BA 67/96

THE HIGHWAYS AGENCY

THE SCOTTISH OFFICE DEVELOPMENT DEPARTMENT

THE WELSH OFFICE
Y SWYDDFA GYMREIG

THE DEPARTMENT OF THE ENVIRONMENT FOR NORTHERN IRELAND

Enclosure of Bridges

This Advice Note presents the historical background in the development of enclosures of bridges and the principles used, to enable the designer to understand more fully the performance requirements laid down in the Standard

Volume 2 home page

VOLUME 2 **HIGHWAY STRUCTURES: DESIGN (SUBSTRUCTURES AND SPECIAL STRUCTURES), MATERIALS**

SECTION 2 **SPECIAL STRUCTURES**

PART 8

BA 67/96

ENCLOSURE OF BRIDGES

SUMMARY

This Advice Note presents the historical background in the development of enclosures of bridges and the principles used, to enable the designer to understand more fully the performance requirements laid down in BD 67/96.

INSTRUCTIONS FOR USE

This is a new document to be inserted into the Manual.

1. Insert BA 67/96 into Volume 2 Section 2.

2. Archive this sheet as appropriate.

Note: A quarterly Index with a full set of Volume Contents Pages is available separately from HMSO.

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REGISTRATION OF AMENDMENTS

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ENCLOSURE OF BRIDGES

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1. INTRODUCTION

General

1.1 This Advice Note gives guidance on evaluating and designing enclosures of bridges. It is to be read in conjunction with the Standard BD 67 (DMRB 2.2.7).

Scope

1.2 It presents, in brief, the historical background in the development of the enclosure and the principles used, to enable the designer to understand more fully the performance requirements laid down in the Standard.

Implementation

1.3 This Advice Note should be used forthwith on all schemes for the construction, improvement, and maintenance of motorways or other trunk roads (in Northern Ireland those roads designated by the Overseeing Organisation). However in the case of schemes which are current at the time of issue of this Standard it need only be applied provided that, in the opinion of the Overseeing Organisation, this would not result in significant additional expense or delay. Design Organisations should confirm its application to particular schemes with the Overseeing Organisation.

Definitions

1.4 For definitions see the Standard.

Background to the Standard

1.5 The traditional method for the protection of bridge superstructure against corrosion is a protective coating eg: paint, concrete cover, silane. Particularly in the case of steelwork periodic maintenance of the protective coating is necessary which is costly and frequently results in inconvenience to road users.

1.6 In 1980 the Transport Research Laboratory (TRL) put forward the concept that if steel structures were enclosed against contaminants in the environment they could be rendered maintenance free for periods of at least thirty years. Hence an alternative to the traditional method of providing long-life multi-coat systems to bridge steelwork is to provide enclosure.

1.7 It has been found that in a polluted environment the levels of airborne particulate contaminants within an enclosure with controlled ventilation are very much lower than the levels outside. The concentration of gaseous pollutants, however, may well be at the same levels as outside but the effect will be less due to reduced air flow inside and different periods of wetness inside the enclosure. As these contaminants are a primary factor in the corrosion process, the rate of breakdown of the protective coatings and the corrosion of the steelwork within the enclosures is very much reduced when compared with exposed steelwork. Furthermore, as access to a bridge for regular inspection can be both difficult and costly, a further advantage can be gained if the enclosure can provide a permanent access for routine inspection and maintenance.

1.8 Trials on bridges at Iden (1979), Exceat (1981) and Queenhill (1984) confirmed the feasibility of the principle of enclosure to protect steel bridges against corrosion. However, up to 1990 only two bridges have had enclosures fitted which have been designed to ‘permanent’ standards with the dual role of corrosion protection and access. These are the Conan Bridge at Inverness where an enclosure in anodised aluminium was installed in 1984, and the A19 Tees Viaduct at Middlesbrough where an enclosure in pultruded glass reinforced plastic (GRP) was installed in 1988/89. Recent examples of enclosures are in evidence at Botley, Oxford (1990) where GRP was used on a part reconstructed bridge, Nevilles Cross (1990) where a pultruded GRP enclosure was used as a platform to reconstruct the concrete bridge deck, Bromley South (1992) where a pultruded GRP enclosure was specified for a new bridge over the railway station and the Winterbrook Bridge (1993) on the Wallingford Bypass where the enclosure was constructed in hand laid GRP.

1.9 With a reduced rate of breakdown of the protective coatings the period to the first maintenance painting will be increased and future maintenance expenditure reduced. Furthermore a less costly initial protection system may be used on a new bridge provided with an enclosure.

1.10 Even when the protective coatings have broken down, the reduced corrosion rate of the steel would increase the time available when the coatings can be repaired. In addition, there is no longer a need to repair for cosmetic reasons within the enclosure. Greater flexibility in maintenance strategies is afforded by enclosure.

1.11 The principal advantages of providing an enclosure are:

i) Cost savings in corrosion protection both at the time of construction and in future maintenance;

ii) The provision of permanent access for inspection and maintenance with consequent improvements in safety;

iii) The reduction and/or elimination of traffic delay costs during construction, inspection and maintenance.

Further benefits may include:

iv) The provision of a working platform at an early stage in the construction of a new bridge, of particular benefit over railways, rivers or existing roads;

v) Protection of concrete soffits eliminating the need for protective coatings or in the case of new structures permitting a reduction in concrete cover;

vi) Improvement of aerodynamic characteristics;

vii) Avoidance of bird roosting and associated health hazards;

The advantages may be offset by the initial cost of providing the enclosure and are lost altogether if the enclosure itself does not prove to be substantially maintenance free.

1.12 Consideration should be given for the repair and replacement of panels or components resulting from local damage caused by fire, vandalism and/or vehicle impact. Where these elements are unique and would require a long period for procurement, allowance should be made for the provision and storage of spare parts.

1.13 Output from the computer program QUADRO indicates a marked increase in road user delay costs due to inspection and maintenance of bridges. Similarly, delay costs associated with bridge replacement during motorway widening may also arise. Additionally, there are the costs of providing safe working platforms for all such work. With railway bridges, increased costs associated with bridge possessions are likely. As a result, there will be a greater incentive for providing enclosures in the future. The requirements for enclosure have therefore been formalised in the Standard.

2. EVALUATION

General

2.1 The decision whether or not to provide an enclosure will depend on its cost-effectiveness based on life cycle costs. It will be necessary to quantify the cost-benefits, some of which may not occur for many years and will require to be discounted to present-day values.

2.2 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. This 40 year period reduces significantly the amount of conjecture that a 120 year appraisal period would require. It should also be noted that this 40 year period falls within the 25 - 40 year period that is commonly used when carrying out life cycle costings appraisals of highway pavements.

2.3 Where a more durable enclosure solution is being considered (ie one with a design life and/or period to first maintenance greater than the minimum periods specified in the Standard), the appraisal should take account of these extended periods in the discounted cost analysis.

2.4 Before detailed cost calculations are carried out it is usually worthwhile to make a general assessment as to whether or not an enclosure is likely to be beneficial. Factors to be considered can be grouped under five headings.

i) Type of Structure

Bridges selected for enclosure will generally be concrete decks supported by plate girders. In addition to protecting steelwork and concrete soffits, an enclosure will normally provide access for inspection and maintenance. For personnel access for inspection and maintenance, it is likely that the headroom within the enclosure will be at least 1 m deep.

ii) Expected Use and Life

The importance of a bridge in the road network will influence the choice of protection. For example, if there will be major disruption to traffic when carrying out construction, inspection and maintenance, then an enclosure should be considered in detail.

If an existing bridge is in need of major maintenance/ refurbishment then the benefit of enclosure during these works which occur early in the discounting period is likely to make enclosure attractive. Similarly if enclosure can be used as a construction platform over existing road, rail or river this undiscounted cost benefit will be significant.

If the life expectancy of the bridge due to obsolescence is less than 40 years then an enclosure may not be economic. If however, the bridge life expectancy of 40 years is due to deterioration then enclosure could economically extend its life.

iii) Accessibility

Accessibility for inspection and maintenance is a prime factor when considering a bridge for an enclosure. Bridge structures are described in Series NG1900 in the Notes for Guidance (MCHW 2) as having either 'Ready Access' or 'Difficult Access'.

The description 'Ready Access' would apply to structures where future restrictions on working time due to road or rail traffic are likely to be minimal and where future access on site is unlikely to be a problem.

The description 'Difficult Access' would apply, for example, to a bridge over a motorway or railway where painting is likely to be restricted to one section at a time or halted completely for certain periods when traffic is heavy. It would also apply to a high bridge, without maintenance gantries built over difficult terrain or over a river where movement on the ground would be difficult and where extensive scaffolding would be required.

Enclosures are more likely to be economic if the bridge has 'Difficult Access'.

iv) Environment

The intensity of corrosion attack is dependent upon the environment. The harshness of the atmosphere is a factor in determining the degree of corrosion protection and will influence the choice of protection. Information on environmental considerations is given in Series NG1900 in the Notes for Guidance (MCHW 2). The choice of protective system for the steelwork may be influenced by shipping, storage and programming considerations.

There could be a significant delay between delivery of steel to site and completion of the enclosure. It is recognised in Clause NG1901.1 (MCHW 2) that on large structures final site painting may not be undertaken for as long as two or more years and that wet blast cleaning may be the most effective method of removing contamination.

Furthermore, as the severity of the environment increases, it is likely that the frequency of maintenance painting will also increase. The benefits of an enclosure are therefore likely to be higher.

v) New or Existing Structures

Consideration should be given for the provision of an enclosure at the design stage when the bridge can be specifically designed to incorporate the enclosure. Constructing an enclosure on an existing structure can involve technical difficulties and costs which are greater than with new works but this is offset when the benefits come earlier in the discounting period. In many instances the available headroom under an existing bridge may preclude the addition of an enclosure.

2.5 Following a favourable assessment of the feasibility and aesthetics of the use of an enclosure the cost-benefits have to be evaluated as required in Section 2 of the Standard. The costs referred to include those which can be evaluated reasonably accurately, such as costs of the enclosure and its attachments, provision of alternative access, costs of inspection and maintenance etc. Also included are the indirect costs of traffic delays for which standard methods of evaluation are available. Because these costs occur at different times, methods have to be used to discount them to their present values. For this purpose BD 36 (DMRB 1.2.1) and BA 28 (DMRB 1.2.2) are used.

Cost of the Enclosure

2.6 It will normally be necessary to carry out an outline design to establish the cost with sufficient accuracy to make meaningful comparisons. Present value calculations can be used to test the sensitivity of the elemental costs and a judgement made as to the overall cost-benefit of an enclosure.

Changes in Cost of the Bridge

2.7 When comparing the construction cost of a bridge with and without enclosure, the designer should take account of any increased vertical highway alignment required to accommodate the enclosure. On flat ground this could result in a requirement for the approach embankments to be lengthened by between 33 and 66 times the amount that the soffit is raised (See TD 9 - (DMRD 6.1)). In such circumstances consideration should be given to the relative costs of raising the bridge to avoid the enclosure being within the impact zone and designing the enclosure to withstand impacts without catastrophic failure.

Inspection and Maintenance Costs

2.8 BD 36 (DMRB 1.2.2), together with its associated BA 28 (DMRB 1.2.1), specify and illustrate the methods to be used in evaluating commuted inspection and maintenance costs.

Road User Delay Costs

2.9 The computer program QUADRO enables Road User Delay Costs to be quantified and these can then be discounted by the methods referred to above. Current information indicates that in general, the Road User Delay Costs greatly exceed the direct maintenance costs. Similarly road user delay costs during construction of a new structure over an existing road can often exceed the additional construction cost associated with details which minimise the delay.

Railway/Waterway Possessions

2.10 The cost of railway/waterway possessions is dependent on the usage of the particular line or waterway. Costs include both direct costs to be paid to the operator and costs associated with carrying out work in a series of short periods of possession. The amount of such costs will require discussion and agreement with the operator in conjunction with the organisation responsible for maintenance.

In some instances, the cost of the track or waterway possessions may already be dealt with in the works agreement for the construction of the bridge or by a general agreement with the affected undertaking (eg Railtrack, British Waterways Board etc).

Safety Boats

2.11 The periods of provision or otherwise of safety boats during construction, inspection and maintenance of bridges over water will be reduced by the provision of enclosure. However safety boats may be required during the erection of an enclosure over water.

3. PERFORMANCE CRITERIA

Durability

3.1 As the enclosure is provided to reduce the maintenance costs of the bridge, it is counter-productive to design an enclosure which incurs significant inspection and maintenance costs itself.

3.2 An enclosure is similar to the soffit plate of a box girder in that condensation runs down onto it and collects against upstands, around fasteners etc. By its very use as an inspection and maintenance platform the enclosure floor will also collect dust and debris which in turn will retain moisture. Since the basis of enclosure in protecting the structure is that significant flow of air is prevented, it cannot be ventilated as a box girder may be, in order to reduce condensation. The enclosure must therefore be durable in this potentially corrosive environment.

3.3 The exterior of an enclosure is often subject to salt spray from a road carriageway below. Enclosure is also intended to be of benefit to prevent corrosion of structures in aggressive environments; vertical surfaces may be exposed to prolonged direct sunlight. Since an enclosure is a prominent visual feature it is essential that the exterior surface is both structurally and aesthetically durable in such an environment.

3.4 Care should be taken when detailing that no items liable to corrode (eg steel bolts, etc) are positioned in areas where moisture can collect.

Safety

3.5 Attention is drawn to the Construction (Design and Management) Regulations and in particular to the duties placed upon designers in respect of health and safety matters during the planning (design) stage, construction, maintenance and during the eventual demolition of the structure. Under these Regulations, designers are required to avoid or reduce hazards and to indicate any unusually hazardous aspects of the construction process.

3.6 The designer should provide the maintaining agent with all the relevant procedures and requirements for entry and use of the space. The details should include the location of all entry and exit points and in particular where the dimensions may restrict entry and exit in an emergency. This is particularly important where it is not possible to provide sufficient exits to prevent the enclosure becoming a confined space. The Health and Safety Executive Information Sheet No. 15 gives guidance on confined spaces.

3.7 Confined spaces are those areas where there are limitations of access and space, inadequate ventilation or replacement of breathable air by gases, fumes or vapours as a result of maintenance works. Confined spaces can also constitute a danger to persons not engaged in work activities where there is ease of accessibility. In the case of children, confined spaces may appear to offer opportunities for games and exploration. The designer of an enclosure should take positive steps to avoid and prevent such entry.

3.8 In an attempt to minimise costs there is a temptation to design an enclosure that is as small as possible. However where the additional headroom is available, the designer should be aware of the benefits that can arise as a result - for example providing additional headroom within to make movement inside the enclosure easier. Furthermore, forms of construction which have frequent cross beams will exacerbate headroom difficulties as these will form serious obstructions to free movement of personnel within the enclosure.

3.9 Although the enclosure must prevent significant air movements to be effective in controlling corrosion, provisions need to be made to introduce adequate ventilation and to extract dust and fumes when the enclosure is in use for inspection and maintenance. In most cases during inspections, natural ventilation provided through small openings will be adequate. In the case of long enclosures where natural ventilation cannot be adequately provided, some form of forced ventilation may be necessary.

3.10 Where maintenance such as grit blasting, painting or welding operations are in progress, ventilation should be provided by removable panels or by mechanical means. Adequate safety precautions should be taken where panels have been temporarily removed.

3.11 Smooth surfaces may need a non-slip coating applied, particularly if they are liable to persistent wetting, or if they are at a significant gradient.

Fire Safety

3.12 Since maintenance work may be carried out within the enclosure it should exhibit adequate resistance to the surface spread of flame resulting from the ignition of paint solvents, the effects of hot weld metal or from the use of flame cutting equipment and other similar maintenance operations. It should resist the effects of an internal fire source, where appropriate, for sufficient time to allow personnel to escape to a point of relative safety.

3.13 Drainage systems should be designed to avoid the possibility of burning material entering the enclosure. For example after an accident involving fuel spillage from a tanker.

3.14 In long enclosures or where access through an enclosure is complex due to numerous obstructions such as cross bracing for the main bridge structure, the travel time of personnel to a point of relative safety may be excessive in which case compartmentalisation of the enclosure may be necessary. Where the spread of smoke could inhibit evacuation, consideration should be given to the provision of smoke baffles.

3.15 As an alternative to the fire safety provisions given in the Standard, a fire engineering approach that takes into account the total fire safety package can be used. In some instances this may be the only viable way to achieve a satisfactory standard of fire safety in enclosures.

Such an approach may be appropriate where:

i) an enclosure is particularly long and/or where points of entry/exit are limited;
ii) movement is severely restricted within the enclosure which would increase the time required for personnel to escape to a point of relative safety;
iii) the spread of smoke could inhibit evacuation.

3.16 Advice in fire engineering matters should be sought at an early stage in the design of enclosure. The Fire Research Establishment and other similar specialist organisations can assist in conceptual studies, fire safety appraisals and fire risk assessment.

Design Loads

3.17 Three design load categories are given in the Standard as follows:

3.18 Category A) is required wherever maintenance work is to be carried out directly from the enclosure. This is most likely to be appropriate where 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:

i) working platforms erected within the enclosure for maintenance purposes;
ii) temporary ladders;
iii) storage of materials and equipment necessary for the maintenance of the bridge structure;
iv) concentrated loads imposed by the bases of supporting platforms and ladders etc;
v) impact loading resulting from mishandling of materials and equipment within the enclosure.

3.19 Category B) 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.

3.20 Category C) may be appropriate to large structures where it is uneconomic to provide Category A) & B) enclosures throughout and where it would be acceptable to simply 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 concentrated. The remainder of the envelope need then only provide the function of a safety net with respect to personnel loading.

3.21 The pressure wave effects are localised and are dependent on the vehicle speed, geometry of the vehicle/ enclosure and, the ambient wind-speed and direction. The design of the enclosure system should account for the rapid reversal of pressure which can occur when vehicles pass under the enclosed bridge, initially - on entry under the bridge, and at the tail end - on exit. In addition, where positive pressures are greater than the dead weight of the enclosure panels particularly in the case of lightweight construction, the support hangars should have sufficient capacity to resist the compression forces imposed. Guidance of appropriate loadings should be sought from the road/railway operator.

Flexure of Enclosure Under Internal Live Loads

3.22 It is important that the maintenance personnel be confident when working in enclosures. It is therefore necessary to limit the flexibility of the walking surfaces of the enclosure since it is quite possible that, although adequately strong, an enclosure may cause unease in the minds of users if it has inadequate rigidity.

Construction Details

3.23 It is important that the enclosure panels and support members are prevented from acting compositely with the bridge structure which could lead to local overstressing of the enclosure members. In addition, connections should be designed for movement arising from significant temperature differentials which can occur between the enclosure panels and the enclosed steelwork. The effects of stress concentration caused by fixings and fasteners should be examined.

3.24 The need to accommodate bridge construction tolerances in the design of the fixings is particularly important when the enclosure is being attached to an existing structure for which dimensions may vary.

3.25 Too small an enclosure can result in areas which are difficult or impossible to maintain. Unless provision has been made for removal of enclosure panels or the provision of hinged panels, adequate space should be left below the bottom flange of a main beam to inspect and paint as necessary. However where vehicle headroom is very restricted it may be appropriate to reduce this dimension to 50 mm and take measures to extend the maintenance period of the inaccessible areas eg, provide additional corrosion protection to the bottom flange to extend or even obviate the need of painting. In such cases inspection would have to be carried out with the aid of a mirror but painting would require removal of parts of the enclosure.

3.26 In addition to meeting safety requirements, access openings should be dimensioned to permit the passage of maintenance equipment and materials, including scaffolding where appropriate.

3.27 It is important that removal of panels for access and repair of accidental damage of the enclosure itself can be carried out with minimum traffic disruption. Whilst panels which are removable from inside the enclosure would ensure minimum delays, this requirement could result in complex details. An alternative to these types of panels for a highway overbridge would be to detail the fixing to permit a rapid replacement of panels from the outside using a suitable hoist which may require a short possession of the bridge - possibly at night. The choice of repair provision requires the approval of the Technical Approval Authority (TAA).

3.28 Whilst it has been shown that an enclosure need not be hermetically sealed it is necessary to prevent significant air flow through it.

Headroom and Accidental Damage

3.29 The minimum headroom requirements given in the Design Standard are those given for new construction in TD 27 (DMRB 6.1.2) - and allow for the provision of maintenance and future resurfacing of the road below.

3.30 Clauses for accidental damage in the Design Standard limits checking of the loads which are transferred from the enclosure to the bridge superstructure, to those which would not have arisen in the absence of enclosure.

Vandalism

3.31 Where enclosures are considered to be a target for vandals alternative access provisions should be considered.

3.32 Construction details which invite vandalism should be avoided.

Fixed ladders give vandals free access to hatch locks and enclosure panels making entry into the enclosure easier. Access ladders which are located within abutments may still not offer a secure arrangement for access to soffit enclosures as the access doors to the abutment can also be a target for vandalism. Flat terrain adjacent to bridge abutments may encourage the building of fires, particularly if the headroom to the enclosure is low. Enclosures may also be prone to damage by vandals if enclosure panels for any part of the structure are within easy reach or where they provide a target for projectiles etc. Incorporation of sloping revetments in these areas or other suitable landscaping measures will mitigate the effects of these acts. Where appropriate, a more robust type of construction may be required in these vulnerable locations.

All methods employed to deter vandalism should take full account of the safety requirements of persons using the enclosure for inspection and maintenance.

Services

3.33 Lighting should be provided for long and/or complex access routes for reasons of safety. However the power supply may be temporary or permanent. The lighting may be kept to a minimum of 0.2 lux, the recommended level for escape route lighting. Personnel should be advised to use alternative light sources in case of power failure.

3.34 The provision for connection to a portable generator should be made wherever possible, except for larger installations where a permanent supply should be considered.

3.35 Where a permanent installation with power distribution is considered necessary, lighting levels of 150 lux approximately should be provided for maintenance work.

3.36 Provision should be made for the ready installation of temporary compressed air and waterlines during major maintenance work. In exceptional circumstances consideration may be given to providing permanent services.

3.37 If a permanent water supply is provided, provision should be made in the design for adequate drainage of the enclosure in the event of a failure of the pipe, and for the enclosure to carry the weight of the water before it has drained away.

3.38 Facilities should be provided to drain service pipes when not in use. This is generally more effective than lagging and would overcome the need to design the enclosure for pipe failure.

3.39 Consideration should be given to the installation of a protected communication system for use in an emergency or if the enclosure is long.

3.40 All permanent services equipment and installations should withstand appropriate environmental conditions including: ingress of dust and water, exposure to corrosive substances and/or explosive gases, vandalism and natural movement of the bridge.

Aesthetics and Appearance

3.41 The appearance of the bridge including the enclosure is particularly important for those structures that are visually prominent or in environmentally sensitive areas. The designer should discuss the enclosure proposal with the TAA at an early stage who will ascertain whether or not a submission to the Royal Fine Art Commission will be required. In Scotland a submission would be made to the Royal Fine Art Commission for Scotland.

3.42 Attention should be paid to the surface finish of the enclosure panels. Sunlight or headlamps shining on highly reflective surfaces may be a traffic hazard. Where profiled panels are used the line or features of the profile along or across the bridge should be in harmony with the bridge structure itself.

3.43 The enclosure should be considered from the outset as an integral part of the bridge design. Ill considered additions of enclosure not integrated with the structural appearance tend to produce visually poor results, and have proved unacceptable to the Royal Fine Arts Commission. Similarly, the fixing, maintenance and economics of applying enclosure-type panels to other surfaces of the bridge deck abutments to improve the appearance of the bridge, but which do not integrate with the functionable enclosure system, have to be carefully assessed. Early consultation with the Architect/Planner on all enclosure schemes is advised.

Inspection Requirements

3.44 Although not specifically stated in BD 63 (DMRB 3.1.4), enclosures fall into the category of Highway Structures and are to be inspected at the same frequency as for the bridge it encloses.

4. CHOICE AND APPROVAL OF MATERIALS AND COMPONENTS

General

4.1 Previous experience with, and data on, all materials should be considered in relation to the likely standards of supervision and workmanship during the construction stage. Records concerning the details and performance of such materials should be maintained.

4.2 Careful attention should be paid to the effect of environmental conditions and other special requirements when selecting materials. The likely performance and suitability of materials can be assessed by the use of previous data, experience and/or tests.

4.3 Where combinations of materials are used, account shall be taken of possible interactions between the materials.

Materials

4.4 The performance of materials used in enclosures is often very dependent upon the quality of production. The specification of these materials should contain appropriate requirements to ensure adequate performance.

4.5 The designer should ensure that materials and components accepted for use in bridge enclosures are fit for the purpose, as demonstrated by suitable independent test results or other justifiable means, and are likely to meet the performance requirements for enclosures under service conditions.

4.6 When drawing up specification clauses for the mechanical properties of materials, the designer may refer to appropriate standards or agrément certificates. When this is not possible the suitability of materials may be demonstrated by past performance and relevant test results or through a particular test programme.

4.7 The durability requirements of bridge enclosures are demanding and in most cases appropriate tests will need to be carried out. However, some durability requirements may be satisfied by reference to agrément certificates or suitably documented experience.

Fasteners

4.8 Due to the likelihood of vibrations all fasteners should be of a type which will not work loose taking full account, where appropriate of the properties of the materials into which the fixings are to be embedded.

5. DESIGN OF STRUCTURAL ELEMENTS

Loads

Wind Loads

5.1 The wind loading on the individual elements of the enclosure and on those parts of the bridge to which it is attached, is dependent very substantially on local positive and negative pressure peaks. Such peak loadings, however, will not directly affect the overall loading on the bridge itself provided the enclosure remains intact; if the design of the bridge is governed by overall wind loading, such overall wind loading requirements are contained in BD 37 (DMRB 1.3) using the bridge cross section as modified by the enclosure. The enclosure and its fixings should be designed taking account of pressure peaks.

Temperature

5.2 The enclosure will be substantially within the shade of the roadway slab or deck. This could to some extent limit the variation of temperature of the bridge, but it is not unreasonable (and it is conservative) to ignore such limitation.

5.3 The enclosure panel material itself may be of low thermal inertia (especially if it is thin sheet). If it is a dark colour and exposed to the full effects of the sun it may rise to a higher temperature than the maximum effective bridge temperature.

5.4 Differential thermal movement between the enclosure and bridge structure depends both on the temperature differences between the two and on any difference in the coefficients of thermal expansion.

Deflection Criteria

5.5 The designer should note that alternative deflection criteria may be adopted if it can be shown to satisfy the general requirement.

5.6 Attention should be paid to the effects of strain of the elements of the enclosure on durability. The likely performance and suitability of materials can be assessed by the use of previous data, experience and/or tests.

Aerodynamic Effects

5.7 The presence of an enclosure may significantly alter the aerodynamic characteristics of a bridge. BD 49 (DMRB 1.3) defines spans below which such effects need not be taken into account. For long spans (over 200 m) only a wind tunnel test is likely to give sufficient information. It should be noted that the addition of an enclosure can convert the aerodynamic shape into a section which is probably more or less prone to regular vortex shedding than the original cross section. It must also be remembered that unless specifically designed with that intent it will not normally alter the stiffness characteristics of the bridge although the mass increase will slightly reduce the natural frequency. A beneficial possibility also exists that the enclosure could increase (perhaps substantially) the damping inherent in the structure.

5.8 Possible remedial measures for any degradation of performance that may occur include:

i) changing the shape of the enclosure (eg sloping the webs, increasing the cantilever overhang etc).

ii) adding further artificial damping.

Partial Load Factor γ_{fL}

5.9 Where the Authority responsible for the bridge can guarantee that the services will be installed as designed, and not subsequently changed without rechecking, there is a case, subject to agreement of the TAA, for using the factor appropriate to the dead load of the material.

5.10 In many cases existing design criteria are based upon the use of steel. Steel will not necessarily be the most appropriate material for enclosures. Where other materials are used safety, suitability and fitness for purpose may have to be established from first principles. Methodologies available include reliability theory. Reliability theory requires the evaluation of the statistical distributions of each of the basic variables governing load and resistance. These may be determined by control tests, field observations, laboratory research or, where such data are deficient for certain load types or materials by organised objective engineering judgement.

5.11 In the absence of statistical data, recourse could be made to 'calibration' against a set of design rules which has been in use for a number of years. Calibration consists of ensuring that new systems would have a reliability equal to that of similar structures to an existing code used as a basis for the calibration. Further, advice on the specialist topic of safety and reliability can be obtained from Bridges Engineering Division.

5.12 For checking the effects of the enclosure on the bridge structure, the factors specified for dead load should be used. This is notwithstanding the fact that, in strict observance of BD 37 (DMRB 1.3) the weight of the enclosure could be considered as 'superimposed dead load' when applied to the structure.

5.13 Whilst on bridges it is normal to allow a reduced maximum wind speed if taken in conjunction with full live load, this is not the case for enclosures where paint stores, for example, could be left stacked inside at the time of a major storm.

Material Factor γ_m

5.14 The designer should make clear the sources of and assumptions behind materials factors used. Particular care must be taken with materials whose properties and/or calibration against the generality of established materials are not well understood.

Strength by Testing

5.15 The use of thin sections as are likely to be appropriate for use in enclosures, with consequent shear lag and greater susceptibility to local buckling, leads to the situation where it is frequently easier to carry out tests on standard panels to determine safe loads rather than make complex calculations for every design situation. Tests must be fully representative of the design configuration and loading and should demonstrate adequate performance at both SLS and ULS. Sufficient numbers of tests must be carried out to determine the statistical parameters of the properties measured.

Strength of Fixings

5.16 The strength of fixings other than simple types using bolts in shear etc, should be determined by testing, and manufacturer's data will normally be available for proprietary products.

5.17 Attention is drawn in the Standard to the necessity of allowing for load distribution. For example, if pairs of hangers are used, one on each edge of the flange of a steel beam, higher loads can result at the supports because the steel flange can restrain flexure of the enclosure.

Technical Approval

5.18 It will be necessary to determine and agree the category of structure with the Technical Approval Authority (TAA) at the preliminary design or assessment stage for Approval In Principle (AIP). An enclosure will be classified as a Category II or Category III structure depending upon its size and complexity.

5.19 An AIP should be submitted for the enclosure alone. The information required for AIP will vary and is unique for each structure, however the AIP model in Appendix A of BA 32 (DMRB 1.1) may be used to develop the required format.

5.20 It will be necessary to agree with the TAA which documents from the schedule in Appendix A of BD 2 (DMRB 1.1) will apply, and identify any other documents specific to the materials/systems proposed.

6. REFERENCES

1. Manual of Contract Documents for Highway Works (HMSO)

Volume 1: Specification for Highway Works (MCHW1)
Volume 2: Notes for guidance on the Specification for Highway Works (MCHW2)

2. Design Manual for Roads and Bridges (HMSO)

Volume 1: Section 1: Approval Procedures

BD 2 Technical Approval of Highway Structures on Motorways and Other Trunk Roads Part 1: General Procedures (DMRB 1.1)

BA 32 Technical Approval of Highway Structures on Motorways and Other Trunk Roads Part 1: General Procedures (DMRB 1.1)

Section 2: Other Procedural Documents

BD 36 Evaluation of Maintenance Costs in Comparing Alternative Designs for Highway Structures (DMRB 1.2.1)

BA 28 Evaluation of Maintenance Costs in Comparing Alternative Designs for Highway Structures (DMRB 1.2.2)

Section 3: General Design

BD 37 Loads for Highway Bridges (DMRB 1.3)

BD 49 Design Rules for Aerodynamic Effects on Bridges (DMRB 1.3)

BD 60 The Design of Highway Bridges for Vehicle Collision Loads (DMRB 1.3.5)

Volume 2: Section 2: Highway Structures: Design (Substructures and Special Structures) Materials

BD 67 Enclosure of Bridges (DMRB 2.2.7)

Volume 3: Section 1: Inspection

BD 63 Inspection of Highway Structures

Volume 6: Section 1: Links

TD 9 Highway Link Design (DMRB 6.1.1)

TD 27 Cross Sections and Headroom (DMRB 6.1.2)
(TD 27/96 supersedes TD 27/86 and SH 2)

3. British Standards (BSI)

BS 5973: 1993: Code of practice for access and working scaffolds and special scaffold structures in steel

4. British Standards Codes of Practice (BSI)

BS 6399: Part 2: 1995: Code of Practice for Wind Loads

5. Legislation

Health and Safety at Work etc Act 1974 (HMSO)

Factories Act 1961 (HMSO)

Control of Substances Hazardous to Health Regulations 1994 (HSE)

The Construction (Design and Management) Regulations 1994 (HSE)

6. Other Documents

Departmental Publication QUADRO 3 Manual (DOT)

TRRL Report SR621: An Alternative to Bridge Painting, Bishop

TRRL Research Report 83: Enclosure - an Alternative to Bridge Painting, Bishop

TRL Research Report 293: Corrosion Protection - The environment created by bridge enclosure, M McKenzie, 1991

Note: In Northern Ireland the equivalent legislation to the references in 5 applies.