Design Manual for Roads and Bridges

Highway Structures & Bridges
Inspection & Assessment

CS 467
Risk management and structural assessment of concrete deck hinge structures

(formerly BA 93/09)

Revision 1

Summary
The use of this document enables the safety and serviceability of concrete hinge deck structures to be assessed and managed, allowing to manage risks and maintain a safe and operational network.

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	Apr 2020	Revision 1 (April 2020) This revision is for minor amendments to the England NAA only. Please see the England NAA revision release notes for details. Revision 0 (March 2020) CS 467 document replaces BA 93/09. This full document has been re-written to make it compliant with the new Highways England drafting rules. This document contains updated content on the risk management of bridges with deck hinges and their structural assessment, highlighting requirements and advice for a risk management plan and clarifying the risk assessment methodologies, to fully align with the other associated DMRB documents, still retaining compatibility with the stages of the current management strategy and the existing requirements for structural assessment of deck hinge structures.

Foreword

Publishing information

This document is published by Highways England .

This document supersedes BA 93/09, which is withdrawn.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

The use of this document enables the safety and serviceability of deck hinges to be managed and assessed, providing key information that is required to manage risks and maintain a safe and operational network.

This document has been developed to replace BA 93/09.

The approach for risk management of deck hinge structures has been developed based on current guidance towards risk management of structures from the industry, as well as GG 104 [Ref 8.N].

The document has been developed in combination with new content in CS 455 [Ref 11.N], including relevant content about using strut-and-tie analysis, and effects of deterioration and detailing on hinge joint assessments.

Assumptions made in the preparation of this document

The assumptions made in GG 101 [Ref 5.N] apply to this document.

Abbreviations and symbols

Abbreviations

Abbreviation	Meaning
ALL	Assessment live loading. Refer to CS 454 [Ref 1.N]
SLS	Serviceability limit state
TAA	Technical Approval Authority. Refer to CG 300 [Ref 10.N].
ULS	Ultimate limit state

Symbols

Symbol	Definition
h	Depth of the hinge, measured as the clear depth between hinge formers
D	Nominal diameter of the scissor bars
K	Constant used in the simplified analysis for fatigue
R_c	Condition risk representing the likelihood of structural failure due to condition risks being realised
R_D	Structural risk representing the likelihood of structural failure due to structural capacity risks being realised
R_{D1}	The structural risk R_D determined based on the as built reinforcement detailing of the deck hinge
R_{D2}	The structural risk R_D determined based on the previous structural assessment findings specific to the deck hinge
R_Q	Consequential risk
R_V	Vulnerable details risk
R_F	Deck hinge form risk
R_O	Other risks
α	Difference between the rotations of the deck on either side of the hinge
γ_{f3}	Partial factor defined in CS 454 [Ref 1.N]
σ_s	Axial tensile stress a tension scissor bar, assuming that all the shear force in the hinge is carried by the tension scissor bars
σ_{sb}	Stress in the scissor bar

Terms and definitions

Terms

Term	Definition
Immediate risk structure	Structures that are considered to represent an immediate and unacceptable safety risk to the public. See also CS 470 [Ref 7.N]
Lower-bound analysis	Lower-bound analyses are based on finding any system of internal forces that are everywhere in equilibrium with the applied loads and which nowhere exceed yield.
Provisionally sub-standard	Structures that are deemed to be sub-standard without an assessment or assessed to have sub-standard load capacity at any stage during the assessment process. See also CS 470 [Ref 7.N]
Structural assessment	The process of determining in terms of vehicle loading the load that an existing structure can carry with an acceptable probability without suffering serious damage that can endanger any persons on or near the structure.
Sub-standard structures	Structures found to be sub-standard in terms of meeting the carriageway loading requirements given in CS 454 [Ref 1.N] or by other means, or after carrying out an appropriate assessment. See also CS 470 [Ref 7.N]

1. Scope

Aspects covered

1.1 This document shall be used for the risk management and structural assessment of bridges with concrete deck hinges.

NOTE 1 *Typical deck hinge details are illustrated in Appendix B.*

NOTE 2 *Bridges with concrete deck hinges include structures with a Wichert truss detail.*

1.2 This document shall be used to prioritise deck hinge structures for structural assessment and risk management.

NOTE *The requirements for managing sub-standard structures, including immediate risk structures, are found in CS 470 [Ref 7.N].*

Implementation

1.3 This document shall be implemented forthwith on all schemes involving the management or assessment of structures with concrete deck hinges on the Overseeing Organisations' motorway and all-purpose trunk roads according to the implementation requirements of GG 101 [Ref 5.N].

Use of GG 101

1.4 The requirements contained in GG 101 [Ref 5.N] shall be followed in respect of activities covered by this document.

2. Risk management process and prioritisation

2.1 All deck hinge structures shall be managed by an ongoing process of review, risk assessment and risk management.

2.1.1 The process of review, risk assessment and risk management should include:

1) existing priority list, where available;
2) review triggers.

NOTE 1 Review triggers can include the following:

1) structures with a change in condition that can affect the load carrying capacity;
2) structures with deck hinges where no previous structural assessment exists;
3) structures with deck hinges which have never had a special inspection undertaken on the deck hinges;
4) structures with deck hinges where there are doubts about the validity of the previous assessment methodology or assumptions made;
5) families of structures known to have deficient deck hinges;
6) structures affected by or incorporated in new schemes;
7) changes to the use of the structure, for example altered lane markings;
8) structures where long term solutions have been implemented and the deck hinge detail is retained.

NOTE 2 Long term solutions can include repair, strengthening and replacement.

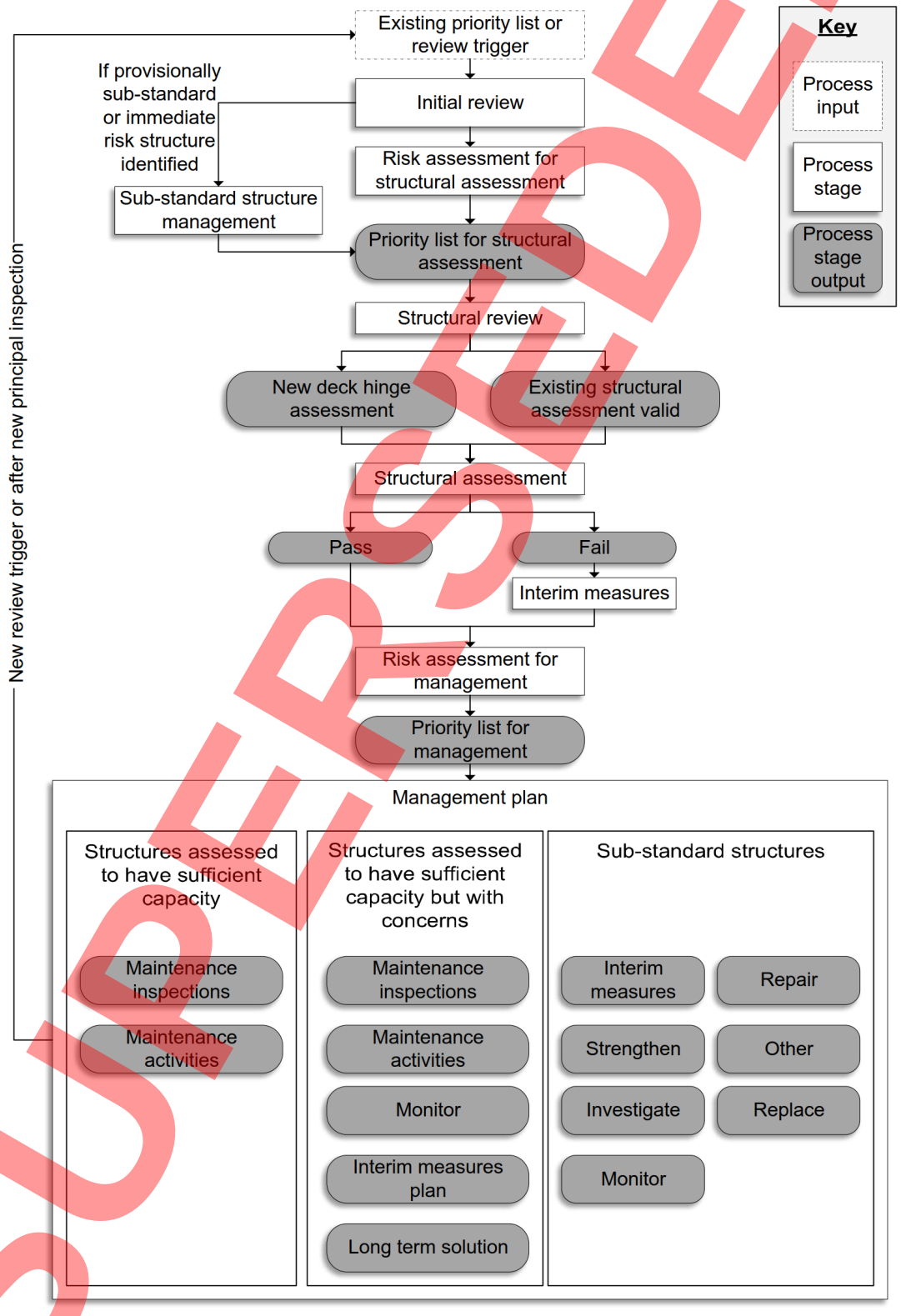
2.1.2 Where a deck hinge structure is currently subject to an existing deck hinge management plan, then the structure may continue to be managed using the existing deck hinge management plan until a new review trigger occurs.

2.2 Where a new review trigger occurs to a deck hinge structure currently subject to an existing deck hinge management plan, then the deck hinge structure shall be managed using the risk management process described in this document and added to the priority list.

2.3 The risk management process shall comprise the following stages, as illustrated in Figure 2.3:

1) initial review;
2) risk assessment for structural assessment;
3) structural review;
4) structural assessment;
5) risk assessment for management;
6) management plan.

Figure 2.3 Deck hinge structures risk management process flowchart



NOTE 1 Each stage of the risk management process is described in Section 3 to Section 8 of this document.

NOTE 2 *The structural assessment outputs refer to whether a structure is structurally assessed as being capable of carrying normal traffic (pass) or not (fail) in accordance with CS 454 [Ref 1.N].*

2.4 Risk assessments shall be undertaken in accordance with GG 104 [Ref 8.N].

2.5 Sub-standard deck hinge structures shall be managed in accordance with CS 470 [Ref 7.N] and in conjunction with this document.

2.6 The risk management process in Figure 2.3 shall be revisited for a deck hinge structure in the following situations:

1) new review triggers occur;
2) following a new principal inspection.

NOTE *The purpose of revisiting the risk management process following a new principal inspection is to verify whether the current risk management process inputs and outputs change as a result of the findings from the new principal inspection.*

2.6.1 Where the current risk management process inputs and outputs are unchanged following a new principal inspection, then the structure may continue to be managed using the existing deck hinge management plan until a new review trigger occurs.

Risk management report

2.7 The risk management report shall be the means by which the key inputs, outputs, justification and decisions from the risk management process is recorded and agreed.

NOTE *A model risk management report is provided in Appendix A.*

2.8 The risk management report shall be a live document, started during the initial review, then reviewed and updated at each stage of the risk management process.

2.9 The risk management report shall be submitted to the Overseeing Organisation for agreement at agreed milestones.

2.9.1 Milestones may be the completion of each stage of the risk management process.

2.10 Where managed through CS 470 [Ref 7.N], a summary of the sub-standard structure management plan shall be included in the risk management report.

Initial review

2.11 The following shall be included in the risk management report following the initial review:

1) the inputs informing the desk study, including review triggers;
2) whether there is need to undertake a new inspection of the deck hinge;
3) the findings from the desk study;
4) recommendations for investigations to be undertaken to provide information needed to complete the risk assessment.

Risk assessment for structural assessment

2.12 The risk management report shall record the inputs and outputs from the risk assessment for structural assessment stage.

NOTE 1 *The inputs for the risk assessment for structural assessment include:*

1) primary and secondary risks used in the risk assessment;
2) justification and evidence informing the determination of the risk ratings.

NOTE 2 *The outputs for the risk assessment for structural assessment include:*

1) the risk rating for each primary or secondary risk;

2) *the primary risk rating;*
3) *where applicable, the refined primary risk rating;*
4) *where applicable, the secondary risk rating.*

NOTE 3 *Risks and risk ratings are described in Section 4 and Section 7 of this document.*

Structural review

2.13 The risk management report shall record a summary of the outputs from the CS 451 [Ref 9.N] structural review.

Structural assessment

2.14 The risk management report shall record a summary of the findings and recommendations from the structural assessment.

Risk assessment for management

2.15 The risk management report shall record the inputs and outputs from the risk assessment for management stage.

NOTE 1 *The inputs for the risk assessment for management include:*

1) *primary and secondary risks used in the risk assessment;*
2) *justification and evidence informing the determination of the risk ratings.*

NOTE 2 *The outputs for the risk assessment for management include:*

1) *the risk rating for each primary or secondary risk;*
2) *the primary risk rating;*
3) *where applicable, the refined primary risk rating;*
4) *where applicable, the secondary risk rating.*

NOTE 3 *Risks and risk ratings are described in Section 4 and Section 7 of this document.*

Management plan

2.16 The risk management report shall include a summary of the risk management plan and recommended risk management measures for the structure.

Prioritisation of deck hinge structures

2.17 Where the structural assessment and management of numerous deck hinge structures are required, they shall be prioritised based on the outputs from the risk management process.

NOTE *A model prioritisation list is provided in Appendix A.*

3. Initial review

3.1 An initial review shall be carried out as a desk study to evaluate whether the information to be used for the risk assessment is:

1) sufficient to enable a risk assessment to be completed;
2) current;
3) valid.

3.2 The initial review shall be undertaken by reviewing the following record information:

1) the most recent risk assessment;
2) as-built drawings, construction records and other as-built information;
3) principal, general or special inspection reports;
4) recommendations from previous inspections and maintenance records;
5) previous structural assessments and recommendations.

3.2.1 A review of any previous structural assessments should cover the following:

1) whether a specific deck hinge assessment has been completed;
2) the assessed load carrying capacity of the deck hinge;
3) the availability and validity of the assessment and check certificates;
4) the availability and validity of the assessment report.

NOTE *Structural assessments are not valid for the management process described in this document if they have not specifically assessed the capacity of the deck hinge.*

3.2.2 Where previous inspections of the deck hinge structure are unavailable or a change in condition is likely since the structure was last inspected on the basis of the findings of the last available inspection, then an inspection of the deck hinge structure should be undertaken.

3.2.3 The type and extent of inspection should be targeted at obtaining the required information for the initial review or evaluating the change in condition.

3.2.4 Where additional information is needed to complete the risk assessments, a recommendation for investigations to be undertaken should be included in the risk management report.

3.2.5 The risk management report should include recommendations on the timescales for undertaking the investigations.

3.3 Where the initial review finds evidence that the deck hinge could be at immediate risk or provisionally sub-standard, then the structure shall be managed in accordance with CS 470 [Ref 7.N].

NOTE *Evidence indicating that a deck hinge can be at immediate risk can include:*

1) significantly deteriorated condition;
2) recent event causing significant defects;
3) signs of a failure mechanism developing.

4. Risk assessment for structural assessment

Risk assessment

4.1 A risk assessment shall be completed to prioritise deck hinge structures for structural assessment.

NOTE 1 *The output from the risk assessment process assigns a risk rating to each structure to enable prioritisation for structural assessment.*

NOTE 2 *Example risk ratings are as follows:*

1) very high;
2) high;
3) medium;
4) low.

4.2 The following primary risks shall be included when completing a risk assessment to determine a primary risk rating for prioritising structural assessments:

1) condition risk, R_C ;
2) structural risk, R_D .

NOTE 1 *The primary risks are used to assess the risk of the structural failure of the deck hinge based on the following:*

1) R_C representing the likelihood of structural failure due to condition risks being realised;
2) R_D representing the likelihood of structural failure due to structural capacity risks being realised;
3) the severity of the consequences at this stage is taken as being very high as it involves a deck hinge structure failure which can lead to collapse.

NOTE 2 *Guidance on each of the primary risks listed and how to use them is provided in Appendix B.*

4.2.1 The primary risk rating should be used to determine an initial priority list for the structural assessment of a group of deck hinge structures.

4.2.2 The effects from the combination of condition and structural risk should be assessed when assigning a risk rating for the primary risks.

NOTE *An example of how the risk rating of a structure changes due to effects in combination can be found in Appendix B.*

4.2.3 The following secondary risks may be used to refine the primary risk rating of a deck hinge structure:

1) consequential risk, R_Q ;
2) vulnerable details risk , R_V ;
3) deck hinge form risk, R_F ;
4) other risks, R_O .

NOTE 1 *Secondary risks can be used to either increase the primary risk rating or to prioritise between a number of structures with the same primary risk rating.*

NOTE 2 *Where secondary risks are used to increase the primary risk rating, this is referred to as the refined primary risk rating.*

NOTE 3 *Where secondary risks are used to prioritise between a number of structures with the same primary risk rating, this is referred to as the secondary risk rating.*

NOTE 4 *Guidance on each of the secondary risks, how to use them in combination with the primary factors is provided in Appendix B.*

Primary risks

Condition risk

4.3 The risk rating for the condition risk, R_C , shall be determined based upon the current condition of the deck hinge.

4.4 The current condition of the deck hinge shall be verified from photographs and information available within inspection information.

4.4.1 Conclusions made in inspection reports should be verified through reviewing the site inspection information.

4.5 The deck hinge shall be evaluated for possible combinations of defects on the structural capacity.

NOTE *The effects on the strength of the section from combinations of defects can be greater than the sum of individual defects (e.g. the interaction between poor longitudinal reinforcement anchorage and the provision of insufficient shear reinforcement). Individual defects can have a limited impact on the capacity (due to alternative load paths being formed), but for multiple defects, alternative load paths could no longer be available.*

Structural risk

4.6 The risk rating for the structural risk, R_D shall be determined based upon either:

1) the as built reinforcement detailing of the deck hinge, R_{D1} ; or,
2) the previous structural assessment findings specific to the deck hinge, R_{D2} .

NOTE 1 *R_{D1} represents the risk of structural failure based on the indicative load carrying capacity and the as-built reinforcement detailing, evaluated in accordance with CS 455 [Ref 11.N] and Section 6 of this document.*

NOTE 2 *The indicative load carrying capacity of the deck hinge can be estimated using the following reinforcement detailing related aspects:*

1) bar arrangement;
2) anchorage;
3) continuity of reinforcement;
4) bearing stresses;
5) arrangement of links surrounding the scissor and dowel bars.

NOTE 3 *R_{D2} represents the risk of structural failure based on the assessed load carrying capacity.*

NOTE 4 *The assessed load carrying capacity can be obtained from previous assessment findings in assessment reports or certificates if available.*

4.6.1 The as built reinforcement detailing may be established through review of record information such as:

1) as-built drawings, construction records and other as-built information;
2) previous investigation or assessment reports;
3) previous structural assessments.

4.6.2 Where there is a lack of record information to determine R_D , recommendation on whether investigations are required to determine the as built reinforcement detailing should be included in the risk management report.

4.6.3 Where there is a need to complete the risk assessment for a structure with lack of record information, then a higher risk rating may be adopted for R_D provisionally to reflect the lack of information.

Secondary risks

Consequential risk

4.7 The risk rating for consequential risk R_Q , shall be determined based upon the current traffic and route type over or under the structure.

NOTE 1 *R_Q represents the consequence of structural failure on the routes carried by or below the structure.*

NOTE 2 *Route types can include highways, railways, waterways, cycleways, bridleways, and footways.*

4.7.1 R_Q should be determined by evaluating the consequences of failure of the deck hinge in terms of the routes over and under the structure, including:

1) number of people killed or seriously injured;
2) damage to vehicles;
3) damage to utilities and services;
4) nature of the route over and under the structure;
5) the viability of diversion routes in the event of structural failure;
6) volume of traffic over and under the structure;
7) length of time to restore normal operation;
8) environmental pollution;
9) political and reputational damage;
10) financial impact.

Vulnerable details risk

4.8 The risk rating for the vulnerable details risk, R_V shall be determined based upon additional vulnerable details present on the structure.

NOTE *R_V represents the risk of structural failure due to additional vulnerable details such as:*

1) post-tensioned elements;
2) evidence of inadequate drainage or waterproofing system;
3) low concrete grade;
4) sub-standard concrete cover;
5) presence of chlorides in concrete or grout.

Other risks

4.9 The risk rating for other risks, R_O shall be taken as low unless otherwise agreed with the Overseeing Organisation.

4.9.1 R_O may be determined based upon other considerations that affect the risk and priority of a structure.

NOTE 1 *R_O represents a tool to include other risks and considerations that can affect the priority of a deck hinge structure.*

NOTE 2 *Examples of other risks and considerations that can affect the priority of a deck hinge structure can include:*

1) Overseeing Organisation preferences;
2) effects on, or caused by, new schemes such as changes to loading;
3) families of structures which have the same construction type.

5. Structural review

5.1 Following the risk assessment for structural assessment, the structure shall be reviewed in accordance with CS 451 [Ref 9.N] to determine if a new structural assessment is required.

5.1.1 The structural review should be undertaken in accordance with the priority list of deck hinge structures resulting from the risk assessment for structural assessment, starting with the highest priority structures first.

5.2 Where the structural review finds the previous structural assessment is no longer valid then the risk assessment for structural assessment shall be revisited to update the priority of the structure.

5.2.1 Where the structural review finds the previous structural assessment is no longer valid, R_{D1} may be used in place of R_{D2} to update the priority of the structure.

NOTE *Examples of previous structural assessments that are no longer valid include the following:*

1) the previous structural assessment did not specifically assess the capacity of the deck hinge;

2) an intrusive investigation finds reinforcement provision that does not match the as built records;

3) a change in the condition of the structure.

5.2.2 Where R_{D1} is used in place of R_{D2} following the structural review, the reason behind this should be recorded in the risk management report.

6. Structural assessment

Assessment processes and basis of assessment

6.1 The assessment processes and basis of assessment for the deck hinge shall follow the requirements of CS 454 [Ref 1.N] and CS 455 [Ref 11.N] supplemented by the additional requirements of this section.

Limit States

6.2 The assessment shall be carried out at the ultimate limit state (ULS).

6.3 Where an assessment of crack width at the serviceability limit state (SLS) is proposed, the methodology and criteria for the assessment shall be subject to technical approval in accordance with CG 300 [Ref 10.N].

6.4 A fatigue assessment shall be carried out.

NOTE *Requirements for fatigue assessment are provided in the corresponding sub-section of this document.*

Assessment actions and assessment action effects

6.5 The assessment actions and assessment action effects that are applied to the deck hinge shall be determined from an assessment of the structure in accordance with CS 455 [Ref 11.N] and CS 454 [Ref 1.N].

NOTE *The distribution of the load effects in a hinge can be affected by the skew of the bridge, particularly when the angle of skew exceeds 10 degrees.*

6.5.1 Where it is possible for longitudinal loading to be transmitted through the deck hinge, including where the longitudinal loading has an adverse effect, the effects of longitudinal loading should be included.

6.5.2 The shear and axial load effects in the hinges may be determined based on the assumption that the hinges behave as pinned supports.

Assessment of resistance

6.6 The assessment of resistance of the deck hinge shall be carried out in accordance with CS 455 [Ref 11.N] and the additional requirements in this document, including the effects of:

1) loss of throat reinforcement cross-section;
2) misplaced reinforcement;
3) concrete spalling and debonding;
4) loss of link reinforcement;
5) reduced effectiveness of bond for bars with low cover or corroded bars;
6) reinforcement with low ductility;
7) reduced concrete resistances and bond due to internal degradation of concrete.

Verification

6.7 The value of γ_{f3} shall be obtained from CS 454 [Ref 1.N] based on the type of analysis used for the assessment.

Methodology for structural analysis of the hinge

6.8 The methodology for the structural analysis of the hinge shall be subject to technical approval in accordance with CG 300 [Ref 10.N].

6.9 A lower-bound analysis such as a strut-and-tie analysis shall be used to quantify the assessed load-carrying capacity at the ULS.

6.10 The vertical resistance of hinges at the ULS shall not be assessed using structural analysis models that rely on concrete in tension as a primary load carrying component.

Assessment based on strut-and-tie analysis

6.11 Where a strut-and-tie analysis is used, the assessment shall be carried out according to the requirements for the strut-and-tie approach to the shear resistance of beams with shear reinforcement in CS 455 [Ref 11.N] and the additional content in this document.

NOTE *The requirements in CS 455 [Ref 11.N] for the strut-and-tie approach to the shear resistance of beams with shear reinforcement include limits on the stresses in struts, nodes and ties.*

6.11.1 Concrete tensile strength should not be included in the calculation of the tensile resistance of ties.

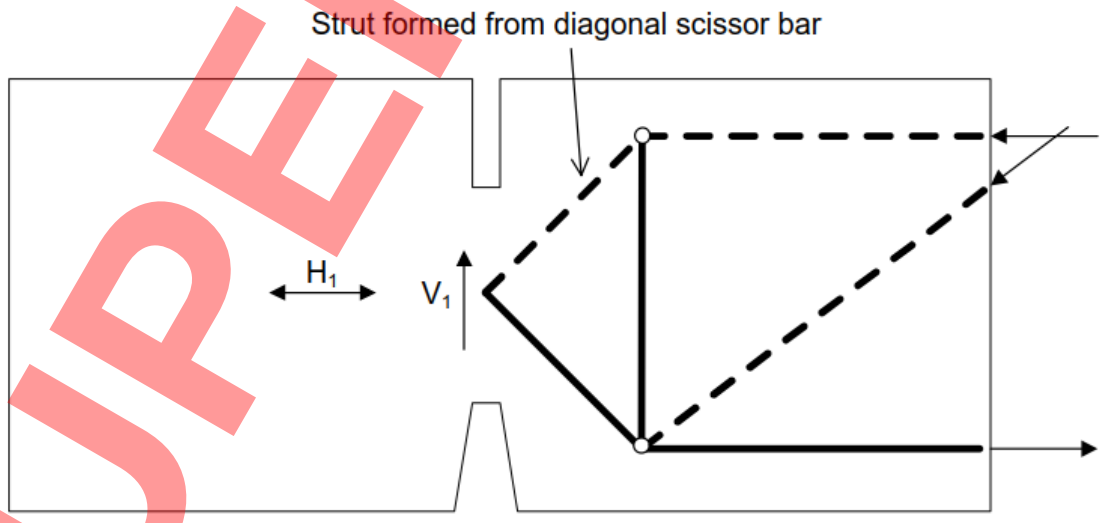
6.11.2 The compressive resistance of struts may be based on either:

1) the compressive strength of concrete as set out in the section on strut-and-tie assessment in CS 455 [Ref 11.N]; or,
2) the compressive strength of the diagonal scissor bar passing through the hinge acting in compression.

6.11.3 The effect of post-tensioning in hinges may be modelled by applying the post-tensioning forces as external actions.

6.11.4 The strut-and-tie analysis may initially be based on the simple approach illustrated in Figure 6.11.4, with the diagonal scissor bars acting in tension and compression.

Figure 6.11.4 Example strut-and-tie model using the diagonal scissor bars in tension and compression



NOTE 1 *In the figures in this section, the dashed lines represent struts, while the solid lines represent ties.*

NOTE 2 *In the example strut-and-tie models illustrated in this section, the struts are provided by the concrete, except for the strut formed from the diagonal scissor bar, as indicated in Figure 6.11.4.*

NOTE 3 *Refer to Appendix B for typical details of a deck hinge.*

6.11.5 Where the approach illustrated in Figure 6.11.4 does not provide sufficient resistance, a complementary strut-and-tie system may be superposed to provide additional resistance, for example, using the approach illustrated in Figure 6.11.5a or Figure 6.11.5b, or an alternative strut-and-tie model.

Figure 6.11.5a Example strut-and-tie model with a concrete compression strut passing through the hinge

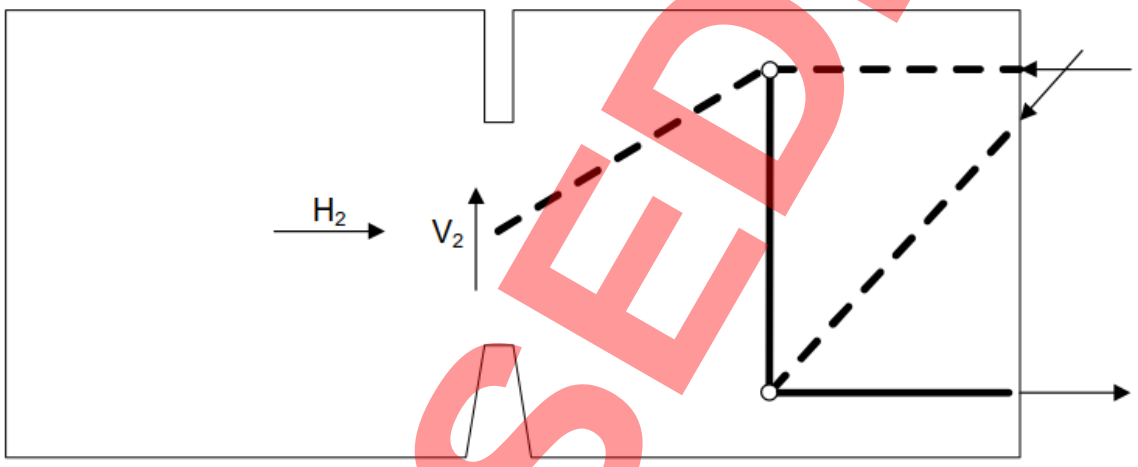
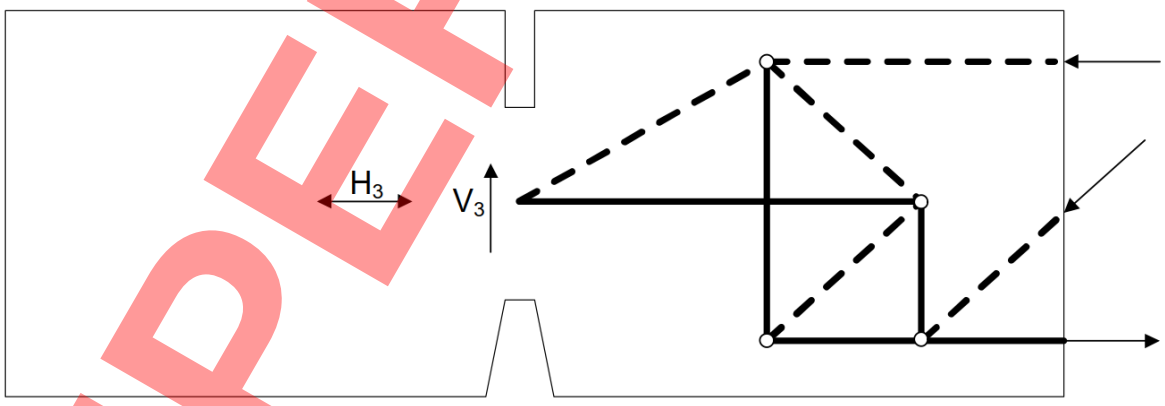


Figure 6.11.5b Example strut-and-tie model using the dowel bar as a tie member



6.12 Where strut-and-tie systems are superposed, the forces in the struts and ties shall be verified for the total superposed effects.

6.13 The components of horizontal force passing through the hinge for each system shall sum to the total net horizontal force coexistent with the applied shear force.

NOTE The total net horizontal force due to external forces can be:

1) zero, for example where the bridge is articulated to prevent net axial forces;

2) compressive, for example due to permanent actions putting the deck into compression;

3) tensile, for example due to restraint of longitudinal traffic actions.

Allowance for Faulty Construction

6.14 Allowance shall be made for construction tolerances in determining the maximum width of the concrete strut that can pass through the throat of the hinge.

6.14.1 Allowance for construction tolerances should be made by either:

1) using direct site measurements of the hinge throat geometry; or,
2) assuming a reduced effective hinge throat dimension equal to 90% of the value shown on record drawings.

Allowance for Deterioration

6.15 Corroded reinforcement shall be assessed in accordance with CS 455 [Ref 11.N].

NOTE 1 *Intrusive investigations can establish the condition of the reinforcement in a hinge joint.*

NOTE 2 *Significant corrosion of scissor bars can be present with few externally visible defects.*

6.16 Where there is damage or deterioration of the concrete in the hinge, the hinge throat dimension shall be reduced based on the depth of sound concrete.

NOTE *The approach of Figure 6.11.4 does not rely on a concrete compressive strut through the hinge, and can be useful where the throat concrete is seriously damaged.*

Fatigue Assessment

6.17 The fatigue life of hinge bars subject to cyclic tensile stress ranges shall be assessed, based on:

1) the stress ranges in the bars;
2) the frequency of the cycles;
3) the degree of corrosion in the bars.

6.18 The method of determining the fatigue life of hinge bars shall be subject to technical approval in accordance with CG 300 [Ref 10.N].

NOTE 1 *The fatigue life of reinforcing bars can be disproportionately sensitive to corrosion losses.*

NOTE 2 *Appendix C includes a relationship between the stress range and the fatigue endurance of reinforcing bars, including corroded bars.*

NOTE 3 *Methodologies for assessment of fatigue in steel structures are provided in CS 456 [Ref 3.I].*

6.19 Calculation of stress ranges in the tension hinge bars shall include:

1) a component due to fluctuating shear across the hinge;
2) a component due to hinge rotation.

6.19.1 The calculation of stress ranges should include the effect of concrete cracking and debonding of reinforcement in the joint.

NOTE 1 *Under shear load, cracks can typically develop from the corners of each hinge former at a right angle to the adjacent tension hinge bars, accompanied by local debonding adjacent to the crack.*

NOTE 2 *When a rotation is applied to the hinge, the cracks can open and close slightly. The stress change in the bar at the hinge can depend on the debonded length: the longer the debonded length, the smaller the resulting stress change in the bar.*

NOTE 3 *Under long-term cyclic loading, as the crack system around the hinge develops, the debonded length tends to increase.*

NOTE 4 *A method for calculating the local stress in the scissor bars is included in Appendix C.*

7. Risk assessment for management

7.1 A risk assessment shall be completed to prioritise structures with deck hinges for management and interventions.

7.2 The risk assessment for management shall be completed as per Section 4 of this document, with the risk ratings updated where required.

Primary risks

Condition risk

7.3 The risk rating for the condition risk, R_C , shall be reviewed to determine if the risk rating assigned is still valid.

7.3.1 The validity of the risk rating for R_C should be verified based upon:

1) findings from the most recent inspection;
2) any recent structure events reported which could affect the condition, for example:
   a) spalling concrete around the deck hinge;
   b) further cracking;
   c) vehicle impact to the structure.

7.4 Where appropriate, R_C shall be updated to reflect the current condition of the structure.

NOTE *Changes in the condition of a structure can affect the validity of the previous CS 451 [Ref 9.N] structural review and previous structural assessments.*

Structural risk

7.5 Where R_{D1} was used in the risk assessment for structural assessment to determine the structural risk rating, this shall be replaced by R_{D2} to reflect the deck hinge structural assessment findings.

7.6 The risk rating for the structural risk R_{D2} , shall be determined based upon the most recent and valid structural assessment findings.

NOTE *Where R_{D2} was used in the risk assessment for structural assessment and there was no new structural assessment required, then in the risk assessment for management, the risk rating for R_{D2} remains unchanged.*

Secondary risks

7.7 Where secondary risks were used in the risk assessment for structural assessment, they shall be reviewed to determine whether the risk ratings are still valid or whether they need to be updated in the risk assessment for management.

NOTE *Examples where the risk ratings for secondary risks need to be updated include:*

1) implementation of new schemes which can affect the structure;
2) changes to traffic volumes;
3) changes to diversion route viability;
4) changes to the nature of the route.

8. Management plan

8.1 The management plan for the deck hinge structure shall be developed and recorded within the risk management report.

8.1.1 The management plan should take into account the conclusions and recommendations from the structural assessment report.

8.1.2 The management plan may comprise a summary of another report or study, where various options are discussed and agreed.

8.2 The management plan shall be a live document, updated following changes to or arising from management measures.

NOTE *Changes to or arising from management measures can include:*

1) recommendations made to undertake investigations, inspections, assessments or studies;
2) recommendations arising from investigations, inspections, structural assessments or studies for management measures to be implemented;
3) updates to management plan following implementation of management measures.

8.3 To determine an appropriate management plan, the structures shall be categorised into the following:

1) structures assessed to have sufficient capacity;
2) structures assessed to have sufficient capacity but with concerns;
3) sub-standard structures.

NOTE 1 *Structures assessed to have sufficient capacity are structures which pass their deck hinge specific structural assessment specific for its current condition.*

NOTE 2 *Structures assessed to have sufficient capacity but with concerns are structures which pass their deck hinge specific structural assessment for its current condition, but with condition concerns which can be detrimental to the structural capacity over time.*

NOTE 3 *Sub-standard structures are structures that do not pass their structural assessment.*

Structures assessed to have sufficient capacity

8.4 A management plan shall be developed for structures assessed to have sufficient capacity.

8.4.1 The management plan should be targeted at maintaining or improving the current condition of the structure such that:

1) the assumptions made for the structural assessment remain valid;
2) its assessed structural capacity does not deteriorate.

8.4.2 The management plan for structures assessed to have sufficient capacity should include the following measures:

1) maintenance inspection regime to CS 450 [Ref 3.N];
2) recommendations for maintenance activities.

Structures assessed to have sufficient capacity but with concerns

8.5 A management plan shall be developed for structures assessed to have sufficient capacity but with concerns.

8.5.1 The management plan should be targeted at maintaining or improving the current condition of the structure such that:

1) the condition concerns are addressed;
2) the assumptions made for the structural assessment remain valid;

3) its assessed structural capacity does not deteriorate.

8.5.2 Structures assessed to have sufficient capacity but with concerns may be managed using the following measures:

1) maintenance inspection regime to CS 450 [Ref 3.N];
2) recommendations for maintenance activities;
3) monitoring regime;
4) plan for interim measures;
5) long term solution.

Sub-standard structures

8.6 The management plan for sub-standard deck hinge structures shall record the following:

1) the interim measures for managing the sub-standard deck hinge structure in accordance with CS 470 [Ref 7.N];
2) long term management measures.

8.6.1 The management plan may record the interim measures by either:

1) including references to the CS 470 [Ref 7.N] documents and records; or,
2) including a summary of the CS 470 [Ref 7.N] interim measures.

8.6.2 Deck hinge structures assessed to be sub-standard may be managed using the following measures:

1) interim measures;
2) monitoring regime;
3) investigations;
4) repair;
5) strengthen;
6) replace;
7) other measures.

NOTE *Interim measures can be found in CS 470 [Ref 7.N].*

Management measures

Maintenance inspections

8.7 An appropriate inspection regime shall be developed and recorded in the management plan.

NOTE *The Inspection Manual for Highway Structures IMHS [Ref 1.I] provides guidance on undertaking inspections of highway structures in general.*

8.8 Where special inspections in accordance with CS 450 [Ref 3.N] are proposed as an appropriate management measure for a deck hinge structure, the management plan shall record a summary of the purpose and frequency of the special inspections.

8.8.1 Special inspections for deck hinge structures should be carried out to determine:

1) presence and extent of expansion joint failure and consequent leakage of water and chlorides on the deck hinge;
2) presence and extent of cracking adjacent to the hinge;
3) presence and extent of efflorescence or any corrosion deposits;
4) presence and extent of concrete delamination or spalling;
5) bridge temperature at the time of the special inspection.

Maintenance activities

8.9 The recommended maintenance activities targeted at maintaining or improving the current condition of the deck hinge shall be recorded in the management plan.

NOTE *Effective maintenance activities for preventing further deterioration to a deck hinge structure can include:*

1) expansion joint replacement;

2) deck waterproofing repairs or replacement;

3) provision of effective drainage systems.

8.10 The timescales and intervals for the recommended maintenance activities to be implemented shall be recorded in the management plan.

Monitoring

8.11 Where monitoring of a deck hinge structure assessed to have sufficient capacity but with concerns is proposed as an appropriate management measure, the management plan shall record a summary of the monitoring regime.

8.11.1 The management plan may record a summary of the monitoring regime by either:

1) including a reference of the monitoring specification; or,

2) including a summary of the monitoring specification such as:

   a) monitoring type;

   b) monitoring frequency;

   c) definition of trigger levels;

   d) action plan if trigger levels are exceeded.

NOTE *Refer to CS 470 [Ref 7.N] for requirements and guidance on monitoring.*

Plan for interim measures

8.12 For a structure assessed to have sufficient capacity but with concerns, the management plan shall record a plan for suitable interim measures to be implemented in the event the condition of the structure deteriorates such that it becomes sub-standard.

NOTE *The plan for interim measures is intended to present in advance suitable interim measures that can be implemented in the event the condition of the structure deteriorates such that it becomes sub-standard.*

Long term solutions

8.13 For a structure assessed to have sufficient capacity but with concerns, the management plan shall record proposed long term solutions for the structure.

8.13.1 Long term solutions recorded in the management plan may include:

1) repair;

2) strengthen;

3) replace.

Interim measures

8.14 For sub-standard structures the interim measures shall be implemented in accordance with CS 470 [Ref 7.N].

Investigations

8.15 Where investigations, either non-destructive testing or invasive investigations, are proposed as an appropriate management measure for a sub-standard deck hinge structure, a summary of the details of the investigation shall be recorded in the management plan.

NOTE 1 *Investigations are useful for obtaining further information on the condition of the structure, enabling other management measures to be developed and targeted at addressing specific issues associated with the deck hinge.*

NOTE 2 *Non-destructive testing is unlikely to compromise the structural capacity of the deck hinge structure and is therefore preferable to invasive investigations in the first instance; however, invasive investigations to expose the reinforcement in the hinge, combined with non-destructive testing as appropriate, can be necessary in some cases.*

NOTE 3 *Examples of non-destructive testing and invasive investigations include:*

1) chloride content testing;
2) cement content testing;
3) half-cell measurements;
4) impact echo testing;
5) radiography;
6) acoustic emission testing;
7) thermography;
8) borescope inspection of bars from small holes drilled to the reinforcement.

8.16 Invasive investigations shall be planned and implemented such that the structural integrity of the deck hinge structure is not compromised.

Repair

8.17 Where repairs are proposed as an appropriate management measure for a sub-standard hinge structure, a summary of the repair details and extents shall be recorded in the management plan.

8.17.1 Repairs proposed as a management measure may include the following:

1) concrete repairs;
2) reinforcement replacement.

8.18 Concrete repairs shall be implemented in accordance with CD 359 [Ref 2.N].

8.19 Proposed repair solutions shall be targeted at reducing the risk rating for the structure.

Strengthening

8.20 Where strengthening is proposed as an appropriate management measure for a sub-standard deck hinge structure, a summary of the strengthening proposals shall be recorded in the management plan.

8.21 Proposed strengthening measures shall be targeted at reducing the risk rating for the structure or eliminating the deck hinge detail.

NOTE *Possible strengthening measures for deck hinge structures include:*

1) provision of additional supports;
2) installing additional reinforcement in the deck hinge;
3) structurally connect the two halves of the deck to eliminate the deck hinge detail.

8.22 Where strengthening works have been implemented to eliminate the deck hinge detail on a structure, the structure shall be removed from the risk management process in this document as it is no longer a deck hinge structure.

Replacement

8.23 Where replacement of the deck hinge structure is proposed as an appropriate management measure for a sub-standard deck hinge structure, a summary of the replacement proposals shall be recorded in the management plan.

8.23.1 Replacement of the deck hinge structure should be proposed where deck hinges have deteriorated so badly that it is practically and economically beyond repair or strengthening.

NOTE *An example of deck hinge deterioration requiring replacement can be where the corrosion of the reinforcement is so extensive, it cannot be effectively replaced in order to improve the structural capacity of the deck hinge structure.*

8.23.2 Replacement of a deck hinge structure should be targeted at eliminating the deck hinge details.

NOTE *It is not always possible for a replacement structure to eliminate the deck hinge details due to site and operational constraints.*

8.24 Where the deck hinge details are retained, replacement solutions shall be targeted at reducing the risk rating for the deck hinge structure.

8.25 Where replacement works have been implemented to eliminate the deck hinge detail on a structure, the structure shall be removed from the risk management process in this document as it is no longer a deck hinge structure.

9. 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. CD 359, 'Design requirements for permanent soffit formwork'
Ref 3.N	Highways England. CS 450, 'Inspection of highway structures'
Ref 4.N	ICE Publishing. Desnerck P, Lees JM, Valerio P, Loudon N, Morley CT. ICE (BE) 171, 'Inspection of RC half-joint bridges in England: analysis of current practice, Proceedings of the Institution of Civil Engineers, Bridge Engineering 171, July 2018, p290-302''
Ref 5.N	Highways England. GG 101, 'Introduction to the Design Manual for Roads and Bridges'
Ref 6.N	CIRIA. CIRIA C778, 'Management of safety critical fixings in-service. Guidance for the management and design of safety-critical fixings'
Ref 7.N	Highways England. CS 470, 'Management of sub-standard highway structures'
Ref 8.N	Highways England. GG 104, 'Requirements for safety risk assessment'
Ref 9.N	Highways England. CS 451, 'Structural review and assessment of highway structures'
Ref 10.N	Highways England. CG 300, 'Technical approval of highway structures'
Ref 11.N	Highways England. CS 455, 'The assessment of concrete highway bridges and structures'

10. Informative references

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

Ref 1.I	TSO. IMHS, 'Inspection Manual for Highway Structures '
Ref 2.I	BSI. PD 6688-1-7, 'Recommendations for the design of structures to BS EN 1991-1-7'
Ref 3.I	Highways England. CS 456, 'The assessment of steel highway bridges and structures'

Appendix A. Model documents

This appendix provides models for the risk management report and priority list.

A1 Model risk management report

A model risk management report is shown in Table A.1.

Table A.1 Model risk management report

Structure information
This should include the following information: 1) structure name; 2) structure reference; 3) structure location; 4) brief description of the structure; 5) form of the deck hinge; 6) summary of the current condition of the structure.
Initial review
This should include the following information: 1) inputs (reference for documents used in the initial review); 2) findings from initial review; 3) where applicable, reference to sub-standard structure management documents.
Risk assessment for structural assessment
This should include the following information: 1) primary risks (including evidence and output); 2) primary risk rating; 3) secondary risks (including evidence and output); 4) where applicable, refined primary risk rating from use of secondary risks; 5) where applicable, secondary risk rating.
Summary of structural review findings
This should include a statement summarising the findings from the structural review agreed with the Technical Approval Authority (TAA) (e.g. whether a new structural assessment specific to the deck hinge is required).
Summary of structural assessment findings
This should include the following information: 1) assessed capacity of the deck hinge from the assessment and check certificates accepted by the TAA; 2) summary of recommendations from the structural assessment report agreed with the TAA; 3) assessed capacity of the deck hinge from the assessment and check certificates accepted by the TAA; 4) summary of recommendations from the structural assessment report agreed with the TAA.

Table A.1 Model risk management report (continued)

Risk assessment for management
This section should include the following information, with risk ratings reviewed and updated where applicable: 1) primary risks (including evidence and output); 2) primary risk rating; 3) secondary risks (including evidence and output); 4) where applicable, refined primary risk rating from use of secondary risks; 5) where applicable, secondary risk rating.
Management plan
This section may include the following information: 1) management measures; 2) recommendations from investigations, studies and reports; 3) references to reports and relevant documents; 4) where applicable, record of CS 470 [Ref 7.N] measures.

A2 Model priority list

A model priority list for a group of structures is shown in Table A.2. This can be used for the priority for assessment and the priority for management.

Table A.2 Model priority list

Priority	Structure name	Structure reference	Primary risk rating	Primary risks	Refined primary risk rating (1)	Secondary risk	Secondary risks rating (2)	Risk management report reference	Current status / comments
1									
2									
3									
4									
5									

Note (1): Refined primary risk rating is applicable when secondary risks are used to increase the primary risk rating.
Note (2): Secondary risk rating is applicable when secondary risks are used to prioritise between a number of structures with the same primary risk rating.

Appendix B. Guidance on risk assessment

B1 General

This Appendix provides illustrative example processes that can be used for risk assessment of deck hinge structures, using the primary and secondary risks described in this document.

The basis of the illustrative example risk assessment processes presented within this Appendix is as follow:

1) primary risks R_C and R_D used to determine a primary risk rating;
2) the severity of the consequences at this stage is taken as being very high;
3) secondary risks R_Q , R_V , and R_O may be used to either:
   a) increase the primary risk rating, resulting in the refined primary risk rating; or,
   b) prioritise within a group of structures with the same primary risk rating, resulting in the secondary risk rating.

Where secondary risks are used to increase the primary risk rating, this is referred to as the refined primary risk rating. For example if bridge A and bridge B both have a high risk rating from the matrix in Table B.1, but bridge A is on a strategic route over a major railway (so R_Q is very high), then the risk rating for bridge A can be increased from high to very high.

Where secondary risks are used to prioritise between a number of structures with the same primary risk rating, this is referred to as the secondary risk rating. For example if bridge C and bridge D both have very high risk rating from the matrix in Table B.1, but bridge C is on a strategic route over a major railway (so R_Q is very high), then bridge C can be prioritised over bridge D.

B2 Primary risk rating

The primary risk rating for an individual structure can be determined from the matrix Table B.1 below using condition and structural risks.

Table B.1 Matrix for determining primary risk rating of a deck hinge structure

		Structural risk R_D			
		R_D Very high	**R_D High**	**R_D Medium**	**R_D Low**
Condition risk R_C	**R_C Very high**	Very high (1)	Very high (1)	High (1)	High (1)
	R_C High	Very high (1)	High (1)	High (1)	Medium (1)
	R_C Medium	High (1)	High (1)	Medium (1)	Medium (1)
	R_C Low	High (1)	Medium (1)	Medium (1)	Low (1)
Note1: The primary risk rating determined from the combination of R_C and R_D .					

B2.1 Condition risk

The condition risk rating R_C can be determined using the steps below:

1) use the latest valid inspection information to collate deck hinge defects;
2) identify each defect using the inspection photographs and the defect decision diagram in Figure B.1 which is adapted from ICE (BE) 171 [Ref 4.N]. Additional guidance on defect types can be found in IMHS [Ref 1.I];
3) determine the damage rating for each defect. Table B.2 provides guidance and uses information taken from ICE (BE) 171 [Ref 4.N];
4) when all defects are recorded, consider their combination, their location and the damage to assign a risk level from Table B.3.

Figure B.1 Defects decision diagram

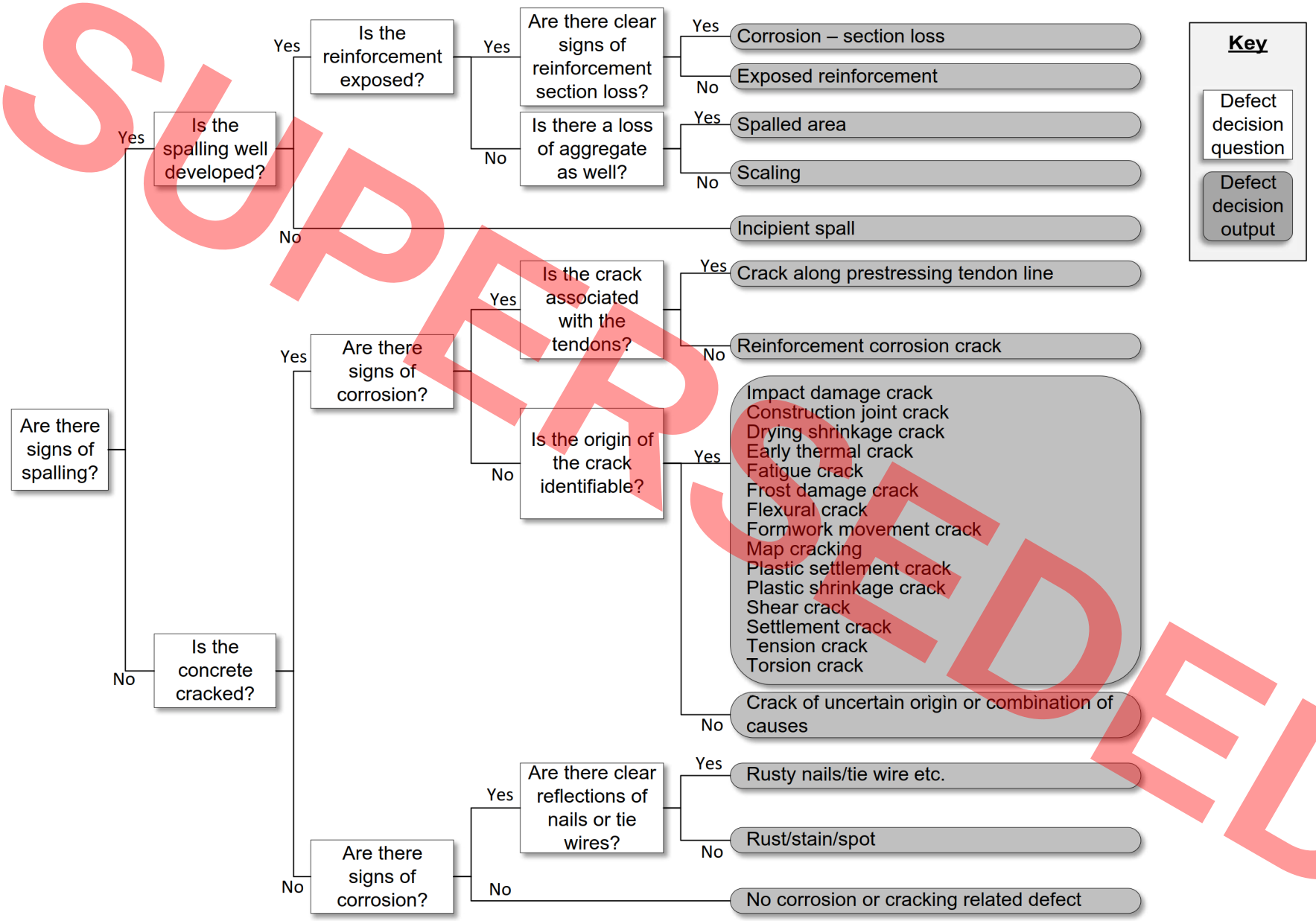


Table B.2 Damage rating

Damage	Very slight	Slight	Moderate	Severe	Very severe
Cracks in prestressed concrete	width<0.05 mm	width 0.05-0.1mm	width 0.1-0.3mm	width 0.3-1.0mm	width 1-3mm with some spalling
Cracks in Reinforced concrete	width<0.1mm	width 0.1-0.3mm	width 0.3-1.0mm	width 1-3mm with some spalling	width >5mm with widespread spalling
Effects of reinforcement corrosion	light rust stains	heavy rust stains	heavy rust stains and cracking along line of bar	heavy rust stains and spalling along line of bars	heavy rust stains and spalling along line of bars, in more than one location or for a number of bars.
Joint leakage/ water staining	clean/clear water, small patches of dampness	clean water seepage to large areas of the joint.	water seepage with discolouration at edge beam/footpath locations	30-70% of joint with discolouration gritted road/ coastal environment	affecting >70% of joint with discolouration with signs of historic presence. gritted road/coastal environment
Spalling/ delamination (1)	<cover 50x50mm	100x100mm	area up to 150x150mm across	area larger than 150x 150mm	multiple areas >250x250mm, or single areas more than 1000x1000mm
Note (1) - The size of a concrete spall should be compared relative to the size of the deck hinge. The criteria is for guidance purposes and is not prescriptive.					

Table B.3 Condition risk

Risk rating	Example of risk rating
Immediate risk(1)	Examples include: 1) more than a single very severe condition defect in the same zones and likely to work in combination such that there are not alternative load paths; 2) more than a single very severe condition defect not in the same zone but which may reduce the number of load paths; 3) single very severe condition defect, such as heavy corrosion of a scissor bar at the throat.
Very high	Examples include: 1) more than a single severe condition defect in the same zones and likely to work in combination such that there are not alternative load paths; 2) more than a single severe condition defect not in the same zone but which may reduce the number of available load paths; 3) single severe condition defect.
High	Examples include: 1) more than a single moderate condition defect in the same zones and likely to work in combination such that alternative load paths may not be available; 2) more than a single moderate condition defect not in the same zone but which may reduce alternative load paths; 3) single moderate condition defect.
Medium	Examples include: 1) more than a single slight condition defects in the same zones or likely to work in combination.
Low	Examples include: 1) slight or very slight condition defects or when in combination are not significant; 2) single or very slight condition defect.
Note (1) - this provides examples of situations where a deck hinge structure can be considered as an immediate risk structure in accordance with CS 470 [Ref 7.N]. This examples given is not an exhaustive list.	

An example table format for recording the information required to assign a risk rating is shown in Table B.4 below.

Table B.4 Example table for recording defect information

Defect description from data	Data reference	Defect identification	Zone	Damage rating	Defects in combination

Table B.4 Example table for recording defect information (continued)

Where it is not possible to accurately record a defect type, for example cracked concrete with no signs of corrosion, then the information that is apparent from the inspection data should be recorded.

Where it is not possible to determine the zone of the defect within the deck hinge as shown in Figure B.2 from the inspection data, for example where rust staining is visible to the soffit, then the location from where the defect is visible should be recorded and the lack of visibility should be considered when assigning a risk rating.

Defective detailing can increase the impact of condition defects and thus the risk level.

B2.2 Structural risk

B2.2.1 Structural risk R_{D1}

The structural risk rating R_{D1} may be determined using the steps below:

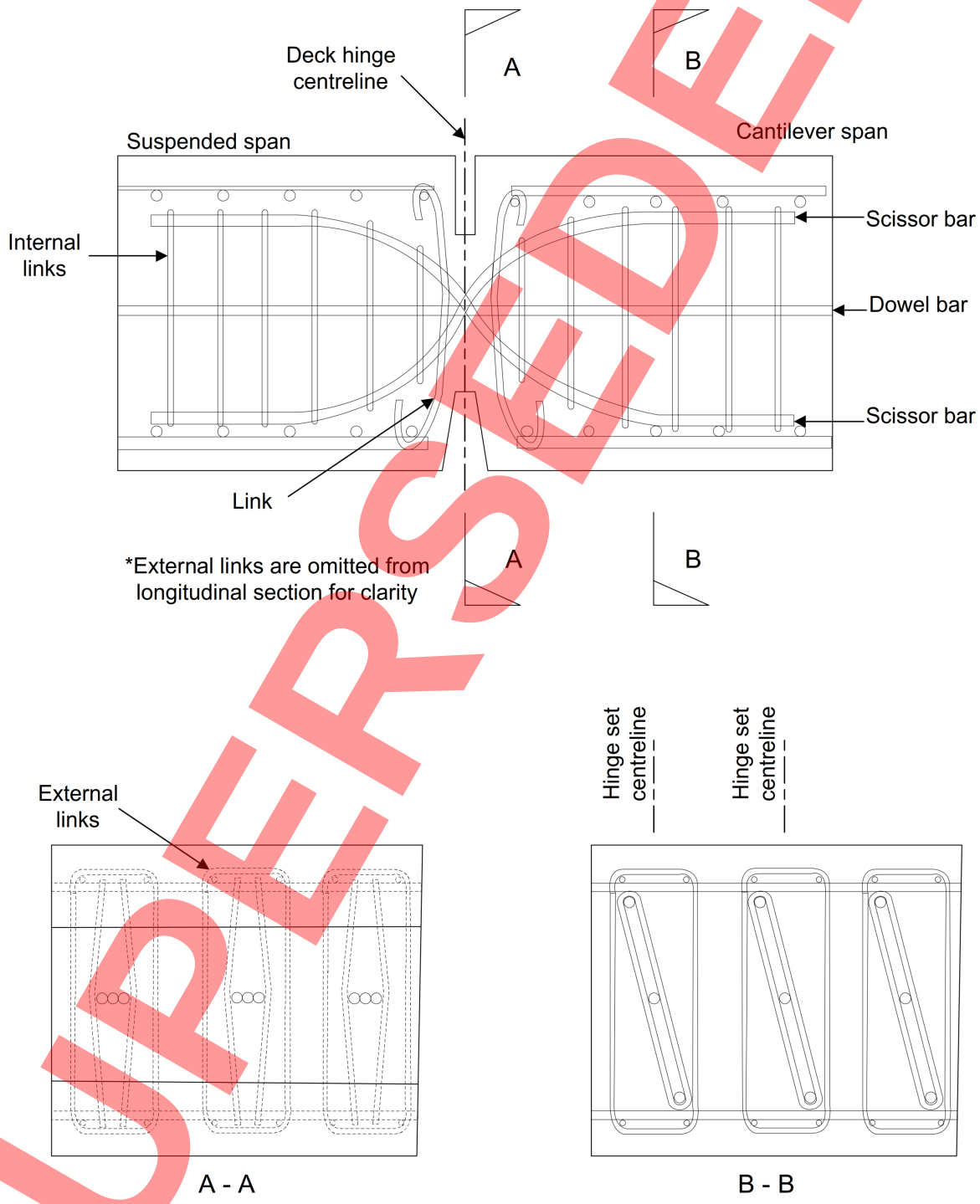
1) estimate from the arrangement of the reinforcement, the available load paths through the deck hinge evaluated in accordance with CS 455 [Ref 11.N] and Section 6 of this document;
2) consider the following reinforcement detailing related aspects:
   a) bar arrangement;
   b) anchorage;
   c) continuity of reinforcement;
   d) bearing stresses;
   e) arrangement of links surrounding the scissor and dowel bars;
3) use Table B.5 to assign a risk rating for detailing

Table B.5 Risk rating for structural risk

Detailing risk rating	Description and illustrative examples - typical detailing
Very high	Detailing shows no clear load path through deck hinge or critically poor anchorage. It appears probable that the detailing is insufficient to prevent a failure mechanism from developing.
High	Load path through the structure affected by poor detailing/anchorage.
Medium	Detailing allows a single clear load path through the deck hinge with adequate anchorage.
Low	Detailing allows multiple load paths through deck hinge, through the combination of complementary systems of well-anchored bars.
Note: Example load paths through deck hinges are illustrated in Section 6 with typical strut-and-tie models.	

The combination of effects from condition and detailing deficiencies may be considered by recording locations using the typical deck hinge details in Figure B.2 and the load paths through the deck hinge. The combination of effects can be used when assigning a primary risk rating in Table B.1.

Figure B.2 Typical deck hinge details



B2.2.2 Structural risk R_{D2}

The structural risk rating R_{D2} can be determined from Table B.6 using the assessed structural capacity.

Table B.6 Risk rating for structural risk from assessed capacity

Risk rating	Examples of risk rating
Very high	Examples: 1) structure requires propping; 2) structure assessed to be able to carry dead load only.
High	Example: 1) load restrictions required on carriageway.
Medium	Example: 1) assessed capacity greater than 40t on elements supporting the carriageways but reduced capacities on the edge beam/ footpath.
Low	Example: 1) assessed capacity greater than 40t ALL throughout the structure.

Where there is a need to complete the risk assessment for a structure with lack of record information, then a higher risk rating may be adopted provisionally to reflect the lack of information.

B3 Secondary risks

B3.1 Consequential risk

The consequential risk R_Q can be determined using the method detailed below:

1) use Table B.7 (derived from CIRIA C778 [Ref 6.N]) to select consequential risk scores;
2) add together the risk scores to determine the total score Q for the structure;
3) use Table B.8 for Q scoring bands to assign a consequential risk rating.

Table B.7 Consequential risk

	Very high	High	Medium	Low
Score Q	**10**	**3**	**1**	**0**
Number of people killed or seriously injured	Potential for one or more people to be killed or seriously injured.	Potential for slight injuries to five or more people.	Potential for slight injuries to fewer than five people.	No potential for injuries or other harm to health.
Potential damage vehicles	Potential for severe damage to one or more: 1) road vehicles; 2) trains; or, 3) floating vessels.	Potential for minor damage to one or more: 1) road vehicles; 2) trains; or, 3) floating vessels.	Potential for minor damage to single: 1) road vehicles; 2) trains; or, 3) floating vessels.	No damage sustained.
Potential damage to utilities and other public or private services	Any of the following: 1) potential for any disruption to one or more nationally and regionally important utility services; 2) potential for severe disruption to one or more locally important utility services; or, 3) potential for moderate disruption to more than one locally important utility service.	Any of the following: 1) potential for severe disruption to a single locally important utility service; 2) potential for moderate disruption to one or more locally important utility service; or, 3) potential for severe disruption to other utility services.	Any of the following: 1) potential for moderate disruption to a single locally important utility service; 2) potential for minor disruption to one or more locally important utility service; or, 3) potential for moderate disruption to one or more other utility service.	Any of the following: 1) No potential for disruption to nationally and regionally or locally important utility service; 2) potential for minor disruption to one or more other utility service; 3) potential for moderate disruption to a single locally important utility service; 4) potential for minor disruption to one or more locally important utility service; or, 5) potential for moderate disruption to one or more other utility service.

Table B.7 Consequential risk (continued)

Nature of route	Any of the following: 1) strategic route; 2) motorway; 3) trunk road; 4) Network Rail route criticality band 1 or 2; 5) mass transit urban railway; or, 6) commercial waterway.	Any of the following: 1) A road/principal road; 2) city centre footpath; 3) cycle superhighway; 4) Network Rail route criticality band 3 or 4; 5) freight only line; or, 6) leisure waterway.	Any of the following: 1) B/C road; 2) urban commuter cycle-path; 3) town centre footpath; or, 4) Network Rail route criticality band 5.	Any of the following: 1) unclassified road; 2) accommodation road; 3) rural cycle path; 4) rural footpath/right of way/bridleway; or, 5) other waterway.
Diversion route	Any of the following: 1) no viable pedestrian or vehicular diversion route exists; 2) no alternative route exists for rail, waterway or utility; 3) rural diversion route $>$ 10 miles; 4) urban diversion route 5 miles; or, $>$ 5) pedestrian diversion route $>$ 1 mile.	Any of the following: 1) one alternative rail, waterway or utility route exists; 2) rural diversion route $>$ 5 miles and $\leq$ 10 miles; 3) urban diversion route $>$ 2 miles and $\leq$ 5 miles; or, 4) pedestrian diversion route $>$ 0.5 miles and $\leq$ 1mile.	Any of the following: 1) multiple alternative rail, waterway or utility route exists; 2) rural diversion route $>$ 1 mile and $\leq$ 5 miles; 3) urban diversion route $>$ 0.5 miles and $\leq$ 2 miles; or, 4) pedestrian diversion route $>$ 0.25 miles and $\leq$ 0.5 miles.	Any of the following: 1) rural diversion route $\leq$ 1 mile; 2) urban diversion route $\leq$ 0.5 miles; or, 3) pedestrian diversion route $\leq$ 0.25 miles.

Table B.7 Consequential risk (continued)

Volume of traffic	Very heavy traffic flow: 1) highway: > 70,000 vehicles/day; 2) Network Rail: > 6 trains/hour; 3) mass transit urban rail: > 10 trains/hour; 4) commercial waterway: > 10 vessels/hour; 5) leisure waterway: > 20 vessels/hour; 6) pedestrian only: heavily used in accordance with PD 6688-1-7 [Ref 2.I].	High traffic flow: 1) highway: > 20,000 and ≤ 70,000 vehicles/day; 2) Network Rail: > 3 and ≤ 6 trains/hour; 3) mass transit urban rail: > 5 and ≤ 10 trains/hour; 4) commercial waterway: > 5 and ≤ 10 vessels/hour; 5) leisure waterway: > 10 and ≤ 20 vessels/hour; 6) pedestrian only: generally used in accordance with PD 6688-1-7 [Ref 2.I].	Low traffic flow: 1) highway: > 5,000 and ≤ 20,000 vehicles/day; 2) Network Rail: > 1 and ≤ 3 trains/hour; 3) mass transit urban rail: > 2 and ≤ 5 trains/hour; 4) commercial waterway: > 2 and ≤ 5 vessels/hour; 5) leisure waterway: > 5 and ≤ 10 vessels/hour; 6) pedestrian only: lightly used in accordance with PD 6688-1-7 [Ref 2.I].	Very low traffic flow: 1) highway: ≤ 5,000 vehicles/day; 2) Network Rail: ≤ 1 train/hour; 3) mass transit urban rail: ≤ 2 trains/hour; 4) commercial waterway: ≤ 2 vessels/hour; 5) leisure waterway: ≤ 5 vessels/hour; 6) pedestrian only: rarely used in accordance with PD 6688-1-7 [Ref 2.I].
Length of time to restore normal network operation	> 1 month	> 1 week and ≤ 1 month	> 1 day and ≤ 1week	≤ 1 day
Potential environmental pollution	Major pollution incident, for example: 1) widespread pollution to major watercourses; 2) affects fisheries or other commercial activities; 3) results in evacuation of premises located off site; 4) required removal of contaminated land or other material; 5) affects neighbouring land owners/occupiers.	Moderate pollution incident, for example: 1) high volume of contaminant contained within the boundaries of the site, eg within holding tanks; 2) results in evacuation of the on-site premises only; 3) does not affect neighbouring land owners/occupiers.	Low pollution incident: 1) localised incident that can be dealt with by a one or two man crew; 2) does not result in contamination of watercourse	No pollution
Political and reputation damage	Very high National media coverage	High Regional media coverage	Low Local media coverage	Very low No media coverage

Table B.7 Consequential risk (continued)

Financial impact	Very high	High	Low	Very low

Table B.8 Risk rating for consequential risks

Risk rating	Total score Q from Table B.7	Example of risk rating
Very high	$45 \leq Q < 100$	Examples: 1) potential for one or more people to be killed or seriously injured; 2) closure of route of strategic importance, no acceptable diversion; 3) very heavy traffic flow etc.
High	$15 \leq Q < 45$	Examples: 1) potential for slight injuries to five or more people; 2) principal or A road, high traffic flow route etc.
Medium	$5 \leq Q < 15$	Examples: 1) potential for slight injuries to fewer than five people; 2) B/C road, low traffic flow, etc.
Low	$Q < 5$	Examples: 1) no potential for injuries or other harm to health; 2) very low traffic flow; 3) unclassified road etc.

B3.2 Vulnerable details risk

The risk rating for the vulnerable details risk, R_V can be determined using Table B.9 below:

Table B.9 Risk rating for vulnerable details

Risk rating	Example of risk rating
Very high	Examples: 1) single vulnerable detail with significant issues; 2) multiple vulnerable details with defects or significant defects; 3) no information.
High	Examples: 1) single vulnerable detail with issues or defects.
Medium	Examples: 1) multiple vulnerable details but without defects or issues.
Low	Examples: 1) no other vulnerable details or a single other detail without defects or issues.

B3.3 Other risks

The risk rating for other risks, R_O can be determined based upon the Table B.10:

Table B.10 Risk rating for other risks

Risk rating	Example of risk rating
Very high	Examples: 1) structure is within forthcoming scheme limits; 2) structure is part of strategic development of the highway network; 3) structure is within a family of structures known to suffer from significant defects.
High	Examples: 1) structure is near to a forthcoming scheme; 2) structure is near a strategic development site; 3) structure is within a family of structures known to suffer defects.
Medium	Examples: 1) structure is within a family of structures that have been targeted for interventions.
Low	Examples: 1) no other factors that is going to affect the risk of the structure; 2) no other issues allow for grouping of the structure.

Appendix C. Fatigue assessment

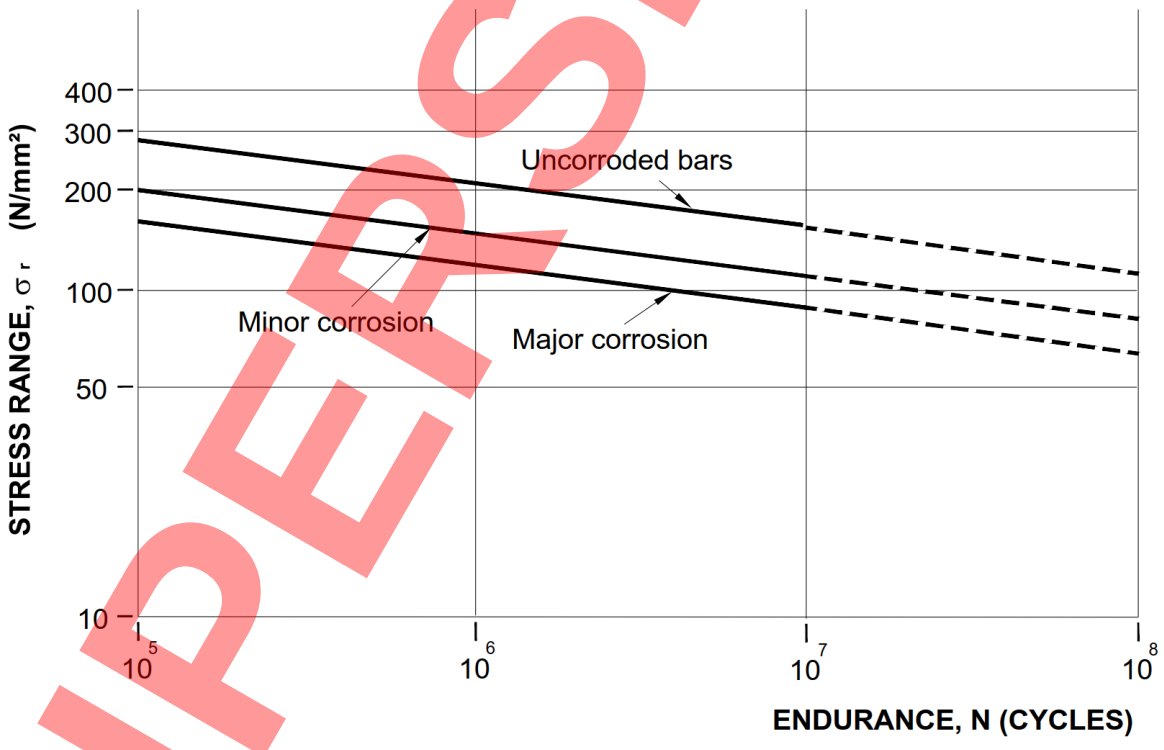
C1 Fatigue endurance of reinforcing bars

The relationship between stress range and fatigue endurance given in Figure C.1 may be used, based on the corrosion severity categories given in Table C.1.

Table C.1 Corrosion severity categories

Category	Description
Minor corrosion	Less than or equal to 25% section loss
Major corrosion	More than 25% section loss
Note: A method for estimating the degree of section loss in corroded bars is provided in CS 455 [Ref 11.N]	

Figure C.1 Relationship between stress range and fatigue endurance



C2 Local stress in scissor bar

For a preliminary fatigue analysis, a value for the local stress in the scissor bar, σ_{sb} , may be taken from:

1) Equation C.1 if there is no damage to the concrete hinge;
2) Equation C.2 if there is damage to the concrete hinge, where a higher proportion of the shear is carried by the scissor bar and the stress due to rotation is reduced.

Equation C.1 Approximate local stress in scissor bar

$$\sigma_{sb} = 0.3 \cdot \sigma_s + K \cdot \alpha \cdot \frac{h}{D}$$

where:

- σ_{sb} is the local stress in the scissor bar due to bending of the bar and axial force in the bar
- σ_s is the axial tensile stress in the tension scissor bar, assuming that all the shear force in the hinge is carried by the tension scissor bars
- K is a constant equal to 0.3MPa
- α is the relative rotation at the hinge in radians
- h is the clear depth of the hinge throat between hinge formers
- D is the nominal diameter of the scissor bars

Equation C.2 Approximate local stress in scissor bar for a damaged hinge

$$\sigma_{sb} = 0.55 \cdot \sigma_s + 0.2 \cdot K \cdot \alpha \cdot \frac{h}{D}$$

Equations C.1 and C.2 are based on stresses in the bars in a young, newly cracked structure, and are based on hinge geometries that are typical for common hinge types in UK bridges.

Equations C.1 and C.2 are conservative for structures with less recent cracking, as the local stress decreases for longer debonded lengths.

Equations C.1 and C.2 are based on a finite element analysis and take account of the stresses induced in the hinge bars due to shear and rotation following the formation of shear cracks.

Equations C.1 and C.2 do not account for vertical cracking in the hinge throat, which can lead to high local stresses in the hinge reinforcement.

Equations C.1 and C.2 do not account for stress concentrations due to corrosion in the scissor bars.

Highway Structures & Bridges
Inspection & Assessment

CS 467
England National Annex to CS 467 Risk management and structural assessment of concrete deck hinge structures

(formerly BA 93/09)

Revision 1

Summary
This National Application Annex gives the Highways England-specific requirements which enable the safety and serviceability of concrete hinge deck structures to be assessed and managed, allowing to manage risks and maintain a safe and operational network.

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	Apr 2020	Revision 1 (April 2020) Removal of incorrect references to BD 97 in sub headings in place of the correct reference, CS 467. Revision 0 (March 2020) Highways England National Application Annex to CS 467.

Foreword

Publishing information

This document is published by Highways England.

This document supersedes BA 93/09, which is 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 National Application Annex (NAA) gives the Highways England specific requirements related to the risk management and structural assessment of deck hinge structures. This NAA describes the requirements for the Asset Management System (AMS) National Structures Programme (NSP) activities in relation to concrete deck hinge structures and how they tie into CS 467 [Ref 4.N].

Assumptions made in the preparation of this document

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

Abbreviations

Abbreviations

Abbreviation	Definition
AMS	Asset management system
NSP	National structures programme module of the AMS

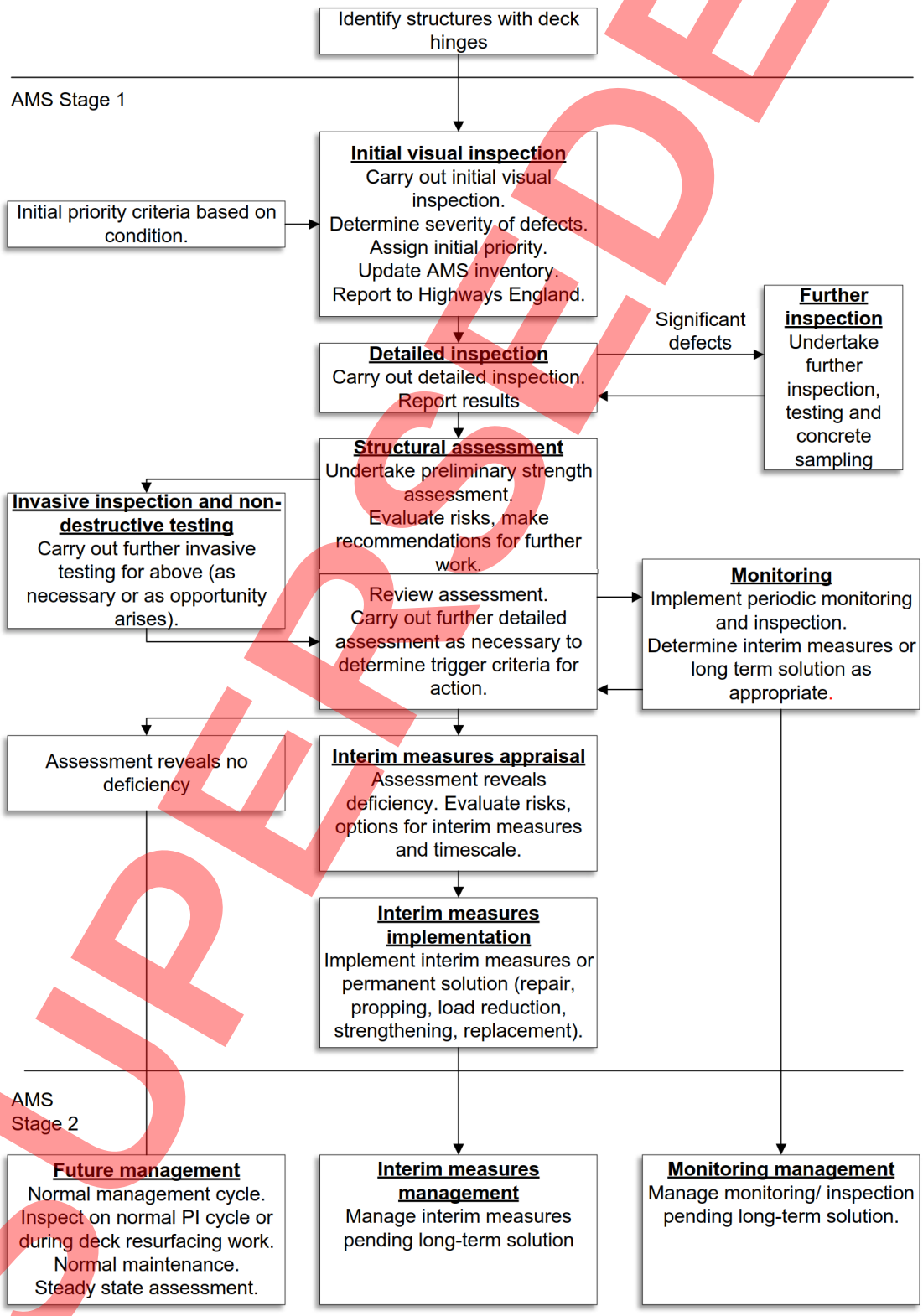
E/1. AMS NSP Activities

AMS NSP activities (additional to CS 467 [Ref 4.N])

E/1.1 The AMS NSP module shall be used to capture data and organise a series of activities for the concrete deck hinge structures programme.

NOTE 1 *The NSP activities are shown in the flowchart in Figure E/1.1N1.*

Figure E/1.1N1 AMS NSP activities flowchart for structures with concrete deck hinges



NOTE 2 The links between the NSP activities and the deck hinge structure risk management process is shown

in Appendix E/A.

NOTE 3 *The processes for interim measures are described in CS 470 [Ref 3.N].*

E/1.2 Information related to the planning, implementation and outputs from the NSP activities shall be recorded in the AMS.

Inspection of deck hinge structures (CS 467 [Ref 4.N])

Initial visual inspection

E/1.3 The initial visual inspection shall be targeted at providing an initial evaluation of the condition of the deck hinge structure.

E/1.3.1 Where previous inspections of the deck hinge structure are unavailable or a change in condition is likely since the structure was last inspected, then an initial visual inspection of the deck hinge should be undertaken, following agreement with Highways England.

E/1.3.2 The initial visual inspection should determine the severity and location of any defects in the vicinity of the deck hinge.

E/1.3.3 Access requirements for a detailed inspection should be determined during the initial visual inspection.

Detailed inspection

E/1.4 The detailed inspection shall be targeted at providing a detailed evaluation of the condition of the deck hinge and quantify defects to inform the structural assessment.

E/1.4.1 Where previous inspections of the deck hinge structure are unavailable or a change in condition is likely since the structure was last inspected, then a detailed inspection of the deck hinge should be undertaken, following agreement with Highways England.

E/1.4.2 The detailed inspection may be undertaken in conjunction with the initial inspection.

Further inspection

E/1.5 Further inspection of the deck hinge structure shall be undertaken where significant defects to or in the vicinity of the deck hinge are found.

E/1.5.1 The further inspection may consist of the following activities:

1) small exposure of reinforcement;
2) concrete testing;
3) concrete sampling.

NOTE 1 *Small exposure of reinforcement typically involves drilling small holes to the reinforcement and inspecting using a borescope.*

NOTE 2 *Concrete testing typically includes half-cell measurement, chloride content, cement content etc.*

E/1.5.2 The further inspection may be undertaken in conjunction with the detailed inspection and/or the initial visual inspection.

Structural assessment (CS 467 [Ref 4.N])

E/1.6 The objectives of the deck hinge structural assessment shall include the following:

1) to determine risks to the structural integrity of the deck hinge;
2) to identify deterioration trigger points for feeding into the management plan;
3) to help identify likely future risk management measures.

Invasive inspection and non-destructive testing (additional to CS 467 [Ref 4.N])

E/1.7 Where the deck hinge structural assessment recommends obtaining additional structural information on the deck hinge and this is agreed by Highways England, then invasive inspections and non-destructive testing shall be undertaken.

Future management (additional to CS 467 [Ref 4.N])

E/1.8 Where the structural assessment concludes that the structure is assessed to have sufficient capacity, then no special actions shall be required apart from maintenance inspection and maintenance activities.

NOTE *Maintenance inspections are covered in CS 450 [Ref 1.N].*

Monitoring (CS 467 [Ref 4.N])

Monitoring

E/1.9 Where the deck hinge structural assessment findings recommends periodic monitoring or inspections and this is agreed by Highways England, then a regime of periodic monitoring and/or inspections shall be implemented.

NOTE 1 *Refer to CS 470 [Ref 3.N] for requirements and guidance on monitoring.*

NOTE 2 *Pending the implementation of a long term solution, monitoring can be a suitable short term solution to mitigate risks for deck hinge structures with concerns about the serviceability and strength of the deck hinge such as:*

1) significant defects found to or in the vicinity of the deck hinge;

2) structural assessment finds that the structural capacity is marginally greater than the assessment actions, but further deterioration can result in reducing the structural capacity below the assessment actions.

E/1.10 Monitoring shall be targeted at measurable critical parameters.

E/1.10.1 For deck hinge structures, monitoring parameters may include:

1) horizontal movement at the joint;
2) vertical movement at the joint;
3) movement due to traffic actions;
4) crack widths;
5) deflections;
6) strains;
7) material deterioration.

Monitoring management

E/1.11 Monitoring shall be managed to ensure that:

1) monitoring is targeted at measurable critical parameters;
2) monitoring trigger levels are defined prior to implementation;
3) monitoring duration and intervals are defined prior to implementation.

E/1.11.1 The monitoring duration should be reviewed periodically, taking into account any changes in condition of the structure.

E/1.12 Where monitoring trigger levels are exceeded, then monitoring trigger actions in accordance with the monitoring specification shall be implemented.

NOTE *Guidance for monitoring specification is given in CS 470 [Ref 3.N].*

E/1.13 Where the monitoring and inspection findings results in a new review trigger for a deck hinge structure, the risk management process shall be revisited for that structure.

Interim measures (CS 467 [Ref 4.N])

Interim measures appraisal

E/1.14 Where the deck hinge structural assessment concludes that the structure is sub-standard, an appraisal of interim measures in accordance with CS 470 [Ref 3.N] to evaluate risks, options and timescales shall be undertaken.

Interim measures implementation

E/1.15 Once the options for interim measures have been agreed, the interim measures shall be implemented in accordance with CS 470 [Ref 3.N].

E/1.16 Confirmation of the implementation of interim measures for the structure shall be recorded in the AMS.

Interim measures management

E/1.17 Interim measures shall be managed to ensure they remain effective in mitigating risks to the road network throughout their service life in accordance with CS 470 [Ref 3.N].

E/2. 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.

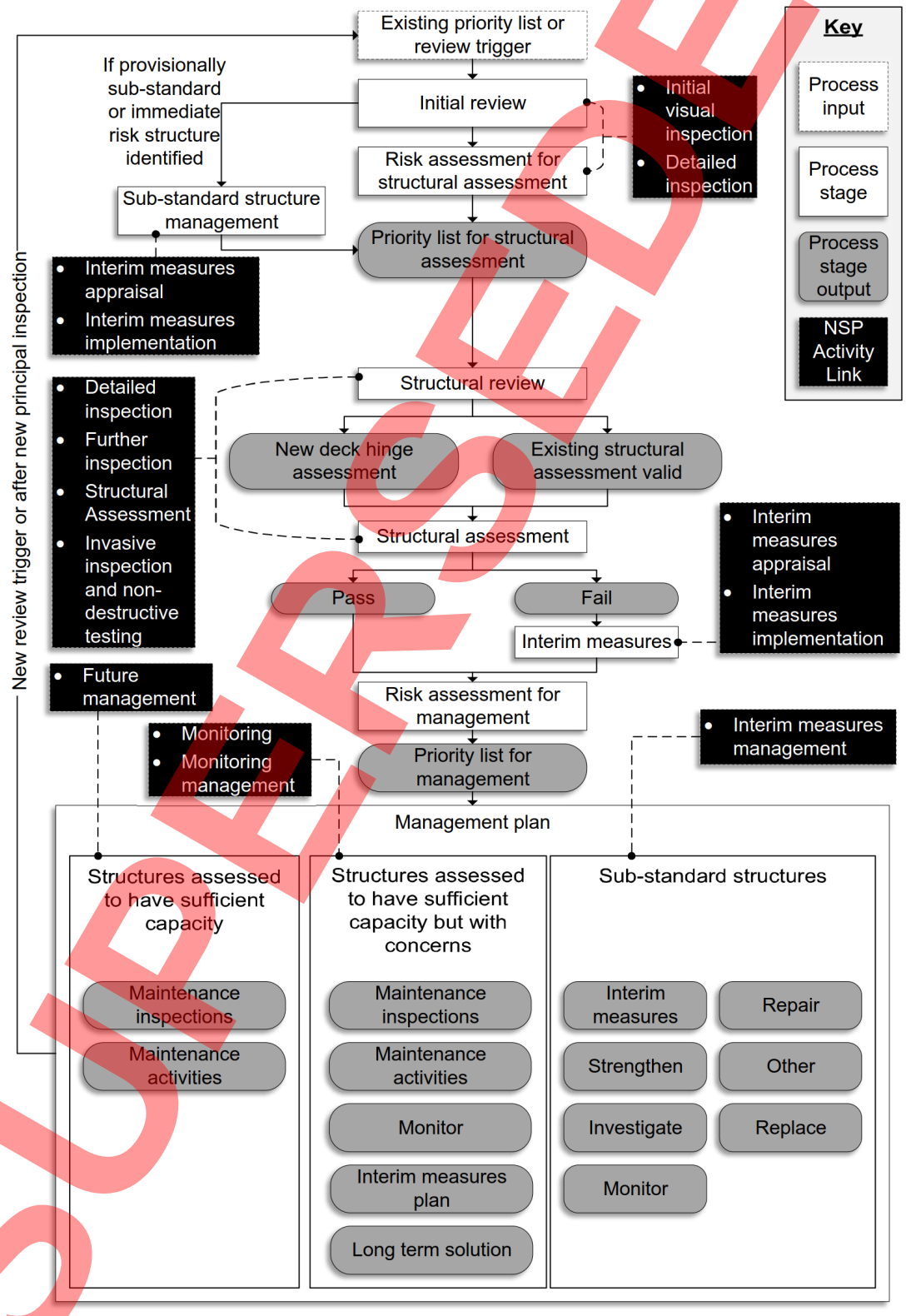
Ref 1.N	Highways England. CS 450, 'Inspection of highway structures'
Ref 2.N	Highways England. GG 101, 'Introduction to the Design Manual for Roads and Bridges'
Ref 3.N	Highways England. CS 470, 'Management of sub-standard highway structures'
Ref 4.N	Highways England. CS 467, 'Risk management and structural assessment of concrete deck hinge structures'

Appendix E/A. Links between NSP activities and deck hinge structures risk management process

E/A1 Map of NSP activities to the deck hinge risk management process (additional to CS 467 [Ref 4.N])

Figure E/A.1 maps the NSP activities to the corresponding stages of the deck joint structures risk management process.

Figure E/A.1 Map of NSP activities to the deck hinge structures risk management process



Department for Infrastructure
An Roinn Bonneagair

Highway Structures & Bridges
Inspection & Assessment

CS 467
Northern Ireland National Annex to CS 467 Risk management and structural assessment of concrete deck hinge structures

(formerly BA 93/09)

Revision 0

Summary
There are no specific requirements for Department for Infrastructure Northern Ireland supplementary or alternative to those given in CS 467.

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 team in the Department for Infrastructure, Northern Ireland. The email address for all enquiries and feedback is: dcu@infrastructure-ni.gov.uk

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Highway Structures & Bridges
Inspection & Assessment

CS 467
Scotland National Annex to CS 467 Risk management and structural assessment of concrete deck hinge structures

(formerly BA 93/09)

Revision 0

Summary
There are no specific requirements for Transport Scotland supplementary or alternative to those given in CS 467.

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 Transport Scotland team. The email address for all enquiries and feedback is: TSStandardsBranch@transport.gov.scot

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Llywodraeth Cymru
Welsh Government

Highway Structures & Bridges
Inspection & Assessment

CS 467
Wales National Annex to CS 467 Risk management and structural assessment of concrete deck hinge structures

(formerly BA 93/09)

Revision 0

Summary
There are no specific requirements for Welsh Government supplementary or alternative to those given in CS 467.

Feedback and Enquiries
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