Design Manual for Roads and Bridges

Highway Structures & Bridges
Inspection & Assessment

CS 453
The assessment of highway bridge supports

(formerly BD 48/93, BD 60/04 and IAN 91/07)

Revision 0

Summary
This document outlines the requirements for the assessment and strengthening of highway bridge supports.

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
0	Mar 2020	CS 453 replaces BD 48/93, BD 60/04 and IAN 91/07. Technical content for strengthening in these documents have been removed as they are now covered by Eurocodes.The full document has been re-written to make it compliant with the new Highways England drafting rules.

Foreword

Publishing information

This document is published by Highways England.

This document supersedes BD 48/93, BD 60/04 and IAN 91/07, which are withdrawn.

This document supersedes TS IA 29.

Where IAN 91 is mentioned it includes TS IA 29.

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

Accidental collisions of large goods vehicles with the supports and superstructures of highway bridges can occur. The Highways Agency (now Highways England) released BD 48 (DMRB 3.4.7) detailing the requirements for the assessment and strengthening of bridge supports that were considered to be particularly at risk with respect to collision loads.

Subsequently IAN 91/07 concluded that the strengthening or protection of bridge supports, other than those 'particularly at risk', does not represent best value for money in terms of making roads safer. It suspended the strengthening and protection of all bridge supports, other than those particularly at risk and directs project sponsors to the Structures Technical Approval Authority (TAA) for advice and suggests that a very small percentage of supports will be in this category.

This document contains the prioritisation, the loading (including broad principles for its application) and some specific guidelines for the assessment and any subsequent strengthening and protection of bridge supports.

Assumptions made in the preparation of this document

The assumptions made in GG 101 [Ref 2.N] apply to this document.

Abbreviations and symbols

Abbreviations

Abbreviation	Definition
TAA	Technical Approval Authority
ULS	Ultimate Limit State
SLS	Serviceability Limit State

Symbols

Symbol	Definition
γ_{fL}	Partial safety factor for loading
γ_{mv}	Partial safety factor for shear
γ_{mc}	Partial safety factor for concrete
γ_{mb}	Partial safety factor for bond

Terms and definitions

Terms

Term	Definition
Robustness	The ability of a structure to withstand events like fire, explosions, impact or the consequences of human error, without being damaged to an extent disproportionate to the original cause.
Smart Motorway Scheme	Smart motorways is the generic term for motorways where technology is combined with operating procedures to actively control traffic flow. Techniques such as varying the speed limits, making the hard shoulder available to traffic and ramp metering are used to make journey times more reliable, improve traffic flow and reduce congestion.

1. Scope

Aspects covered

1.1 This document shall be used for the assessment of existing bridge supports.

NOTE 1 *This document does not cover the assessment of geotechnical structures, such as corrugated-steel buried structures or reinforced soil abutments.*

NOTE 2 *The assessment of CCTV masts, lighting columns, sign and signal gantries and pipe bridges are not within the scope of this document.*

1.2 Where the traffic flow underneath an existing bridge has or is anticipated to significantly increase (e.g. following the introduction of a smart motorway scheme) this document shall be used for the assessment of the bridge supports.

1.3 The intention behind these requirements is that the overall structural integrity of the bridge shall be maintained following an impact but that local damage to a part of the bridge support can be accepted.

1.4 For bridges other than highway or foot/cycle track bridges, such as rail bridges, over a highway, the application of this document shall be agreed with the authority responsible for the bridge.

1.5 Where foot/cycle track bridge ramps and stairs are structurally independent of the main highway-spanning structure and do not span over the highway themselves, their supports shall not be assessed for the enhanced collision loading.

Implementation

1.6 This document shall be implemented forthwith on all schemes involving bridge supports on the Overseeing Organisations' motorway and all-purpose trunk roads according to the implementation requirements of GG 101 [Ref 2.N].

Use of GG 101

1.7 The requirements contained in GG 101 [Ref 2.N] shall be followed in respect of activities covered by this document.

2. Prioritisation

2.1 All supports shall be categorised into one of the following 3 groups in accordance with Figure A1.1 in Appendix A:

1) Group 1 - "Particularly at risk" supports.
2) Group 2 - "At Risk" supports.
3) Group 3 - "Low Risk" supports.

Group 1 supports

2.2 Supports in group 1 shall be divided into two subgroups in accordance with figure A1.1.

2.3 Group 1a supports shall be further assessed as outlined in section 5.

2.4 Where further assessment of a group 1a support determines it necessary to strengthen or protect the support, immediate action shall be taken to mitigate the risk of a weak/vulnerable support.

2.5 Group 1b supports shall be further assessed as outlined in section 5.

2.6 Where further assessment of a group 1b support determines it necessary to strengthen or protect the support, this repair shall be undertaken as part of the next suitable major maintenance project that allows this activity to be carried-out without significantly delaying the project or disrupting the network.

2.6.1 Where no suitable project that allows this activity to be carried out has been identified, a risk assessment should be carried out and the supports managed in accordance with the outcome of that risk assessment.

2.7 Where it can be demonstrated by assessment, Category 2 in accordance with CG 300 [Ref 3.N], that collapse of one or more spans will occur following the application of the collision loading for supports in group 1a and 1b, strengthening or protection with a very high containment barrier shall be provided.

2.8 Where collapse cannot be confirmed the structure shall be moved into group 2.

Group 2 supports

2.9 Where deemed necessary by the TAA, further structural analysis on group 2 supports shall only be carried out when a suitable major maintenance project has been confirmed within the forward programme.

2.9.1 Where an assessment has shown that the support requires protection, group 2 supports should be placed in the forward programme to be protected but only as part of the next suitable major maintenance project when the existing vehicle restraint system is planned for renewal, to minimise the disruption to the network.

Group 3 supports

2.10 Confirmation of group 3 categorisation shall be recorded on the Overseeing Organisation's structures management information system with supporting information.

3. Collision loading

3.1 The loading requirements outlined in section 3 shall be used for the assessment of group 1 and group 2 supports.

Nominal loads

3.2 The supports shall be assessed for their ability to resist both the main and residual load components acting simultaneously in accordance with Table 3.2.

Table 3.2 Collision loads on supports of bridges over highways

	Load normal to carriageway below (kN)	**Load parallel to carriageway below (kN)**	**Point of application on bridge support**
Main load component	500	1000	At the most severe point between 0.75m and 1.5m above ground level adjacent to support
Residual load component (Figures shown in brackets shall be applied to footbridges in urban locations with robust plinths)	250 (100)	500 (100)	At the most severe point between 1m and 3m above ground level adjacent to support

3.2.1 Where protective plinths 1.5m high are provided to footbridge supports, the plinths may be assessed for the combined main and residual load components and the bridge supports may be assessed for the reduced residual load component shown in Table 3.2.

3.3 The loads shall be applied horizontally as secondary live loads in combination 4 in accordance with the requirements of CS 454 [Ref 1.N].

3.4 Loads normal to the carriageway shall be applied separately from loads parallel to the carriageway.

3.5 For all bridge elements except foundations and elastomeric bearings, the effects due to vehicle collision shall only be applied at the ultimate limit state.

3.6 The value of partial safety factor for loading γ_{fL} shall be taken as 1.5.

3.7 Where a permissible stress approach is used to assess foundations, and where elastomeric bearings are assessed at the serviceability limit state only, a γ_{fL} factor of 1.0, shall be used.

4. Analysis

General

4.1 The method of analysis shall be agreed with the TAA.

4.1.1 Where bridge supports are assessed, a quasi-static analysis should be carried out in the first instance.

4.1.2 Where the structure fails this assessment dynamic analysis may be used.

NOTE *The quasi-static approach can be simpler to apply than the dynamic analysis but it can yield more conservative results.*

4.1.3 For the assessment of bridge supports using the quasi-static approach, the nominal loads given in Table 3.2 may be multiplied by a reduction factor of:

Equation 4.1.3 Reduction factor for nominal loads in Table 3.2

$$\left(\frac{30}{30+m}\right)$$

where: m is the mass of the support member in tonnes.

NOTE *The deck loading or weight of foundation cannot be included when calculating m as this reduction is based on momentum conservation and assumes that the support member alone participates in the dynamic response.*

4.2 Where using a quasi-static analysis for the assessment of bridge supports this reduced value of impact loading shall be applied statically.

4.2.1 Where assessments of foundations, deck slabs and other members directly connected to the support member are being carried out, the loads in Table 3.2 may be reduced by 50% and treated as acting statically.

4.2.2 Where assessments of more remote members are being carried out, for example piling systems, the loads shown in Table 3.2 may be reduced by 75% and treated as acting statically.

NOTE *It has been shown by laboratory impact tests Watson & Inkester 1982 [Ref 1.I], that a considerable amount of the impact energy can be lost through local damage and vibration.*

5. Assessment

5.1 Concrete bridge supports shall be assessed in conjunction with the requirements of CS 455 [Ref 5.N].

NOTE *Vehicle collision on abutments can normally be neglected as they are assumed to have sufficient mass to withstand the collision loads for global purposes.*

5.1.1 When considering shear, flexure and bonding, the values of γ_{mv}, γ_{mc} and γ_{mb} may be reduced by 10%, for both characteristic and worst credible strength applications CS 454 [Ref 1.N].

5.2 Steel supports shall be assessed in conjunction with the requirements of CS 456 [Ref 6.N].

5.3 Where an impact has occurred, the overall integrity of a damaged structure shall be assessed at the ultimate limit state.

5.4 Under the primary live loading derived using combination 1 serviceability limit state γ_{fl} factors given in Table 1 of CS 454 [Ref 1.N]; γ_{f3} shall be taken as 1.0.

5.5 When HB loading is applied, only 30 units shall be applied.

5.6 The structure shall be assessed to see if the support system as a whole will still be capable of carrying the imposed load from the deck above, following a collision.

5.6.1 Non-linear methods such as plastic analysis may be used for assessment.

NOTE *In many instances considerable damage can be sustained by the bridge (including large rotations, lateral displacements and local damage) or by an individual support member (including failure of the member, its bearings or foundations), without the structure itself failing.*

5.7 Where the removal of bridge supports would not affect the overall integrity of the structure, and where it has been checked that after impacting and removing one support, a vehicle will not damage adjacent supports and thereby cause a collapse of the bridge deck, the supports shall not be assessed for collision loads.

5.8 Where there are multi-level carriageways, such as those encountered in motorway, all-purpose trunk road or principal road interchanges, the collision loads shall be assessed for each level of carriageway separately.

5.9 Assessment shall be carried out in two stages.

Stage 1 At the moment of impact.

5.10 A check shall be made at the moment of impact at ULS only, using the nominal impact loads with partial factors γ_{fl} appropriate to load combination 4 in accordance with 'The assessment of Highway Bridges and Structures' CS 454 [Ref 1.N].

5.11 No other live load shall be included.

5.12 Local damage shall be ignored.

5.13 Full transfer of the collision forces from the point of impact shall be assumed.

5.14 The load-path to transfer the impact loads to foundations, bearings or other supports shall be determined.

5.15 Each structural element in the load-path shall be assessed starting with the element which sustains the immediate impact.

5.16 Where a structural element is determined to be inadequate it shall be assumed to have affected the transfer to the next element(s) in the load path.

5.17 Where a structural element is determined to be inadequate it shall be neglected in carrying out the stage 2 check.

NOTE *Inadequacy of a structural element at this stage can help to absorb the impact force.*

5.18 Each element in the load-path shall be assessed on the same basis.

5.19 The bearing and supports shall be assessed on their ability to resist impact loads to prevent the whole structure being bodily displaced by the impact.

NOTE *The Overseeing Organisation can require that certain other elements are adequate to resist the impact loads.*

Stage 2. Immediately after the impact

5.20 The bridge shall be checked using combination 1 in accordance to CS 454 [Ref 1.N] to ensure that it will be able to stand up immediately after an impact whilst still carrying traffic which can be crossing.

5.21 The check shall be carried out at ULS only using the partial load factors normally appropriate to SLS.

5.21.1 The partial factors γ_m and γ_{f3} should take their usual ULS values.

5.22 HA loading and/or a maximum of 30 units of HB loading shall be applied for bridges carrying public highways.

5.23 The check shall take into account what local damage might reasonably have occurred.

5.24 The bridge support check immediately after a collision shall disregard elements that were assumed or found to be inadequate at Stage 1.

Foundations

5.25 Foundations shall be assessed in accordance with CS 454 [Ref 1.N] and CS 459 [Ref 4.N].

5.26 Where checking for bearing of foundations, the ultimate bearing capacity shall be used.

5.27 Foundations shall be assessed on their ability to resist the impact forces transmitted from the collision.

5.28 The check on the foundations shall be carried out at ULS only, both for structural elements and soil-structure interaction.

5.29 Where a check against the sliding of the base and bearing capacity is carried out, even for piled foundations, the collision loads shall be reduced by 50%.

5.30 Where a check against overturning is carried out, the full loading shall be applied.

Group 1a and 1b supports

5.31 All assessments shall be subject to technical approval in accordance with CG 300 [Ref 3.N].

Group 2 supports

5.32 For Group 2 supports, category 0 technical approval shall apply for the assessments unless otherwise agreed with the TAA.

5.33 For Group 2 supports, the assessments shall be limited to quantifying the capacity of the support to resist collision loading.

6. Strengthening and protection

6.1 Group 1 and 2 supports which fail assessments shall require strengthening or additional protection so as to be able to sustain the collision loads given in current design standards.

Strengthening

6.2 Strengthening schemes for structures which fail assessment shall be designed in accordance with current design standards.

6.2.1 Wherever possible, strengthening should be carried out with other maintenance or improvement works in order to minimise delays to road users.

Protection

6.3 Protection schemes for structures which fail assessment shall be designed in accordance with current design standards.

6.3.1 Where a bridge support is protected by a vehicle restraint system the support should be assessed for the residual load components only, unless more accurate information on the likely resulting impact loading is available.

6.3.2 For Group 1 supports, protection may be achieved through the provision of a very high containment level barrier (H4a) with full working width.

6.3.3 For Group 2 supports, protection may be achieved through the provision of a higher containment level barrier (H1 or H2) with full working width.

7. 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. CS 454, 'Assessment of highway bridges and structures'
Ref 2.N	Highways England. GG 101, 'Introduction to the Design Manual for Roads and Bridges'
Ref 3.N	Highways England. CG 300, 'Technical approval of highway structures'
Ref 4.N	Highways England. CS 459, 'The assessment of bridge substructures and retaining structures and buried structures'
Ref 5.N	Highways England. CS 455, 'The assessment of concrete highway bridges and structures'
Ref 6.N	Highways England. CS 456, 'The assessment of steel highway bridges and structures'

8. Informative references

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

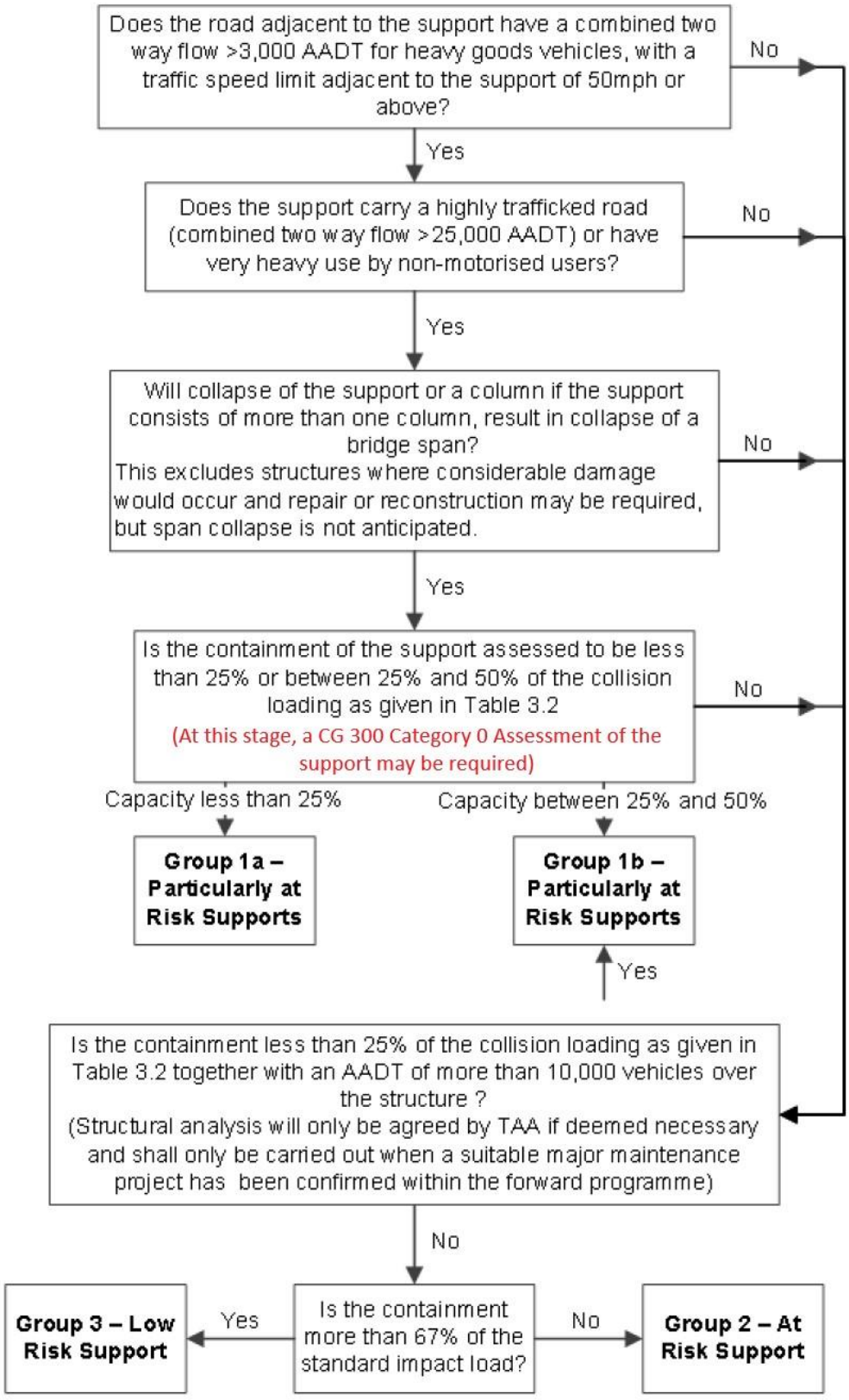
Ref 1.I	American Concrete Institute. Alan J. Watson and John E. lnkester. Watson & Inkester 1982, 'Impact Loading of a Reinforced Concrete Beam-to-Column Joint'

Appendix A. Prioritisation of bridge supports

A1 Prioritisation of bridge supports process

The following flow chart is to be used for the prioritisation of bridge supports:

Figure A.1 Prioritisation of bridge supports process



NOTE 1 The risk of structural collapse reduces with increasing number of columns.