Design Manual for Roads and Bridges

Highway Structures & Bridges
Design

CD 362
Enclosure of bridges

(formerly BD 67/96, BA 67/96)

Revision 1

Summary
This document describes the requirements for the implementation of an enclosure as a means of bridge protection. This document gives the methods of evaluating and the design requirements.

Application by Overseeing Organisations
Any specific requirements for Overseeing Organisations alternative or supplementary to those given in this document are given in National Application Annexes to this document.

Feedback and Enquiries
Users of this document are encouraged to raise any enquiries and/or provide feedback on the content and usage of this document to the dedicated Highways England team. The email address for all enquiries and feedback is: Standards_Enquiries@highwaysengland.co.uk

This is a controlled document.

Contents

Release notes

Version	Date	Details of amendments
1	Mar 2020	Revision 1 (March 2020) Update of references only. Revision 0 (May 2019) CD 362 replaces BD 67/96. This full document has been re-written to make it compliant with the new Highways England drafting rules. It also includes relevant information from BA 67/96 which is withdrawn.

Foreword

Publishing information

This document is published by Highways England.

This document supersedes BD 67/96 and BA 67/96, which are withdrawn.

Contractual and legal considerations

This document forms part of the works specification. It does not purport to include all the necessary provisions of a contract. Users are responsible for applying all appropriate documents applicable to their contract.

Introduction

Background

This document contains the requirements for the evaluation and design of a bridge enclosure to form a protection against corrosion.

The traditional method for the protection of bridge superstructures against corrosion is a protective coating, particularly in the case of steel. Periodic maintenance of the protective coating is necessary which is costly and frequently results in traffic delays.

In 1980, the Transport Research Laboratory (TRL) put forward the concept that steel structures which are enclosed against contaminants in the environment, could be rendered maintenance free for periods of at least thirty years.

Trials on bridges at Iden (1979), Exceat (1981) and Queenhill (1984) confirmed the principle of enclosure to protect steel bridges against corrosion. Hence an alternative to the traditional method of providing long-life multi-coat systems to bridge steelwork is to provide an enclosure. The research reports, TRL SR621 [Ref 1.I], TRL RR293 [Ref 2.I] and TRL RR83 [Ref 3.I] discuss the principle of bridge enclosures in detail and provide further information on the concept.

An enclosure around bridge deck support steelwork provides an additional method of protecting the steel against corrosion. An environment of low corrosivity is produced which reduces the rate of breakdown of the protective coatings to the steelwork. A less costly initial protection system can be used within an enclosure on a new bridge. The reduced rate of corrosion of the steel and a reduced requirement for cosmetic repair give greater flexibility to maintenance strategies for bridges with enclosures.

An enclosure also provides access for inspection and maintenance of the bridge.

Assumptions made in the preparation of this document

The assumptions made in GG 101 [Ref 12.N] apply to this document.

References in this document to BS EN document include their UK National Annexes and all relevant Published Documents (PDs).

Mutual Recognition

Where there is a requirement in this document for compliance with any part of a "British Standard" or other technical specification, that requirement may be met by compliance with the Mutual Recognition clause in GG 101 [Ref 12.N].

Abbreviations

Abbreviations

Abbreviation	Definition
TAA	Technical Approval Authority
TRL	Transport Research Laboratory

Terms and definitions

Terms

Term	Definition
Category A	Area designation within the enclosure designed to carry live loading due to inspection and maintenance activities.
Category B	Area designation within the enclosure designed to carry live loading due to inspection activities only.
Category C	Area designation within the enclosure not intended for personnel access (including side panels).
Enclosure	The complete unit which forms a boundary around the primary steelwork of a bridge below deck level enclosing the steelwork in a protective environment.
Enclosure components	Enclosure panels, support members, fixings and fasteners.
Enclosure internals	Access ways, permanent services and equipment and non-structural elements and items such as cabling, service pipes (including contents), lighting and ventilation plant within the enclosure.
Enclosure panels	The structural panels forming the outer shell of an enclosure.
Fasteners	Typically bolts, nuts, washers, rivets, pins and screws.
Fixings	An assembly of fasteners, brackets and other items that are used to attach either an enclosure panel or support member to the structure or an enclosure panel to a support member.
Support member	A member to which the enclosure panel is affixed for support. NOTE: Members can be designed as separate items for individual installation or attached to the enclosure panel during manufacture.
Unconventional materials	Materials whose properties are not given in European Standards, European Technical Approvals, British Standards.

1. Scope

Aspects covered

1.1 The requirements in this document shall apply to the evaluation and design of enclosures of the structural steel elements below deck level of the bridge.

1.2 The requirements in this document shall not apply to the enclosure of elements above deck level.

1.3 The requirements in this document shall apply to enclosures for existing bridges and new bridges.

1.4 The requirements in this document shall only apply to enclosures acting non-compositely with the bridge superstructure.

1.5 The procedures for design approvals by the TAA on behalf of the Overseeing Organisation in accordance with the requirements in CG 300 [Ref 14.N] shall apply.

Implementation

1.6 This document shall be implemented forthwith on all schemes involving the design and installation of bridge enclosures on the Overseeing Organisations' motorway and all-purpose trunk roads according to the implementation requirements of GG 101 [Ref 12.N].

Use of GG 101

1.7 The requirements contained in GG 101 [Ref 12.N] shall be followed in respect of activities covered by this document.

2. Evaluation

General

2.1 The whole life costs of the bridge with and without an enclosure shall be evaluated and compared.

2.2 The following costs of the bridge with an enclosure shall be evaluated for the comparison:

1) the cost of the enclosure itself and its maintenance;
2) any change in the cost of the bridge and associated works as a consequence of attaching the enclosure to it;
3) the cost of permanent access provisions for inspection and maintenance;
4) the costs of using temporary access facilities during inspection and maintenance where it is impractical to provide access facilities within an enclosure;
5) inspection and maintenance costs of the bridge;
6) road user delay costs or railway/waterway possession costs during installation of the enclosure; and,
7) road user delay costs or railway/waterway possession costs during inspection and maintenance of the enclosure and the bridge.

2.3 The following costs of the bridge without an enclosure shall be evaluated for the comparison:

1) the cost of permanent or temporary access provisions for inspection and maintenance;
2) inspection and maintenance costs of the bridge; and,
3) road user delay costs or railway/waterway possession costs during inspection and maintenance of the bridge.

2.3.1 The whole life costs of the bridge with and without an enclosure should be compared on the basis of their present value evaluated for a 40-year appraisal period.

NOTE 1 The appraisal of highway structures considers a 40-year period after which the power of discounting is such that the net present value of subsequent costs has very little effect on a life cycle cost analysis.

NOTE 2 The 40-year period used for appraisal of highway structures significantly reduces the amount of conjecture that could be required for a 120-year appraisal period.

NOTE 3 The 40-year period used for appraisal of highway structures falls within the 25-40 year period that is commonly used when carrying out life cycle costs appraisals of highway pavements.

2.4 Where the whole life cost of the bridge with an enclosure are similar to, or less than that of the bridge without an enclosure, the provision of an enclosure shall be further investigated through a detailed benefits assessment of all the factors which influence the inclusion of an enclosure.

2.5 A general assessment of the benefits of providing an enclosure shall be carried out prior to evaluating detailed life cycle costs.

NOTE Appendix A gives a method for carrying out a general assessment for the application of an enclosure.

Cost of enclosure

2.6 An outline design of the enclosure shall be carried out to obtain an estimate of the cost.

2.6.1 Where previous experience of an enclosure of similar size and form is available, this may be used to assist the estimation of the cost of the enclosure being considered.

Changes in the cost of the bridge

2.7 Where an enclosure is being considered, the change in the cost of the bridge as a consequence of attaching the enclosure shall be quantified by comparing the additional costs to the bridge with the reduction in costs.

2.7.1 Additional costs to the bridge as a consequence of attaching an enclosure should be evaluated for the purpose of comparison from:

1) additional structural material in the bridge required to carry the additional loads (dead, superimposed dead, live and wind loads and transferred impact loads) associated with the enclosure;
2) any strengthening works to an existing bridge to carry the additional loads associated with the enclosure;
3) special details required for the attachment of the enclosure;
4) special measures needed to counter any adverse aerodynamic effect due to the enclosure; and,
5) cost to the bridge and approach roads associated with raising the level of the bridge soffit in order to maintain the accepted minimum headroom clearance below the enclosure.

2.7.2 Reduction in costs to the bridge as a consequence of attaching an enclosure should be evaluated for the purpose of comparison from:

1) a less costly paint system applicable to internal surfaces;
2) a reduction in concrete cover to the reinforcement of an enclosed concrete slab on a composite bridge;
3) the benefits of reduced wind loads where the enclosure improves the aerodynamic characteristics of the bridge;
4) savings associated with the avoidance of the need for special arrangement like access platforms under the bridge; and,
5) savings in formwork and falsework costs where the enclosure can be used to provide either support or access during construction and maintenance.

Inspection and maintenance costs

2.8 Inspection and maintenance costs shall be evaluated for the bridge, with and without an enclosure, and compared over the whole life of the structure.

2.9 Maintenance costs for the main structural elements shall be calculated, with and without enclosure, and compared using documents CD 355 [Ref 16.N].

2.9.1 The comparison of inspection and maintenance costs may be simplified by ignoring the elements of the bridge which are common to both with and without enclosure.

Road user delay costs

2.10 Traffic delays due to lane closure below an overbridge and on the deck of the bridge for access purpose, during inspection and maintenance shall be costed.

2.10.1 Traffic delays caused by lane closure due to plant or temporary access requirements should be included in the delay costs.

2.10.2 Traffic delays due to installation of the enclosure should be included in the delay costs.

2.10.3 Road user delay costs should be evaluated using a methodology agreed with the Overseeing Organisation and discounted using the methods described in document CD 355 [Ref 16.N].

Railway/waterway possessions

2.11 The whole-life cost of railway or waterway possessions for the construction, inspection and maintenance of the bridge, with or without enclosure, shall be evaluated.

2.11.1 The additional costs of working during railway and waterway possessions due to enforced restrictions should be included in the evaluation.

Other safe access requirements

2.12 Whole-life costs for the provision of all other safe access requirements such as safety boats when working on a waterway shall be evaluated for the comparison of costs for the bridge with and without an enclosure.

3. Performance criteria

Durability

3.1 The enclosure shall be designed as a permanent feature of the bridge structure.

3.2 The enclosure together with the components and internals shall have a design life of at least 40 years with a life to first maintenance of at least 20 years.

3.3 The required frequency for maintenance work on the enclosure components and internals shall be the same as, or less than, the required frequency for maintenance work on the enclosed bridge deck support steelwork.

3.4 Items of the enclosure which are designed to require regular replacement, such as seals, shall be designed for ease of access without disruption to traffic.

3.5 Where materials of different electrochemical potential are connected together, either within the enclosure or in attaching the enclosure to the bridge, they shall be isolated to prevent bimetallic corrosion.

3.6 Items of the enclosure which are particularly vulnerable to corrosion due to design detailing or their position shall be identified to ensure that the corrosion protection is as effective as on the surrounding structure.

NOTE 1 The enclosure can cause condensation to form on internal surfaces and collect on its floor, along with dust and debris arising from inspection and maintenance activities.

NOTE 2 The control of corrosion can be achieved by preventing significant air movement. However, the need for safe inspection and maintenance has to be considered.

NOTE 3 Prevention of corrosion by forced ventilation is not viable in a potentially corrosive environment.

3.7 For new steelwork within the enclosure, the minimum corrosion protective system shall be Type II, Table 19/2B in MCHW NG [Ref 13.N], unless environmental conditions mean that a more robust approach is required to meet the Overseeing Organisation's site specific requirements.

3.8 For existing steelwork to be incorporated within an enclosure, the protective coating shall be treated in accordance with the maintenance specification requirements for the site agreed with the Technical Approval Authority (TAA) on behalf of the Overseeing Organisation.

Safety

3.9 The enclosure shall be designed to provide safe access for inspection and maintenance of all parts of the bridge it encloses.

3.10 Ventilation shall be provided during inspection and maintenance activities.

3.10.1 Safety measures should be designed where panels are temporarily removed for ventilation purposes during inspection and maintenance operations.

3.10.2 Provision for ventilation and safe methods for dust and fume extraction during inspection and maintenance should be included in the design.

3.11 Forced ventilation within the enclosure shall be used where natural ventilation is inadequate for dust and fume extraction.

3.12 The enclosure shall be designed to carry live loading according the following functions:

1) category A - areas designed for both inspection and maintenance activities;
2) category B - areas designed for inspection only; and,
3) category C - areas not intended for personnel access (including side panels).

3.13 All the areas for designated live loads category A, B or C shall be:

1) shown on the record/maintenance drawings; and,
2) clearly marked out within the enclosure.

3.14 Emergency access and exit routes within the enclosure shall be designed to category A or B.

3.15 Enclosure access shall be provided for safe entry points and emergency exits for personnel and equipment.

3.15.1 The dimensions of access openings should permit entry and exit for personnel and equipment in an emergency.

3.15.2 Enclosure access should be vandal resistant and fitted with locks which can be released from the inside without the use of a key.

3.15.3 Entry points should be placed so as to give access to all parts of the main superstructure elements without interfering with the traffic.

3.15.4 Access to the enclosure should be from underneath the bridge.

3.16 All entry points and emergency exits shall be designed so that a casualty on a stretcher can be evacuated.

3.17 Notices shall be provided at all entrances stating the safe loads that can be imposed upon the enclosure.

3.18 All walking surfaces within the enclosure shall be non-slip, self-draining and hazard free.

3.19 Permanent access ladders and guardrails shall be provided on access ways at changes in level within the enclosure.

3.20 Emergency routes and exits from within the enclosure shall be indicated by signs.

3.21 Where the enclosure access ways are long or complex, lighting shall be provided.

3.22 Emergency routes and exits shall be provided with emergency lighting of minimum intensity of 0.2 lux.

3.23 Where the operation of mains power boards, valves or other major equipment affect personnel safety, warning notices and signs shall be provided.

Fire safety

3.24 Fire resistance of the enclosure shall be in accordance with the classification of spread of flame - Test Class 2 when tested to BS 476-7 [Ref 10.N].

3.25 Category A or category B areas within the enclosure which are designated to support inspection and maintenance activities shall maintain their structural integrity at the point of fire source for at least 10 minutes when tested to BS 476-21 [Ref 9.N].

3.26 Drainage pipes which pass through the enclosure shall be able to contain burning liquids without leakage at all times.

3.27 In the event of a fire occurring within the enclosure, fire safety provisions shall be such that personnel can safely exit the enclosure and reach a place of safety within 2.5 minutes.

3.28 Where the enclosure is long or has a complex interior, and escape time to a point of safety is increased, an alternative approach shall be investigated to develop a fire safety plan to meet the fire safety requirements.

NOTE *A fire safety plan can be devised to take account of complexities within the enclosure which inhibit escape or cause smoke build up, and advice for this can be sought from specialist fire consultants.*

Enclosure components, supports and fixings

3.29 The enclosure, panels, supports and fixings shall be designed for ease of installation, inspection and replacement.

3.30 Fixings and joints shall be designed to allow for construction tolerances in both the bridge and the enclosure.

3.31 Allowance shall be made within the enclosure supports and fixings for relative movement between enclosure and bridge structure due to live loading of the bridge and enclosure.

3.32 The enclosure and its supports shall be designed to withstand movements of the bridge superstructure, including vibrations of the bridge deck.

3.33 Limits of stress or displacement due to the action of the enclosure supports on the bridge structure shall be detailed and recorded.

3.34 Enclosure supports, such as hangers, shall be designed to be replaceable during service without disruption to traffic.

3.35 Enclosure supports and fixings shall be adjustable to accommodate the requirements of the permanent structure and be designed to facilitate a method of installation which does not overstress the components.

Headroom and accidental damage

3.36 The minimum headroom of a bridge with an enclosure shall be measured to the soffit of the enclosure and as given in document CD 127 [Ref 3.N] with allowance made for the provision of maintenance and future resurfacing of the road below.

3.36.1 Where necessary the headroom provision should be agreed between the TAA for the Overseeing Organisation and any other private or public body whose asset is affected.

3.37 Bridges with enclosures shall be designed to withstand vehicle impact loads, calculated using document BS EN 1991-1-7 [Ref 5.N].

3.38 For existing bridges vehicle impact loading shall be calculated as follows:

1) where the headroom to the soffit of the enclosure is equal to or greater than 5.70 metres, neither the bridge superstructure nor enclosure need be designed to withstand the effects of vehicle impact loads; or,
2) where the headroom to the soffit of the enclosure is less than 5.70 metres, the bridge superstructure is to be assessed only to withstand those effects of vehicle impact loads which are transferred from the enclosure.

3.39 For new bridges, vehicle impact loading shall be calculated as follows:

1) where the headroom to the soffit of the enclosure is equal to or greater than 5.70 metres, neither the bridge superstructure nor enclosure need be designed to withstand those effects of vehicle impact loads;
2) where the bridge superstructure has a headroom equal to or greater than 5.70 metres but the headroom to the soffit of the enclosure is less than 5.70 metres, the bridge is to be designed so that it can withstand those effects of vehicle impact loads which are transferred from the enclosure; or,
3) where the headroom to the soffit of the enclosure and the bridge superstructure are each less than 5.70 metres, the bridge superstructure is to be designed to withstand those effects of direct vehicle impact loads on the bridge superstructure and those loads which are transferred from the enclosure.

3.40 Where the headroom of the enclosure is less than 5.70 metres, the enclosure shall be designed such that:

1) there is no general loss of support due to lateral displacement of the enclosure under impact;
2) local damage in one area does not cause progressive collapse; and,
3) damaged parts of the enclosure are readily identified and replaced.

Clearance within the enclosure

3.41 Internal clearance within the enclosure shall be provided to allow access to all bridge parts requiring inspection and maintenance without removal of enclosure panels.

NOTE *Too small an enclosure can result in areas which are difficult or impossible to maintain.*

3.42 The maximum headroom within the enclosure shall be agreed with the TAA on behalf of the Overseeing Organisation.

3.43 Expansion joints and bearings shall be replaceable while working within the enclosure.

3.44 The enclosure shall be designed to accommodate movement during the jacking procedure required to replace expansion joints and bearings.

3.44.1 Where replacement of expansion joints or bearings is not possible from within the enclosure, a maintenance procedure should be prepared which can include removal of panels in a safe manner with minimum disruption to traffic.

3.44.2 A clear gap of minimum 200mm should be maintained between the enclosure panels and the bridge steelwork soffit.

3.45 Clearance for personnel shall be maintained along the sides of the enclosure for access and maintenance of bridge edge beams.

3.46 Where clearances between steelwork and the enclosure are critical, specialised inspection techniques shall be devised to access confined spaces.

3.47 Additional surface protection shall be applied where access to steelwork within the enclosure is limited.

Inspection and maintenance requirements

3.48 The enclosure shall be designed to facilitate future inspection and maintenance of the bridge and enclosure.

3.49 The enclosure shall be inspected as an integral part of the structure during its design life in accordance with the requirements of CS 450 [Ref 11.N].

3.50 All the records relevant for the execution of inspection and maintenance activities including access provisions shall be captured, stored and updated to ensure effective whole life management in accordance with CG 302 [Ref 1.N].

Services

3.51 Provision shall be made for services within the enclosure for use during inspection and maintenance.

3.51.1 Provision should be made for temporary services within the enclosure where all parts of the enclosure requiring maintenance are accessible using temporary equipment for supply.

3.51.2 Permanent services should be designed within the enclosure where temporary provision is not practical.

3.51.3 Permanent services should be designed to withstand the conditions within the enclosure over the life span of the bridge.

3.51.4 Permanent services should be provided for:

1) electrical power supply and equipment to provide a minimum lighting level of 150 lux within the enclosure;
2) water supply;
3) compressed air supply; and,
4) a protected communication system for use in an emergency where the enclosure size or complexity inhibits personal communication.

NOTE *When not in use, drainage of water supply pipes is generally more effective than lagging and overcomes the need to design the enclosure for pipe failure.*

Enclosure panels

3.52 The enclosure panels shall be resistant to fungal attack, road deicing salts and airborne chemical pollutants.

3.53 Enclosure panel surfaces shall not reflect light in a manner to distract motorists or be a traffic hazard.

3.54 Individual enclosure panels shall be easily replaceable in the event of damage.

3.54.1 Provision of spare enclosure panels with long procurement periods should be included in the maintenance strategy.

3.54.2 Replacement of enclosure panels should be made from within the enclosure with a minimum use of external works.

3.54.3 Enclosure panels should be arranged to be removable individually without major disruption to surrounding areas.

3.55 The enclosure and its attachment to the bridge shall prevent significant movement of air through the enclosed space.

3.56 Panel joints shall be detailed so as to prevent solid objects from passing between them.

3.57 Panel joints shall accommodate differential movements of adjacent panels due to flexure or thermal action.

3.58 Flashing and sealing at the corners between enclosure panels and at joints between the enclosure and the primary bridge structure shall be designed to prevent the ingress of moisture and pollutants.

NOTE 1 *It has been found that in a polluted environment the levels of airborne particulate contaminants within an enclosure with controlled ventilation are much lower than the levels outside.*

NOTE 2 *The concentration of gaseous pollutants within the enclosure can be at the same levels as outside, but the effect is less due to reduced air flow and different periods of wetness inside the enclosure.*

Drainage

3.59 Drainage shall be provided to prevent water accumulating inside the enclosure from any source.

3.60 Drainage shall be provided to disperse leakage from service pipes or during maintenance activities.

3.61 Drainage shall be provided to prevent water gathering at areas that are vulnerable to corrosion, such as fasteners and stiffener positions on the enclosure floor.

Vandalism or unauthorised access

3.62 The design shall include mitigation measures to reduce damage and prevent unauthorised access.

3.62.1 Areas of the enclosure which are accessible to the general public should be designed to limit vandalism, or to reduce the consequences of vandalism.

3.62.2 Design against vandalism and unauthorised access should not compromise the safety of the inspection and maintenance personnel.

3.62.3 The enclosure material should be such that graffiti can be removed from it without undue difficulty or damage.

Aesthetics and appearance

3.63 The overall appearance of the bridge with enclosure shall be attractive in appearance and aesthetically pleasing in relation to the road and the surrounding area.

NOTE 1 *Guidelines on the factors to consider in the design process with respect to the appearance of bridges are provided in CD 351 [Ref 15.N].*

NOTE 2 *Early involvement of architects and planners is beneficial so that the enclosure and bridge are harmonious, particularly where the structure is in a visually prominent or environmentally sensitive area.*

3.64 The enclosure surface shall not deteriorate visually during the life span of the bridge.

4. Properties of enclosure materials and components

General

4.1 The enclosure component materials shall be chosen so that:

1) their properties satisfy the safety, strength and rigidity requirements at serviceability limit state and ultimate limit state;
2) their properties satisfy durability and fatigue requirements for the life span of the bridge;
3) they are resistant to the environmental conditions during the life span of the bridge; and,
4) where unconventional materials are specified that are not in common use, the manufacturing process and quality assurance are feasible and practical.

Enclosure material properties

4.2 Where unconventional materials are proposed, the design values shall be established by testing.

4.2.1 Previously published test data from an independent accredited testing organisation may be used to assist the establishment of design strengths of enclosure components.

NOTE *Manufacturers test data that has been independently verified by an accredited organisation can be used.*

Enclosure component properties

4.3 Testing to establish the strength of enclosure components shall be specified where the components or the design configuration is unconventional or unique.

4.3.1 The design strength of enclosure components should be derived from full-scale testing.

4.3.2 Testing of the support members, fixings and fasteners should include the resistance to vibration and fatigue over the life span of the bridge.

4.3.3 Previously published test data from the manufacturer or an independent accredited testing organisation may be used to assist the establishment of design strengths of enclosure components.

Testing of enclosure materials and components

4.4 Testing houses that are used to establish the design strength of enclosure materials and components shall be accredited in accordance with relevant European standards.

4.4.1 Design values of unconventional enclosure materials and components that are established by testing should be derived according to BS EN 1990 [Ref 8.N].

NOTE *Section 4.2 and Section 5.2 of BS EN 1990 [Ref 8.N] give general methodology of testing and analysis of results in order to achieve a reliability that is compatible with conventional materials.*

4.4.2 Testing of enclosure materials and components should be representative of the loading on the bridge structure at ultimate limit state and serviceability limit state.

4.4.3 Tests to establish design values of unconventional enclosure materials and components should include the effects of ageing and environmental influence.

5. Design of structural elements

General

5.1 The enclosure components shall be designed using limit state principles in accordance with BS EN 1990 [Ref 8.N].

5.2 The design values for the enclosure components shall be calculated by the global and local analysis of the bridge structure at ultimate limit state and serviceability limit state.

5.3 In addition to structural design the enclosure components shall be designed against fire, vibration, fatigue and environmental damage.

5.4 Where the enclosure is designed for an existing bridge, the bridge shall be assessed to CS 454 [Ref 2.N] taking into account the full effects of the enclosure.

Method of analysis

5.5 The method of analysis shall be agreed with the TAA for the Overseeing Organisation as part of the CG 300 [Ref 14.N] process.

5.6 In general, global analysis shall be either by elastic methods (linear or non-linear) or plastic methods appropriate to the limit state being considered and materials used.

5.7 Plastic methods of analysis shall only be used for materials which exhibit sufficient ductile behaviour to cater for large strains and deflections.

Dead loads and superimposed dead loads

5.8 Nominal values for dead loads of enclosure components and superimposed dead loads of enclosure internals shall be calculated from the densities of the materials given in BS EN 1991-1-1 [Ref 4.N].

5.8.1 Where enclosure materials are not included in BS EN 1991-1-1 [Ref 4.N], values for dead load calculation may be obtained from the manufacturer.

Live loads

5.9 Components of the enclosure shall be designed to withstand live loading within the designated areas for each category A, B and C.

NOTE *Explanation of enclosure live loads is given in Appendix B.*

5.10 Category A areas shall be designed to withstand the following:

1) a vertically downward uniformly distributed load (UDL) of 2.5 kN/m² over a total area of 10 m² of any shape, which can be continuous or divided to give the most adverse effect, together with a uniformly distributed load of 0.75 kN/m² elsewhere; and,
2) in addition to the loading given in (1), a single-point load of nominal value 1.25 kN applied to an area 150 mm square in any direction on all surfaces of the enclosure, including side panels.

5.11 Category A areas shall be checked for two point-loads of nominal value 2.5 kN at 0.7-metre centres applied to an area 150 mm square in conjunction with a uniformly distributed load of 0.75 kN/m² elsewhere.

5.12 Any part of the live load which causes a relieving effect on the element being assessed shall be omitted.

5.13 Where heavy equipment is to be used inside the enclosure, or where the enclosure is required to temporarily support superstructure loads such as from the construction of the deck, these additional loads shall be applied explicitly.

5.14 Category B areas within the enclosure shall be designed to withstand the following:

1) a uniformly distributed load of 1.5 kN/m² over a total area of 10 m² of any shape, which can be continuous or divided to give the most adverse effect, together with a uniformly distributed load of 0.75 kN/m² elsewhere; and,
2) where the depth of the structure is such that additional scaffolds and ladders are required to provide inspection access, category A loading will apply.

5.15 Category C areas shall be designed to withstand a live load uniformly distributed load of 1.0 kN on any 300- mm square area.

Wind loads

5.16 Local wind loading on the enclosure components and the overall wind loading on the bridge as modified by the enclosure shall be evaluated using BS EN 1991-1-4 [Ref 6.N].

NOTE Enclosure components can be subject to pressure peaks due to local effects from wind action and air flow caused by traffic movement acting in combination with all other live and dead loads.

5.16.1 Specialist guidance to evaluate the air pressures on enclosure panels caused by traffic flow may be required.

Temperature loading

5.17 The maximum and minimum effective bridge temperatures specified in BS EN 1991-1-5 [Ref 7.N] shall be used unaltered by the presence of an enclosure.

5.17.1 The design should allow for the temperature of the enclosure panels to be 15°C greater than, or 5°C less than, the bridge structure.

5.17.2 The enclosure support members should be taken as the same temperature of either the enclosure panels or the bridge structure, whichever gives the more onerous conditions.

5.17.3 A detailed assessment may be carried out in order to establish a more accurate temperature range.

NOTE 1 Temperature difference between bridge and enclosure depend on such factors as the thermal inertia of the enclosure material, colour and aspect to the sun.

NOTE 2 The temperature difference given in BS EN 1991-1-5 [Ref 7.N] is conservative for an enclosure in the shade of a bridge.

Deflection criteria

5.18 The deflection criteria for serviceability limit state shall be as shown in Table 5.18.

Table 5.18 Deflection criteria for serviceability limit state

Loaded areas	Deflection criteria
Category A and B	The deflection under the specified single point load is less than 15 mm.
Category A and B	The deflection under the specified uniformly distributed loads does not exceed 1/100 span between support members, or 50 mm whichever is the lesser.
Category C	The deflection under the specified patch load does not obstruct the function and operation of the bridge.

5.19 The elastic strain at the surface of the enclosure panel shall be limited to that which cannot affect the durability of the panel materials.

Aerodynamic effect

5.20 The bridge with the enclosure shall be evaluated using BS EN 1991-1-4 [Ref 6.N] to ensure that it is aerodynamically stable.

NOTE The addition of an enclosure to a bridge changes its aerodynamic behaviour.

Partial factor (safety or serviceability)

5.21 For the design of the enclosure, the values of the partial factors shall be taken from BS EN 1990 [Ref 8.N] for dead loads, superimposed dead loads, temperature loading and wind loading.

5.22 Where the partial factors of an unconventional enclosure material are not given in BS EN 1990 [Ref 8.N], the values shall be derived from first principles and approved by the TAA.

5.22.1 The partial factors of an unconventional material should be derived from the expected variability of the material properties, manufacturer's tolerances and dimensional tolerances.

5.22.2 The partial factors of an unconventional material should be derived with the same level of safety and reliability to be compatible with the standard.

5.22.3 The partial factors of an unconventional material may be derived by calibration against a material of comparable properties where the partial load factor is established and verified.

5.23 For the design of the enclosure, the values of the partial factor for live loads shall be taken as 1.0 for serviceability limit state and 1.5 for ultimate limit state for all load combinations considered.

5.24 Load combinations as defined in BS EN 1990 [Ref 8.N] shall be used.

NOTE *The value of partial factor is not reduced when applying combinations of loading for wind and live load.*

5.25 For design and assessment of the bridge and enclosure, including for evaluating the effects of the enclosure on the bridge, the partial factors for the design of the enclosure shall be used.

6. Normative references

The following documents, in whole or in part, are normative references for this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Ref 1.N	Highways England. CG 302, 'As-built, operational and maintenance records for highway structures'
Ref 2.N	Highways England. CS 454, 'Assessment of highway bridges and structures'
Ref 3.N	Highways England. CD 127, 'Cross-sections and headrooms'
Ref 4.N	BSI. BS EN 1991-1-1, 'Eurocode 1 - Actions on Structures - Part 1-1: General actions- Densities, self weight, imposed loads for buildings'
Ref 5.N	BSI. BS EN 1991-1-7, 'Eurocode 1 - Actions on structures - Part 1-7 General actions - Accidental actions'
Ref 6.N	BSI. BS EN 1991-1-4, 'Eurocode 1: Actions on structures. Part 1-4: General actions – Wind actions'
Ref 7.N	BSI. BS EN 1991-1-5, 'Eurocode 1: Actions on structures. Part 1-5: General actions – Thermal actions'
Ref 8.N	BSI. BS EN 1990, 'Eurocode: Basis of structural design'
Ref 9.N	BSI. BS 476-21, 'Fire tests on building materials and structures. Part 21: Methods for determination of the fire resistance of loadbearing elements of construction'
Ref 10.N	BSI. BS 476-7, 'Fire tests on building materials and structures. Part 7: Method of test to determine the classification of the surface spread of flame of products'
Ref 11.N	Highways England. CS 450, 'Inspection of highway structures'
Ref 12.N	Highways England. GG 101, 'Introduction to the Design Manual for Roads and Bridges'
Ref 13.N	Highways England. MCHW NG, 'Manual of Contract Documents for Highway Works Volume 2: Notes for Guidance on the Specification for Highway Works'
Ref 14.N	Highways England. CG 300, 'Technical approval of highway structures'
Ref 15.N	Highways England. CD 351, 'The design and appearance of highway structures'
Ref 16.N	Highways England. CD 355, 'The design for highway structures'

7. Informative references

The following documents are informative references for this document and provide supporting information.

Ref 1.I	Transport Research Laboratory. Bishop, R. R. TRL SR621, 'An alternative to bridge painting'
Ref 2.I	Transport Research Laboratory. McKenzie, M. TRL RR293, 'Corrosion Protection - The environment created by bridge enclosure.'
Ref 3.I	Transport Research Laboratory. Bishop, R. R. TRL RR83, 'Enclosure - an Alternative to bridge painting.'

Appendix A. General assessment of a bridge enclosure

A1 General

Before proceeding with the cost evaluation and comparison of the bridge with and without an enclosure, the following factors should be considered as having a decisive influence on the evaluation.

A1.1 Type of bridge structure under consideration

Enclosures suit bridges with concrete decks supported on plate girders. A minimum headroom within the enclosure of 1m will usually provide personnel access benefits for inspection and maintenance.

A1.2 Expected maintenance on new or existing bridges

Enclosures are beneficial on bridges where major disruption can take place to traffic during inspection and maintenance. Advantage can be taken by adding enclosures to existing bridges during major works for maintenance or upgrade. Outstanding life expectancy of an existing bridge can also influence the effectiveness, either to extend a lifespan or conversely be uneconomic over a short remaining life.

A1.3 Accessibility for bridge inspection and maintenance

Bridges which are difficult to access for inspection and maintenance can benefit by the addition of an enclosure more than those which are easily accessible.

Examples of difficult to access bridges may include high bridges, bridges over water or rail, and motorway bridges, where a maintenance gantry could cause disruption to traffic flow.

A1.4 Bridge environment.

The harshness of the surrounding environment of the bridge site can influence the choice of coating and the maintenance costs. Enclosures can be more beneficial in harsher environments.

A1.5 New or existing structures

Enclosures on new structures benefit from easier design considerations whereas an existing bridge can require more costly designs which involve complications due to access during construction and infringement of headroom.

Appendix B. Enclosure live loading

B1 General

Three categories of design load are given for live loading within the enclosure.

B1.1 Category A

Category A loading is required wherever maintenance work is to be carried out directly from the enclosure. This is most likely to be appropriate where the enclosure is being added to an existing structure which is in need of major refurbishment.

In addition to personnel loading, the loading is intended to account for live load resulting from:

1) working platforms erected within the enclosure for maintenance purposes;
2) temporary ladders;
3) storage of materials and equipment necessary for the maintenance of the bridge structure;
4) concentrated loads imposed by the bases of supporting platforms and ladders; and,
5) impact loading resulting from mishandling of materials and equipment within the enclosure.

B1.2 Category B

Category B loading is the most likely category to be appropriate to a new structure where the use of the enclosure should be restricted to inspection access and major maintenance works are not anticipated.

B1.3 Category C

Category C loading can be appropriate to large structures where it is uneconomic to provide Category A & B loading throughout the enclosure. For such cases it is envisaged to provide main walkway areas and use these to install additional working platforms over the particular part of the structure that is being inspected or where maintenance activity is expected. The remainder of the enclosure need only provide the function of a safety net with respect to personnel loading.