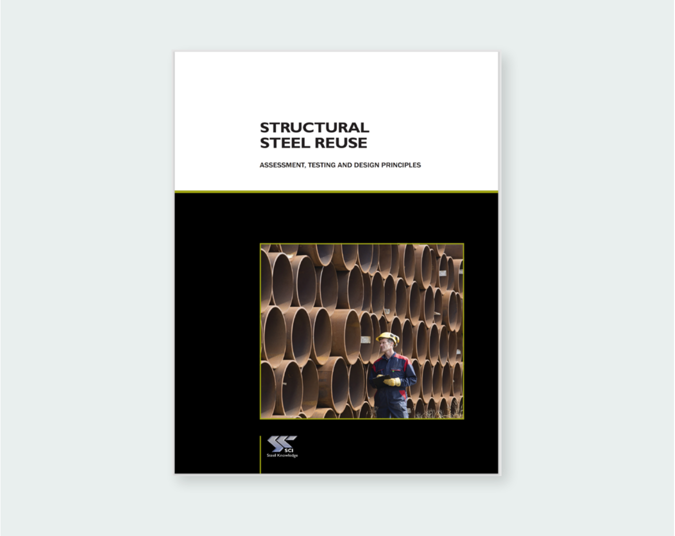
Lifting and positioning of the Tan House footbridge. Copyright Glen Crouch.

Span installation of the Tan House footbridge. Copyright Glen Crouch.

NORMATIVE SYSTEM AND TESTS

Normative system: refer to existing guidance on reuse if the steel properties are unknown.
Repurposed steel will not be supplied with a CE or UK mark but may be supplied with certificates confirming the properties. If the properties are unknown, then the steel will need to be tested following the protocols for reused steel in order to comply with BS EN 1090-2. Guidance documents SCI P427 and PD CEN/TS 1090-201 cover the use of repurposed steel and complement BS EN 1090-2 in detailing the required testing regimes.

Structures fabricated from repurposed steel components should comply with existing guidance and norms for new steel. The design procedure should also comply with Eurocode requirements, as well as client-specific requirements, such as the DMRB or Network Rail Standards, and appropriate allowance should be made for any steel properties that deviate from those typically used.



SCI P427 Structural steel reuse

PD CEN/TS 1090-201 Reuse of structural steel

QUALIFICATION OF STEEL ELEMENTS

Repurposed steel cannot be categorised into the standard steel grades. It is therefore important that the material specification allows for materials with 'equivalent properties', as worded in BS EN 1090-2, to be used.

The original manufacturing certificates should be reviewed. Intended use, storage and transportation history should also be recorded. The provenance and history of the steelwork will influence whether additional testing is required.

The material condition should be inspected. Repurposed steel has no previous service life and is therefore anticipated to be in good condition. However, it may have been damaged by extended storage periods and transportation. Detailed visual inspections will be required to identify areas of corrosion and defects, such as cracks.

The material properties can be demonstrated through testing. Repurposed steel may not have been manufactured to the standard structural steel grades (i.e S355 or S275)and may not be supplied with the required mill certificates. Repurposed steel components cannot be CE or UK marked retrospectively but BS EN 1090-2 authorises the use of repurposed steel for structural purposes if appropriate material testing is performed. The fabricated assembly can then be CE marked.

Compliance with the required material properties and standards can be demonstrated through testing. It is therefore important that the material specification allows for materials with 'equivalent properties', as worded in BS EN 1090-2, to be used.

The material properties of the repurposed steel will need to be determined by testing following the process detailed in PD CEN/TS 1090-201 and SCI P427. Key properties to be tested include yield strength, ductility, fracture toughness and hardness.

Further detail on the tests to be undertaken can be found on page 53. For repurposed steel, the yield strength may be higher or lower than a typical structural grade. This needs to be considered by the designer. Other properties that may differ from those that are typically specified include the toughness, which determines the sub-grade.

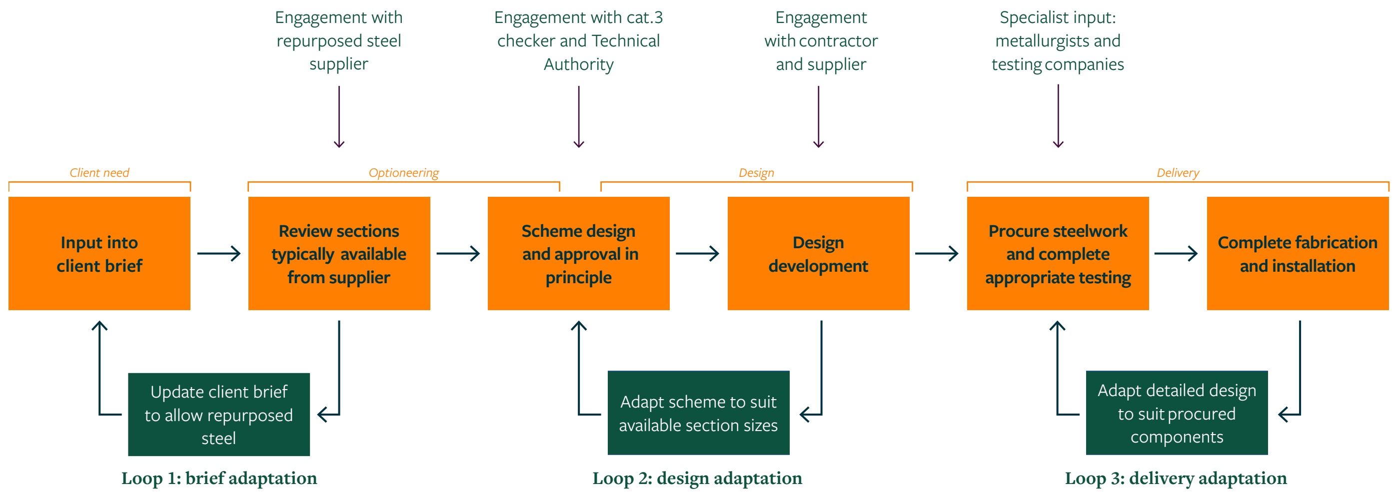
If additional material testing (beyond that specified in PD CEN/TS 1090-201 and SCI P427) is undertaken, it may be possible to reduce the factors of safety on the material properties during the design.

The geometry and geometrical tolerances should be assessed. The section sizes used in other industries are unlikely to align with those typically used in structural applications and the geometrical tolerances may deviate from those specified in BS EN 1090-2.

Detailed geometrical surveys will be required to determine the section sizes and to confirm compliance with the code. If the geometrical tolerances do not comply with BS EN 1090-2 then the deviation will need to be taken into account during the design phase. If geometrical tolerances are confirmed to be tighter than those assumed in BS EN 1090-2, then some of the conservative assumptions recommended in the Eurocode could be refined.

There is no previous fatigue life. Repurposed steel has had no previous service life and has not been subject to fatigue. Assuming that the material properties comply with all requirements, the sections could therefore be used in all types of bridge, including those subject to fatigue.

RESOURCE-LED DESIGN AND CONSTRUCTION PROCESS



Loop 1: Brief adaptation to suit available repurposed sections.

There is a relatively limited range of sections readily available on the repurposed steel market, although circular hollow sections are widely available in a range of sizes, from 21mm in diameter to over 2m in diameter. These sections typically come from the oil and gas industries. They can be easily used for piles, columns or some main members, such as cross-beams or as part of a truss.

Loop 2: Design adaptation to optimise the use of repurposed steel.

Designers will need to engage early with suppliers to assess the availability of repurposed steel. If the required sections are unavailable, then the design may need to be adapted to suit the supply. Some sections are more commonly available and their use can de-risk the future delivery.

Iteration is required to determined whether it is optimal to use the minimum section required (as determined from the analysis) or whether to use a larger section which is available in repurposed steel. Instead of using an overly-thick section, it may be best to specify new steel to control the weight of the structure and limit the impact on foundations.

Loop 3: Delivery adaptation to mitigate unexpected test results and supply challenges.

Sufficient time and budget needs to be allocated for the contractor to perform the required tests on the steelwork. The results could impact the design and require new steel to be used instead of repurposed. The project specification should have sufficient flexibility to enable repurposed and new steel to be used.

Specified sections may be unavailable at the time of purchase. Early procurement of sections or vesting are feasible and can significantly reduce project risk. Suppliers are willing to engage with clients and contractors to find the most appropriate arrangement for each project.

FURTHER CONSIDERATIONS

The design working life of the structure should be determined in accordance with the Eurocodes. Repurposed steel sections have had no previous service life and can be considered to be new. The use of repurposed steel should therefore have no impact on the design life of the structure. Corrosion protection measures should be detailed in the same way as for new steel.

Repurposed steel is cheaper than new steel. Scrap steel is typically £300 per tonne cheaper than new steel[1]. Depending on the level of testing required, it is possible that using repurposed steel will be more cost-effective than procuring new steel.

There is no negative impact on programme. Until the repurposed steel components are procured, there is uncertainty as to whether the design will need to be altered to suit the components available at the time of fabrication, which may cause programme delays.

With appropriate planning, collaboration and procurement, using repurposed steel should not have a negative impact on the project programme. If the designer reviews stock levels and selects commonly available components, the risk is reduced. Designers can also specify a range of sizes and grades, and can even allow for new components to be used, all of which reduce the likelihood of redesign and delays.

Early engagement with suppliers will de-risk material-supply challenges and logistics. Repurposed steel is available from a limited number of suppliers including Cleveland Steel and EMR, who are both keen to support projects using repurposed steel. Their stock will be made known on request. Some sections are more commonly available than others. Engagement with suppliers at an early stage is therefore recommended in order to develop a resource-led design, and consideration should be given to early procurement and vesting to reduce uncertainty and risk.

Transport from the supplier yard to the fabrication yard should be considered. However, no significant logistical challenge is foreseen. To reduce project risks, components may be purchased ahead of fabrication and these may need to be stored.

Additional consideration may need to be given to sections that have significant welds. Line pipes often have a longitudinal weld running along the full length of the pipe. Additional testing may be required to confirm the condition of the weld and there may be other design considerations, depending on the final use and the type of weld.

Surplus circular hollow sections that can be repurposed.

1. Institution of Structural Engineers: Circular economy and reuse: guidance for designers

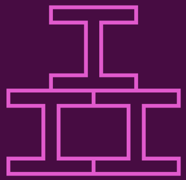
IDEAL OPPORTUNITIES FOR REUSE

Repurposed steel is equivalent to new materials in terms of structural properties. It can therefore be utilised in all types of bridge construction, with no additional concerns about fatigue, meaning that it can be used for footbridges, road bridges and railway bridges.

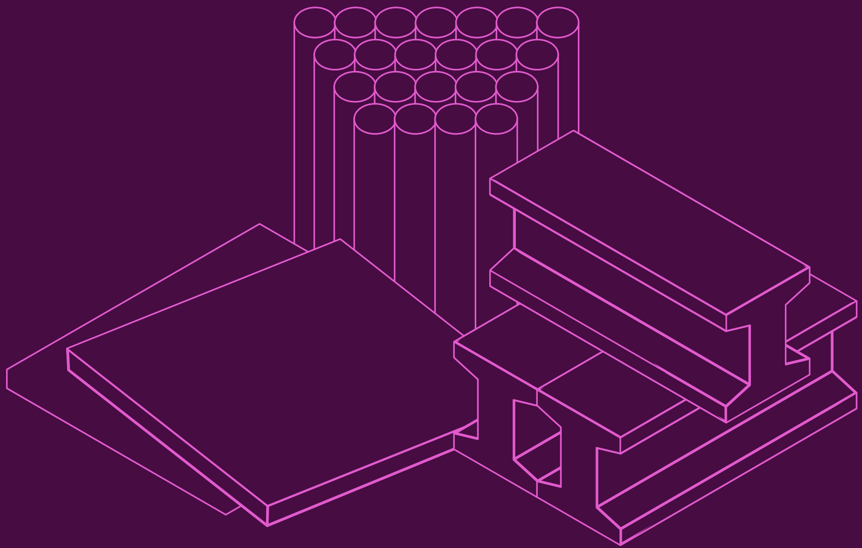
Repurposed steel sections are currently mainly available as pipes and can therefore easily replace circular hollow sections. They may also be an alternative to boxes or open sections.

> *Repurposed steel can be used for all types of bridges. The circular sections will be best placed for piles, piers and masts. But they can also be used for main structural elements, such as top and bottom chords of a truss or to form an arch. Small sections would be adequate for ancillary elements such as handrails.*

Dunkirk footbridge: the lower part of the masts are of constant sections and could have been designed with repurposed steel. Photo credit: Anne-Claude Barbier.



RECLAIMED STEEL



This section of the report focuses on reclaimed steel which has been recovered from a donor structure and is intended to be used in the fabrication or erection of a recipient structure. The source of the steel could be from a building or from a bridge.

Key facts:

- The most relevant guidance documents are SCI P427 *Structural steel reuse* and PD CEN/TS 1090-201:2024 *Execution of steel structures and aluminium structures - Reuse of structural steel.*
- Testing protocols depend on the provenance of the steel and the availability of existing information.
- Reclaimed steel with no previous fatigue life can be used for bridges, according to PD CEN/TS 1090-201. It should be noted that this is precluded in SCI P427.
- Current guidance does not cover the use of reclaimed steel with a previous fatigue life.
- Responsibilities for the qualification of materials may have to be redefined as certification of sections is not possible.

The resource-led process results in:

- limited availability: the reclaimed steel supply chain is in development
- sections can come from stockists or directly from the demolition of an asset owned by the client
- early engagement with all stakeholders being critical
- designers needing to develop their knowledge on execution requirements and material testing in order to correctly specify reclaimed materials.

CASE STUDY 3
LEWES FOOTBRIDGE

Project Team

Client: Human Nature

Designers and Structural Engineers: Expedition Engineering

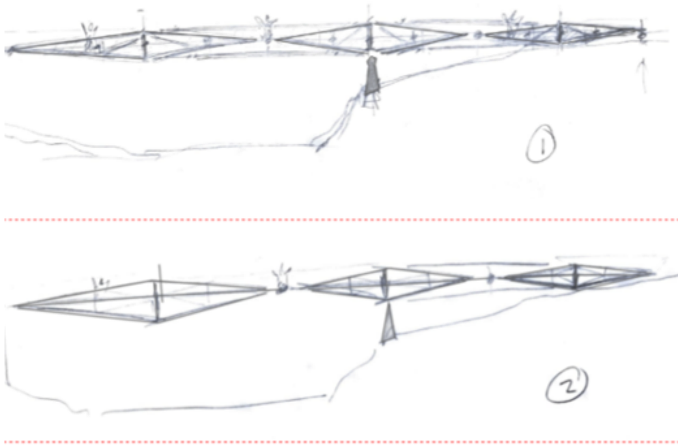
Expedition Engineering met with Human Nature, the Developer of the Phoenix Project in Lewes, to assess the feasibility of a new footbridge made of reused materials salvaged on site.

The site comprises old warehouses, built at different times. Some of these buildings will be transformed into homes or community centres in the new masterplan, while others are to be demolished. The client was keen to investigate options for reuse to minimise disposal costs and waste.

The first step consisted of a site visit to:

- define the site constraints
- estimate the potential for reuse: small angles were found in the oldest structures, as well as UB beams and 10mm floor plates; lengths of elements were between 2m and 12m.

As the steel comes from buildings and the new bridge is a footbridge for pedestrians and cyclists, fatigue is not a concern. Both SCI P427 and PD CEN/TS 1090-201:2024 are applicable. They define the design and testing requirements to deliver a compliant scheme.

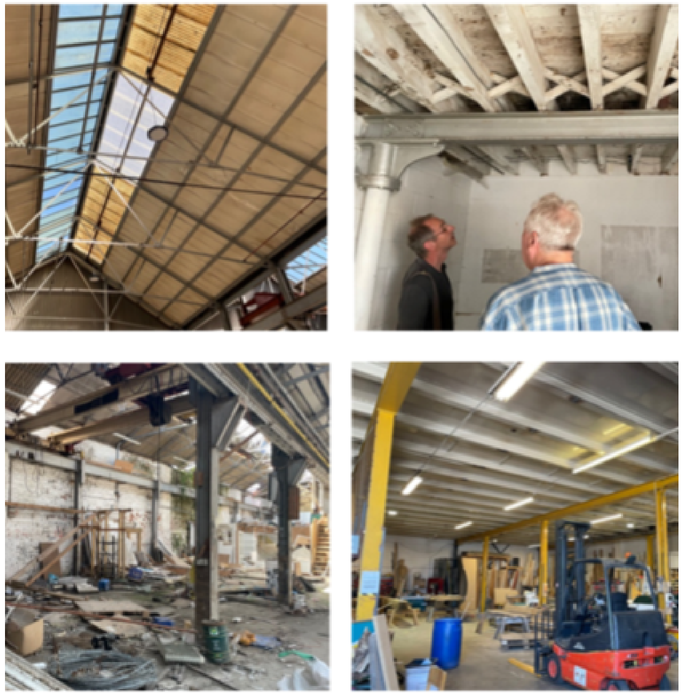


Concept designs by Expedition Engineering.

The second step was a concept development with different options to meet the site requirements (and usual design demands), as well as to test the inclusion of reclaimed elements in different bridges typologies. In parallel, we shared a modified design process with the client to raise awareness of the need for careful dismantling and material testing.

The third step currently focuses on the selection of an option. The client is waiting for planning permission to be granted and funding to be secured before progressing.

The resource-led design results in the first step being a careful assessment of the available sections.



Warehouses at the Lewes site.

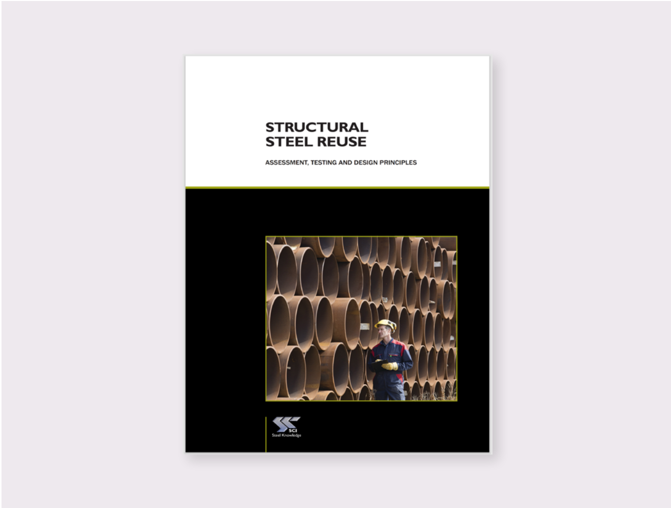
NORMATIVE SYSTEM AND TESTS

Normative system: refer to existing guidance on reuse and assessment codes for fatigue life.
The use of reclaimed steel in a new design is not currently covered explicitly by the Eurocode suite.

BS EN 1090-2 applies to structures that use reclaimed steel and is directly complemented by PD CEN/TS 1090-201. It authorises the use of reclaimed steel in structural fabrications and with appropriate testing of the reclaimed elements the fabrication can be CE or UK marked. Both SCI P427 and PD CEN/TS 1090-201:2024 detail the required testing regimes to determine the material properties and comply with BS EN 1090-2.

The design procedure when using reclaimed steel should follow the Eurocode design process, with adaptations (restrictions on the analysis and design approach) as detailed in SCI P427. Although produced for building design, these amendments and restrictions are also likely to be applicable when designing bridges using reclaimed components.

SCI P427 excludes reused steel that comes from a donor structure that was subject to fatigue. The previous life and stress history of the reclaimed elements can, however, be assessed using the Eurocode and assessment standards such as CS 456 or PD CEN/TS 17440:2020.



SCI P427 Structural steel reuse

CS456 The assessment of steel highway bridges and structures

PD CEN/TS 1090-201 Reuse of structural steel

PD CEN/TS 17440 Assessment and retrofitting of existing structures

QUALIFICATION OF MATERIALS

The provenance will inform testing protocols. PD CEN/TS 1090-201 presents four testing protocols (A, B, C and D), which depend on the provenance of the steelwork. For steelwork with full traceability and inspection documents, no additional testing is required and it is covered by Protocol A. Protocols B and C cover the testing required for steelwork produced in or after 1970, and pre-1970s with a known provenance. Protocol D covers the testing procedure for steelwork with no known provenance. For bridges, understanding the stress history and previous service life is extremely important. Using a material that has no known provenance would not be recommended for bridge design.

The condition of the material should be carefully inspected. Reclaimed steel has had a previous design life and has also undergone deconstruction, transportation and storage. There is a high chance that components could be damaged and therefore a detailed visual inspection will be required to identify areas of corrosion, including pitting and defects such as cracks, holes and plastic deformation.

Geometrical deformations should be surveyed. Detailed geometrical surveys will be required to determine the section sizes of the reclaimed components and to confirm compliance with BS EN 1090-2. If the geometrical tolerances do not comply with BS EN 1090-2, the deviations will need to be considered during the design phase. Equally, if the geometrical tolerances are confirmed to be tighter than those assumed in BS EN 1090-2, then some of the conservative assumptions could be refined.

The properties of the material should be tested. Although reclaimed steel components cannot be CE or UK marked, BS EN 1090-2 authorises the use of reclaimed steel for structural purposes if appropriate testing is performed. The assembly can then be CE or UK marked by the fabricator. The material properties will need to be determined by testing following the process detailed in PD CEN/TS 1090-201 or SCI P427. The key properties to be tested include yield strength, ductility, fracture toughness and hardness. The testing protocols become progressively more extensive (ranging from A to D), based on the origin of the steelwork. Further detail on the tests to be undertaken can be found on page 53.

For reclaimed steel produced post-1970, it is likely that the yield strength will comply with the grades typically specified for structural design. Other properties, however, may differ from those that are typically specified in bridge design, such as the toughness, which determines the steel sub-grade. Further information, see page 54. For reclaimed steel produced pre-1970, the strength grade may vary from the grades typically specified for structural design. This will need to be considered by the designer.

If sufficient additional material testing (beyond that specified in PD CEN/TS 1090-201 and SCI P427) is undertaken, there is an opportunity to reduce the factors of safety on the material properties, in accordance with the statistical approach defined in the Eurocodes.

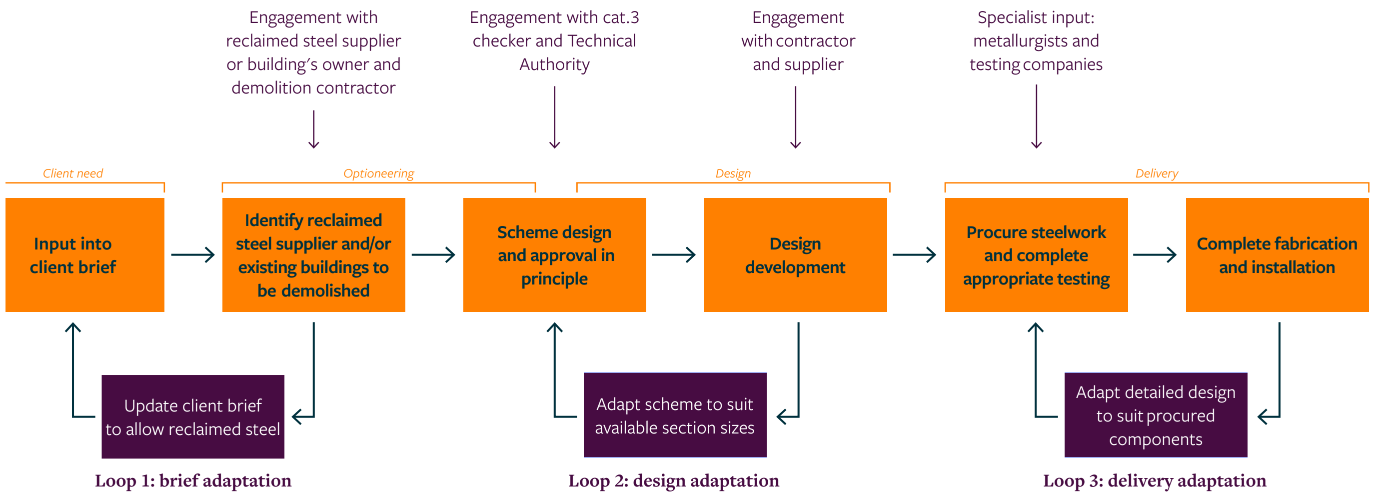
Unless the original certifications are supplied, reclaimed steel will not be classified in the same way as new steel as it is not supplied directly from the manufacturer. To enable reclaimed steel to be used, the material specification should allow for 'materials with equivalent properties' to be used.

The fatigue life should be assessed. It is critical to correctly assess the previous and future fatigue life of reclaimed steel components.

- If the reclaimed steel has no previous fatigue life, it can be used for any type of new bridge, according to PD CEN/TS 1090-201. It should be noted that SCI P427 is more restrictive and does not recommend the use of reclaimed steel for structures subject to fatigue.
- If the reclaimed steel had a previous fatigue life (for example, coming from a rail or road bridge), its use is currently not covered by SCI P427 or PD CEN/TS 1090-201.

If the donor structure is in the early stages of its fatigue life, and if the recipient structure will not be subject to fatigue, then it may be possible to reuse components, provided that appropriate assessments and inspections are undertaken. The designer will be required to justify the derogation from the current guidance. For further information on fatigue, see page 57.

RESOURCE-LED DESIGN AND CONSTRUCTION PROCESS



Loop 1: brief adaptation to enable use of reclaimed steel

Reclaimed steel can come from stockists or from the demolition of an existing asset. This asset may or may not be owned by the same client. In all cases, the brief should allow for these reclaimed elements to be identified, certified and reconditioned.

The project aims and requirements may need to be adjusted to suit the materials available.

Loop 2: design adaptation to optimise reclaimed steel use

If a project aims to use reclaimed steel, then the design should consider which sections are commonly available on the market or are available from the donor asset.

Typically, most reclaimed steel in the supply chain comes from warehouses and buildings. The sections available reflect the source and therefore commonly consist of UBs and UCs. The supply of hollow sections and angles is quite limited. Element lengths are typically between 10m and 15m, but the usable length will be shorter than this, as an allowance needs to be made for removing existing connections. The sections come in a range of depths, most commonly between 200mm and 600mm deep.

Loop 3: delivery adaptation to align the supply chain

Sufficient time and budget needs to be allocated to perform the required tests. The results could impact the design and require the use of alternative steel.

If the components come from a donor structure, there will not be certainty on the available stock and condition until the asset has been deconstructed. Some sections may not be suitable for reuse and new sections may need to be procured.

If components are sourced from a supplier the specified sections may not be available at the time of purchase. Early procurement of sections or vesting are feasible and can significantly reduce project risk. Suppliers are willing to engage with clients and contractors to find the most appropriate arrangement for each project.

CHANGES TO THE DESIGN PROCEDURE AND RESTRICTIONS

SCI P427 details proposed adaptations to the Eurocode design procedure for reclaimed steel. It also imposes some restrictions on the analysis and design approach. Although produced for buildings, these amendments and restrictions are also likely to be applicable when designing bridges.

Only the main recommendations from SCI P427 are highlighted here. Please refer to the original document for more information.

Global analysis: elastic only.
Although ductility tests are completed as part of the certification process, structures designed from reclaimed steel should not be designed using plastic global analysis.

Section checks are to use an increased safety factor. The ductility tests are considered sufficient to allow the plastic cross-sectional resistance of sections to be taken. However, the material partial factor (γm1) used in the calculation of the buckling resistance is increased to 1.15. This reflects the increased uncertainty when using reclaimed steel.

Geometric imperfections should be assessed.
Testing for geometric imperfections should demonstrate that the components are compliant with BS EN1090-2 and that the standard design rules can be followed. It should, however, also be noted that if sufficient testing is undertaken, it may be possible to use less conservative buckling curves as per the Eurocode.

Toughness and sub-grade may have to be tested to demonstrate J2 compliance. Steel bridges typically have a higher sub-grade than buildings as they experience a wider range of temperatures. The design recommendations in P427 assume that all post-1970s steel is a minimum of grade JR. For buildings and internal steelwork, this is likely to be sufficient. For bridges, additional testing to determine the suitability of the sub-grade is likely to be required.

Connections should be removed or tested.
Typically, it is assumed that reclaimed components will be used as plain sections and that any existing connections will be removed. If new welds are required, then appropriate chemical composition tests are needed to determine the carbon equivalent value (CEV). The welds should be designed using the same methods for new steel. If welded connections are to be reused, SCI P427 recommends checking the strength of the weld, which can also be assumed to equal the strength of the base material. Careful inspection and testing of the welds is also recommended.

For steel produced prior to 1970, refer to SCI P440. An additional guidance note SCI P440 covers reclaimed steel manufactured before 1970. It is important to note that steel produced prior to 1970 was subject to different standards than modern steel. Additional testing requirements and additional changes to the design procedure are detailed in SCI P440.

The French Professional Recommendation for the reuse of structural steel elements is similar to P427.
However, it excludes coverage of stainless steel and weathering steel.

FURTHER CONSIDERATIONS

The design working life will depend on the reconditioning of the reclaimed steel. Reclaimed steel sections have had a previous service life and may therefore be damaged and/or corroded. Any reuse will be subject to thorough visual inspection and survey. Reconditioning is also expected, including removal of existing coating and corrosion layers, and cleaning. Welds are particularly at risk of fatigue damage.

Steel not previously subjected to fatigue:
Once all damage has been removed or repaired, the design life can be defined in accordance with the same criteria as new steel. Steel properties do not deteriorate over time and therefore the steel can be considered in the same way as new. Corrosion protection measures will be detailed similarly to new steel.

Steel previously subjected to fatigue:
Fatigue can cause microcracks in the steel structure. These cracks grow as the number of stress cycles progresses and fatigue therefore has a significant influence on the design life. The remaining fatigue life of the reclaimed elements will need to be assessed. This will indicate the design life for the recipient structure, provided that it will be subject to no more fatigue. However, if the recipient structure is to be subject to fatigue, extreme care is needed when carrying out the fatigue assessments (previous and future) and the design life is likely to be significantly reduced.

Sufficient allowance for testing and project iterations should be included in the programme. With appropriate planning, collaboration and procurement, using reclaimed steel should not have a negative impact on programme. If the designer reviews stock levels and selects commonly available components, the risk is reduced. Designers can also specify a range of sizes and grades, and can even allow for new components to be used, all of which reduces the likelihood of redesign and delays.

For projects that reclaim steel from other assets, the risk to the programme of the new structure depends on the wider project programme, and the demolition date.

Securing the supply of reclaimed steel is key to reducing uncertainty. Repurposed steel is available from a limited number of suppliers including Cleveland Steel and EMR, who are both keen to support projects using reclaimed steel. Their stock will be made known on request. Some sections are more consistently available than others. Consideration should be given to early procurement and vesting in order to reduce uncertainty and risk.

Reclaimed steel is cheaper than new steel but an allowance for testing and procurement should be included in the budget. Scrap steel is typically £300 per tonne cheaper than new steel[1], suggesting that there is a sufficient price difference to cover the additional testing that may need to be completed on the reclaimed steel sections.

For reclaimed steel, the additional costs associated with careful deconstruction should also be considered. The location of the asset being demolished may have a significant impact on the cost viability of reusing sections.

> *Many sites in city centres will require carefully controlled demolition procedures, with only a small additional cost being required to enable sections to be recovered. In this instance, using reclaimed steel is likely to be cost-effective.*

1. Institution of Structural Engineers - Circular economy and reuse: guidance for designers

IDEAL OPPORTUNITIES FOR REUSE

Using reclaimed steel for road and rail bridges is currently not covered by SCI P427 and PD CEN/TS 1090-201 due to fatigue restrictions.

However, reclaimed steel can be used for most footbridges. It could also be used in road and rail bridges for non-fatigue critical components: for example, foundations, elements in piers and other ancillary components such as handrails and gantries.

Care should be taken when using reclaimed steel for safety-critical components such as vehicle restraint systems, as their design is often subject to approvals with crash tests.

> *Currently, reclaimed steel can be used for structural purposes only on footbridges. However, it is worth considering it for architectural elements such as handrails or parapets, or non-fatigue sensitive elements, on other types of bridges.*

Lower Thames Crossing footbridge competition - shortlisted: Useful Studio and Expedition Engineering. The truss is made of reclaimed steel elements.

03

CONCLUSIONS

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MAIN TAKEAWAYS

Discussions with key stakeholders from the bridge construction industry (clients, designers, fabricators and policy-makers) have confirmed the growing interest in the circular economy for bridges. The main drivers are the reduction of carbon impact and a desire to explore alternative designs.

Current guidance on the reuse of structural steel provides a useful framework for bridges, with the limitations detailed in the previous sections.

This report responds to the need for more information, advocating for knowledge-sharing and skills upgrade to better understand how to deal with existing structures in general.

1

Reuse is a viable alternative to recycling.

2

There are three types of reuse.

3

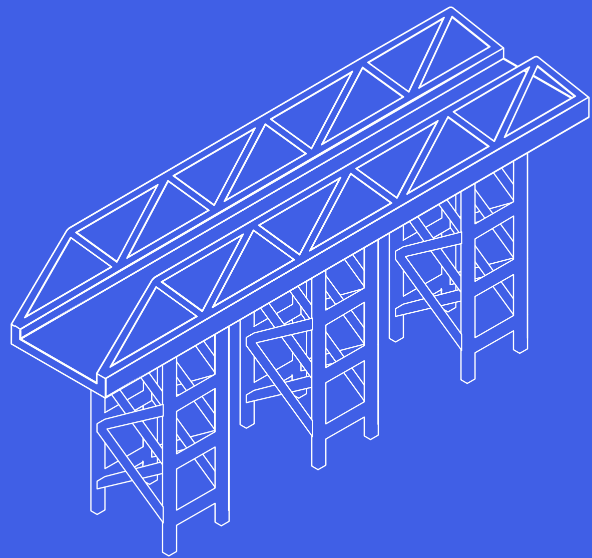
The design and construction process should be resource-led.

4

Existing guidance on steel reuse is applicable for bridges.

5

Footbridges are the most likely recipients for reused steel.



MAIN TAKEAWAYS

1. Reuse is a viable alternative to recycling.
The production of 'green steel', using recycled steel and fossil-free energy, is an area that is developing rapidly. As a result, scrap steel is becoming a valuable resource, and efforts to reuse need to be justified to compete with the easy recycling solution. It is, however, acknowledged that the climate-change crisis will not be overcome solely through the use of new technologies, however green they may be. Moderation and low-tech solutions will also be required to decrease the demand for energy. Reuse options are part of this strategy: valuing the existing, with minimum post-processing.

2. There are three types of reuse

- Reuse of a whole span or large sections of a steel bridge, with some logistical challenges if a relocation is needed.
- Repurposed steel, targeting new steel left over from other industries, which is perfectly adequate for the construction industry but in need of recertification.
- Reclaimed steel from existing structures with a previous life, which needs to be carefully assessed before being reused.

3. The design and construction process should be resource-led.
In all types of reuse, the design and construction process will be modified to take into account the additional project loops. It is crucial to first assess the availability and the condition of existing steel elements. In addition, strong support and clear signals from clients are essential to unlocking initial implementations. Finally, sharing knowledge and lessons learned will help demystify and improve the process.

4. Existing guidance on steel reuse is applicable for bridges.
In the UK, the two main guidance documents for reference when designing with reused steel are the SCI P427 *Structural steel reuse: assessment, testing and design principles guide* and the recently published PD CEN/TS 1090-201:2024 *Execution of steel structures and aluminium structures. Reuse of structural steel*. Both of them apply restrictions to steel subject to fatigue. However, the documents are relevant for bridges and should be the starting point for any bridge project using reused steel.

> *In a resource-led design and construction process, all stakeholders must be more aware of execution constraints and material testing requirements.*

5. Out of bridge types, footbridges are the most likely recipients for reused steel.
This report highlights implementation restrictions in SCI P427 and PD CEN/TS 1090-201, which indicate that footbridges are the most likely source and recipient for reused steel, due to their non-sensitivity to fatigue.

DESIGNING FOR FUTURE REUSE

Due to the usual requirement for 120-year design life, there is limited emphasis on bridge design to ease future reuse or material reclamation. However, a few simple changes in the way we currently design could help future reuse.

Marking or digital identification of all steel components. Marking the material grade and key properties of all structural steel components will significantly reduce, and potentially eliminate, the testing required for a future reclamation project. The reduced need for testing also reduces the associated costs and risks, as designers will be able to work with accurate information. Other forms of marking steelwork include soft stamps and low-stress stamps, as well as more novel techniques such as QR codes and microchips.

The AVA footbridge, an example of a modular footbridge.

Accurate drawings and BIM models.
Having accurate data dramatically reduces the challenges associated with reusing a span or bridge component. The records may be sufficient to eliminate the need for testing and BIM models and drawings reduce the uncertainty relating to material quantities and sizes available.

Modular design and design for deconstruction.
Modular design facilitates future reuse as components can be separated easily and reassembled in a different configuration. The ability to break an existing asset down into short, independently stable elements also facilitates transport and relocation.

Fatigue monitoring.
For railway and road bridges, fatigue-monitoring technology may help designers justify reusing the bridge for an alternative purpose and also aid the maintenance and monitoring of the asset during its original life. Methods for monitoring fatigue include devices such as CrackFirst™.

Understanding weathering steel and pitting risks.
Today, many bridge assets are constructed from weathering steel due to the reduced maintenance requirements. A particular challenge associated with weathering steel is the development of fatigue cracks at pitting locations. Typically, fatigue cracks develop in zones that can be predicted by the designer and inspections for fatigue cracks focus on these areas. However, pitting can cause fatigue cracks to develop in the parent material in unpredictable locations. These cracks can be very challenging to spot and it is therefore not advisable to reuse a weathering steel structure or component that has been subjected to fatigue without significant inspection and assessment.

WHAT IS A CIRCULAR (FOOT)BRIDGE OF THE NEAR FUTURE?

On the basis that bridges can be considered for reuse, whether as donor or recipient, designers are encouraged to think differently, to adapt current bridge typologies and innovate.

AI generated images of bridges fabricated from reused steel - we can do better!

Reuse of a span
Where an existing span is to be reused and/or relocated, the overall form and dimensions will remain the same and the design should therefore focus on strategic and light modifications. Designers' work will primarily focus on assessment, necessary repairs, foundations and finishes. Additionally, the client should be prepared to adapt the brief and potentially deviate to usual norms.

Repurposed and reclaimed steel
Matching current design needs with the availability of salvaged steel can be challenging. However, truss bridges are well-suited for reclaimed and repurposed steel, as truss elements are typically short and can easily accommodate reclaimed pieces.

The reconditioning process usually involves removing connections, making it simple to adjust the elements to the required length.

Beam bridges using large UBs from buildings can be adapted for shorter spans, with 10-12m-long UBs available in the reclaimed market. These elements are also suitable for access ramps, typically supported by regular columns.

Repurposed gas pipes are ideal for structures with masts, such as suspension or cable-stayed bridges.

Additionally, reclaimed steel can be used in non-structural components of bridges, such as parapets, which can account for up to 20% of the steel tonnage.

NEXT STEPS

This report serves as an introductory exploration, aiming to provide a comprehensive perspective on a relatively under-appreciated subject: reused steel for bridges. The interviewees have expressed a high level of engagement with this topic. Consequently, we recommend leveraging the industry's interest with the following next steps:

Developing a business case

Current information on scrap steel prices, new steel prices, and anticipated testing costs indicates that reusing steel is economically viable and may offer economic benefits. However, further research is needed to explore the full economic business case.

While testing costs can be estimated, reconditioning costs are more difficult to quantify. The impact of removing finishes, straightening components, and other fabrication processes needs to be better understood.

Collecting data from both the building sector and the bridge industry will be crucial in determining the true costs of steel reuse.

Collation of case studies

As with any innovation or deviation from the norm, the industry may be slow to adapt. Case studies and data sharing are essential to encourage clients, designers, and fabricators to explore reuse.

We have gathered a range of case studies in this report to demonstrate that reuse can be highly effective and successful. However, more case studies and knowledge sharing are needed. First-hand evidence is one of the most powerful ways to show the viability of reuse.

It is therefore proposed that a case study collection exercise be conducted to gather additional valuable data, helping to demonstrate the benefits and feasibility of reused steel. Sharing lessons learned will also support future design teams.

UK bridge database

One of the biggest challenges in the circular economy is connecting available resources with projects seeking to use reclaimed elements.

Creating a database of deconstructed bridges, those in storage, or those scheduled for future demolition could support a more circular economy. Several international databases, such as the Nationale Bruggenbank in the Netherlands[1], and Historic Bridges in the USA, have already been established. These platforms provide key details about bridges, allowing users to assess their suitability for reuse in new projects. A similar database should be developed for assets in the UK to support this effort.

Publicity and education

While reuse becomes common in the building sector, it remains unusual in the bridge industry, with many misconceptions surrounding its application for both buildings and bridges.

This report marks the beginning of an important effort to raise awareness and educate the construction sector on the key challenges of reuse and how to overcome them.

Education, guidance, and training will be crucial to ensuring the successful implementation of reuse projects and making them the standard practice rather than the exception.

1. Nationale Bruggenbank (National Bridge Bank)

04

TECHNICAL ADDENDA

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SUMMARY OF GUIDANCE DOCUMENTS

This report is based on the review of existing guidance and expert interviews. The main reference documents are listed in the table below, with a brief summary and an indication of the level of coverage for bridges.

The full content of these reference documents has not been reproduced here. Please refer to the published documents for complete coverage and guidance.

Ref	Document name	Scope	Coverage of steel reuse in bridges
1	Circular economy and reuse guidance for designers (IStructE)	– Review of circular economy principles and their application to the built environment. – Guidance on building retrofit and use of reclaimed steel in buildings with several case studies. – Points to SCI 427 and its supplement SCI P440 as the industry standard for assessing and qualifying steel for reuse to be compliant with BS EN 1090.	– No coverage of steel reuse in bridges. – The guidance does not extrapolate findings to bridges, nor does it restrict steel reuse to bridges.
2	Structural Steel Reuse: Assessment, Testing and Design Principles (SCI P427)	– A guidance document on assessing and classifying steel for reuse. Includes testing methods. – Recommends different testing protocols based on the recipient structure's consequence class. – Gives design recommendations when reusing steel, which include modified buckling and sectional resistance partial factors.	– Does not recommend reuse of steel that was previously subjected to fatigue (e.g. from road or rail bridges). – Does not recommend use of reclaimed steel in structures to be subject to fatigue (e.g. road and rail bridges). – Precludes the use of steel that has been subject to fire.
3	Reuse of pre-1970 steelwork - supplement to P427 (SCI P440)	– A supplement to SCI P427 covering steel produced between 1932 and 1970. – Design recommendations when reusing steel including modified material partial factors, and modified formulations for compression and lateral torsional buckling resistance. – Cautions on the variable chemical composition of pre-1970 steel which affects the ability to produce defect-free welds.	– Same as SCI P427.
4	PD CEN/TS 1090-201:2024 Execution of steel structures and aluminium structures. Reuse of structural steel	– A technical specification for assessing and classifying steel for reuse. Includes testing methods. – Recommends different testing protocols based on the steel's provenance, year of manufacture, and available documentation. – Provides informative guidance on assessing corrosion and fire protection systems, and connections. – Requirements are well aligned with those detailed in SCI P427	– Does not recommend reuse of steel in structures to be subjected to fatigue (e.g. road and rail bridges). – Allows reuse of steel previously subjected to fatigue if its future use will not involve fatigue, i.e. allows reclamation from bridges (different from SCI P427).
5	Reuse of structural steel elements (*Réemploi d'éléments structuraux en acier - Recommendations professionelles*) Notre librairie | CTICM	– A guidance document on assessing and classifying steel for reuse. – Recommends testing protocols, but limits their use to Execution Class 1 and 2 structures unless the donor structure was constructed to Execution Class 3. – Details requirements for deconstruction.	– Allows reuse of steel previously subjected to fatigue if its future use will not involve fatigue, i.e. allows reclamation from bridges (different from SCI P427). – Excludes coverage of stainless steel and weathering steel.
6	PD CEN/TS 17440:2020 Assessment and retrofitting of existing structures	– A technical specification that provides amended provisions to BS EN 1990 so that its design principles can be applicable to the assessment of existing structures and elements. – Provides general guidance on the assessment process, covering surveys, modelling, and verifications.	– Does not specifically address bridges but the UK NA points to the Design Manual for Roads and Bridges, which includes CS 456.
7	CS 456: The assessment of steel highway bridges and structures	– A Highways England document, which provide requirements and methods for assessing existing steel structures and structural elements on motorways and other trunk roads. – Applies to structures designed using BS 5400-3, BS 5400-10 and other older standards.	– Covers assessment of existing bridges which can qualify, reuse or inform strengthening and retrofitting. – Does not apply to bridges designed to BS EN 1993-2.

Note: The use of reused products in structural applications is allowed within the European regulatory framework. Guidance documents 2, 3, 4, and 5 are based on BS EN 1090 which lists the essential properties that must be defined for products not covered by European standards. Provision of these properties should enable CE marking of fabrications made using reclaimed and repurposed steel.

SCI P427 SUMMARY AND REVIEW

Scope

SCI P427 *Structural Steel Reuse: Assessment, Testing and Design Principles* includes:

- guidance on how to CE mark reclaimed structural steelwork
- design recommendations
- guidance on the assessment of reclaimed steelwork for reuse
- information on fabrication issues.

Applicability to bridges

The guidance was primarily written for buildings but doesn't exclude bridges. However, some restrictions relating to its application limits its use for road and railway bridges. A simplified interpretation of the restrictions relating to fatigue indicates that reclaimed steel cannot be used in road or rail bridges, and it cannot be sourced from road or rail bridges. However, one could assess the remaining fatigue life of an existing bridge and take a view on the suitability for a new structure. Part of the bridges' family but not subject to fatigue, footbridges can be designed and fabricated following SCI P247.

Testing requirements

SCI P427 provides testing guidance to characterise the material properties required by the European standards (BS EN 1090-1 and BS EN 1090-2) for the execution of steel structures. Provision of these material properties is crucial for mitigating the absence of CE/UK marking of the reclaimed elements and for enabling the CE/UK marking of the assembled steelwork by a certified fabricator. The protocol's testing guidance can also be applied to steel manufactured to an alternative standard (e.g. for the oil and gas industries) to qualify it for structural use, as in the case of the Tan House footbridge.

A key parameter for defining the extent of testing is the consequence class. For reclaimed steel to be used in CC3 structures, the number of destructive tests required is higher, in order to achieve greater reliability. Bridges are typically Execution Class 3 and CC3 and therefore typically require the more testing on the reused components. If appropriate the testing could be reduced by specifying a lower execution class.

SCI P427 Design scope

Steel that can be reclaimed	Structures in which reclaimed steel cannot be used
Steel erected after 1970 (SCI P440 extends the SCI guidance to pre-1970 steel)	Subject to fatigue
Steel not subjected to fatigue (e.g. reclaimed from bridges)	Plastically analysed structures that rely on the formation of plastic hinges (no plastic global analysis)
Steel not subjected to significant strains (e.g. plastic hinges)	Structures subject to seismic loading, where the steel is expected to provide resistance to seismic action
Steel without loss of section due to corrosion (5% loss is significant)	
Steel not exposed to fire	
No spliced or built-up members (unless welds are tested)	
Steels that don't meet the geometric tolerances in BS EN 1090-2	

Note: SCI P427 only covers steel produced after 1970 as it meets the assumed material properties used in the development of Eurocodes. Its supplement, SCI P440, provides the amended guidance for steel produced between 1932 and 1970.

Our opinion:

The SCI P427 protocol and its supplement SCI P440 are the current best practice in the assessment and testing of reclaimed steel for reuse in structures. The restriction on fatigue calls for engineers to better understand this critical behaviour under cyclic loading before designing with reclaimed steel elements. Ideally, we would like the certification process to be clearer, to better support fabricators in how to certify a structure when the mill certificates cannot be provided.

PD CEN/TS 1090-201:2024 SUMMARY AND REVIEW

Scope

PD CEN/TS 1090-201:2024 *Execution of steel structures and aluminium structures. Reuse of structural steel* is a normative guidance document and follows the same general principles as SCI P427. It covers:

- information on the deconstruction of existing structures
- assessment of reclaimed structural components
- the testing regime
- fabrication challenges.

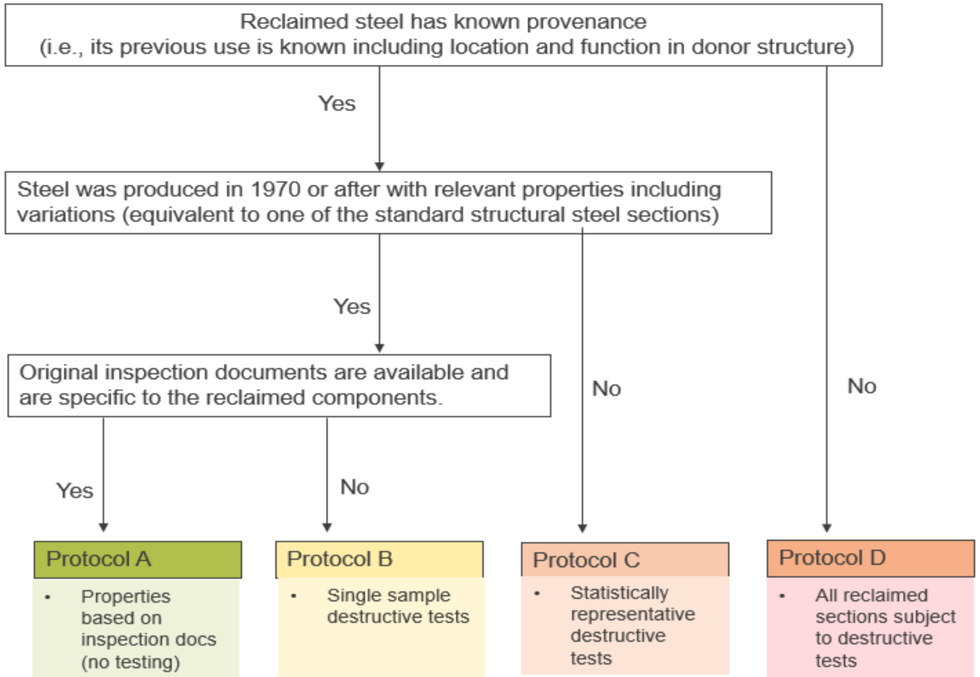
It defines a reusability and quality assessment for reclaimed steel, enabling a choice of testing protocol.

Applicability to bridges

The guidance was primarily written for buildings but doesn't exclude bridges. The restriction on fatigue is different from SCI P427: it prohibits the use of reclaimed steel for future structures subject to fatigue **but** authorises the reuse of steel previously subject to fatigue. This means that an old road or rail bridge could be dismantled, with elements being reused for the fabrication of a new footbridge (with the appropriate inspections, tests and certifications being in place).

Testing requirements

The list of material properties to be specified is compliant with the requirements in BS EN 1090-2. The test unit (up to 20,000 tonnes) definition is also similar to SCI P427. However, the extent of testing depends on the level of information available regarding material properties and previous usage (see flow chart to the right).



PD CEN/TS 1090-201:2024 flow chart for choice of testing protocol.

Our opinion:

PD CEN/TS 1090-201:2024 is a useful guidance document to complement SCI P427. However, it should be used together with additional knowledge of the wider context regarding the challenges of reclaimed steel, particularly for structures subject to fatigue. Further clarification on how fabricators should approach the certification process for elements that do not have mill certificates is required.

MATERIAL TESTING SUMMARY AND REVIEW

New versus reclaimed steel

Conventionally, steel bridge design relies on the selection of element sizes and material properties from a list of nationally and internationally accepted product standards. Global steel manufacturers produce steel, and guarantee that the dimensional tolerances and material properties are compliant with the relevant standards. In this way, the supply chain and design requirements are consistent and appropriately documented. In contrast, when the design philosophy is based on reuse of steel, the process starts with the identification of steelwork that can be salvaged for reuse. At this stage, it is likely that the dimensional tolerances and material properties are all unknown. It follows that the process of testing must be sufficiently robust so that the properties of the steel can be reliably determined and characterised. SCI P427 and PD CEN/TS 1090-201:2024 provide a protocol for structural reuse in buildings. This protocol is also considered a reasonable starting point for the reuse of steel in bridges, but there are several issues that will require more detailed consideration in the case of reuse for steel bridges.

Justifications for properties of materials

Table 1 of BS EN 1090-1 stipulates that for all structural steel grades >S275, the steel shall be issued with a type 3.1 inspection document in accordance with BS EN 10204. New steel will come with this mill certificate, which cannot be supplied for reclaimed steel. In order to comply with this requirement, designers and fabricators should refer to BS EN 1090-2, which allows for the properties to be defined by a testing regime. It then becomes critical that the project specifications explicitly cover this topic to avoid future blockages in the certifications.

UK or CE marking

SCI P427 and PD CEN/TS 1090-201:2024 set out a protocol for the fabricated steelwork to be CE marked following the requirements of BS EN 1090-1 and BS EN 1090-2, in the absence of BS EN 10204 Type 3.1 mill certificate. The responsibility for the use of reclaimed steel then falls onto the designer, who must specify appropriately the properties to be declared, and the steelwork fabricator, who must ensure the supplier's declaration covers the properties specified by the designer.

Failure to use steel that has been appropriately certified could potentially invoke a non-conformance of the fabricator's certification. Furthermore, for EXC3 and EXC4, BS EN 1090-2 requires that constituent products be fully traceable at all stages. For bridge structures, the absence of such documentation, irrespective of the testing regime, may prove to be a potential significant commercial blockage.

Repurposed steel

Section 2.3 of SCI P427 discusses steel manufactured to an alternative product standard, not encompassed within the constituent product list set out in BS EN 1090-2. The examples given were those manufactured to American, or offshore, manufacturing standards. As such, this relates to new, unused steel which is being repurposed for structural use. An example of where this practice was employed is the London 2012 Olympic stadium, where line-pipe for oil and gas production was repurposed in the design and construction of the stadium.

Assuming that the unused material would be expected to have existing original certification declaring the material properties, it is considered that the protocol set out in SCI P427 in this respect could reasonably be extended to bridge structures. Designers should, however, be mindful of the fracture toughness limitations in BS EN 1993-1-10 and ensure that any repurposed steel meets those performance requirements. Furthermore, in the case of welded line-pipe materials, designers should also consider the performance of any welds from the manufacturing process in their assessment of the fatigue strength of the design.

MATERIAL PROPERTIES TO DECLARE FOR RECLAIMED STEELWORK

Item	Property	Procedure for buildings	Procedure for bridges
A	Strength (yield and tensile)	Determined by destructive and non-destructive tests	As for buildings
B	Elongation	Determined by destructive tests	As for buildings
C	Stress reduction of area requirements (STRA)	Generally not required to be declared	As for buildings
D	Tolerances on dimensions and shape	Based upon dimensional survey	As for buildings
E	Impact strength or toughness	If required, determined by destructive tests Conservative assumption as a default	Bridges are typically subject to low temperature service conditions. The UK National Annex to Eurocode 3 places restrictions on steel sub-grades relative to the minimum service temperature. It follows that impact toughness must be determined by destructive testing and any non-compliant sub-grades excluded.
F	Heat treatment delivery condition	Conservative assumption as the default	As for buildings
G	Through-thickness requirements (Z-quality)	Generally not required to be declared	Consideration should be given to the through-thickness requirements for elements used in plated girders.
H	Limits on internal discontinuities or cracks in zones to be welded	Generally not required to be declared	The presence of internal discontinuities or cracks in zones to be welded should be evaluated. Such discontinuities will potentially have a significant effect on the fatigue life. In practice, the presence of existing flaws will likely preclude the use of the material in a future bridge structure.
In addition, if the steel is to be welded, its weldability shall be declared as follows:			
I	Classification in accordance with materials grouping system defined in CEN ISO/TR 15608, or	Not applicable for reclaimed steelwork	Attribution of materials group will potentially minimise the number of new welding procedures that are required.
J	A maximum limit for the carbon equivalent of the steel, or	Maximum to be declared from manufacturer's test certificate	Where this is not known, item K is perhaps a more reliable approach, given that any one batch may represent multiple different steel melts.
K	A declaration of its chemical composition in sufficient detail for its carbon equivalent to be calculated.	Determined by non-destructive and destructive tests	The composition should be determined in sufficient detail to determine the IIW carbon equivalent value. Consideration should also be given to the boron content, which can have a significant detrimental effect on weldability.

Section 3.4 of SCI P427 sets outs the material properties to be declared for reclaimed steelwork. Table 3.1 of the same document provides a summary, which is reproduced above, but with an additional column for discussion in relation to steel bridges.

COMMENTARY ON THE REQUIRED TESTING

This section aims to provide more detail on the scope of the tests, and may be used as background information.

Hardness test

In simple terms, a hardness test determines the ability of a material to resist permanent deformation by penetration of another, harder material. The objective of the hardness testing in SCI P427 protocol is to identify the strength grade of the materials intended for reclamation.

A hardness test can be conducted either in a laboratory or using a portable hardness-measuring device. It should be noted, however, that portable hardness measurements have a lower accuracy and reliability than laboratory tests. The results should therefore only be taken as indicative.

Once the hardness result is obtained, the results can be used in conjunction with accepted correlations which can convert the hardness reading to the yield and tensile strength, from which the steel grade can be generally characterised.

The intention is that every piece of steel proposed for reclamation should be subject to hardness testing to enable elements of the same size and steel grade to be grouped together.

Tensile test

A tensile test establishes the yield strength, ultimate tensile strength, elongation and stress reduction of area (if required).

Impact strength or toughness

The Charpy impact test establishes the material's resistance to brittle fracture, known as the steel sub-grade. It is expressed as the energy (Joules) required to break an impact specimen at a given test temperature. The specimen is 55mm long by 10mm wide by 10mm thick and has a 2mm-deep notch with a 45° angle with a 0.25-radius tip. The impact strength is typically expressed as 27J at the given test temperature. The reported value is the average from three specimens.

The design requirements for the resistance to brittle fracture are set out in BS EN 1993-1-10. These requirements can also be found in PD 6695-1-10. The UK National Application document sets a Charpy impact-test value depending on the and minimum service temperature. For steel bridges, it is likely that the temperature difference is greater than 20°C, and the 'JR' sub-grade will therefore be prohibited. This may be a concern when reusing steel from buildings which are usually 'JR' sub-grade. In such a case, the steel will have to undergo the Charpy impact test to assess its resistance to brittle fracture under more stringent temperature conditions. It is possible that a 'JR' steel passes the J2 test, but this needs to be demonstrated.

Heat treatment delivery condition

Different steelwork construction products (plate, I-sections, hollow sections, etc.) are manufactured and supplied in different supply conditions, which will influence the steel properties and possibly subsequent processing. For example, not only would designers use a different buckling curve for cold-finished structural hollow sections, but in the case of cold-finished Rectangular Hollow Sections (RHS), there are restrictions on welding in cold-formed zones. When assessing steel for possible reclamation, consideration should therefore be given to the supply condition.

Through-thickness testing

Through-thickness testing is required when there is a perceived risk of lamellar tearing during subsequent fabrication. The risk of lamellar tearing can be assessed following the principles set out in BS EN 1993-1-10. The through-thickness test measures the short-transverse reduction of area of the test sample The greater the short-transverse reduction of area, the more resistant the steel is against lamellar tearing. To undertake this test it may be necessary to weld on extension pieces, depending on the material thickness. This is generally done using electron-beam welding. As such, the testing procedure is more involved and consequently more expensive than a conventional tensile test.

COMMENTARY ON THE REQUIRED TESTING

Consideration may also be given to undertaking non-destructive lamination checks. This could be achieved using ultrasonic inspection.

Limits on internal or cracks in zones to be welded
The existence of flaws in the structure can have a significant detrimental impact on the fatigue life, hence the requirement to inspect, qualify and quantify the impact of any cracks, with the intention of repairing them.

Weldability
Where welded connections are envisaged for the future use of the steel, it is essential to quantify the weldability of the stock steel. It is anticipated that fabricators involved with bridge structures would want details of the actual steel carbon equivalent value rather than relying upon assumptions.

Note: The extent of testing is likely to be established on a project-by-project basis, taking into consideration both the information available regarding the past use and future use of the steel.

Material-testing costs
The following table sets out prices obtained from a commercial test-house and provides an indication of costs associated with material testing. Unless otherwise indicated, the price is for a one-off test. Economies of scale would be expected when testing batches of steelwork.

Timescales for conducting the testing will depend on quantities, but it is anticipated that results could be released progressively as results become available. This can be negotiated at the time of enquiry. Typically, a limited test programme might be expected to be reported back within a period of, say, two working weeks.

Material test	Approximate cost
Tensile testing	£110 per sample
Charpy impact testing	£225 per set of three test specimens
Chemical analysis	£110 per sample hardness testing (portable hardness testing)
Hardness testing (portable hardness testing)	£750 per day, plus expenses
Micro-section to determine supply condition	£150 per sample with a microsection and hardness survey
Through-thickness testing	£225 per sample (this assumes a minimum of 10 samples)

IMPORTANCE OF EXECUTION CLASS

Definition and relation to consequence class
To be compliant with the Eurocodes, structures must be built within appropriate tolerances and have an appropriate level of quality management. Execution classes specify requirements for the level of quality control during construction. They can be specified for the works as a whole or for an individual component. The Execution Class is specified by the design engineer and is dependent on the Consequence Class (CC), which defines levels of consequences for loss of human life, or economic, social and environmental impacts.

Why are bridges typically EXC3?
Annex B of BS EN 1990 gives indicative consequence classes for different types of structures. It is common practice to consider all bridges as CC3 structures and therefore EXC3. For the execution of steel structures, the requirements in each execution class (EXC1, EXC2 and EXC3) are detailed in BS EN 1090-2 and are increasingly onerous. The Execution Class is also described in the structural design requirements, as detailed in the table NA.4 in the UK NA to BS EN 1993. This table states that:

- all structures built using higher grades of steel (greater than S460) are to be EXC3
- all structures subject to fatigue are to be EXC3
- all structures subject to seismic loads are to EXC3
- all CC3 structures are to be EXC3.

The impact of the consequence class
The SCI P427 covers all CC structures and describes different testing regimes for each class. SCI P427 prescribes non-destructive testing for all reclaimed sections, in addition to statistical testing to determine mechanical properties if reclaimed steel is to be used in a CC3 structure. Statistical testing refers to a minimum of three destructive tests per test group, and an assessment of the characteristic values of the mechanical properties according to BS EN 1990.

Definition of consequence classes (Annex B, BS EN 1990)

	Consequence*	Application
CC3	High consequences very great	Grandstands, public buildings
CC2	Medium consequences considerable	Residential and office buildings, public buildings
CC1	Low consequences small or negligible	Agricultural buildings (e.g. storage buildings), greenhouses

**Consequence for loss of human life, or economic, social or environmental*

Our opinion:
A review of consequence and execution classes is critical to better frame the level and extent of testing for reclaimed steel. CC2/ECX2 can be specified for footbridges located in more rural environments where a lower consequence class can be justified (and if compliant with other requirements on steel grade, fatigue and seismic loads). The benefit of a CC2 structure is fewer destructive tests (non-statistical) per test group. It is also possible to differentiate members or parts of the structure and define different CC/EXC to refine the testing regime.

UNDERSTANDING FATIGUE

Fatigue design

In the context of steel bridge design, fatigue is the process by which a crack can form and then grow incrementally under repeated or fluctuating loading. Under continued cyclic loading, the fatigue crack will continue to grow to a point where it reaches a critical size when either general yielding occurs, because the net-section stresses exceed the material's tensile properties, or brittle fracture occurs, because the applied stress intensity at the crack tip exceeds the materials fracture toughness for the given service conditions.

The magnitude of the loading required to produce fatigue cracking is typically much less than that needed to break the element in a single load application. Fatigue failures have occurred in as little as a few hundred, and as many as several millions, of load cycles.

Designing for fatigue

The rules for the fatigue design of steel bridges in the UK are set out in BS EN 1993-1-9. For the purposes of design, a range of construction details have been fatigue tested, which in turn has resulted in a family of S-N curves. The construction details, along with the relevant design curve, are presented in the Eurocodes in tabular form, but cover:

- plain members and mechanically fastened joints
- welded built-up sections
- transverse butt welds
- weld attachments and stiffeners
- load-carrying welded joints
- hollow sections
- lattice girder node joints
- orthotropic desks – closed stringers
- orthotropic decks – open stringers
- top flange to web junction of runway beams.

Assessing the fatigue life

Critically, for any reused steel to be used in bridge construction, the fatigue life would inevitably be split between the damage accumulated in its 'first life' and that projected to occur in its 'future life'. If both can be readily quantified it might be argued that this is no different from assessing the future life of a new bridge structure built with new unused steel.

Applicability of SCI P427 and fatigue restrictions

SCI P427 excludes the reuse of steel that has been subject to fatigue loading. In the absence of any traceability and history for the reused steel, this is considered a sensible and an appropriately conservative position to adopt. It will be evident that any structure that is subject to cyclic loading will be accumulating fatigue damage and, as such, it will inevitably have consumed a proportion of its fatigue life. In the absence of detailed knowledge of the stress-history experienced by the steel from a previous life, it is impossible to assess the potential consequence that it may or may not have on any potential future use.

The same may be said for any steel that is put forward for reuse. A lack of traceability and history creates an element of uncertainty and an inability to assess the potential consequences. However, where the history of the existing steel is known and future fatigue loading can be discounted, it might be argued that the broad prohibition of reused steel may be considered overly conservative.

Designer's responsibilities

The bridge designer has the responsibility to assess the fatigue life of the steel structure. Normally, bridges are designed with a 120-year design life. It is considered that there are foreseeable circumstances, in which the bridge may be subject to cyclic loading, but that the impact of fatigue is non-critical. For example, footbridges will unquestionably experience cyclic loading, but the loading is such that it is unlikely to present a significant concern over the life of the structure. Under such circumstances, the bridge designer may be prepared to consider the adoption of reused steel that they might not otherwise do.

UNDERSTANDING FATIGUE

Monitoring fatigue

Fatigue damage ultimately manifests itself in the form of cracking. It follows that some degree of monitoring in combination with targeted non-destructive testing (NDT) may be used to assess the condition of a structure at the time of inspection. As designers, it is important to reflect upon the accuracy and reliability of NDT. BS 7910, Annex T provides guidance on the use of NDT in terms of individual techniques, their limitations and accuracy. Devices such as CrackFirst™ (a fatigue damage sensor) can be used to monitor the structural toe of welded steel structures. These can only be used on new structures.

Once fatigue cracking has been identified, the use of conventional S-N-based design principles is no longer an appropriate method for assessing the consequences. At this point, unless the damage is repaired, it would be necessary to assess the future fatigue life following fracture mechanics principles as set out in BS 7910, which discusses methods for assessing the acceptability of weld flaws, or similar.

Existing steel bridges: a similar case to reuse

Whilst this report is largely concerned with the reuse of steel, which is, in turn, used to fabricate a new structure, it might be argued that the rehabilitation of existing structures that are exhibiting fatigue damage in the form of cracking, are equally examples of steel reuse. Repair and reuse, as opposed to replace.

This approach has been used on existing bridge structures that have developed fatigue cracking. Repair techniques have been developed and the fatigue implications assessed. This approach is quite different from reusing steel from an unknown source. It is assumed that the material grades and sub-grades are generally well understood. However, designers may still wish to undertake a limited assessment of existing materials during the design development stage. For example, if the remedial measures require new materials to be welded to the existing materials, it may be prudent to assess the weldability.

A similar approach might be considered where an existing span or structure could be moved to an entirely new location. Assuming there is reasonable confidence in the condition and prior stress-history of an existing structure, it should be feasible to undertake a cumulative damage assessment considering the ‘first life’ and the future use.

Increased risk of fatigue failure in corroded areas

In any assessment of existing steel or structure, the condition of the steel will influence the potential to reuse it. For steel bridge design, the primary concern relates to fatigue and the impact that the reuse of steel may have on the fatigue life going forwards. It should, however, equally consider the condition of the structure in terms of any corrosion present. Corrosion may affect the fatigue strength in one of two ways:

1. Corrosion pits on the steel surface can significantly impact the fatigue strength because of the stress concentration effect associated with the corrosion damage.

2. The corrosive environment can cause a faster crack growth and/or crack growth at a lower tension level than in dry air.

This would be equally applicable to weathering steels, which are typically designed with a corrosion allowance relative to the environmental conditions in which the structure is located. It follows that a conservative approach might be the prohibition of materials exhibiting corrosion damage.

PRIMARY REFERENCES

Number	Document name	
1	BS EN 1990:2023	Eurocode: Basis of structural and geotechnical design.
2	BS EN 1993-1-1:2022	Eurocode 3: Design of steel structures - General rules and rules for buildings.
3	BS EN 1993-2:2006	Eurocode 3: Design of steel structures - Steel bridges.
4	BS EN 1993-1-9:2005	Eurocode 3: Design of steel structures - Fatigue.
5	BS EN 1993-1-10:2005	Eurocode 3. Design of steel structures - Material toughness and through-thickness properties.
6	BS EN 1090-1:2009+A1:2011	Execution of steel structures and aluminium structures - Requirements for conformity assessment of structural components.
7	BS EN 1090-2:2018+A1:2024	Execution of steel structures and aluminium structures - Technical requirements for steel structures.
8	BS EN 10204:2004	Metallic products. Types of inspection documents.
9	CEN ISO/TR 15608:2017	Welding - Guidelines for a metallic materials grouping system.
10	PD 6695-1-10:2009	Recommendations for the design of structures to BS EN 1993-1-10.
11	PD 6705-2:2020	Structural use of steel and aluminium - Execution of steel bridges conforming to BS EN 1090-2. Guide
12	BS 15:1948	Structural steel.
13	BS 4360:1990	Specification for weldable structural steels.
14	BS 5400-3:2000	Steel, concrete and composite bridges - Code of practice for design of steel bridges.
15	BS 5400-10:1980	Steel, concrete and composite bridges - Code of practice for fatigue.
16	BS 7910:2019	Guide to methods for assessing the acceptability of flaws in metallic structures.
17	SCI P419 - 2017	Brittle fracture: selection of steel sub-grade to BS EN 1993-1-10.
18	SCI P382 - 2012	Steel Bridge Group: Model project specification for the execution of steelwork in bridge structures.
19	PAS 2080:2023	Carbon management in infrastructure and built environment.
20	DMRB	Design Manual for Roads and Bridges.

END

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